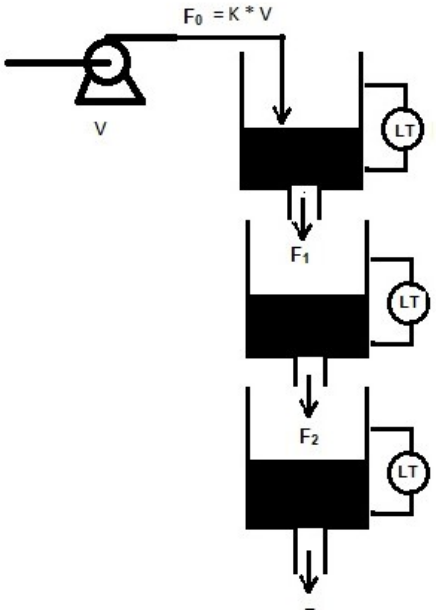
Process Simulation & Control using MATLAB and SIMULINK

Mathematical Model of tank level system

$$\frac{dh_1}{dt} = \frac{F_0}{A_1} - \frac{a_1}{A_1}\sqrt{2gh_1}$$

$$\frac{dh_2}{dt} = \frac{a_1}{A_2}\sqrt{2gh_1} - \frac{a_2}{A_2}\sqrt{2gh_2}$$

$$\frac{dh_3}{dt} = \frac{a_2}{A_3}\sqrt{2gh_2} - \frac{a_3}{A_3}\sqrt{2gh_3}$$



Control objective:

Control the 3rd tank level by manipulating pump voltage V, where $F_0 = K\,V$

Add q_2 input flow on the tanks 2 and set q_2 as manipulated variable.

Which one is difficult to control?

Data for Simulation in Matlab/Simulink

A_1, A_3 = 28 cm^2 A_2 = 32 cm^2 V^s = 3 V

a_1 = 0.06725 cm^2 a_2 = 0.05683 cm^2
a_3 = 0.07089 cm^2 K=3.14

Creating S function

1. In Matlab Command window type <edit sfuntmpl>

   >> edit sfuntmpl

2. It will open sfuntmpl.m file.
3. First line of the file is

```
function [sys,x0,str,ts,simStateCompliance] = sfuntmpl(t,x,u,flag)
```

4. Nice documentation is provided in this file describing the features.
5. Change the name of function ‘sfuntmpl’ to your function name. For eg., change to ‘tank3f’
6. Save the file in your working folder as tank3f.m

Creating S function (initialization)

7. Now edit the file as per your system of equations.
8. Do not change in the main function, i.e, tank3f function.
9. Initialization should be done in the

function [sys,x0,str,ts,simStateCompliance]=mdlInitializeSizes

This system consist of 3 continuous state (h_1,h_2, h_3) and 1 input (V)and 1 output variables (h_3). We will consider all 3 state as output variables.

Change statements in the function mdlInitializeSizes

```
sizes.NumContStates  = 3;
sizes.NumOutputs     = 3;
sizes.NumInputs      = 1;
x0 = [10.00042; 14.003851; 8.9998];   % initial condition
```

Creating S function (derivative)

Differential equations should be entered in

function sys=mdlDerivatives(t,x,u)

- h1=x(1); %state 1: height in tank 1
- h2=x(2); %state 2: height in tank 2
- h3=x(3); %state 3: height in tank 3
- F1=u; % Flow
- % All the necessary parameters
- A1=28;
- A2=32;
- A3=28;
- a1=0.06725;
- a2=0.05683;
- a3=0.07089;
- g=981;
- % Parameters end

Creating S function (derivative)

% Compute xdot:

- dh1dt =F1/A1 - (a1/A1)*sqrt(2*g*h1);
- dh2dt = (a1/A2)*sqrt(2*g*h1) - (a2/A2)*sqrt(2*g*h2);
- dh3dt = (a2/A3)*sqrt(2*g*h2)-(a3/A3)*sqrt(2*g*h3);
- sys = [dh1dt;dh2dt;dh3dt];

sys=[der1;der2];

% end mdlDerivatives

Creating S function (output)

Output from the s-function block is defined in function

sys=mdlOutputs(t,x,u)

If all state variables are also output variables, i.e, h_1, h_2, h_3 are also output then write the function as below:

```
function sys=mdlOutputs(t,x,u)

sys = x;

% end mdlOutputs
```

