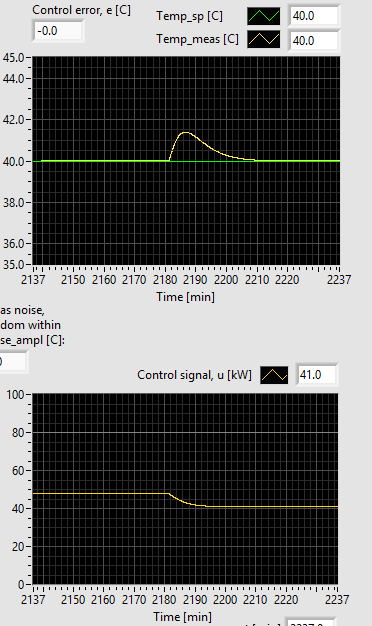
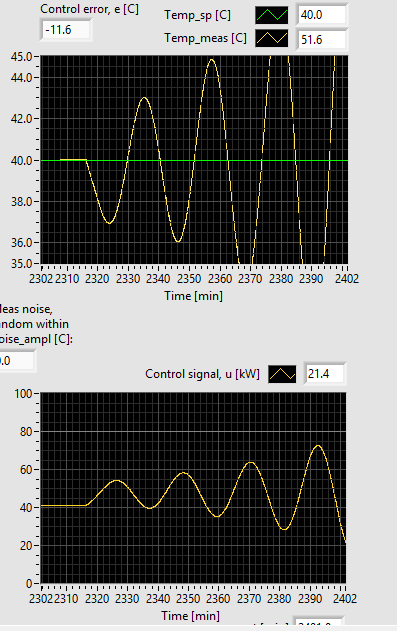
**EXERCISE 1**

**Question 1.**

**a.** **What happens to the stability of the control system if the process time-delay is relatively large?**

When the process time delay is increased, the control system becomes highly unstable. This can be observed be changing the values of process time-delay (T\_delay) in the temperature control simulator.

The process time delay is increased to 200 seconds and a step change is given to the inlet temperature (disturbance) following figures shows the response of outlet temperature for two different values of process time delay.

1. t\_delay = 30 s b. t\_delay = 200s

Figure 1. Response of PIC controller for a. T\_delay=30 s and b. T\_delay = 200s

It can be observed that in case of a process time delay of 30 seconds the PID controller effectively tracks the set-point but for a higher value of process time delay (200s) the system becomes highly unstable.

**b.**

For the PID controller with the following values. Kp = 2 and Ti = 100 a measurement noise of amplitude 0.20 C is provided. The D term is activated and the value is set to Td = 25s.

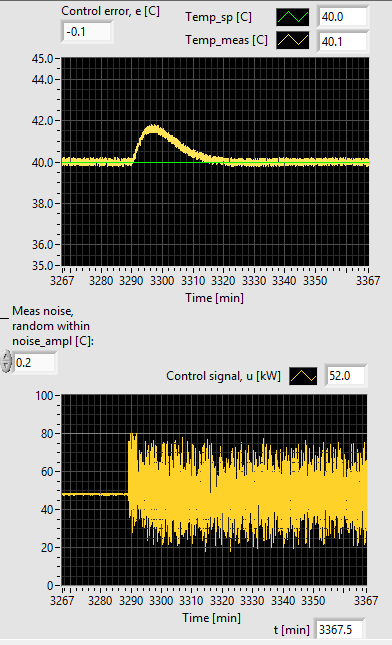
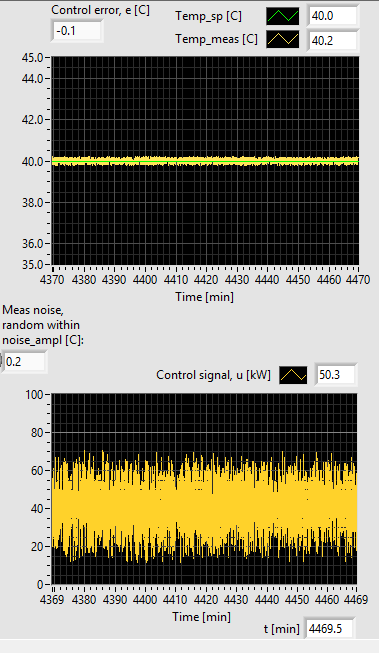
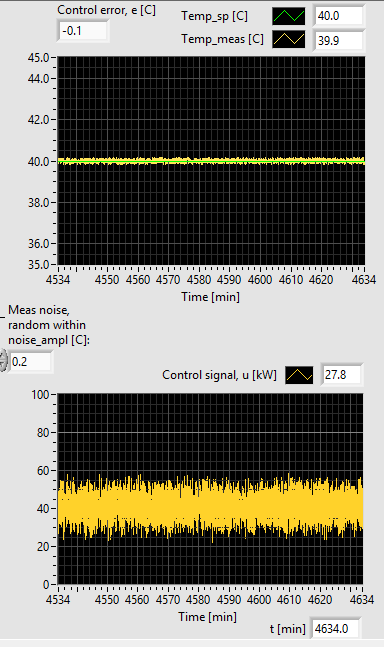


