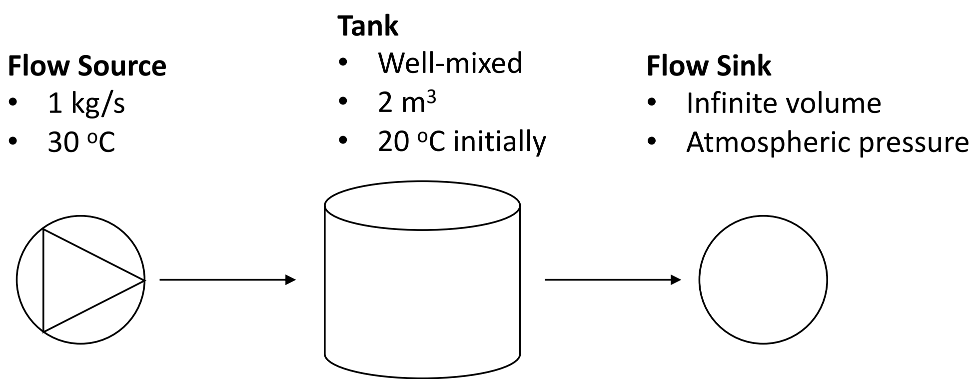
# Modelica Buildings Library Tutorial with Modelon IMPACT

Presented at the 14th International Modelica Conference

9/20/2021

## Part I: Simple Thermofluid System

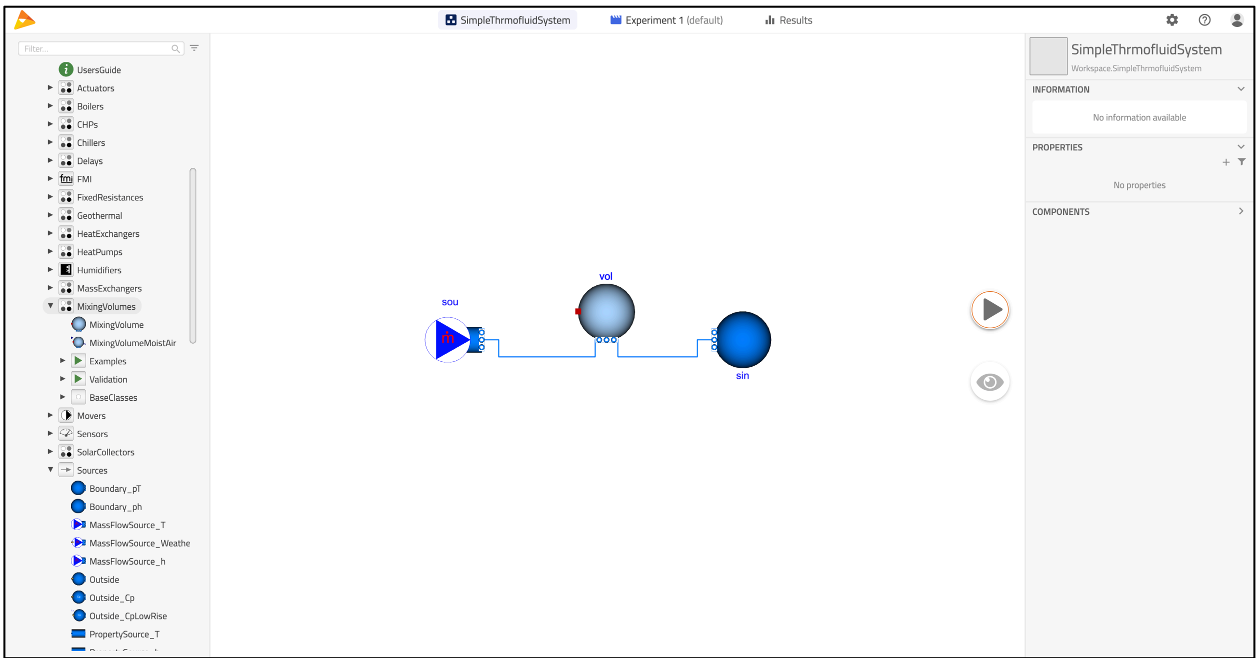
Let's start by implementing a simple thermofluid system model consisting of a water flow source of 1kg/s water at 30 $^oC$, a well-mixed tank with no heat loss, a volume of 2 $m^3$, and an initial temperature of 20 $^oC$, and an infinite-volume flow sink that is at atmospheric pressure. A schematic of such a system is presented in the Figure below. It is maybe useful to think of the flow source as a pump with an infinite supply of water.

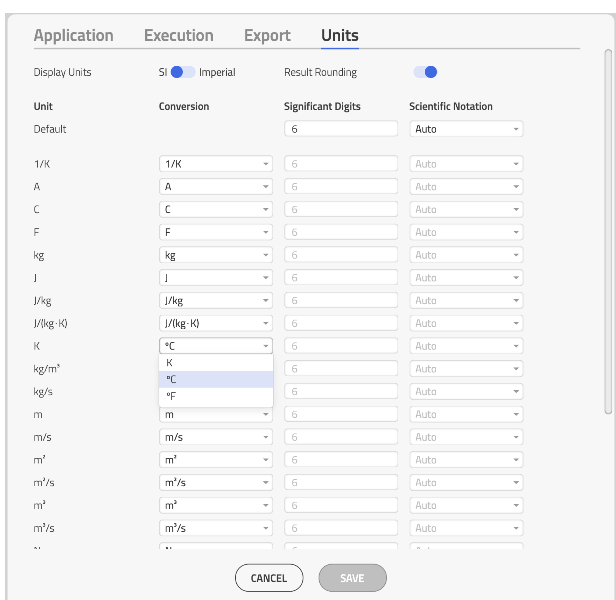



We use three component models for an ideal flow source, a mixing volume, and a flow boundary condition. Then, we'll use what is known as a media model (or medium), which is a collection of algebraic equations for thermodynamic variables used to specify to each of the first three components that water is flowing through them (as opposed to air or some other fluid). To implement the system model, drag and drop the component models defined in the table below. Then, parameterize them as described in the table. Finally, connect the components as you see in the diagram.