If output variable is only h_3 or x(3) then write function as below:

```
function sys=mdlOutputs(t,x,u)

sys = x(3) ;

% end mdlOutputs
```

Simulink model

1. Save the tank3f.m after writing the functions as described in earlier slides.
2. Open Simulink model either

   typing <simulink> in the command window

   >> simulink

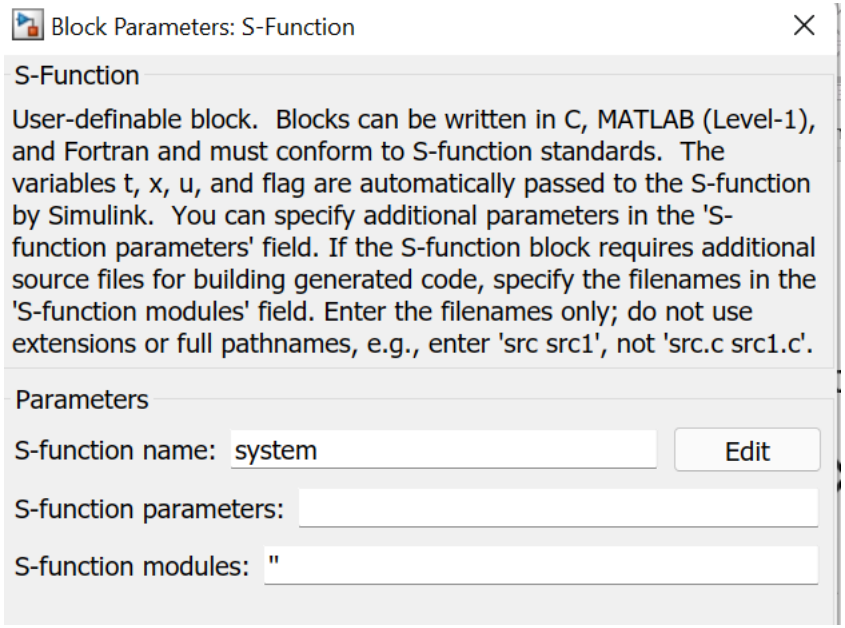
   or click <Home> -> <new> -> <simulink model>
3. Click on <blank model> to open blank model
4. Open library browser under tools menu. This will open built-in library function block available
5. Drag the s-function block from the library browser to the model window.

Simulink model

This will show in the model window as below

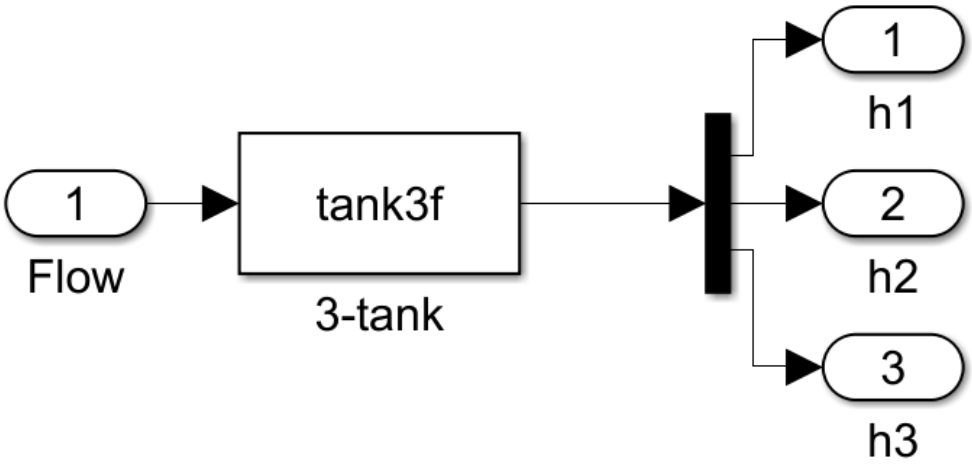
The system name should be changed by double clicking on the s-function block in the model window

Change the s-function Name from ‘system’ to ‘tank3f’.



