# Lab 3, Analysis and Design of Discrete 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, steady-state error).

## 2 The Process

The process to control is exactly the same as in lab 2 and 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.

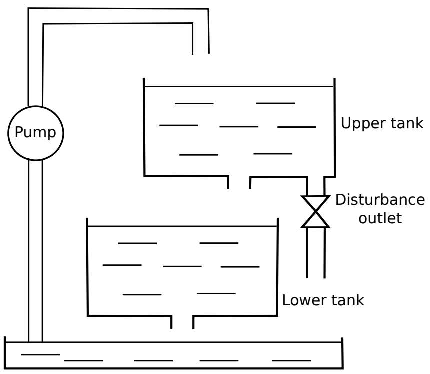


Figure 1: The controlled process

# 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

There is no need to measure time constants and amplification again since the process to control is identical to the process in lab 2. Instead, use the values you measured in lab 2 to create a second order model, $G_P = \frac{K_P}{(1+T_1 s)(1+T_2 s)}$. If you are unsure of your measured values you can set $K_P = 0.7$, $T_1 = 6s$ and $T_2 = 51s$.

Set the sampling time to 10% of the process' fastest (smallest) time constant and discretize the transfer function $G_P$.

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; for example you could place the poles in $0.2 \pm j0.1$ or $0.6 \pm j0.3$. 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 a third pole in origo.

- ***To design the controller, you shall calculate $K_r$, $C(z)$ and $D(z)$. It is very important that you finish this calculation before the lab since it is quite time consuming.***

## Task 3, Controller Implementation

The controller will be the same PLC system that was used during lab 2. Implement the controller you designed in the previous task in a program in ISaGRAF. You can reuse the `pidcontr` program from lab 2 and change the sampling time in steps GS1, GT9, GT10 and the control law in step GS10.

# 4 Lab Tasks, to be solved at the lab

## Task 1, Controller analysis

a) Set up the lab equipment the same way you did in lab 2, see the tutorial for lab 2 for details.

b) Download your controller program to Smart I/O and set the reference value to for example 5000. Let the system stabilize and then make a small change in the reference value, for example to 5200. Plot the step response of the system using

Fluke View and measure settling time, stability, overshoot and steady-state error of the process when using your controller.

c) Measure settling time, stability, overshoot and steady-state error of the process when using your controller and introducing a disturbance.

d) Does the system behave as expected? If it does not, why do you think it behaves differently?

e) If your system has a steady-state error, try to elliminate it by adjusting the controller gain, $K_r$.

## Task 2, Improved Controller

If time allows, try to improve your controller by introducing an integrator as described in section 19.4 in the text book.