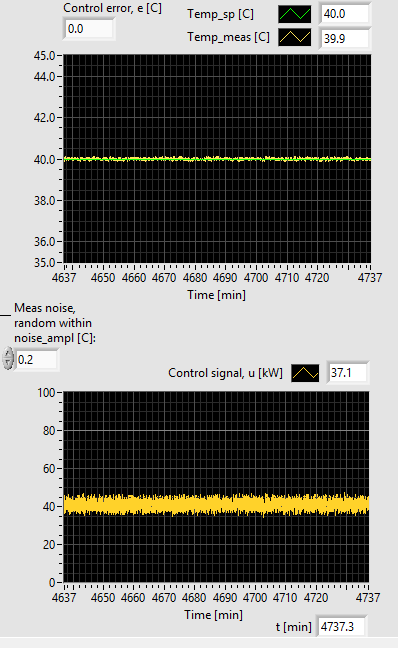
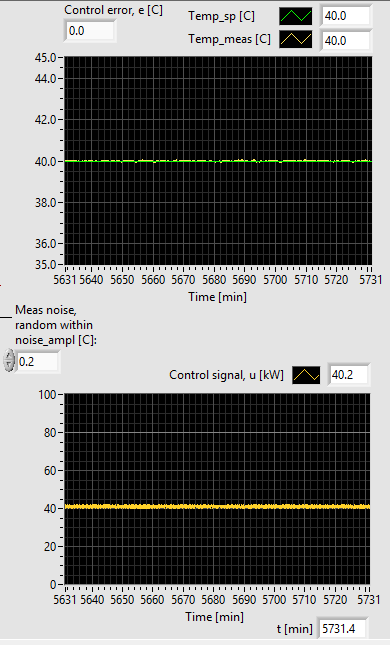
Figure 2. Comparison control signal for PI and PID controller.

Figure 2 shows the difference between the control signal for a PI control and PID controller. At time t = 3290s the derivative term of the controller is changed from 0s to 25s. The addition of a derivative term (D) results in highly aggressive behavior for the controller. The fluctuations in value of the control signal increases.

The measurement filter time constant is increased and the response of the control function to changes in the filter time is presented in Figure 3. Table 3 shows more detailed information on the amplitude of control signal fluctuation and the filter time constant. Increasing the filter time constant decreases the fluctuations in control signal. At a filter time-constant value of 10 seconds the fluctuation are considerably low. Increasing the value further would not cause any significant reduction in the fluctuation; this can be inferred from the values provided in Table 1.