Simulink model

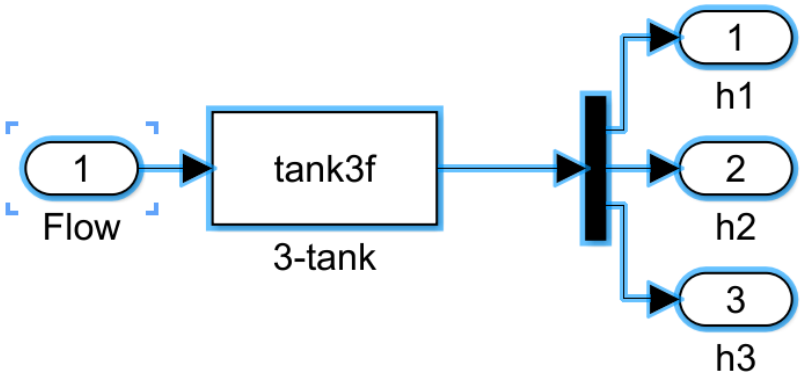
Now add input and output connection to the block.



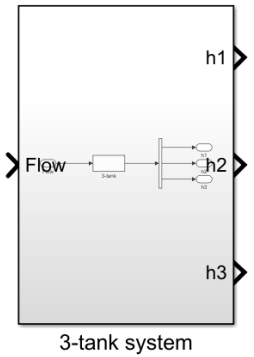
We also add one input port block (‘In 1’) and rename them as ‘Flow’.
Similarly for three output (h_1, h_2 and h_3) from the block we use ‘Demux’ block from library browser.
Connect the Demux block with 3 output port block (‘out 1’) and rename them h_1, h_2, h_3.

Simulink model (subsystem creation)

Select all the elements and block by pressing <ctrl> and A at the same time.

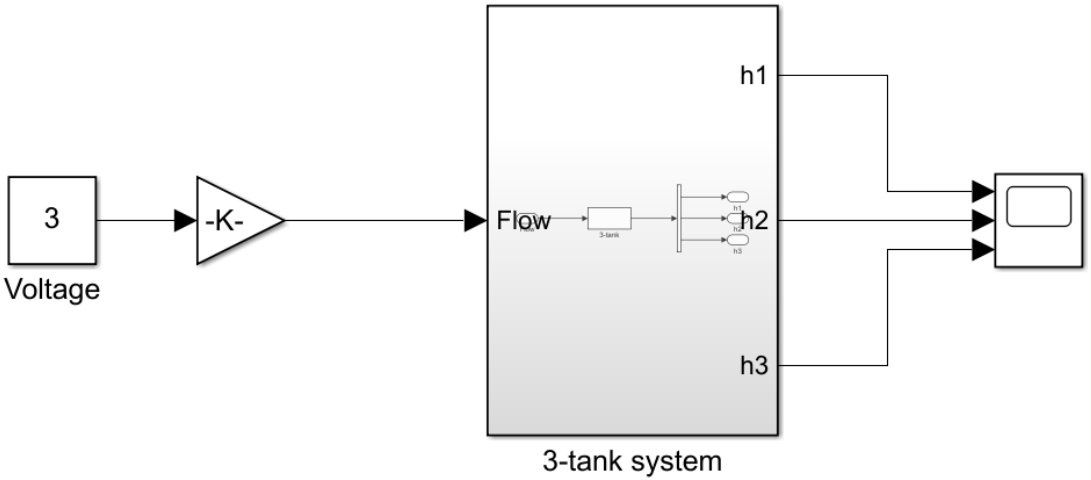


Create subsystem by clicking on ‘Create Subsystem’ under diagram menu and remove the ports and connecting lines.



