Short Tutorial on Matlab

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Part 4. Subsystems in Simulink®

Suppose we want to model the control of the temperature and flow rate as shown in Figure 1.

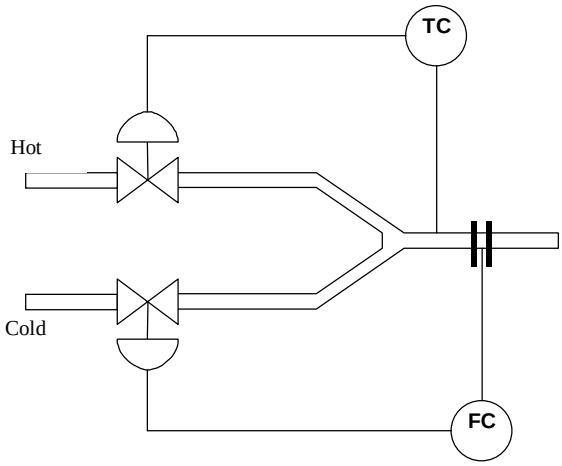

Figure 1.

where the temperature of the flow out is described by the following equation:

$$dT/dt = [\ F_{hot}\ T_{hot}\ +\ F_{cold}\ T_{cold} - (F_{hot} + F_{cold})T\ ]/V$$

and we will control the flow F by manipulating F_{cold} and control the temperature T by manipulating F_{hot}. (For our example, we will use V=0.5).

1. Model the temperature mixing process.

a) Load the blocks and change their names and parameters as given in Table 1.

Remarks:

i) To rename a block, double-click the name and then change the text.
ii) To change the direction of the ports in **`Mult3`** block, right click and the select [**`Format`**]→[**`Rotate block`**] twice.
iii) To change the direction of the outport of block **`Sum1`**, right-click and select [**`Format`**]→[**`Rotate block`**] once.

b) Next, layout the blocks and connect the blocks to match Figure 1.

Table 1.

Simulink Sublibrary	Blocks	Name	Parameters
Sources	**In1**	F_hot	Port number: 1
Sources	**In1**	T_hot	Port number: 2
Sources	**In1**	T_cold	Port number: 3
Sources	**In1**	F_cold	Port number: 4
Sinks	**Out1**	T	Port number: 1
Sinks	**Out1**	F	Port number: 2
Math Ops	**Product**	Mult 1	
Math Ops	**Product**	Mult 2	
Math Ops	**Product**	Mult 3	
Math Ops	**Gain**	1/V	Gain: 2
Math Ops	**Sum**	Sum	List of signs: | + +
Math Ops	**Sum**	Sum1	List of signs: + + -
Continuous	**Integrator**	Integrator	Initial Cond: 60

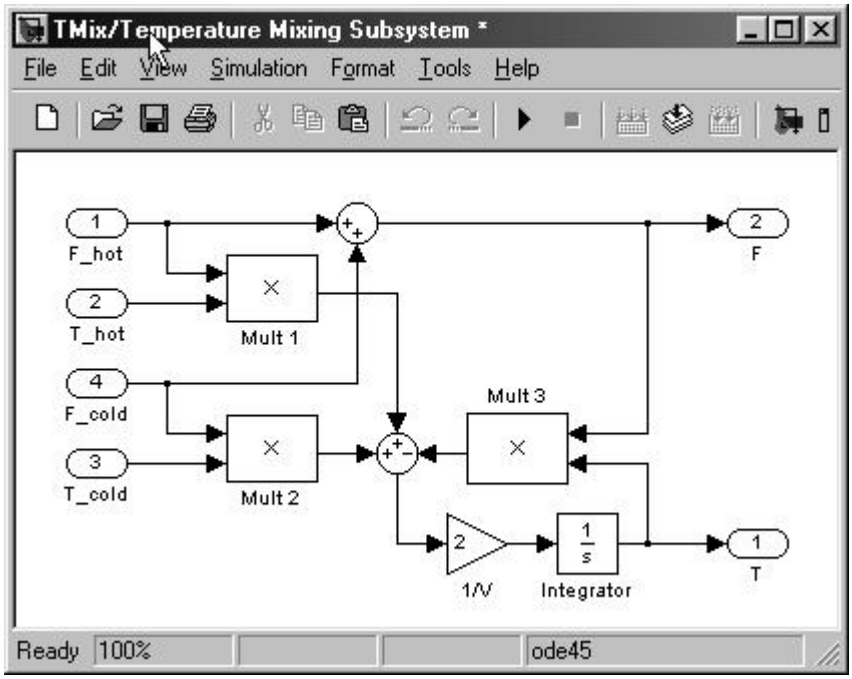

Figure 1.

