

User's guide to  
The International Building Physics Toolbox  
- A (very) brief manual

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# Building Physics Toolbox for Simulink

- A (very) brief manual

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## 1 Introduction

In this manual the technique of creating a room model from the individual blocks from the Building Physics Toolbox, will be presented. Keep in mind, that the blocks are created by different persons, so you should always check the documentation for the individual block prior to its use.

The basis of the toolbox is presented in the working draft “Modelling Building Physics in Simulink” by (Nielsen et al., 2002) and in “BFTools\_H Building physics toolbox block documentation” by (Kalagasidis, 2002). Also a common “general report”, written in cooperation between DTU (Technical University of Denmark) and CTH (Chalmers University of Technology) has been written (DTU and CTH, 2002). For further information than what is given in this brief manual, please consult with any of these three documents. They are available from the homepage of the International Building Physics Toolbox. New blocks can be added to the toolbox by contacting this home page. Make sure that the block is documented according to the description in (Nielsen et al., 2002), (Kalagasidis, 2002) or (DTU and CTH, 2002)

A new model can be created by the easy drag and drop interface existing in Simulink (Mathworks, 2001). A general description of the use of Simulink

can be found in the Using Simulink book (Mathworks, 2001). The modeling tool requires only small knowledge about programming, but it is, however, an advantage to be familiar with the Matlab package, which Simulink is a part of.

Notice, that this is not a comprehensive manual. It only aims at giving the basic idea about the use of the Building Physics Library.

## 2 Data arrays

The most important property of the Building Physics Toolbox is the data exchange, which is taken care of by data arrays. A total of seven arrays are used. They are:

- Construction array
- System array
- Geometry array
- Zone array
- Radiation array
- Gains array
- Surface weather data array

The information from each block that is needed by other blocks is passed in the arrays.

## 3 Blocks

The blocks are the building stones of the model. There are different types of blocks, currently divided into five categories:

- System
- Construction element
- Zone element
- Helpers
- Gains

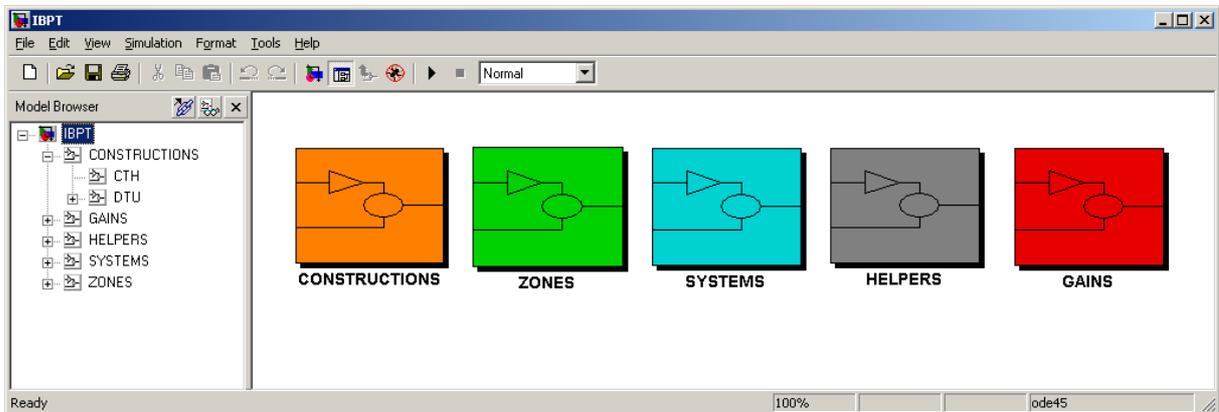
An example of a system could be a ventilation unit, a construction element could be a wall, a zone element could be a room and helpers could include weather data.

## 4 Basics of the toolbox

A model is built using blocks and arrays. The different blocks want certain input arrays and produce certain output arrays. In all cases, the different arrays a block requires and outputs can be seen in the block.

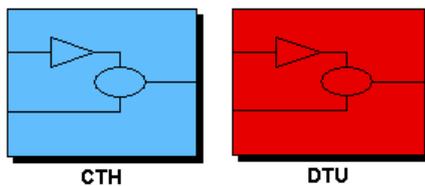
Besides from the blocks mentioned above, further blocks are used which are available in the Simulink Library Browser.

In the figure below, the building library (International Building Physics Toolbox) is shown.