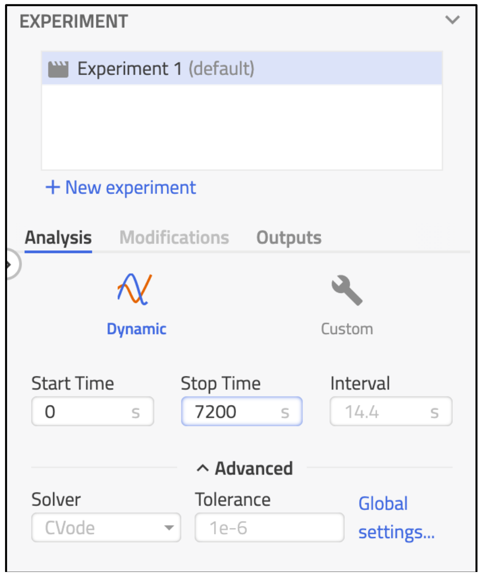
Temperature parameters are defined below in Kelvin, but you can change the unit settings in IMPACT to specify temperatures in $^oC$. This will also make result plots of temperature variables in $^oC$ later on.

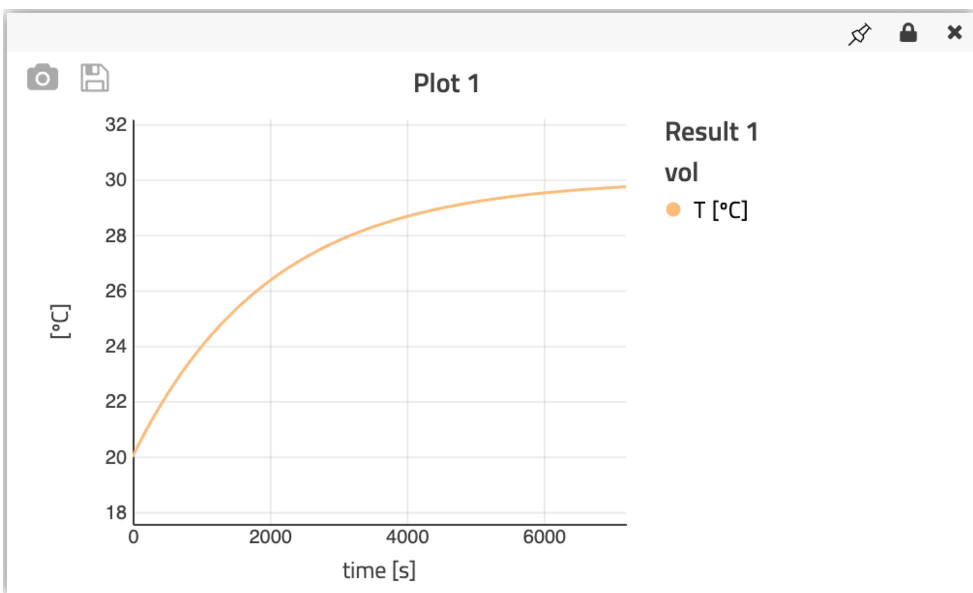
| Component Model | Name | Description | Parameters |
|---|---|---|---|
| Buildings.Fluid.Sources.MassFlowSource_T | sou | Ideal flow source | General<br>• Medium=Water<br>• m_flow=1<br>• T=273.15+30 |
| Buildings.Fluid.Sources.Boundary_pT | sin | Infinite flow sink | • Medium=Water |
| Buildings.Fluid.MixingVolumes.MixingVolume | vol | Mixing volume | • Medium=Water<br>• V=2<br>• m_flow_nominal=1 |



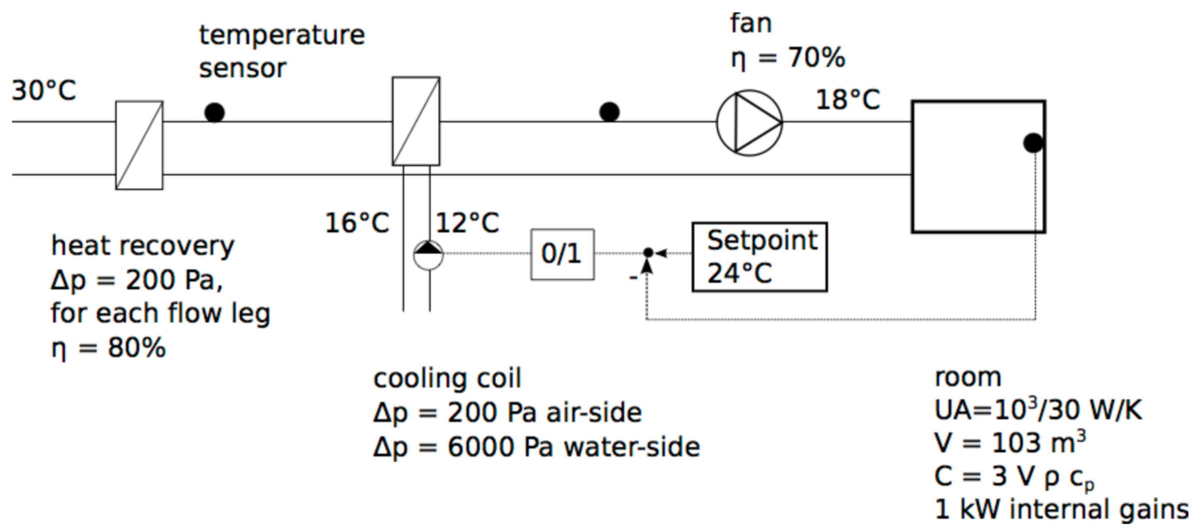
Now let's simulate the model for 2 hours and see how the temperature of the water in the tank changes over time. Set up the experiment so the start time is 0 s and final time is 7200 s. Then, simulate the model and plot the results.



## Part II: Space Cooling Tutorial

This tutorial is adopted from the SpaceCooling tutorial from the Modelica Buildings Library. We will implement a space cooling system with supply fan, cooling coil, fresh air supply with heat recovery, and space temperature control. The system diagram is shown in below.

