Using Apama Analytics Builder for Cumulocity IoT

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About this Guide

This guide describes how to build and use models using Apama Analytics Builder for Cumulocity IoT.

Documentation roadmap

This documentation is provided in the following formats:

- HTML
- PDF

In addition, the following is available which can be accessed from the model editor, which is one of the tools of Apama Analytics Builder for Cumulocity IoT:

- Reference information for the Apama blocks: block descriptions, parameters, input port details, and output port details.

Document Conventions

Convention	Description
Bold	Identifies elements on a screen.
Narrowfont	Identifies service names and locations in the format *folder.subfolder.service* , APIs, Java classes, methods, properties.
Italic	Identifies: Variables for which you must supply values specific to your own situation or environment. New terms the first time they occur in the text. References to other documentation sources.
`Monospace font`	Identifies: Text you must type in. Messages displayed by the system. Program code.
{ }	Indicates a set of choices from which you must choose one. Type only the information inside the curly braces. Do not type the { } symbols.

Convention	Description
|	Separates two mutually exclusive choices in a syntax line. Type one of these choices. Do not type the | symbol.
[ ]	Indicates one or more options. Type only the information inside the square brackets. Do not type the [ ] symbols.
...	Indicates that you can type multiple options of the same type. Type only the information. Do not type the ellipsis (...).

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1 Getting Started with Apama Analytics Builder for Cumulocity IoT

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What is Apama Analytics Builder?

Apama Analytics Builder runs as an application in Cumulocity IoT, which is a web-based platform for managing IoT devices (see also “https://www.cumulocity.com/”). It allows you to build analytic models that transform or analyze streaming data in order to generate new data or output events. The models are capable of processing data in real time.

You build the models in a graphical environment by combining pre-built *blocks* into *models*. The blocks in a model package up small bits of logic, and have a number of inputs, outputs and parameters. Each block implements a specific piece of functionality, such as receiving data from a sensor, performing a calculation, detecting a condition, or generating an output signal. You define the configuration of the blocks and connect the blocks using *wires*. You can edit the models, simulate deployment with historic data, or run them against live systems. See “Understanding Models” on page 15 for more detailed information.

Apama Analytics Builder consists of the following tools:

- **Model manager.** When you invoke Apama Analytics Builder, the model manager is shown first. It lists all available models and lets you manage them. For example, you can test and deploy the models from the model manager, or you can duplicate or delete them. You can also create new models or edit existing models; in this case, the model editor is invoked. See “Using the Model Manager” on page 23 for detailed information.
- **Model editor.** The model editor lets you define the blocks that are used within a model and how they are wired together. User-visible documentation (the so-called *Block Reference*) is available in the model editor, describing the functionality of each block. See “Using the Model Editor” on page 31 for detailed information.

The blocks are implemented in the Apama Event Processing Language (EPL). At runtime, Apama's EPL code runs in an Apama correlator to execute the models. Some runtime behavior and restrictions are important to understand. These are documented in later chapters.

Apama Analytics Builder and Cumulocity IoT

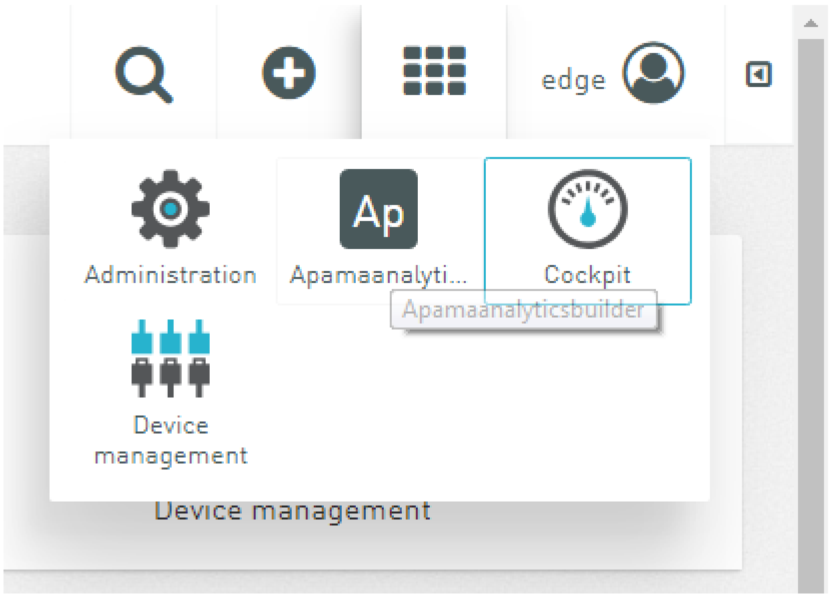
Cumulocity IoT is a platform for connecting, monitoring and controlling remote devices. For an overview, see the *Concepts guide* at “https://www.cumulocity.com/guides/”. Apama Analytics Builder runs as a component within the Cumulocity IoT platform.