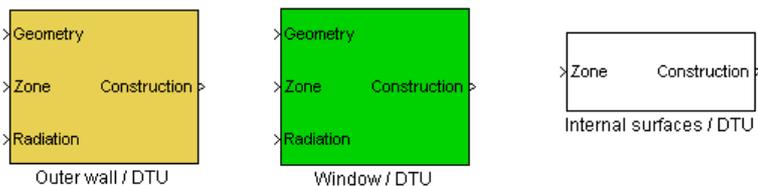
**Figure 1 Building Physics Toolbox with blocks existing March 20, 2002.**

By double clicking any of these entrances, the following appears:



**Figure 2 View of one submenu**

From this, the blocks developed by DTU or CTH can be found. For instance, assuming that constructions and after that DTU is double clicked the following appears:



**Figure 3 Constructions (walls and windows) from DTU**

More models are added to the toolbox as they are developed and documented.

The toolbox can be placed in any directory on the computer. It is here assumed, that it is placed in a directory called bptoolbox under the work directory in Matlab. Typically the directory will then be called `c:\Matlab\work\bptoolbox`

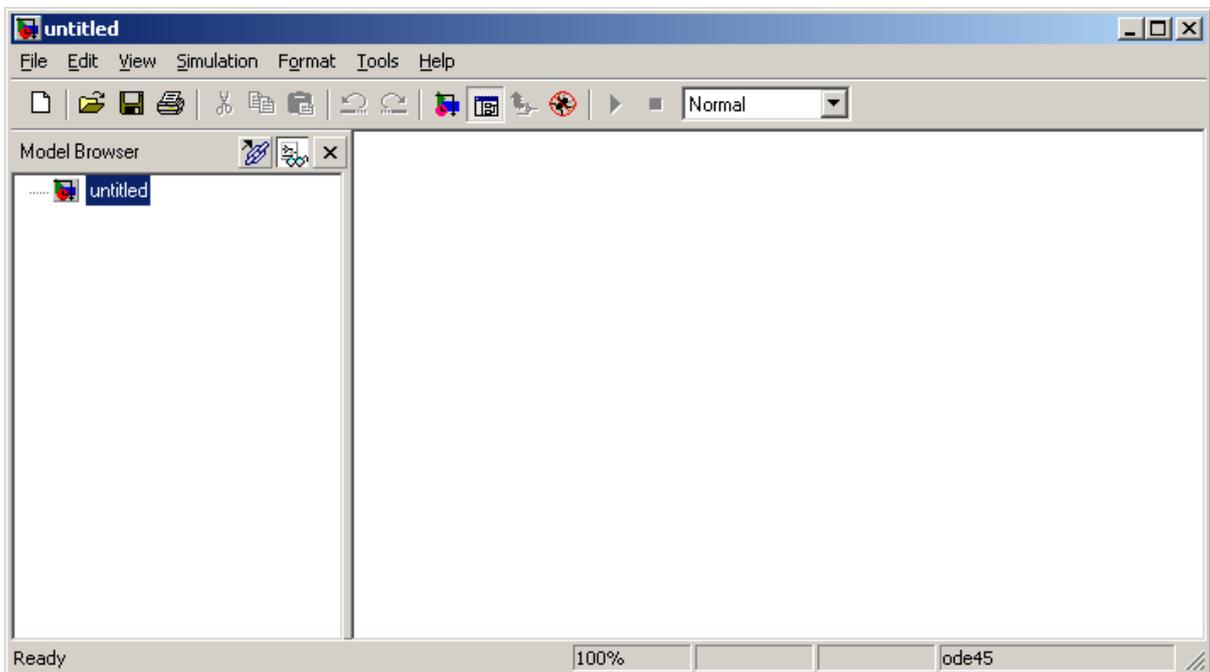
## 5 Creating a model

### 5.1 Opening the toolbox

Go to the directory in which the toolbox is placed and open the toolbox by typing `buildlib` from the Matlab prompt – or by choosing File/Open from the Simulink Library Browser. Now open the file called IBPT.

### 5.2 Creating a new model

In the `buildlib` library choose File/New/Model. A new empty Simulink model appears.



**Figure 4** An empty Simulink model

The model can now be built from scratch.

When using Simulink, the blocks from the Building Physics Toolbox does not need to be placed in the same directory as the one where the model is saved. In this manual, however, it is assumed that it is the case that model and library is in the same directory.