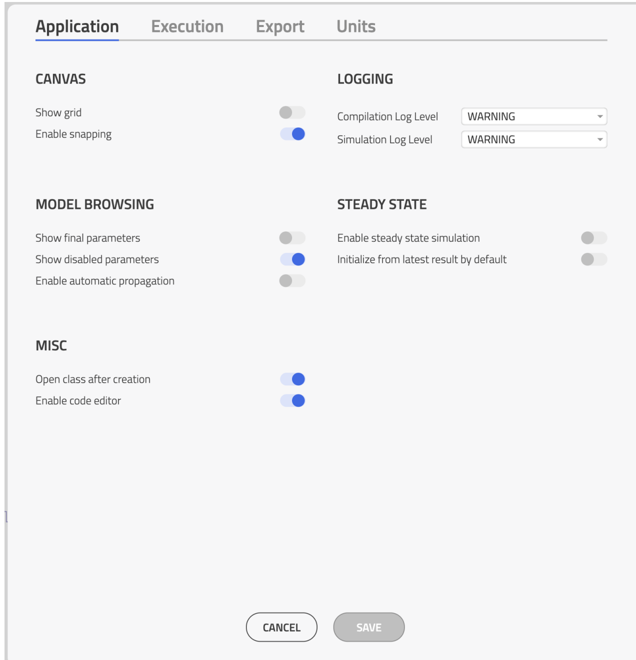


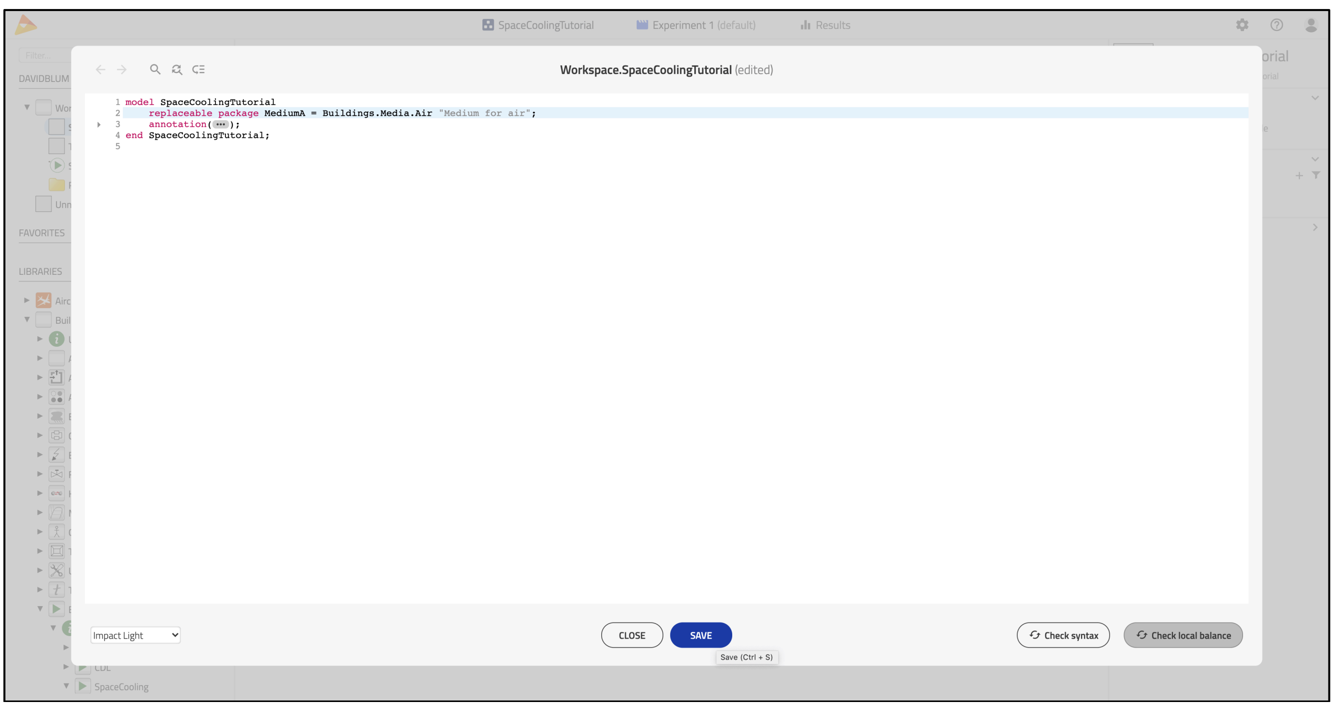

## 1. Room Model

We will first implement the room model, represented by a volume of air with an enlarged heat capacity to account for internal thermal mass. In furniture and building constructions, prescribed heat source for the internal convective heat gain, and a heat conductor for steady-state heat conduction to the outside.

First, declare a moist air media model at the top level to be able to propagate to lower-level component models. Note that declaring a moist air media model will allow for accounting for humidity variations, particularly across the cooling coil. Declare the media model by first enabling the code editor under “Settings (Gear icon in upper right) > Application > MISC > Enable code editor,” then changing the model view to source code by right-clicking in the canvas and selecting “Edit source”, and then writing the appropriate declaration as follows:

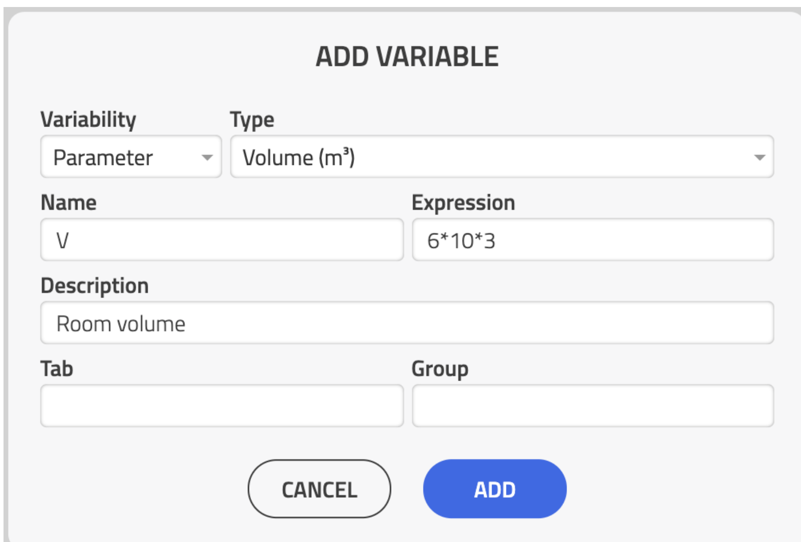
```
replaceable package MediumA = Buildings.Media.Air "Medium for air";
```