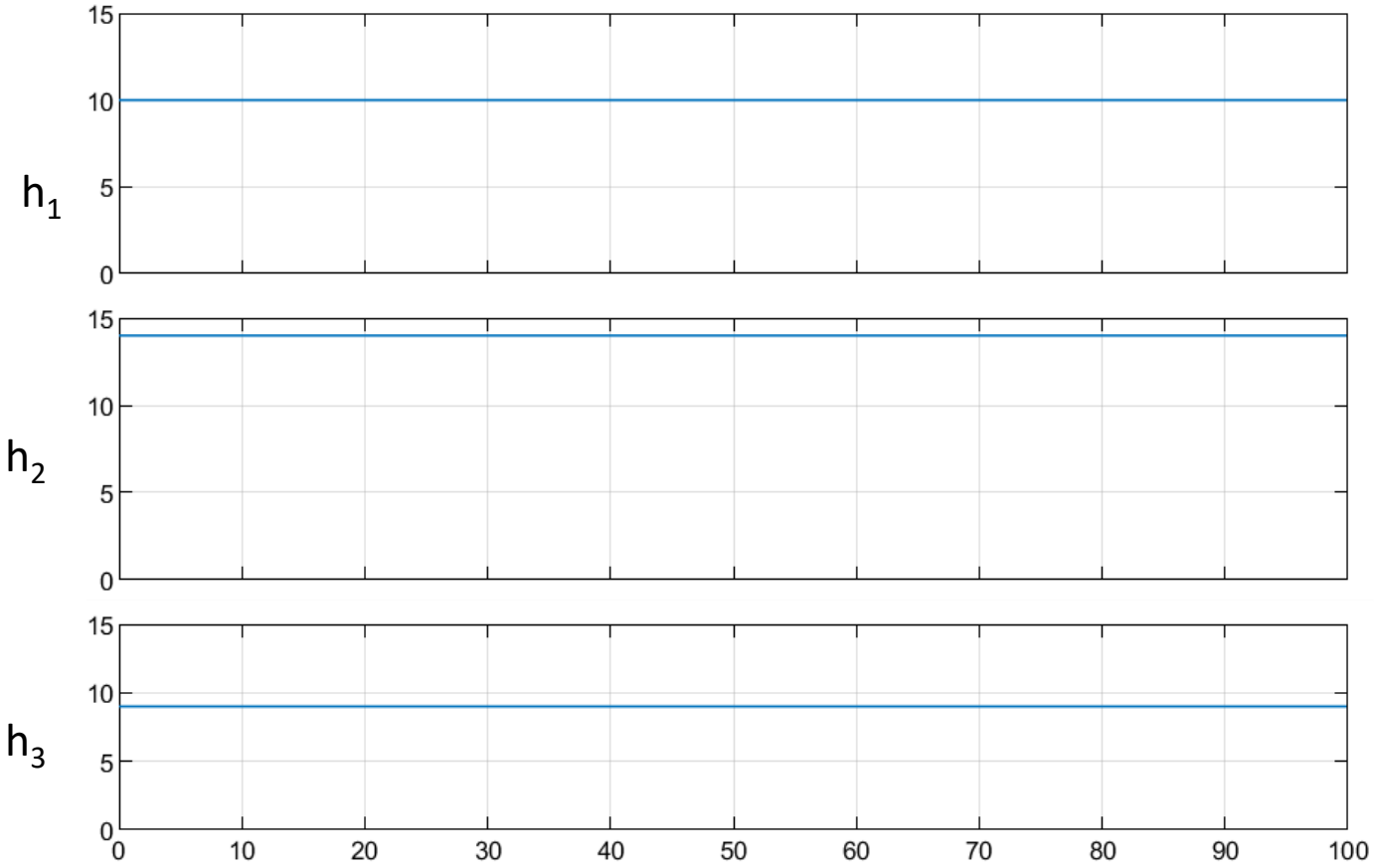
Simulink model (running 3-tank model)

Add input connection to the 3-tank system for Flow using ‘gain’and ‘const’ block and set values of gain as 3.14 and const as 3.
Add ‘Scope’ block, modify scope block with 3 input port and connect outpout ports of 3-tank system block



Simulink Model 3-tank (Result)