### 5.3 Adding blocks to the model

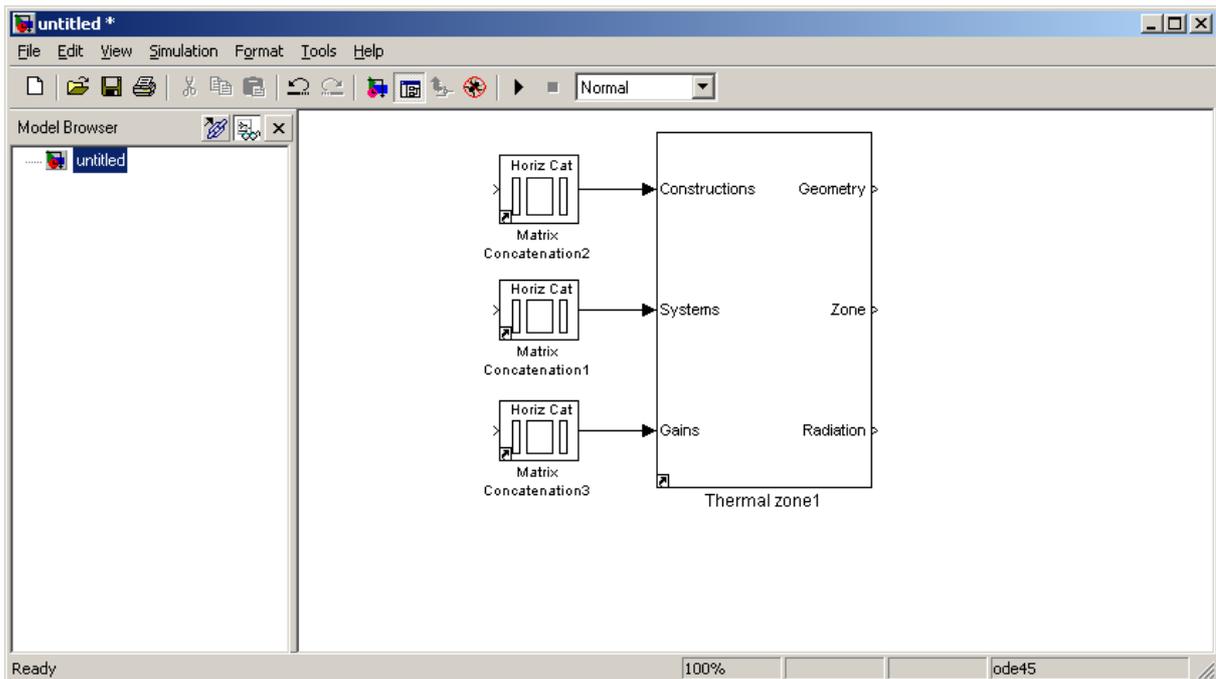
Arrange the IBPT library and the new model so that both are visible on the computer screen. Now a block from the IBPT library can be added to the model by a drag and drop operation, like copying a file from one directory to another using the Windows interface.

## 5.4 Creating a model

In the following, the basics behind building a model are shown.

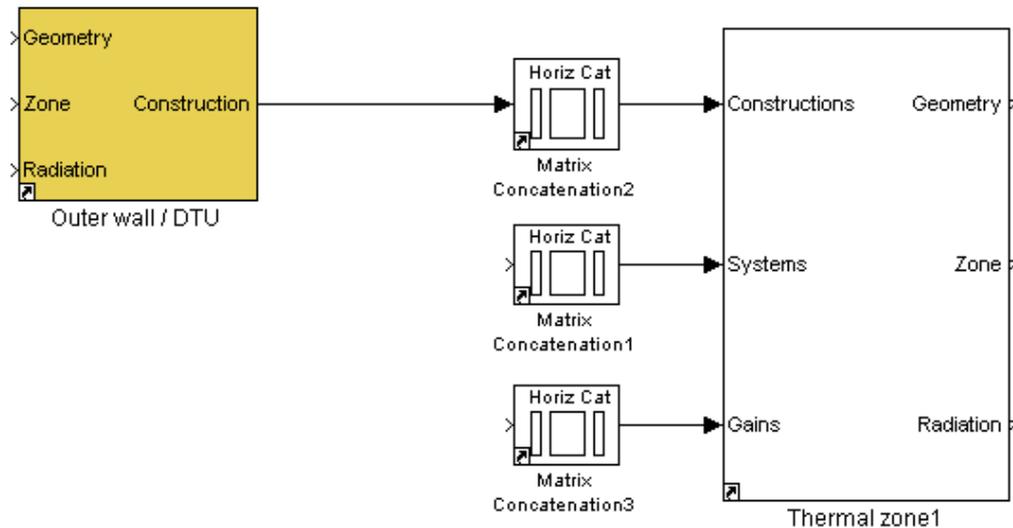
### 5.4.1 Adding a thermal zone

In Figure 5, a model with the thermal zone added, as well as concatenation blocks and initial conditions blocks. The thermal zone, including concatenation block and initial conditions blocks, is available by clicking IBPT\zones\DTU. The contents can be copy/pasted into the model. The numbers in the concatenation blocks must be altered. This is shown later.



