Lab-Report
Control Engineering

Proportional Control of a Liquid Level System

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2. Introduction

A control system is an arrangement of physical components connected or related in such a manner as regulate itself or another system. For testing and simulating such systems either lots of hand calculations have to be done, or a tool like Matlab icluding Simulink can be used.

3. Objectives

The objectives of the Lab were to simulate a liquid level control system with an electrically driven pump and a pressure sensing liquid level transducer whose output corresponds with the level of water in the liquid tank.
Figure 1 shows the simplified overall block diagram of the system.

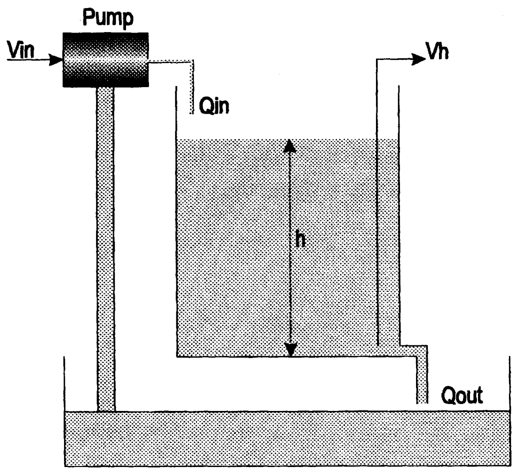


Figure 1

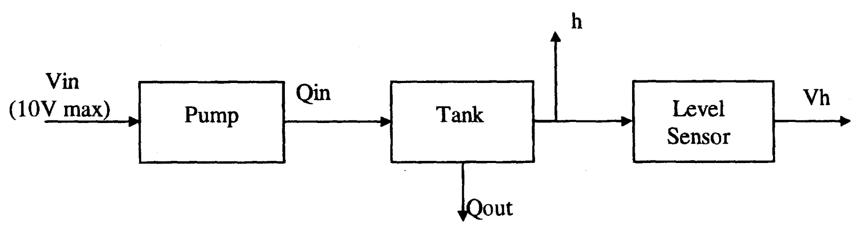


Figure 2

figure 1

The equations governing the tank are as follows:

$$A\frac{dh}{dt} = Q_{in} - Q_{out}$$
$$Q_{out} = C_d a\sqrt{2gh}$$

where A is the cross sectional area of the tank $=0.01m^2=100cm^2$
Q_{in} is the flow rate of water into the tank
Q_{out} is the flow rate of water out of the tank (cm^3/sec)
C_d is the discharge coefficient of the tank outlet =0.7
a is the Area of the tank outlet $=0.473cm^2$
g is the gravitational constant

The pump and the liquid level gains were obtained from a graph containing the pump and the level sensor characteristics.

Pump gain $P_g = 440\frac{cm^3}{min/V} = 7.33\frac{cm^3}{sec/V}$

Level gain $L_g = 0.4\frac{V}{cm}$

$C_d a\sqrt{2g}$ C_d is a constant, which can be calculated by $C_d a\sqrt{2g} = 14.67$