2. Group the blocks into a subsystem.

a) From the menu, select [**Edit**]→[**Select All**].
b) From the menu again, select [**Edit**]→[**Create Subsystem**].
c) Rename the subsystem to be : **Temperature Mixing Subsystem.**

d) Resize the subsystem and move the inports and outports so they match Figure 2.

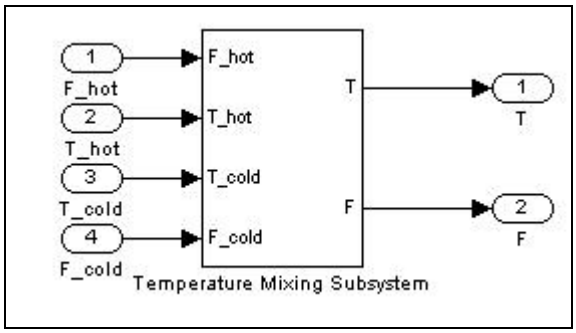

Figure 2.

Note: You can "open" the subsystem by double-clicking the subsystem block. (you can continue to edit the subsystem when the subsystem is opens as a separate window).

3. Create the PI controller subsystems.

a) From the Simulink Library Browser, go to the **`Ports & Subsystems`** subdirectory.
b) Click-drag the **`Atomic Subsystem`** block into the Model window.
c) Rename this block: **`PI Temperature Controller`**
d) Open the subsystem block (by double-clicking the subsystem block).
e) Delete the line connecting **`In1`** block and **`Out1`** block.
f) Rename **`In1`** as **`error`** , and **`Out1`** as **`u`**.
g) Next, insert blocks into this subsystem window as prescribed in Table 2.
h) Fix the block layout and connections between blocks to match Figure 3.

Table 2.

Simulink Sublibrary	Blocks	Name	Parameters
Sources	**`Constant`**	Integral Time	Constant value:10
Sources	**`Constant`**	u_bias	Constant value:0.5
Math Ops	**`Sum`**	Sum	List of signs: | + +
Math Ops	**`Sum`**	Sum1	List of signs: | + +
Math Ops	**`Product`**	Product	
Math Ops	**`Gain`**	Kc	Gain: 0.05
Math Ops	**`Math Fcn`**	Reciprocal	Function: reciprocal
Continuous	**`Integrator`**	Integrator	Initial Cond: 0

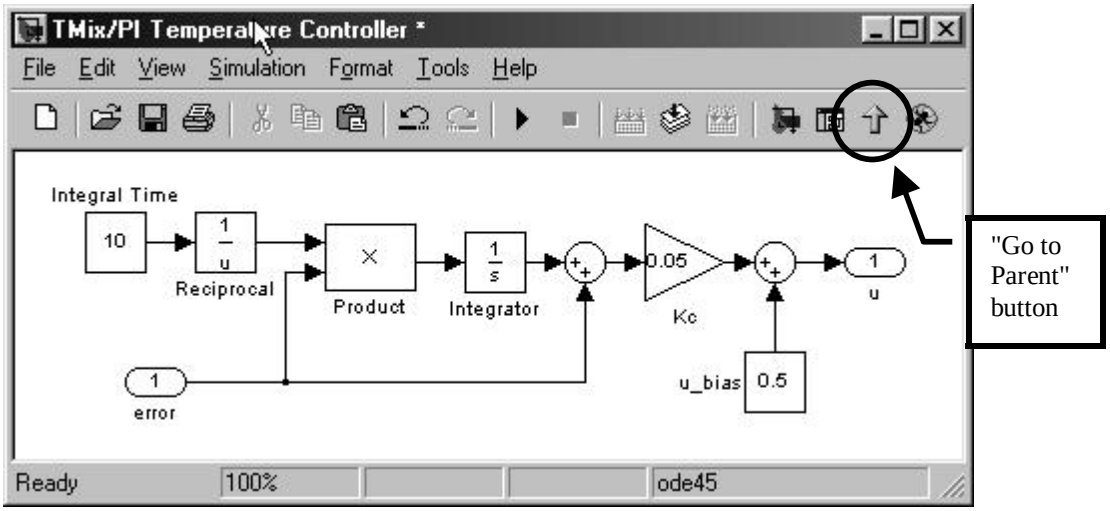

Figure 3.

i) Click on the "**`Go to Parent`**"-button. This would send you back to the Model window.
j) Right-click on "**`PI Temperature Controller`**" and select [**`Copy`**]. Right-click at a different position in the Model window and select [**`Paste`**]. Rename the new subsystem block as "**`PI Flow Controller`**".
k) Go back to the Simulink Library Browser and add some more blocks into the Model window as described in Table 3.