**Figure 5** The thermal zone added to the model

Further blocks can be added by dragging a wall from the IBPT\constructions window. This is shown in Figure 6. (Notice that only the model is shown, not the entire Simulink Window. This the case for the rest of the figures)

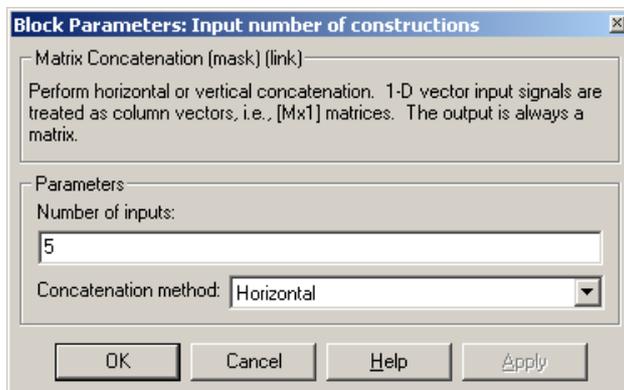


**Figure 6 Wall added to model**

The wall is connected to the concatenation block by a line. This line can be added by clicking and holding the mouse button from the “>” with the text “to room” on it and over to the concatenation block.

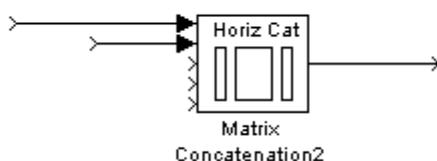
#### 5.4.2 Working with concatenation blocks

If the model has more than 2 walls/windows (which it will most likely have) the concatenation block must be changed. This can be done by double clicking the concatenation block. The following window appears.



**Figure 7 Concatenation block opened**

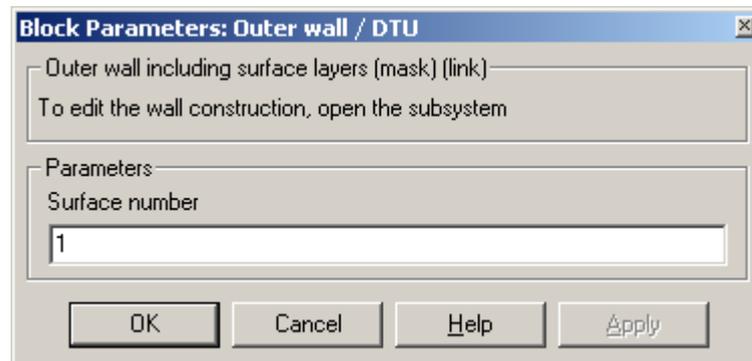
Notice the difference between horizontal and vertical concatenation – in this case a horizontal concatenation must be used. The number of available inputs must be inserted in the “Number of inputs:” field. If for instance 5 is chosen the concatenation block will look like this:



**Figure 8 Concatenation block with five inputs**

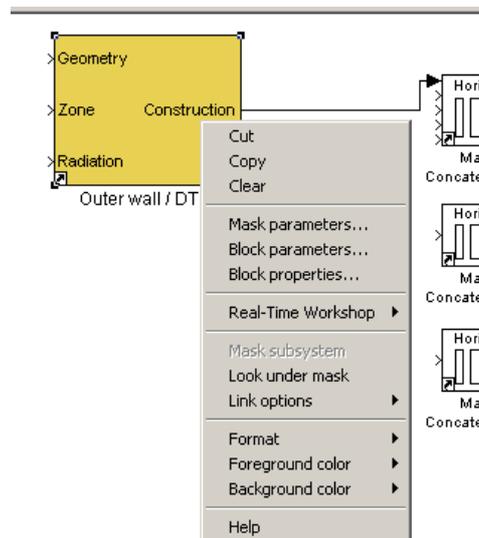
### 5.4.3 Masked subsystems

A masked subsystem is a block where parameters can be passed to the block by double clicking the block. By double clicking the outer wall, the following dialog appears:



**Figure 9** An example of a mask

If a block at a lower level of the subsystem is required. In this case to set the material properties of the wall construction, simply right click the block