Application
Execution
Export
Units
CANVAS
Show grid
Enable snapping
LOGGING
Compilation Log Level
WARNING
Simulation Log Level
WARNING
MODEL BROWSING
Show final parameters
Show disabled parameters
Enable automatic propagation
STEADY STATE
Enable steady state simulation
Initialize from latest result by default
MISC
Open class after creation
Enable code editor
CANCEL
SAVE


SpaceCoolingTutorial
Experiment 1 (default)
Results
Workspace.SpaceCoolingTutorial (edited)
model SpaceCoolingTutorial
replaceable package MediumA = Buildings.Media.Air "Medium for air";
annotation(...);
end SpaceCoolingTutorial;
Impact Light
CLOSE
SAVE
Save (Ctrl + S)
Check syntax
Check local balance
FAVORITES
LIBRARIES
SpaceCooling

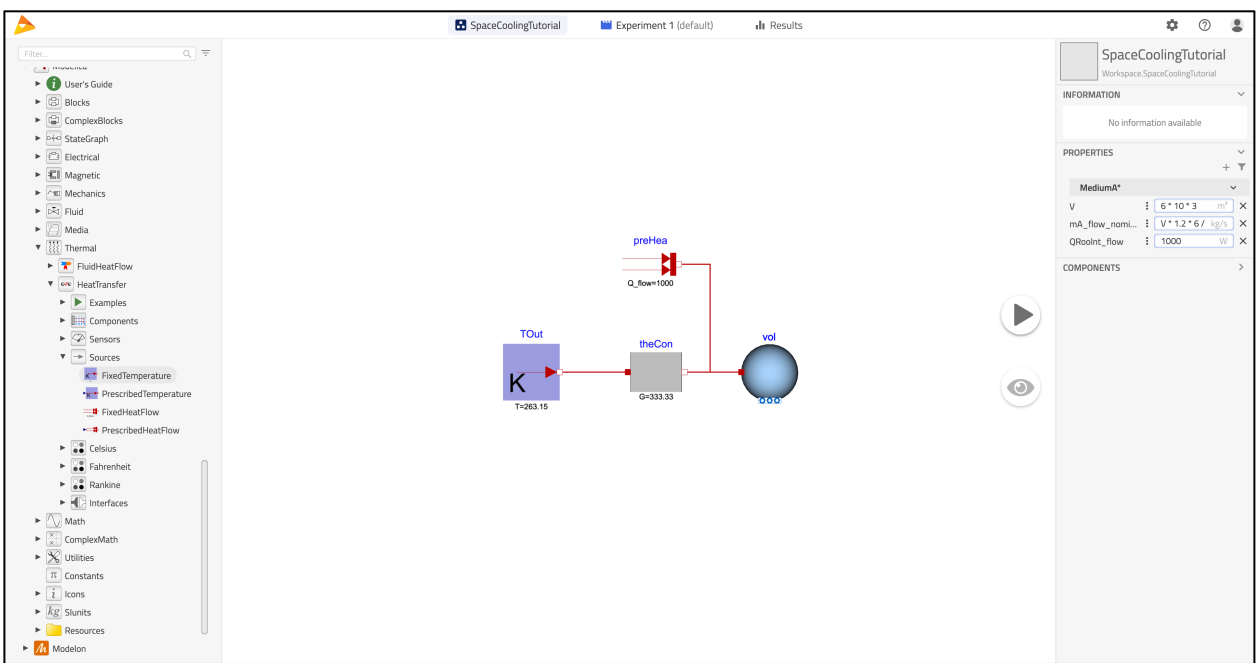
Next, we will declare system-level parameters for the room volume, nominal air mass flow rate, and internal heat gains of the room. These system-level parameters will be propagated down to lower-level models. Declare the system-level parameters using the “Properties > Add variable (Plus icon)” according to the table below.

| Variability | Type | Name | Expression | Description |
|---|---|---|---|---|
| Parameter | Volume | V | 6*10*3 | Room volume |
| Parameter | MassFlowRate | mA_flow_nominal | V*1.2*6/3600 | Nominal mass flow rate |
| Parameter | HeatFlowRate | QRooInt_flow | 1000 | Internal heat gains of the room |