1. t\_filter = 0s b. t\_filter = 1s

1. t\_filter = 5s d. t\_filter = 10s

Figure 3. Control signal response of the system for different measurement filter values

Table 1. Fluctuations in control signal for different values of measurement filter time.

|  |  |  |
| --- | --- | --- |
| Measurement Filter [s] | U\_min | U\_max |
| 0 | 41 | 58 |
| 1 | 42 | 55 |
| 5 | 46.5 | 49 |
| 10 | 47.2 | 48.7 |
| 20 | 47.5 | 48.5 |
| 30 | 47.7 | 48.3 |

**c. Use the On/off controller. Is the mean value of the control error zero or non-zero?**

The on/off controller option is set in the simulator with the default values of u\_min = 0 and u\_max = 80. The controller action is shown in the Figure 4. From looking at the response of the output temperature, the mean value of control error appears to be a non-zero error.

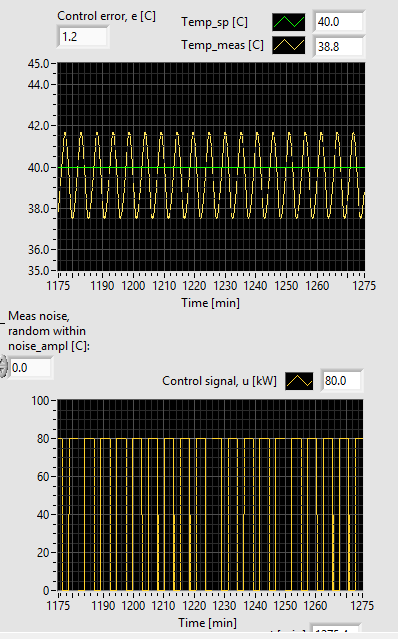


Figure 4. Response of an ON/OFF controller.

**Question 2.**

1. **Derive the transfer function, H(s), from force F to position y.**

Applying Laplace transformation.

Assuming that at t = 0 the values of *y* and are equal to 0.

1. **Try to replicate the responses shown in Figure 2.8 in the textbook by using the lsim function in Matlab.**

The code for implementing the transfer function is attached as an m file (<Problem2b.m>) along with this report. The transfer function H(s) is run using the lsim function and the response is presented in Figure 5. The figure matches the response plot presented in the book.

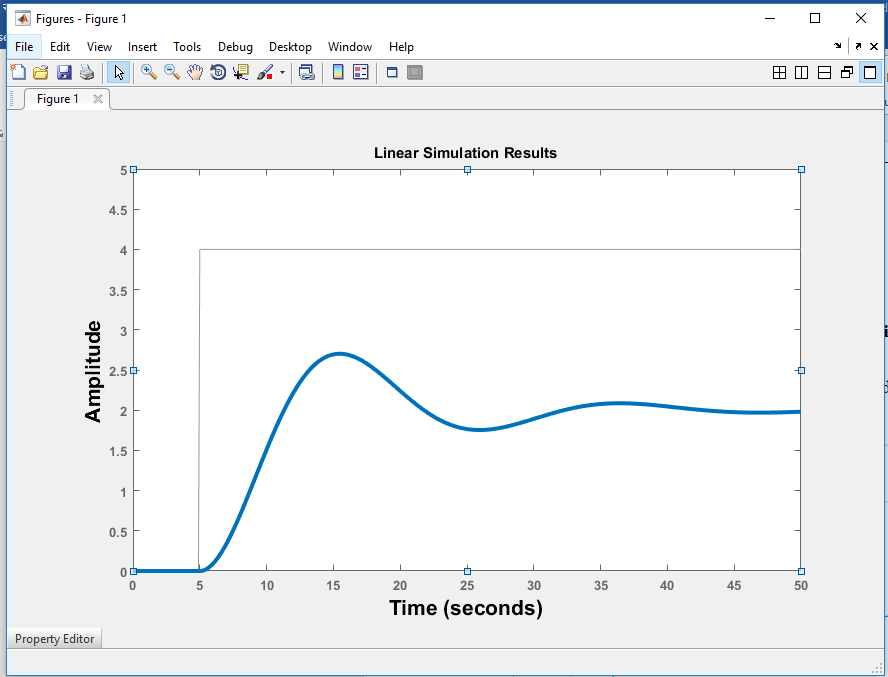
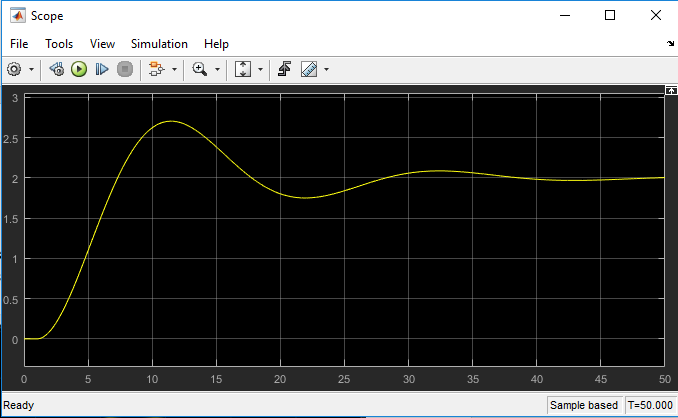