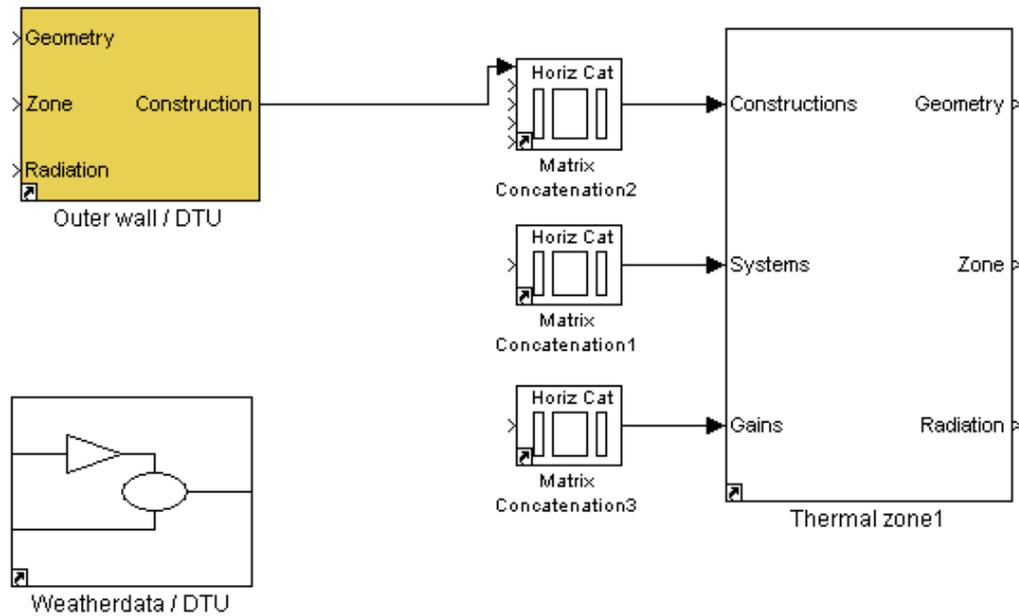


**Figure 10** Accessing a masked subsystem

From the menu, choose 'Look under mask'. Now the masked subsystem will appear.

### 5.4.4 Adding weather data

The weather block is simply dragged into the model. This is shown in Figure 11. The weather data block does not need to be connected to the other blocks in the model. The data is transmitted by 'goto' and 'from' blocks in the model.

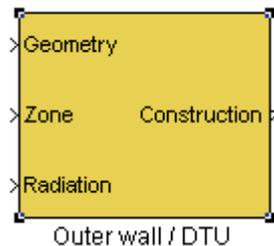


**Figure 11 Model with weather data block**

#### 5.4.5 Adding a construction

As shown in Figure 6, the wall can be added by dragging it into the building model.

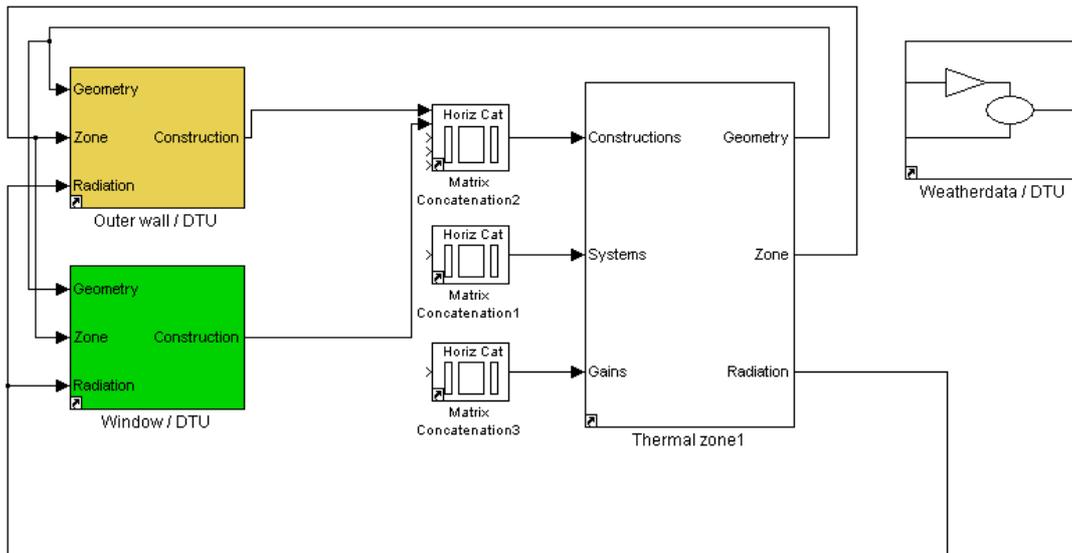
The wall requires three inputs; namely a geometry array, a zone array and a radiation array.



**Figure 12 Wall**

The three input ports must be connected to the output ports of the thermal zone of.

In the following figure, a window is also added, and the blocks are connected to the thermal zone



**Figure 13 A wall and window added to the model**

Notice, that the geometry vector from the thermal zone is input into both selector blocks. This branching of a line can be done by right clicking the line of the geometry vector and dragging it into the second selector.

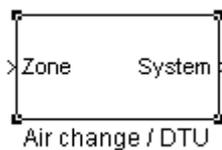
Similarly for the systems and gains.

#### 5.4.6 Numbering of constructions

The constructions must in all cases be numbered. The numbering is available in the mask of all constructions. Make sure to use a consecutive numbering (i.e. 1, 2, 3 and so on and NOT 1, 3, 4 ...) of the blocks. This is important for the inputs to the thermal zone.