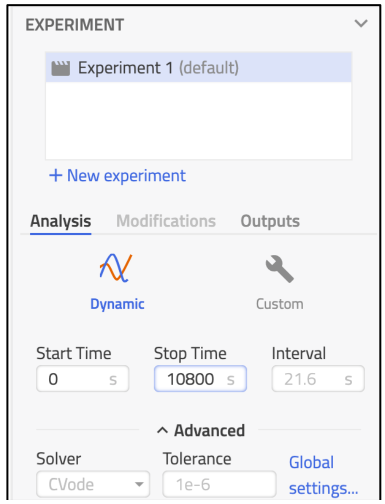


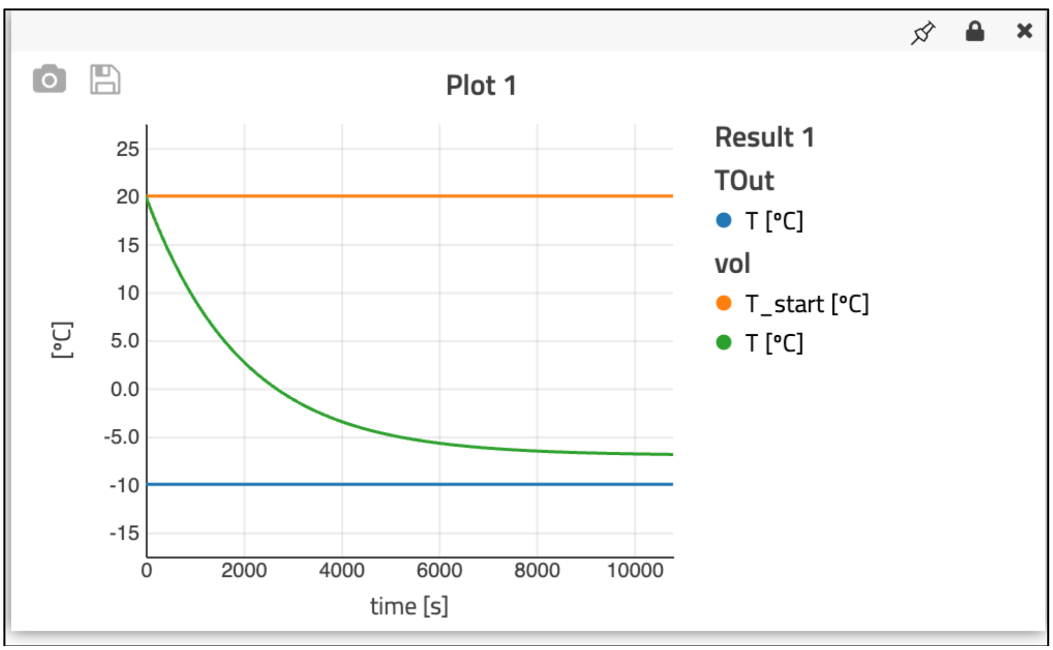
Now let's implement our room model. Drag and drop the component models defined in the table below. Then, parameterize them as described in the table. Finally, connect the components as you see in the diagram.

| **Component Model** | **Name** | **Description** | **Parameters** |
|---|---|---|---|
| Buildings.Fluid.MixingVolumes.MixingVolume | vol | Room air volume | <u>General</u><br>• Medium = MediumA<br>• V=V<br>• m_flow_nominal=mA_flow_nominal<br><u>Dynamics</u><br>• energyDynamics=Modelica.Fluid.Types.Dynamics.FixedInitial<br>• mSenFac=3 |
| Modelica.Thermal.HeatTransfer.Components.ThermalConductor | theCon | Thermal conductance with the ambient | <u>General</u><br>• G=10000/30 |
| Modelica.Thermal.HeatTransfer.Sources.FixedTemperature | TOut | Outside temperature | • T=273.15-10 |
| Modelica.Thermal.HeatTransfer.Sources.FixedHeatFlow | preHea | Prescribed internal heat gain flow rate | • Q_flow=QRooInt_flow |



Finally, let's simulate the model for 3 hours, or 10800 seconds, and observe the response. First, edit the "Stop Time" in the "Experiment" tab. Then, simulate the model and view the results.



## 2. System Model

Now we're ready to implement the system model, operating under open-loop control. If you have not completed 1. Room Model, start by copying the model "Buildings.Examples.Tutorial.SpaceCooling.System1." Then define the system-level parameters as defined in the table below.

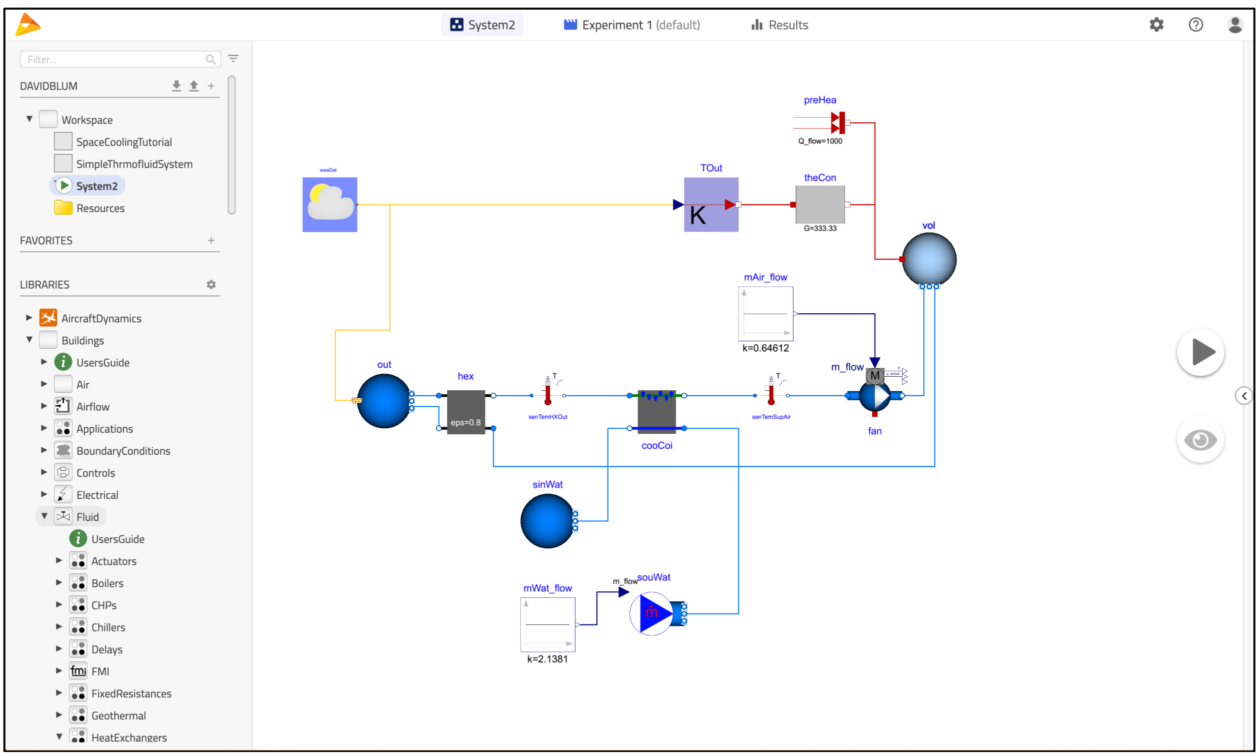
| Variability | Type | Name | Expression | Description |
|---|---|---|---|---|
| Parameter | Real | eps | 0.8 | Heat recovery effectiveness |
| Parameter | Temperature | TRooSet | 273.15+24 | Nominal room air temperature |
| Parameter | Temperature | TASup_nominal | 273.15+18 | Nominal air temperature supplied to room |
| Parameter | Dimensionless Ratio | wASup_nominal | 0.012 | Nominal supply air humidity ratio [kg/kg] |
| Parameter | Temperature | TOut_nominal | 273.15+30 | Design outside air temperature |
| Parameter | Temperature | THeaRecLvg | TOut_nominal - eps*(TOut_nominal-TRooSet) | Nominal air temperature leaving the heat recovery |
| Parameter | Dimensionless Ratio | wHeaRecLvg | 0.0135 | Nominal air humidity ratio [kg/kg] leaving the heat recovery |
| Parameter | HeatFlowRate | QRooC_flow_nominal | -QRooInt_flow-10E3/30*(TOut_nominal-TRooSet) | Nominal cooling load of the room |
| Parameter | MassFlowRate | mA_flow_nominal<br><br>* Note this is a change to an existing parameter | 1.3*QRooC_flow_nominal/1006/(TASup_nominal-TRooSet) | Nominal air mass flow rate, increased by factor 1.3 to allow for recovery after temperature setback |
| Parameter | TemperatureDifference | dTFan | 2 | Estimated temperature raise across fan that needs to be made up by the cooling coil |
| Parameter | HeatFlowRate | QCoiC_flow_nominal | mA_flow_nominal*(TASup_nominal-THeaRecLvg-dTFan)*1006+mA_flow_nominal*(wASup_nominal - wHeaRecLvg)*2458.3e3 | Cooling load of coil, taking into account economizer, and increased due to latent heat removal |
| Parameter | Temperature | TWSup_nominal | 273.15+12 | Water supply temperature |
| Parameter | Temperature | TWRet_nominal | 273.15+16 | Water return temperature |
| Parameter | MassFlowRate | mW_flow_nominal | -QCoiC_flow_nominal / (TWRet_nominal-TWSup_nominal)/4200 | Nominal water mass flow rate |