Run the simulation for 100 mins



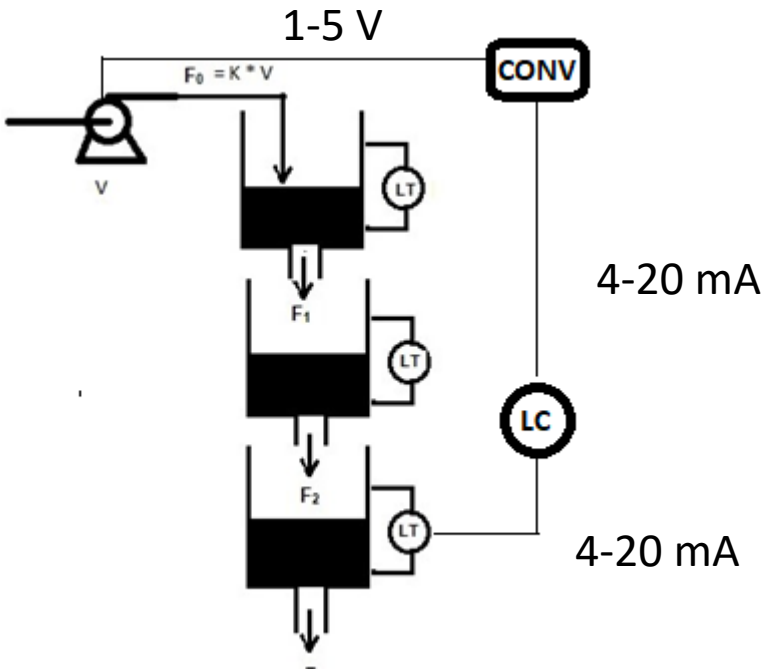
Process with instrumentation

The simulation of the 3-tank level system is the basic process simulation where no instruments are attached to the process.

Most of the time we do control analysis based on this kind of process behavior/simulation because instrument gain and dynamics are neglected.

However, it is advised to include instrument dynamics in the overall process behavior so that any disturbances/noise due to instruments can be considered while designing/tuning the control system.