#### 5.4.7 Adding a system

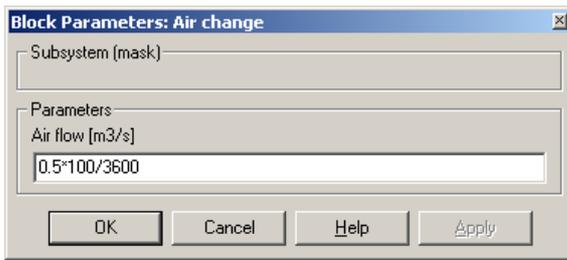
To add a system, go to IBPT\systems and drag the system into the model. An example of a system is shown in Figure 14.



**Figure 14 System block (here an air change block)**

The system requires as input the room state array, and gives back a system array.

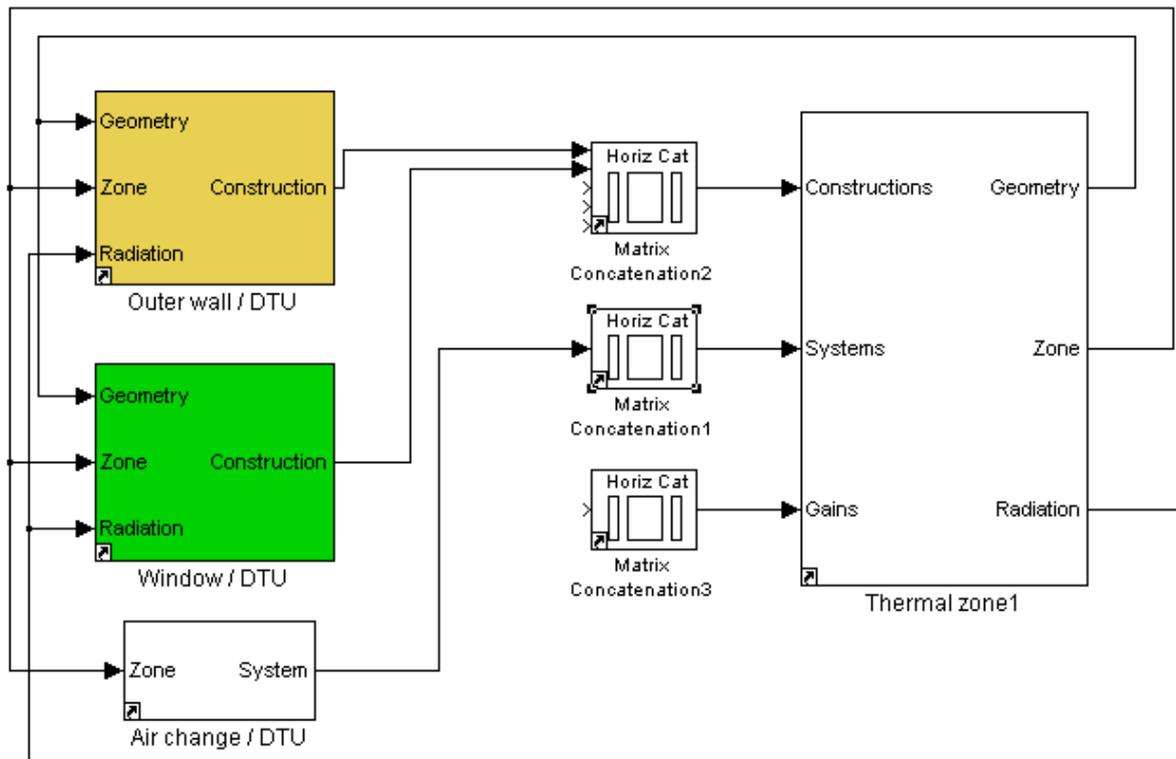
By double clicking the block, a dialog box appears, in which the required parameters can be altered. In the “air change” block, this dialog looks like this:



**Figure 15 Parameters for Air change block**

In the block, the parameters have been set to half an air change pr. hour if the room volume is 100 m<sup>3</sup>.

A correctly connected system block will look like this in the model



**Figure 16 System block added to model**

Again the same procedure for the concatenation and initial conditions as for the constructions blocks must be followed.

Notice, that some systems require other data arrays as inputs. This could for instance be the geometry array.

#### 5.4.8 Adding a gain

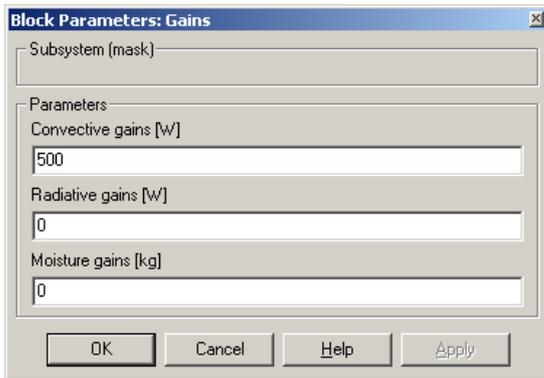
To add a system, go to `buildlib\gains` and drag the gain block into the model. An example of a system is shown in Figure 17.



