BUILDING A MODEL OF A PHYSICAL PROCESS

Laboratory Work #1.1

1. Goal of the lab:

To show the students how to build a SIMULINK model of a physical process, how to change its parameters, how to obtain input-output data, used in system identification.

2. Introduction

The process of interest is a buffer system as shown in Figure 1.1 consisting of a cylindrical tank, with inlet and outlet flow rates of F_i m3/hr and F_o m3/hr, respectively.

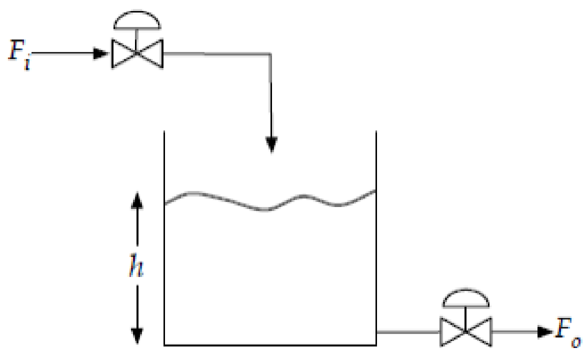

Figure 1.1 Schematic of the liquid level system

The objective is to build a model that explains changes in level h(t) with respect to changes in inlet flow rate Fi (t). The end-use of this model could be in simulation, control and/or monitoring of the liquid level system.

In a realistic situation, one would perform real-time experiments on the liquid level process with a custom-designed input. The input design would be usually preceded by a preliminary experiment to obtain essential process characteristics for determining the appropriate sampling rate and the frequency content of the input. Keeping in view the main objective of the example, the experiment is replaced by the simulation of a first-principles model with an appropriate input design and sampling interval in place.

The deterministic first-principles model of the liquid level system (based on conservation of mass) is

$$\frac{dh(t)}{dt} + \frac{1}{A_c} C_v \sqrt{h(t\,)} = \frac{1}{A_c}\, F_i(t)$$

with the usual assumptions of (i) incompressible fluid and (ii) the outlet flow rate being proportional to the square root of the pressure head (valve equation):

$$F_O(t) = C_v\sqrt{h(t)}$$

where Cv is the valve coefficient at the outlet. The quantity Ac is the cross-sectional area of the cylindrical tank. The system is brought to a steady state before exciting it with the designed input. With the operating conditions set to Fi (t) = 4.5 ft.3/min., Cv = 1.5 and Ac = 0.5 ft2, the nominal level is 9 ft.

The following SIMULINK model is used for modelling the liquid level system (Figure 1.2).

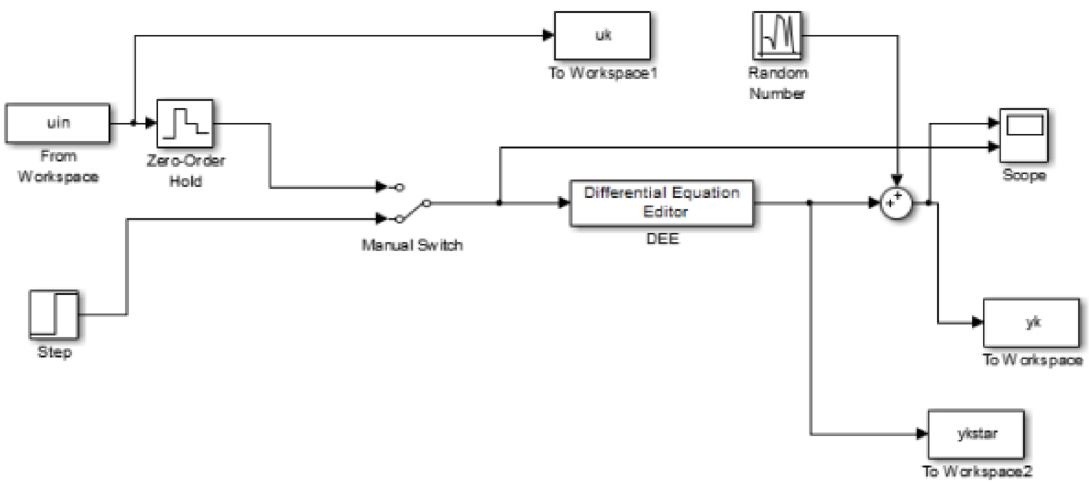

Figure 1.2 SIMULINK model of the system

All system parameters and conditions are preliminary set in Model Explorer/Model Workspace (Figure 1.3)