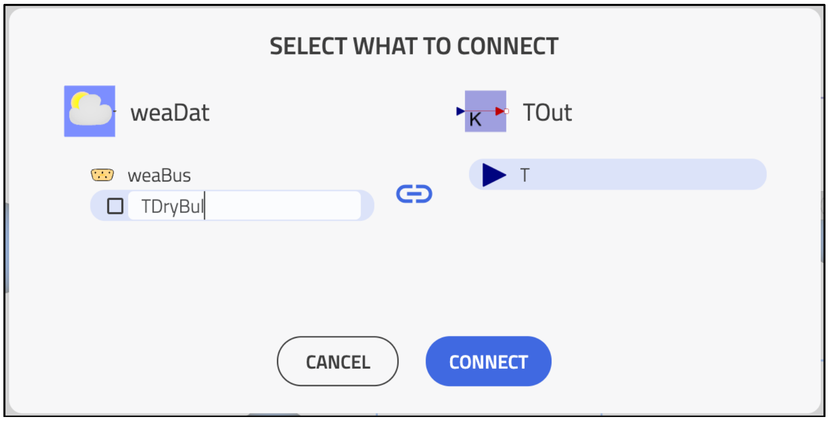
Now let's implement our system model. First, replace the component "TOut" with a "Modelica.Thermal.HeatTransfer.Sources.PrescribedTemperature." Then, add a new top-level media model called "MediumW" as "Buildings.Media.Water" similar to how the media model for air was added before. Then, drag and drop the additional component models defined in the table below. Then, parameterize them as described in the table. Finally, connect the components as you see in the diagram.

Pay special attention the arrangement of the cooling coil model such that port a2 is towards the top left of the component. Also note that connecting the weather bus from the component "weaDat" to "TOut", type the variable from the bus wanting to be connected, "TDryBul," as shown in the screen shot below.

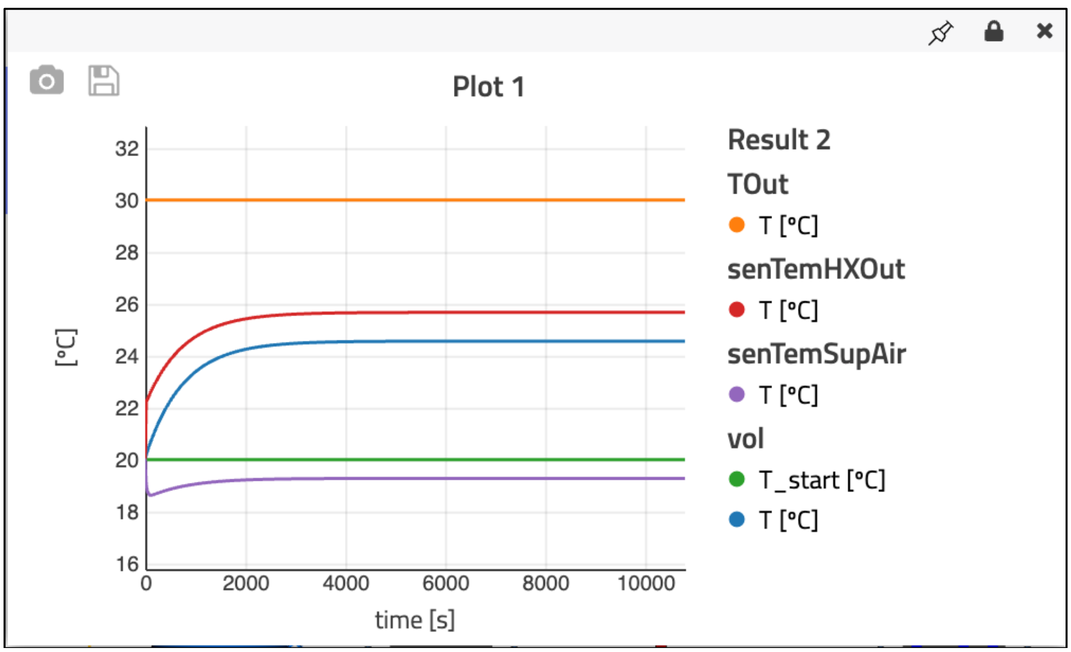
| **Component Model** | **Name** | **Description** | **Parameters** |
|---|---|---|---|
| Buildings.Fluid.Movers.FlowControlled_m_flow | fan | Supply air fan | • Medium=MediumA<br>• m_flow_nominal=mA_flow_nominal<br>• energyDynamics= Modelica.Fluid.Types.Dynamics.SteadyState |
| Buildings.Fluid.HeatExchangers.ConstantEffectiveness | hex | Heat recovery | • Medium1=MediumA<br>• Medium2=MediumA<br>• m1_flor_nominal=mA_flow_nominal<br>• m2_flor_nominal=mA_flow_nominal<br>• dp1_nominal=200<br>• dp2_nominal=200 |
| Buildings.Fluid.HeatExchangers.WetCoilEffectivenessNTU | cooCoi | Cooling coil | • Medium1=MediumW<br>• Medium2=MediumA<br>• m1_flow_nominal=mW_flow_nominal<br>• m2_flow_nominal=mA_flow_nominal<br>• dp1_nominal=6000<br>• dp2_nominal=200<br>• use_Q_flow_nominal=true<br>• Q_flow_nominal= QCoiC_flow_nominal<br>• T_a1_nominal=TWSup_nominal<br>• T_a2_nominal=THeaRecLvg<br>• W_a2_nominal= wHeaRecLvg<br>• show_T=true<br>• energyDynamics=Modelica.Fluid.Types.Dynamics.FixedInitial |
| Buildings.Fluid.Sources.Outside | out | Ambient air source | • Medium=MediumA |
| Buildings.Fluid.Sources.MassFlowSource_T | souWat | Source for water flow rate | • Medium=MediumW<br>• use_m_flow_in=true<br>• T=TWSup_nominal |
| Buildings.Fluid.Sources.Boundary_pT | sinWat | Sink for water circuit | • Medium=MediumW |
| Buildings.BoundaryConditions.WeatherData.ReaderTMY3 | weaDat | Weather data reader | • filNam=Modelica.Utilities.Files.loadResource("modelica://Buildings/Resourc |