**Figure 17 Gain block**

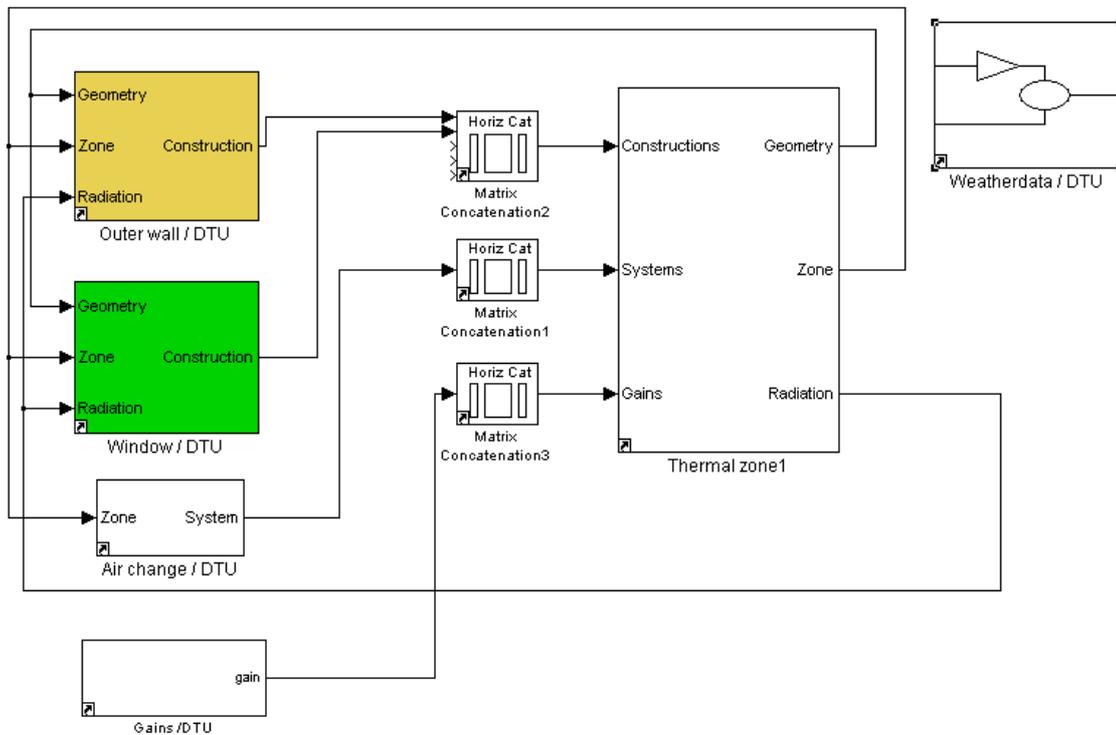
The gain block does not require an input, but only gives an output vector, which must be connected to the lower concatenation connected to the thermal zone.

By double clicking the block, a dialog box appears, in which the required parameters can be altered. In the “gains” block, this dialog looks like this:



**Figure 18 Parameters in Gains block**

A correctly added gain block looks like this:



**Figure 19 Gain block added to model**

Again the same procedure for the concatenation and initial conditions as for the constructions blocks must be followed.

#### 5.4.9 Setting parameters for the thermal zone

After the model has been created for the room with walls, windows, systems and gains, it is necessary to add the correct parameters into the thermal zone.

Notice, that this description is only valid for the DTU thermal block. It is only an example given to show the methodology of using the toolbox.

This can be done by double clicking the Thermal Zone. A dialog box appears.

The image shows a dialog box titled "Block Parameters: Thermal zone". It contains the following fields and values:

- Zone (mask): [Empty text box]
- Parameters:
  - Surface areas: [Empty text box]
  - Surface orientations: [Empty text box]
  - Surface tilts: [Empty text box]
  - Internal heat capacity [J/K]: [Empty text box]
  - Room volume: [Empty text box]
  - Solar gain to air: 0.3
  - Initial air temperature: 20

Buttons at the bottom: OK, Cancel, Help, Apply.

**Figure 20 Parameters for Thermal Zone block**

In this block, the area, orientation and tilt of the areas attached to the model can be set along with the internal heat capacity and room volume. The three set of parameters for the surfaces must be supplied as arrays. These arrays should be in the form shown here. If a model has seven surfaces; that is six walls and one window, it should look like this:

```
[area1 area2 area3 area4 area5 area6 area7]
```

It is very important, that area 1 corresponds construction that has been given the number 1, and so on!