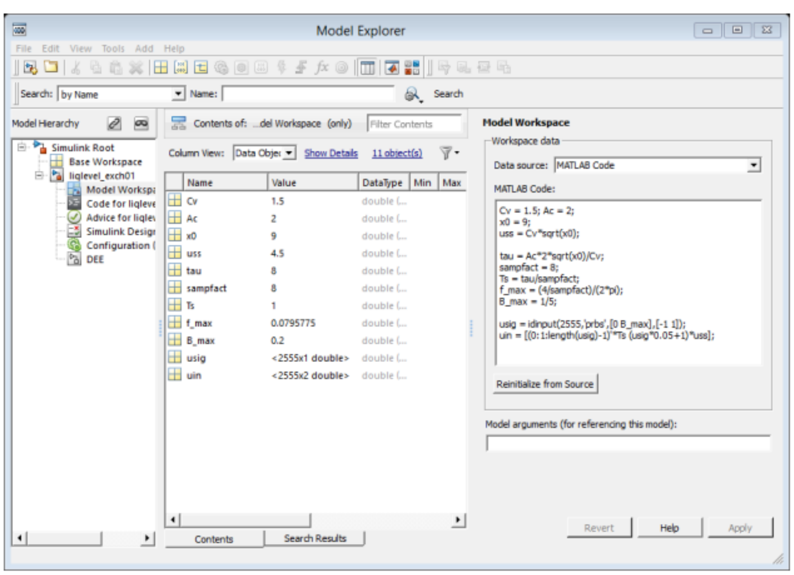

Figure 1.3 Model Explorer

Two types of inputs are intended to be used in simulation: discrete-time pseudorandom binary signal (PRBS) and step input (Figure 1.4). They can be switched using "Manual Switch" block.

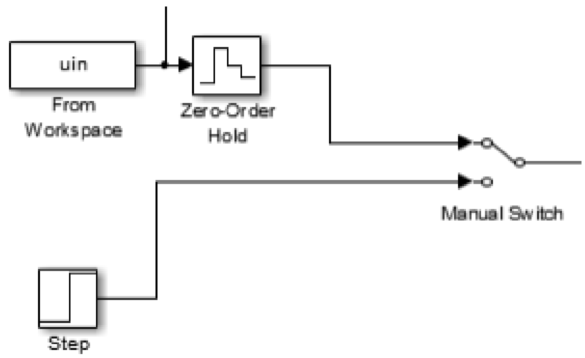

Figure 1.4 System inputs

The response of the sampled-data (ZOH-process-sampler) system is obtained by numerically integrating the non-linear ODE in (1.1) from time t = 0 to t = 2045 and observing at Ts = 1 min. sampling intervals (in the MATLAB / SIMULINK environment).

The solution of the equation is performed in "Differential Equation Editor" (DEE) block in SIMULINK (Figure 1.5).

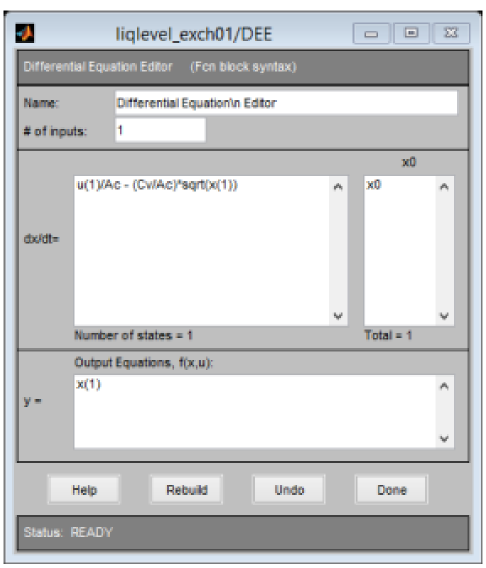

Figure 1.5 "Differential Equation Editor" (DEE) block.

To render the simulation realistic, a measurement error in the form of an ideal random (unpredictable) noise sequence is added to the true response such that the output SNR is set to a value of 10.

The output of the system, together with the desired input can be visualized in the “Scope” block in SIMULINK. In addition, the variables uk, yk and ykstar are transferred to MATLAB workspace using SIMULINK blocks “To Workspace”.

The length of the simulation is set to (length(uin)-1)*Ts, which result in 2555 points in each of the characteristics observed.

3. Tasks:

3.1 Now run the simulation. Observe the input and output characteristics.
3.2 Change the type of the input signal and run the simulation again.
3.3 Add some random noise ($variance = 0.5$) to the output signal and run the simulation again.
3.4 Change the parameters $C_v = 2$, $A_c = 4$, $x_0 = 7$ in the MATLAB code and run the simulation again without a noise added.

4. Questions:

4.1 How would you change the length of the simulation?
4.2 How would you change the system parameters and conditions?
4.3 How would you add white noise to the output of the system?