Devices and sensors can be connected to Cumulocity IoT. See the information on interfacing devices in the *Concepts guide* and the introduction to MQTT in the *MQTT developer's guide*, both available at the above URL.

Sensors result in `Measurement` or `Event` objects in Cumulocity IoT, and devices can receive `Operation` objects created within the Cumulocity IoT platform. All of these objects (`Measurement`, `Event`, `Operation`) will be associated with a single device in the Cumulocity IoT platform. A device may have multiple types of measurement associated with it, and the types of measurements each device supports may be the same as other devices or different to other devices. Once devices are connected to Cumulocity IoT, information about these devices is stored in the Cumulocity IoT inventory. These are visible in the Device Management application, which can also be used to view `Measurement`, `Event` or `Operation` objects associated with that device. See the information on device management in the *User's guide*, available at the above URL.

The Cumulocity IoT platform includes an Apama correlator component, which is managed by the Cumulocity IoT platform (this is not manually started or stopped) and is preconfigured to communicate to Cumulocity IoT. This correlator hosts the Apama Analytics Builder runtime, and also executes any custom Apama rules added using the **Own applications** page of the Administration application. See the information on managing applications in the *User's guide* and the information on developing applications in the *Concepts guide*, both available at the above URL.

The Apama Analytics Builder application is available via the application switcher after logging in to the Cumulocity IoT web interface:



The Apama Analytics Builder application allows you to create models that interact with the devices and sensor measurements. Models can receive `Measurement` and `Event` objects from devices, which provide the inputs to calculations or pattern detection performed within a model. Models can create new `Measurement` objects which can represent derived values from sensors (for example, an average temperature) or the measurements can be used as an input to other analytic models (see "Connections between models" on page 61). Models can create new `Operation` objects which are sent to devices to control the devices (for example, to sound an alarm bell, display a message on a screen, or switch a device off). The models are also stored in the Cumulocity IoT inventory, but can be imported or exported via the model manager.

Prerequisites

Apama Analytics Builder supports the same browsers as Cumulocity IoT, with the following exception: browsers on smartphones and tablets are not supported.

Starting Apama Analytics Builder

Apama Analytics Builder can be accessed from Cumulocity IoT, using the application switcher which is available in the top bar of the Cumulocity IoT user interface. For detailed information on how to use Cumulocity IoT, see "https://www.cumulocity.com/guides/".

Ask your administrator for the URL that is required to start Cumulocity IoT.

2 Understanding Models

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Models

A model is a container which can have a network of blocks connected to each other with wires.

The behavior of a block inside a model does not depend on other blocks. There can be multiple instances of the same block in a model where each instance may behave differently, depending on the configurable parameters or the inputs connected to the block.

Blocks

Blocks are the basic processing units of the model. Each block has some predefined functionality and processes data accordingly. A block can have a set of parameters and a set of input ports and output ports.

The palette of the model editor offers for selection the following types of blocks:

- Input blocks, which receive data from external sources. An input block normally represents a device that has been registered in Cumulocity's inventory. See also "Input blocks" on page 17.
- Output blocks, which send data to external sources. An output block normally represents a device that has been registered in Cumulocity's inventory. See also "Output blocks" on page 17.
- Processing blocks, which receive data from the input blocks and send the resulting data to the output blocks. See also "Processing blocks" on page 17.

A block can receive data from another block through its input ports. A block can send data to another block through its output ports. Different blocks will have different numbers of input or output ports, and some blocks have only input ports or only output ports. For most blocks, it is not required to connect all of the input or output ports.

A block can have configurable parameters that define the behavior of the block. These parameters are either optional or mandatory, depending on the requirement of the block.

When using the same block multiple times, you can specify different values for the same parameter. For example, the **Threshold** block has a configurable parameter named **Threshold Value**. If you are using two instances of the **Threshold** block and configure this parameter differently for each block, the blocks will report different breaches of the threshold.

Note: Two output ports cannot be connected to same input port, whereas one output port can be connected to multiple input ports.

Input blocks

An input block is a special type of block that receives data from an external source. It converts the data into a format understandable to wires and transfers the data to the connected blocks.

For example, when an input block receives a measurement event from Cumulocity IoT, it extracts the required information from the event and then transfers the information to the connected blocks for further processing.

Output blocks

An output block is a special type of block that receives data from a connected processing block. It converts the data into a format understandable to an external source and transfers the data to the external source.