| | | | |
|---|---|---|---|
| | | | es/weatherdata/USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.mos"))<br>• pAtmSou=Buildings.BoundaryConditions.Types.DataSource.Parameter<br>• TDryBulSou=Buildings.BoundaryConditions.Types.DataSource.Parameter<br>• TDryBul=TOut_nominal |
| Buildings.BoundaryConditions.WeatherData.Bus | weaBus | Weather bus access | |
| Buildings.Controls.OBC.CDL.Continuous.Sources.Constant | mAir_flow | Fan air flow rate | k=mA_flow_nominal |
| Buildings.Controls.OBC.CDL.Continuous.Sources.Constant | mWat_flow | Water flow rate | k=mW_flow_nominal |
| Buildings.Fluid.Sensors.TemperatureTwoPort | senTemHXOut | Temperature sensor for heat recovery outlet on supply side | • Medium=MediumA<br>• m_flow_nominal=mA_flow_nominal |
| Buildings.Fluid.Sensors.TemperatureTwoPort | senTemSupAir | Temperature sensor for supply air | • Medium=MediumA<br>• m_flow_nominal=mA_flow_nominal |






Finally, let's simulate the model for the same 3 hours as previously. Double check the Experiment is set up so "Start Time" is 0 s and "Stop Time" is 10800 s. Then, simulate the model and view the results.