Table 3.

Simulink Sublibrary	Blocks	Name	Parameters
Continuous	**Transfer Function**	Valve 1	Numerator:[20] Denominator: [0.01, 0.14, 1]
Continuous	**Transfer Function**	Valve 2	Numerator:[20] Denominator: [0.01, 0.14, 1]
Sources	**Constant**	T_set	Value: 65
Sources	**Constant**	F_set	Value: 20
Sources	**Constant**	T_hot	Value: 70
Sources	**Constant**	T_cold	Value: 50
Sinks	**To Workspace**	T	Save Format: Array
Sinks	**To Workspace**	F	Save Format: Array
Discontinuities	**Saturation**	Sat1	Upper Limit: 1 Lower Limit: 0
Discontinuities	**Saturation**	Sat2	Upper Limit: 1 Lower Limit: 0
Math Ops	**Sum**	Sum1	List of Signs: **-+|**
Math Ops	**Sum**	Sum2	List of Signs: **|+-**

Remark: This means a valve transfer function which is slightly under-damped.

l) Next, delete all **inport** (1,2,3,4) and **outport** (1,2) blocks.
m) Reposition and connect the blocks to match the Model window shown in Figure 4.

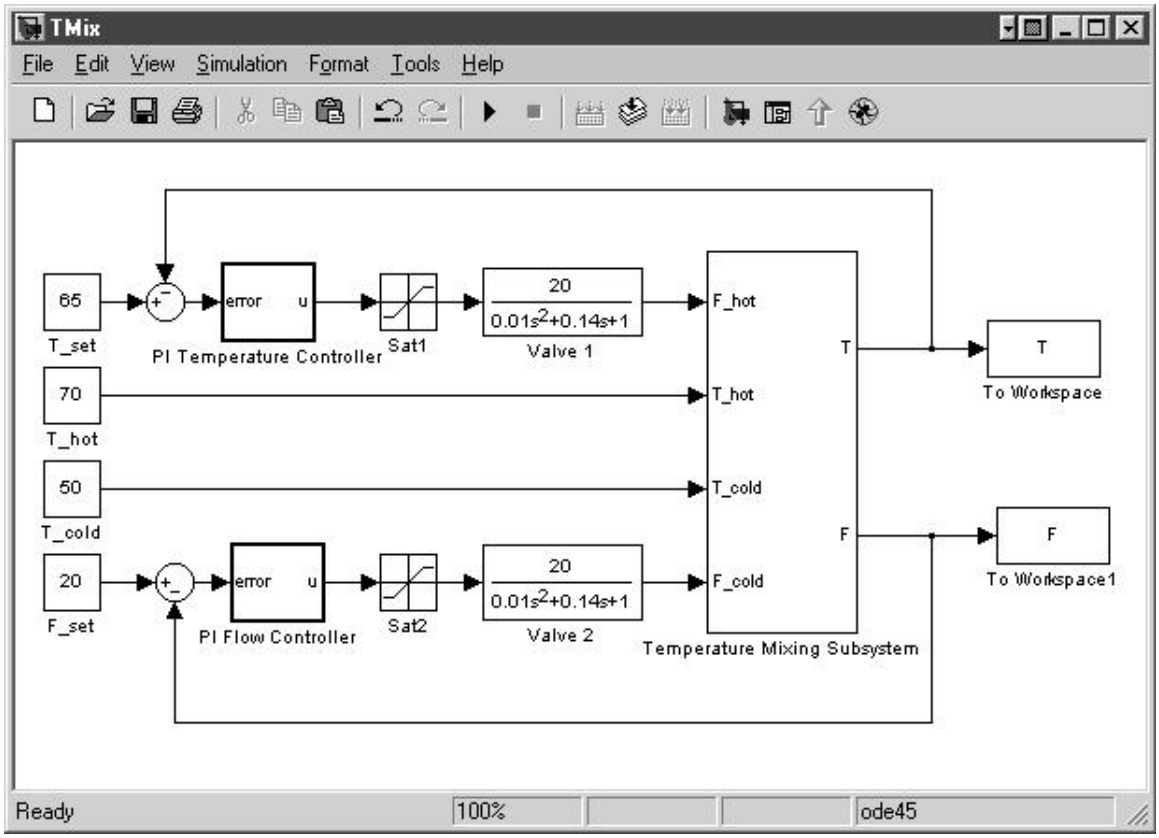

Figure 4.

n) Run the simulation and plot out the response of T and F.
o) Change the values for the PI ontrollers to improve the response. One possible set of tuning variables are:

	Temperature Controller	Flow Controller
Kc	0.1	0.1
Integral Time	2	5