4. Lab procedure

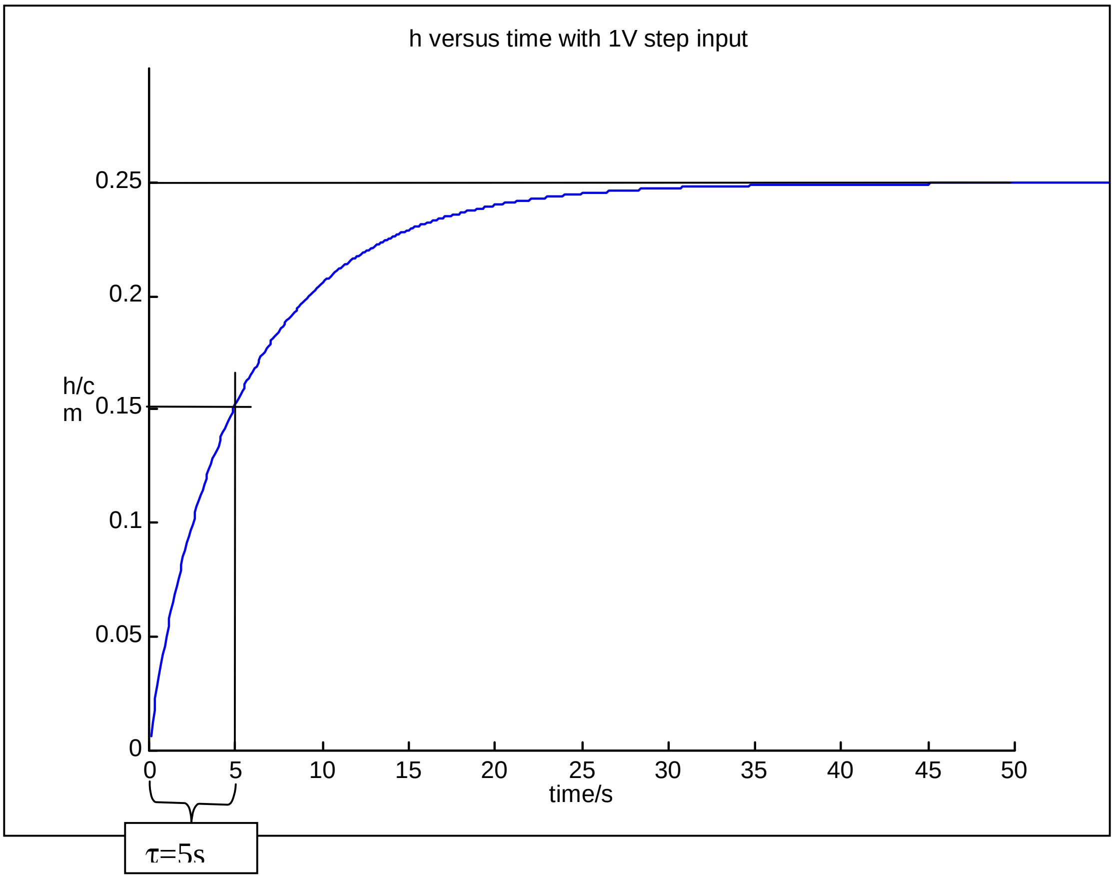
a) Simulation diagram

First part of the Lab procedure was to design a simulation diagram of the system with V_{in} as the reference input an h and V_h as the system outputs.
Figure 2 shows the resulting diagram.

figure 2

b) Response of h versus time

The next part was to perform a transient response on the system and plot the response of h versus time.



From this plot the time constant τ of the system can be obtained, by reading the time which the output needs to reach 63 per cent of its input.

The plot was obtained by using the workspace function of Simulink. It writes the simulation result into a matrix, which can be used in Matlab with the plot function. Also the labels and the titles were added by means of the appropriate Matlab functions.

c) Open loop Transfer function

From b) Response of h versus time the open loop gain, the time constant τ and the open loop gain can be determined. Hence the transfer function can be determined.

Assuming a 1st order function H(s) is given by $H(s) = \frac{g}{1+s\tau}$

where g is the open loop gain and τ the time constant.

Hence: $H(s) = \frac{0.25}{1+5s}$

Another way to derive the transfer function is to describe the transient function take the Laplace function of it and apply an step input to it.

$$h(t) = g(1 - d^{-\frac{t}{\tau}})$$

Laplace transform:

$$G(s) = g\left(\frac{1}{s} - \frac{1}{s+\frac{1}{\tau}}\right) = \frac{g}{s^2\tau + s}$$

applying a step input means to multiply H(s) by s

$$H(s) = \frac{g}{1+\tau s} = \frac{0.25}{1+5s}$$

which leads to the system's transfer function.

d) Output versus different input voltages

Next part of the Lab was to simulate the system and also the transfer function with different step input voltages.

V_{in}=10V

V_{in}=8V

V_{in}=6V

V_{in}=4V

V_{in}=2V

V_{in}=10V

V_{in}=8V

V_{in}=6V

V_{in}=4V

V_{in}=2V

When comparing the two graphs, it can be seen, that the system cannot be of first order. This is due to the square root of h in the backward loop of the system.

e) Controller driven pump

Last part of the Lab was to add a controller with gain K to the system, such that the controller drives the pump. The output of the controller is then $V_C=K*(V_{in}-V_h)$. The input of the system is now the reference height h_{in}, which was to set to 15cm.
For various values of K a transient response should be obtained with and without a maximum pump voltage of 10V.
Figure 3 shows the resulting block diagram, where Gain4 is the added controller and Gain3 the Pump.