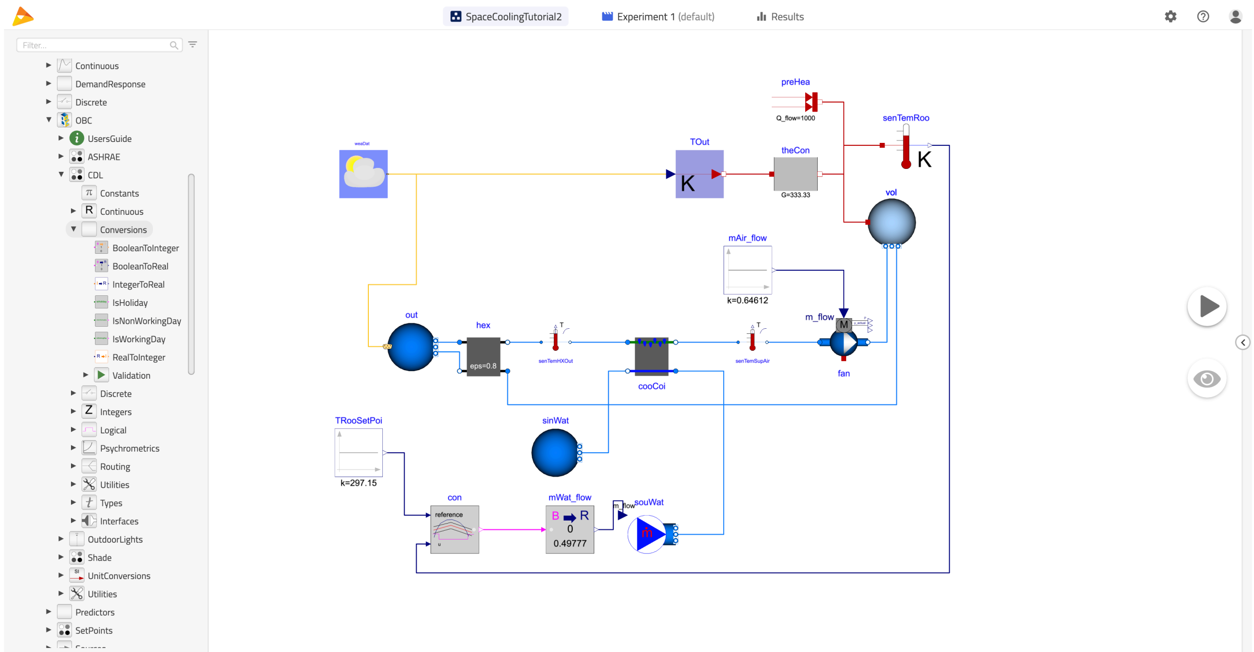


## 3. Closed Loop Control

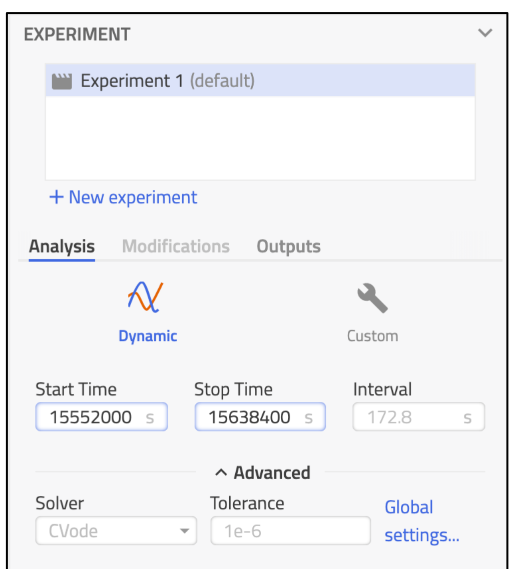
Now let's simulate the system in more realistic ambient conditions and add feedback control in the form of an on/off controller based on room temperature measurement controlling the flow of chilled water.  If you did not complete 2. System Model, then start by copying "Buildings.Examples.Tutorial.SpaceCooling.System2."

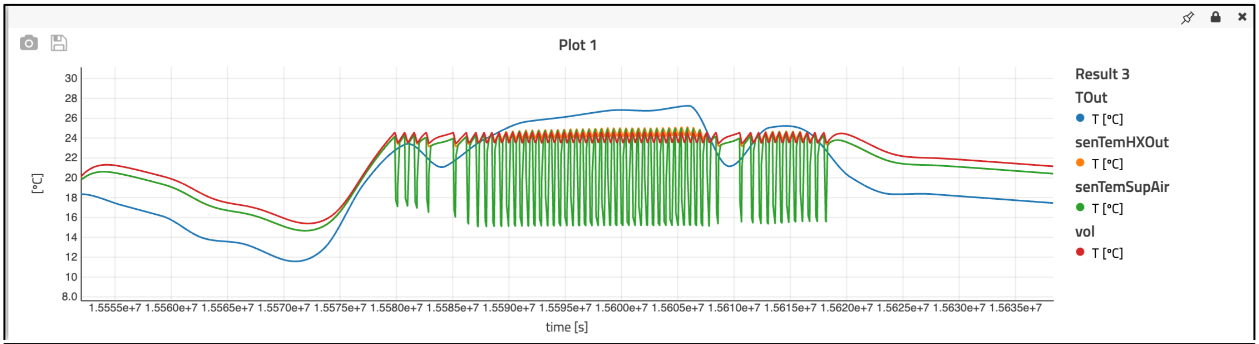
First, let's change the source of the outside dry bulb temperature to the weather file instead of a constant value.  Do this by selecting "Use data from file" for the parameter "weaDat.TDryBulSou."  Then, add control by dragging and dropping the additional component models defined in the table below.  Then, parameterize them as described in the table.  Finally, connect the components as you see in the diagram.

| **Component Model** | **Name** | **Description** | **Parameters** |
|---|---|---|---|
| Buildings.Controls.OBC.CDL.Logical.OnOffController | con | Controller for coil water flow rate | • bandwidth=1 |
| Buildings.Controls.OBC.CDL.Continuous.Sources.Constant | TRooSetPoi | Room temperature set point | • k=TRooSet |
| Modelica.Thermal.HeatTransfer.Sensors.TemperatureSensor | senTemRoo | Room temperature sensor | |
| Buildings.Controls.OBC.CDL.Conversions.BooleanToReal<br><br>*Replacing Buildings.Controls.OBC.CDL.Continuous.Sources.Constant | mWat_flow | Conversion from boolean to real for water flow rate | • realTrue=0<br>• realFalse=mW_flow_nominal |




Finally, let’s simulate the model for one day during summer from hour 4320 to 4344, and observe the response. First, edit the “Start Time” and “Stop Time” in the “Experiment” tab. Then, simulate the model and view the results.




Plot 1
[°C]
30
28
26
24
22
20
18
16
14
12
10
8.0
1.5555e+7 1.5560e+7 1.5565e+7 1.5570e+7 1.5575e+7 1.5580e+7 1.5585e+7 1.5590e+7 1.5595e+7 1.5600e+7 1.5605e+7 1.5610e+7 1.5615e+7 1.5620e+7 1.5625e+7 1.5630e+7 1.5635e+7
time [s]
Result 3
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senTemSupAir
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vol
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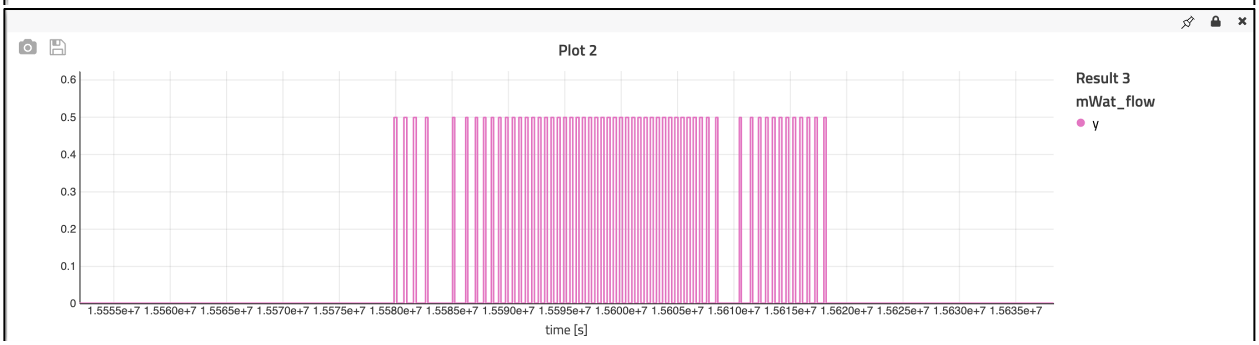
Plot 2
0.6
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0.3
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0
1.5555e+7 1.5560e+7 1.5565e+7 1.5570e+7 1.5575e+7 1.5580e+7 1.5585e+7 1.5590e+7 1.5595e+7 1.5600e+7 1.5605e+7 1.5610e+7 1.5615e+7 1.5620e+7 1.5625e+7 1.5630e+7 1.5635e+7
time [s]
Result 3
mWat_flow
y