Lab 3, Analysis and Design of Descrete Controllers

IE1304, Control Theory

1 Goal

The goal is to learn how to design a discrete controller, using pole placement. You will design the controller and analyze its characteristics (settling time, stability, overshoot, steadystate error).

2 The Process

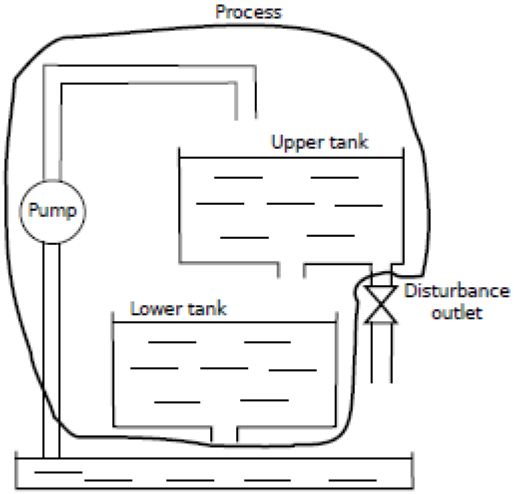


Figure 1: *Controlled process. Disturbance outlet and reservoir are not part of process.*

The process to control is depicted in fig 1. It consists of two water tanks, the lower tank is filled from the upper tank, which in turn is filled by a pump. There is an outlet from the lower tank and, to introduce a disturbance, also the upper tank has an outlet.
The measured value is the level of the lower tank. Note that disturbance outlet and reservoir below tanks are not part of the process.

3 Preparation Tasks, to be solved **BEFORE** the lab

Task 1, Reading

- Read Chapter 19.1-19.5 in the course text book, and understand how a controller can be designed with pole placement.
- Read Section 4 in this tutorial and try to understand what to do during the lab.

Task 2, Controller design

a) Pole placement

In this lab we will treat the process as the second order model it actually is,

$$G_P(s) = \frac{K_P}{(1+T_1 s)(1+T_2 s)}$$

For now, you can set $K_P = 3$, $T_1 = 6$ and $T_2 = 21$. These values are close to the actual model values. Set the sampling time to 10% of the process' fastest (smallest) time constant.

Recall the effects of different pole locations mentioned at lecture 11. Use the controller design described at lecture 11 and on page 351 in the text book which gives the transfer function from reference value to measured value

$$H(z) = \frac{K_r B(z)}{A(z)C(z) + B(z)D(z)}$$

Place the poles in the area showed in the figure on page 355 in the course text book. The process is quite slow, therefore we must place the poles quite close to the unit circle or we will get too high values for control input, $u(k)$. Since both $A(z)$ and $B(z)$ is of second order the pole placement method described in the text book will tell that three poles are needed, you can place one of the poles in origo.

Create a Matlab script that calculates $C(z)$, $D(z)$ and K_r as described at lecture 11 and on page 353-354 in the text book. How to create the script is described in detail in **`script-howto.pdf`**, which can be downloaded from the course web site.

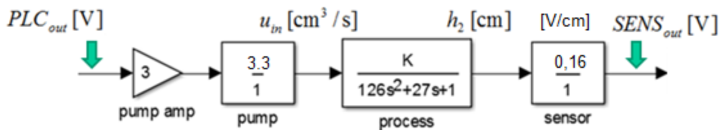
b) Evaluation

Use Simulink to simulate the step response of the whole feedback loop (controller and process together). Remember that the control input is pump voltage. At the lab, the step will be from about 1.5V to 3V, try the same step when simulating. Remember to check the step response also of the control input, $u(k)$. At the lab, the highest possible amplitude of $u(k)$ is 12V. There is very useful help for the Simulink simulation in **`script-howto.pdf`**, which can be downloaded from the course web site. Try different pole locations, calculate corresponding values of $C(z)$, $D(z)$ and K_r and simulate the feedback loop until the step response when input changes from 1.5V to 3V meets the following requirements.

- Rise time < 9s
- Settling time < 20s
- Overshoot < 10%
- Steady state error = 0
- Watch out for unjustifiably high control signals!

4 Lab Tasks, to be solved at the lab

Task 1, Process Transfer Function



- Set up the lab equipment the same way you did in lab 2, see the tutorial for lab 2 for details.
- To get the step response of the process, download the ISaGRAF program **`stepresp`** to SmartI/O. Pressing the start button makes the program fill the tanks. Wait for the lower tank level to stabilize at about 6 cm. Again press the start button. The program will generate a step, increasing the level to about 27 cm. The start of the step time will be indicated with a pulse. The step begins on the pulse's negative slope. Plot the process' step response using the oscilloscope in the same way as in lab 2. Use the plot to calculate the process' time constants as described on pages 112-113 in the text book (and practiced with the web-quiz). The amplification of the process can be found by calculating

  $$K = \frac{\Delta SENS_{OUT}}{\Delta PLC_{OUT}}$$

  Every time the start button is pressed, the level will alternate between 6 cm and 27 cm and a pulse will indicate the step time.

Task 2, Controller design

Design a pole placement controller the same way you did in preparation task 2.

Task 3, Controller evaluation

The controller is an ISaGRAF program called **`polplace`**, download it to Smart I/O. Before pressing the start button, enter the values of K_R, C_1, D_0 and D_1 that you calculated in the previous task. Also set the reference value (called **`ref`** in the program) to 10, which means the water level in the lower tank will be about 10 cm. Let the system stabilize and then change the reference value to 20, plot the step response using the oscilloscoper. Reference input, measured output, error and control signal can be seen in ISaGRAF. Also measure control input, the signal from controller to process. Its maximum amplitude is about 12V. Tune the controller by moving the poles and calculating new values for K_R, C_0, D_0 and D_1 until the system meets the requirements specified in preparation task 2b. Note that new values can be entered without stopping the **`polplace`** program.