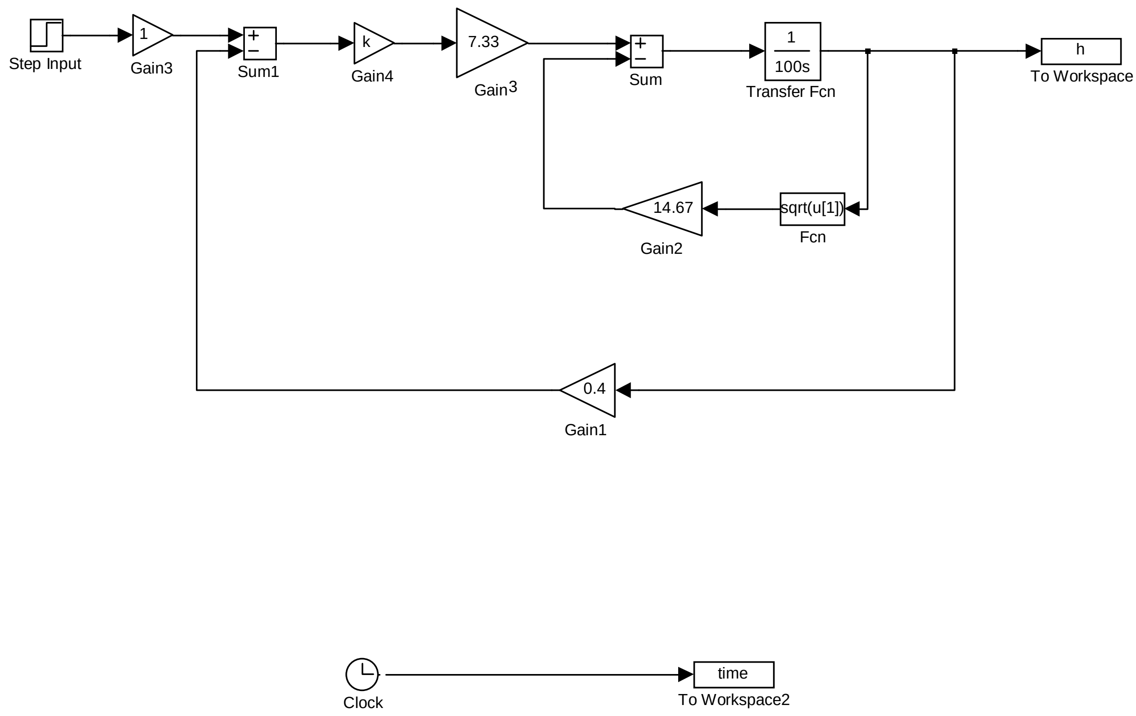


figure 3

i. without constrained pump-voltage

k=1

k=0.7

k=0.5

k=0.3

k=0.1

The simulation without a constrained pump voltage is not very realistic, because every electric an mechanic devices have restrictions, which bring them away from their ideal characteristics.
For example the voltage applied to the pump must not be increased over a maximum level in order to prevent damage from the pump. This decreases the time at which the tank reaches its maximum level like shown at the figure on the next page.
If the gain K of the controller exceeds a level about 0.7 the water height exceeds the desired level of 15cm.

ii. With pump voltage constrained to 10V

k=1

k=0.7

k=0.5

k=0.3

k=0.1

It can be easy seen, that the rising time is much greater than in the diagram above, because the power supply of the pump is reduced to 10V. Hence the pump can only transport a relativly small amount of liquid.
For the simulation of the pump voltage constrained to 10V a

5. Conclusion

Matlab is a very powerful tool to simulate very complicate processes without the need of solving complex equations. ‘But it is very essential to understand the process, which is to simulate to prevent wrong results and in some special cases Matlab can provide wrong results. So the results have to be always checked on their correctness.