For example, when an output block receives data from a connected processing block, it packages the data into an operation object and then sends the operation to Cumulocity IoT.

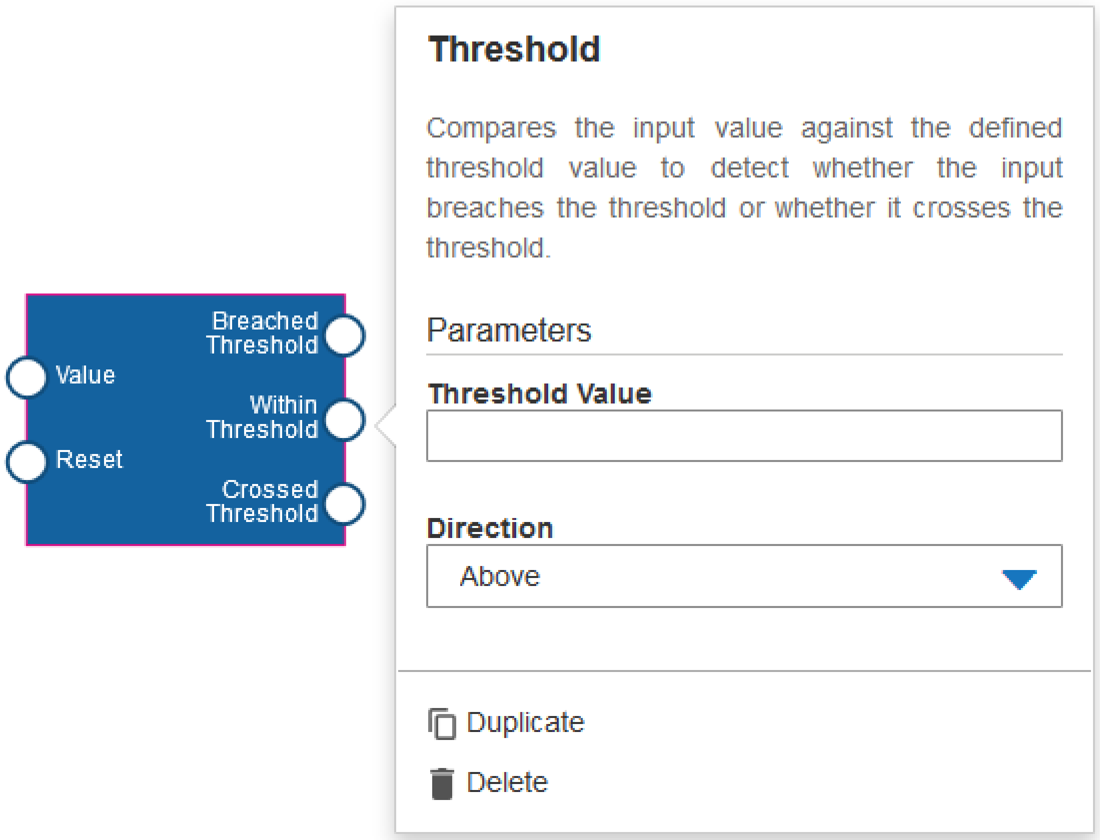
Processing blocks

There are different types of processing blocks. They are grouped into different categories in the palette in the model editor, depending on their functionality.

This category	includes blocks that
Logic	perform logical operations on the data. Blocks such as **AND** and **OR** are in this category.
Calculations	perform mathematical operations on the data. Blocks such as **Difference**, **Threshold**, **Direction Detection**, **Delta** and **Expression** and are in this category.
Aggregates	perform aggregation of the data over a window of values. Blocks such as **Average (Mean)** and **Integral** are in this category.
Flow Manipulation	manipulate the flow of the data. Blocks such as **Time Delay**, **Gate**, **Pulse** and **Latch Values** and are in this category.
Utilities	provide miscellaneous utility functions. Blocks such as **Toggle** and **Missing Data** are in this category.

Example of a processing block - the Threshold block

The following example shows what a block looks like in the model editor, together with the block parameter editor. It shows the **Threshold** block, which detects whether the input value breaches the threshold or whether it crosses the threshold.



Threshold

Compares the input value against the defined threshold value to detect whether the input breaches the threshold or whether it crosses the threshold.

Parameters

Threshold Value

Direction

Above

The parameters are:

- **Threshold Value**. `float` type. This value is compared against the input value.
- **Direction**. The direction in which to look: whether the input value is above or below the defined threshold, or whether it crosses the threshold.

The input ports are:

- **Value**. `float` type. The input value to the block, to be compared against the defined threshold value.
- **Reset**. `pulse` type. When a signal is received, the state of the block is reset so that any previously received input values are no longer used.