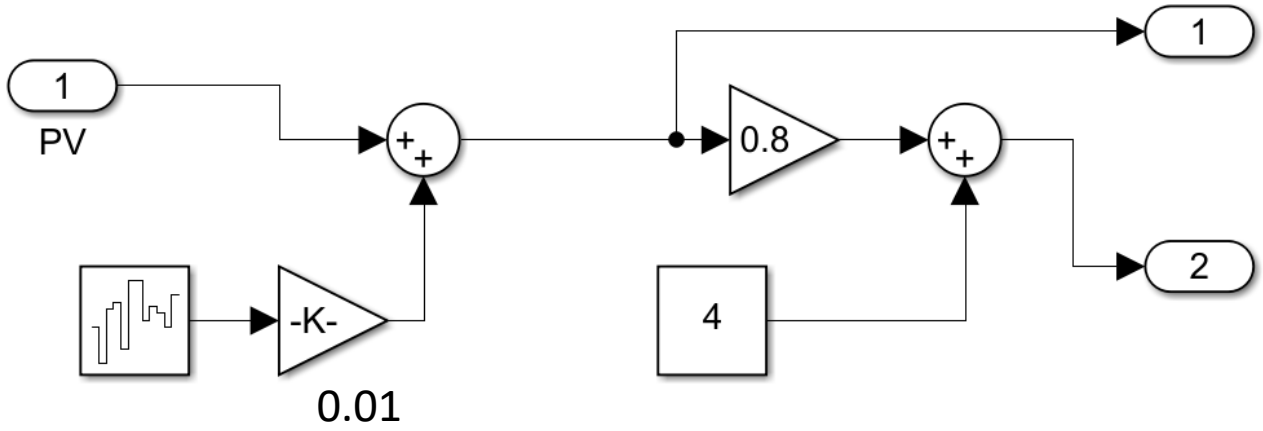
Process with instrumentation



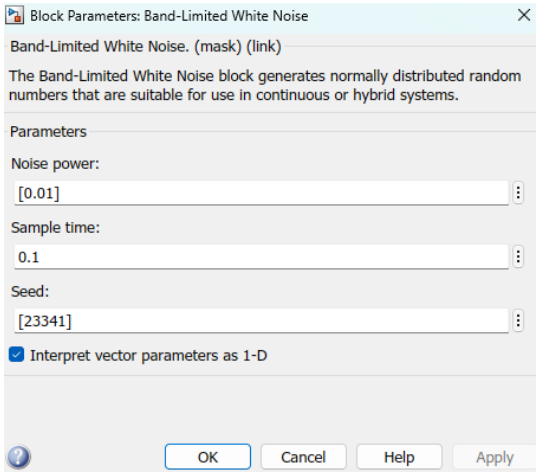
Composition Analyzer

1. What should be the gain of the level measurement?
2. What is the measurement noise?
3. What is the measurement delay?

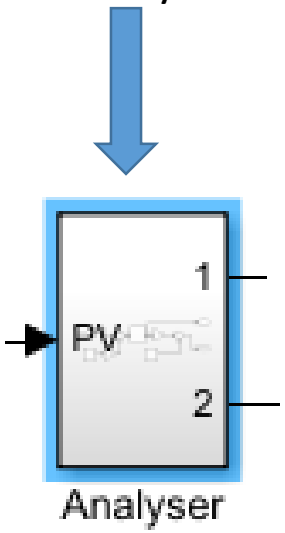
Sensor block : Simulink diagram



Noise signal



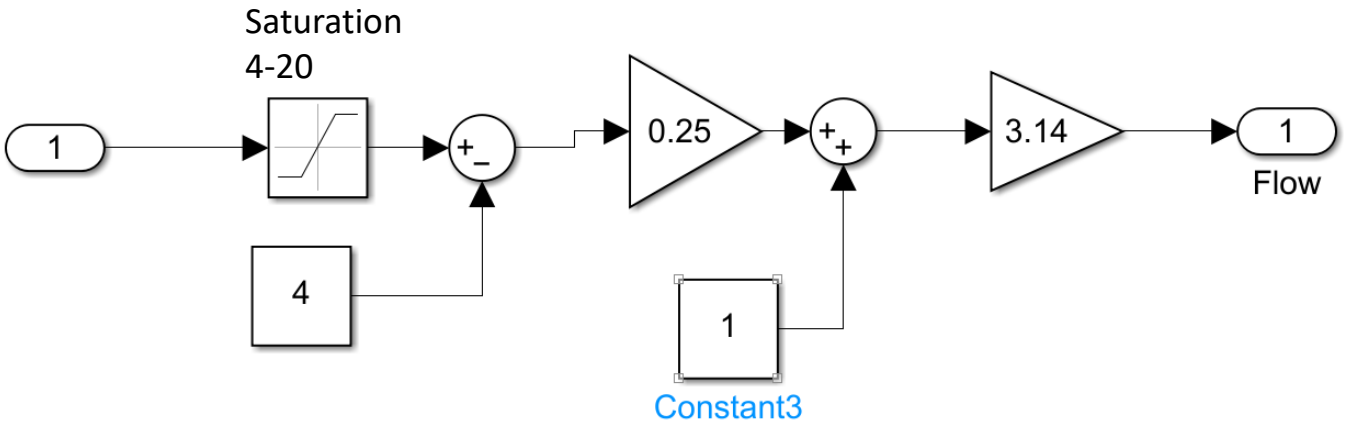
Create Subsystem



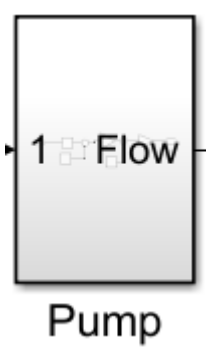
Level measurement Gain

Input : 0-20 cm
Output : 4-20 mA
Gain = 16/20 = 0.8

Pump: Simulink Diagram



Create
Subsystem



PID Controller Block

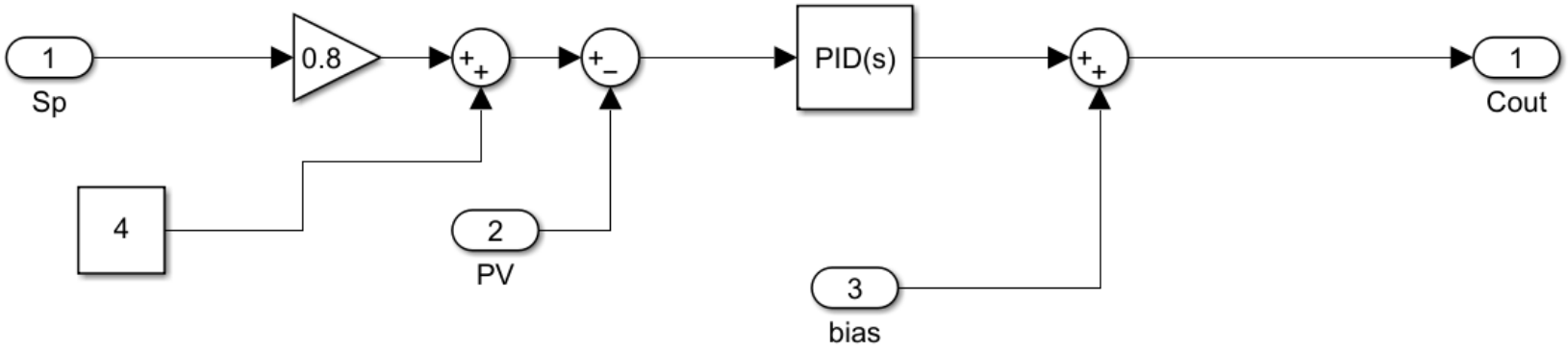
Simulink has a built-in PID controller block.