The same goes for the orientation and tilt arrays.

The orientation of a surface must be given in degrees where 0 corresponds to south, 90 corresponds to west, -90 corresponds to east and 180 corresponds to north.

The tilt of a surface is also given in degrees where 0 corresponds to a floor, 90 corresponds to a wall and 180 corresponds to a ceiling.

#### 5.4.10 Loading required variables

Depending on the blocks used in the simulation model of the room, one or more set of input data must be loaded. These include material database and weather data and other required data.

In the blocks described here, it is necessary to load a material database and weather data. This can be done by typing

*load database*

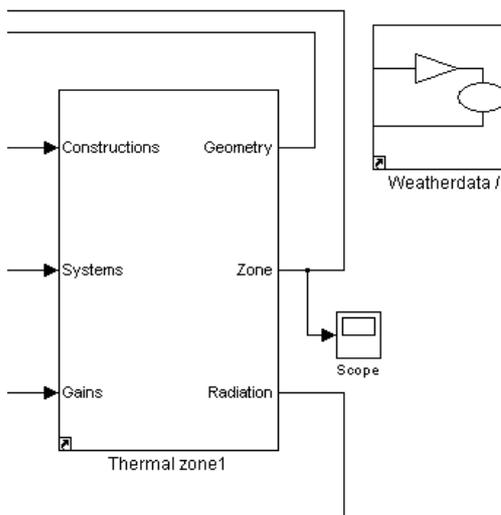
and

*load weather*

from the Matlab prompt. Here *database* is the name of the database given by the group whose database is required. For instance the database from DTU is called DTU\_DATABASE

#### 5.4.11 Finishing touches

Finally, to get output from the simulation “scopes” and “to File” blocks can be added to the model. A scope generates a graph of the variable it is connected to. For instance the air temperature can be plotted by adding a scope on the “zone” array coming from the thermal zone. Scope and “to file” blocks can be found under Sinks in the Simulink Library.



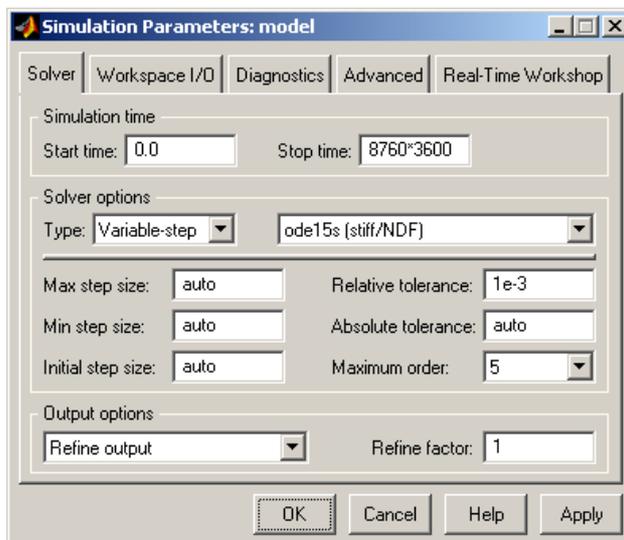
**Figure 21 Scope connected to the zone array**

Make sure to set all the scopes and “to file” blocks required to gain information about the properties and behaviour of the model.

For further information about the use and application of how to get data out of a Simulink model, please consult with the Simulink user’s manual (Simulink, 2001)

### 5.5 Starting a simulation

Finally, also the calculation time and solver must be defined in the model. Choosing Simulation\Simulation parameters menu (or pressing CTRL+E), the following window appears:



**Figure 5.1** Setting simulation parameters

Here the start and end time of the simulation, the type of solver and the tolerances can be defined. Here the stop time is set to one year. Normally the ode15s solver is most efficient for this type of modelling.

A simulation can be started by pressing the  button on the toolbar at the top of the model window.



**Figure 22** Simulink toolbar

## 6 References

Kalagasidis, A. S. (2002): *BFTools\_H Building physics toolboks block documentation*, Department of Building Physics, Chalmers Institute of Technology, Sweden

Nielsen, T. R., Peuhkuri, R., Weitzmann, P., Gudum, C. (2002): *Modelling Building Physics in Simulink*, BYG·DTU SR-02-03, BYG·DTU

Mathworks (2001): *Using Simulink: Simulink. Dynamic System Simulation for Matlab*, Mathworks. Available from the Mathworks homepage.

Rode, C., Gudum C., Weitzmann P., Peuhkuri R., Nielsen, T. R., Sasic Kalagasidis, A., Hagentoft, C-E.: *International Building Physics Toolbox – General Report*. Department of Building Physics, Chalmers Institute of Technology, Sweden, Report R-02:4, 2002.