Figure 5. Step response of the transfer function

**c.**

A Simulink file ‘[Problem2C\_sim](Problem2c_sim.slx)’ is created to implement the transfer function H(s). The simulator is run using commands provided in a matlab code presented in the file ‘[Problem2C.m](Problem2c.m)’. The code takes the values of mass of spring, dampening ratio and spring constant and builds the transfer function. It runs the Simulink file using the ‘*sim’* command and the plot is displayed from the scope of the Simulink file. The result of the simulation is presented in the figure below. The plot matches closely to the plot presented in the book.



**Question 3.**

**a.**

The system mentioned in exercise 2.3 is described using the following set of differential equations.

(1)

(2)

The following values are chosen for the parameters mentioned in the equation above.

A1=10 m

A2=15 m

rho=1000 kg/m3

Kp=5 m

Kv1= 2

Kv2= 0.5

g=10 ms-2

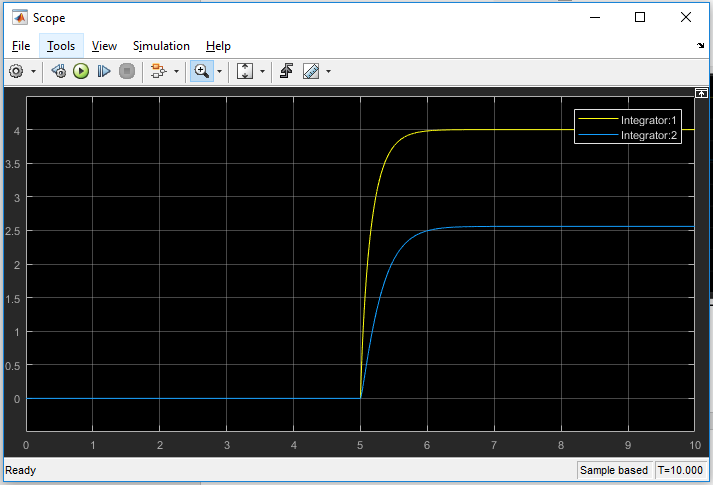
G=1

The system is modeled in Simulink and can be found in the file named ‘[Problem3\_sim](Problem3_sim.slx)’ in the assignment folder. A matlab file is created with the name ‘<Problem3.m>’, which contains values of the parameters as inputs and runs the Simulink file using the *sim* command.

The values of control signals and the value of .

**b.**

The simulation is run with the value of is maintained at ‘0’ for the first 5 seconds and then a step increase from 0 to 80 is provided to it. The figure below gives the response of the tank level caused by the step change in control signal.





From the Simulink model, the values of levels in the tank are as follows

*h1 =* 4.00 m

*h2 =* 2.56 m

At steady state the differential terms of the equation becomes 0. Therefore, the steady state equations are as follows.

*From Equation 1*

*From Equation 2*

The analytical solution at steady states matches the values obtained from the simulations.