This block can be configured as P or PI or PD or PID controller

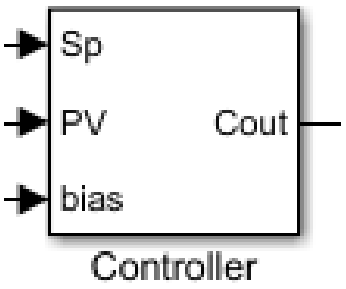
However, this block needs to be augmented with setpoint and bias.

Since, setpoint will be given in terms of process variable, measurement block gain needs to be included.

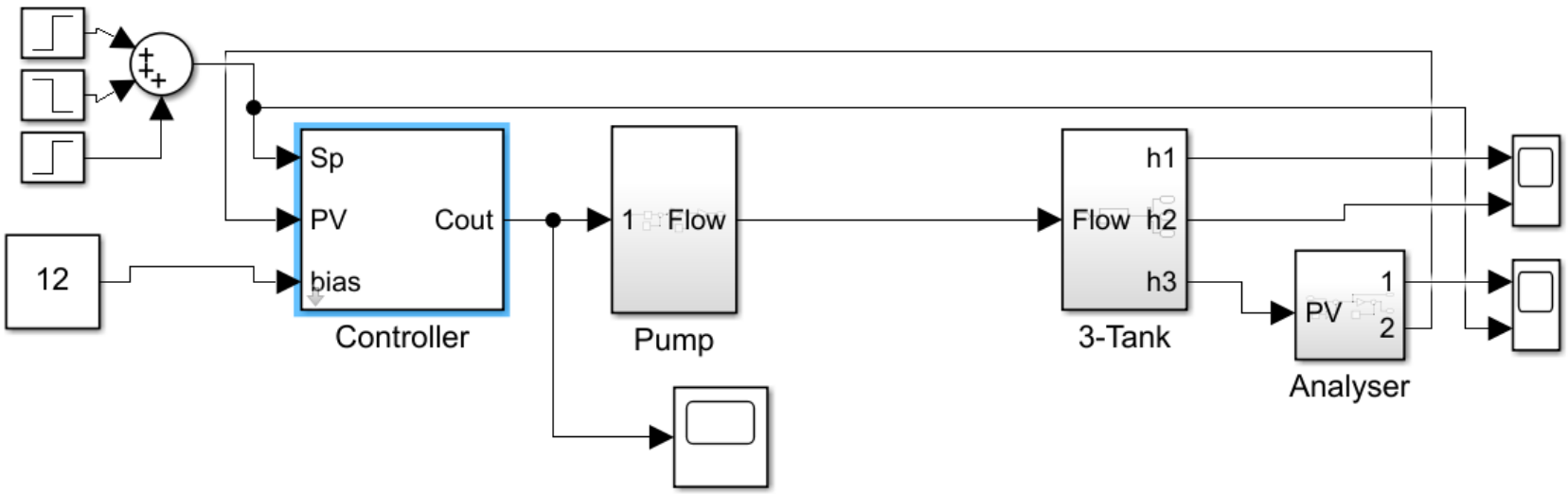
PID Controller: Simulink



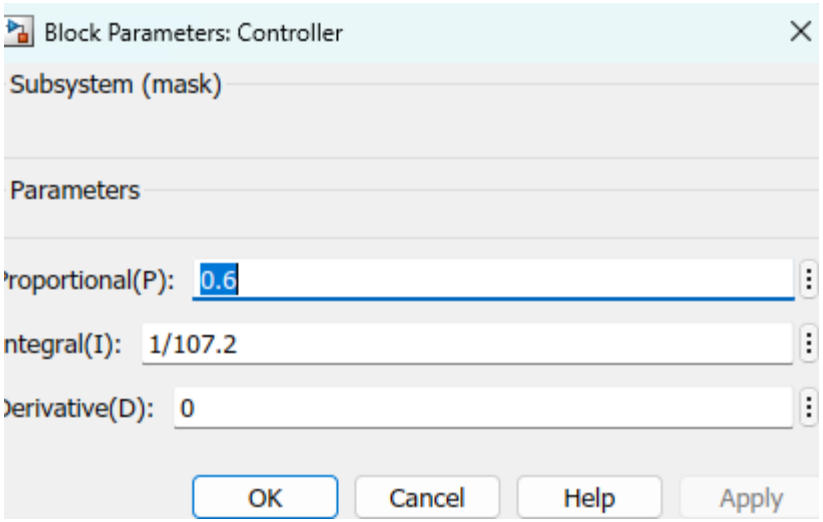
Create
Subsystem

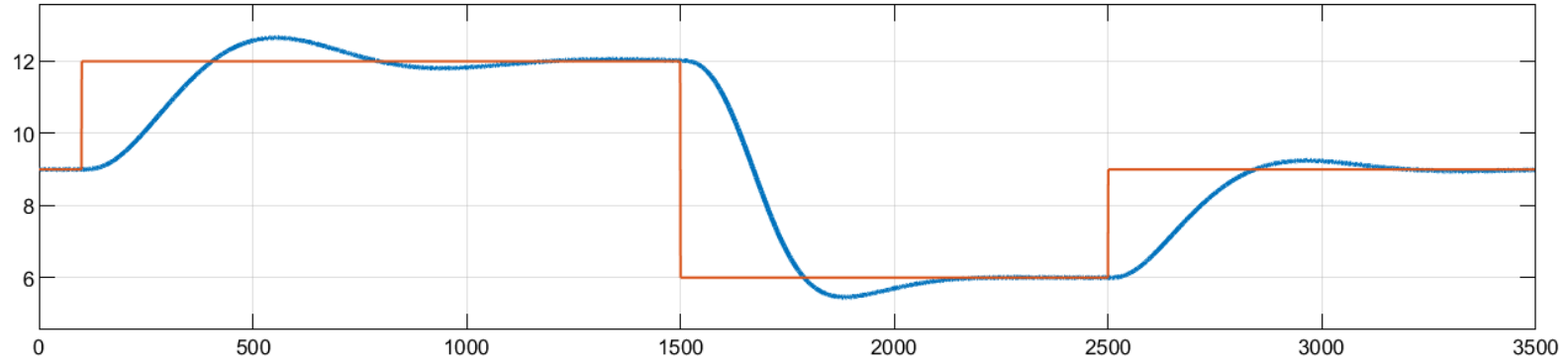


Feedback Control Block diagram in Simulink

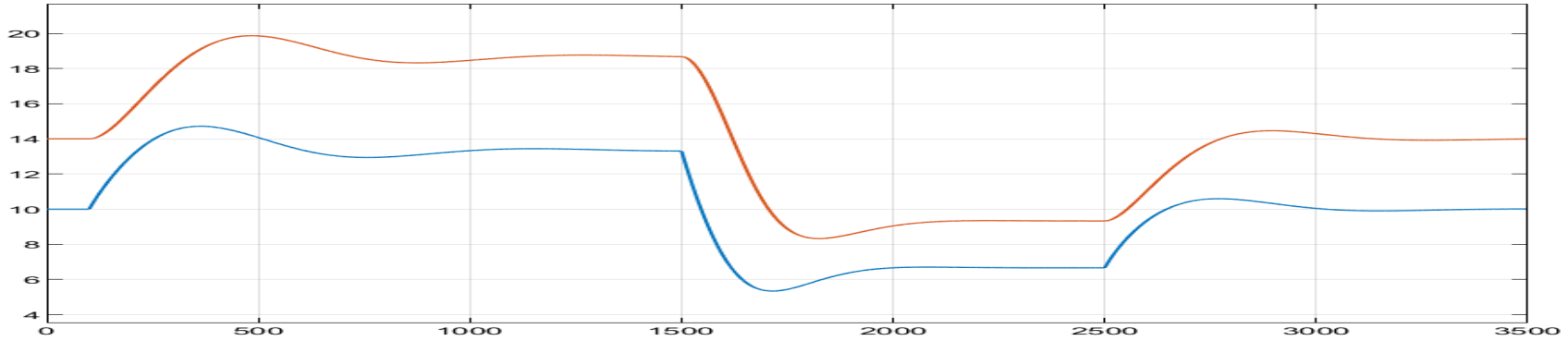


Proportional Gain : 0.6
Integral Time constant : 107.2





3rd tank level under PI control



1st and 2nd tank level