The output ports are:

- **Breached Threshold**. `boolean` type. Is set to `true` when the threshold has been breached. That is, the input value is beyond the range of the defined threshold value.

- **Within Threshold.** `boolean` type. Is set to `true` when the threshold has not been breached. That is, the input value is within the range of the defined threshold value.
- **Crossed Threshold.** `pulse` type. Sends a signal when the input value crosses the threshold, going from one side of the threshold to the other.

Wires

One block is connected to another block with the help of wires. All data transfer between the output port of one block and the input port of another block is done using wires. All connections must be made between compatible types. See "Wires and Blocks" on page 49 for detailed information.

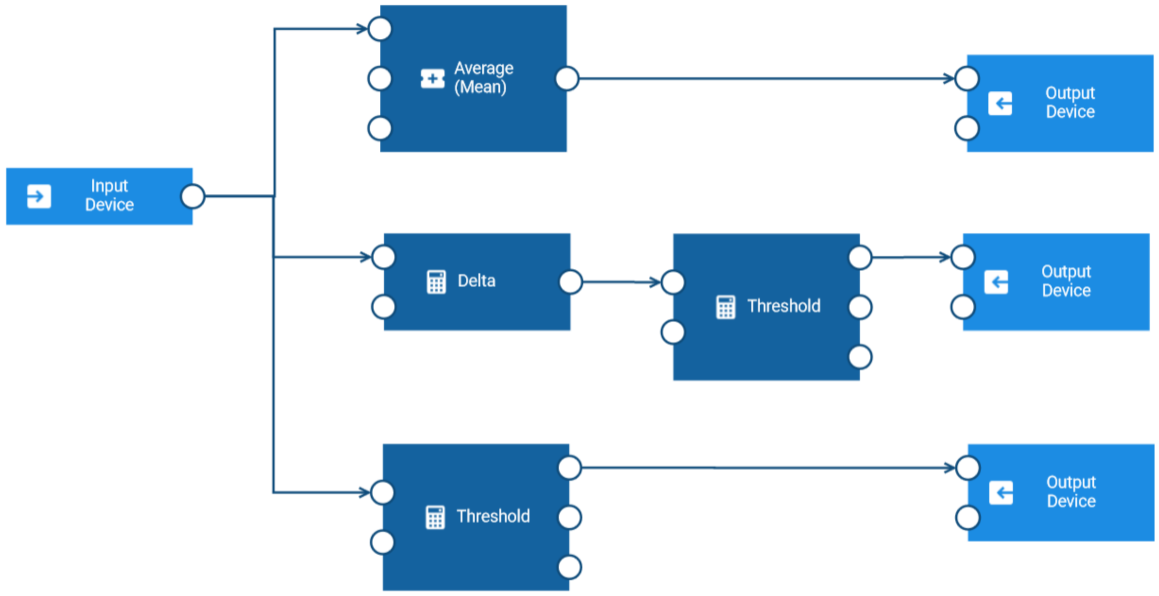
Note: The network of blocks in a model cannot contain any kind of cycles. See "Wire restrictions" on page 58 for more information.

Sample use case

Consider a situation where you are getting real-time sensor data and you want to analyze this data. For the sake of simplicity, let us assume that there is only one sensor and that you are interested in the following:

- You want to know the average value of the sensor readings over a period of time.
- You want to detect sudden changes in the sensor readings using a defined threshold value.
- You want to ensure that the sensor readings are within a certain range and that an alert is created if the readings go beyond that range. For example, you are getting pressure readings and you want to ensure that the maximum pressure does not go beyond the range that the device can handle.

The model for this example has the following blocks:



- An input block which shows **Input Device** as the device name

  The incoming data is in real time and continuous. The input block receives the data from the sensor. It passes the data to the **Average (Mean)**, **Delta** and **Threshold** blocks. The input ports of these blocks are connected to the output port of the input block.

- An **Average (Mean)** block

  This block finds the average (or mean) of the readings that it receives over a period of time and passes this to the connected output block.

- A **Delta** block

  This block calculates the difference between successive input values and passes the calculated value to the connected **Threshold** block.

- Two different instances of a **Threshold** block

  A **Threshold** block compares the input value against the defined threshold value to detect whether the input breaches the threshold or not.

  The first instance is connected to the **Delta** block and reports a breach if the delta value goes beyond the threshold.

  The second instance is connected to the input block and reports a breach if the input value is not within the threshold.

- Three instances of an output block which show **Output Device** as the device name

  The first instance sends the average of the sensor reading.

  The second instance generates an output if the values of successive sensor readings change by more than the configured threshold.

The third instance generates an output if the sensor value goes beyond the configured threshold.

3 Using the Model Manager

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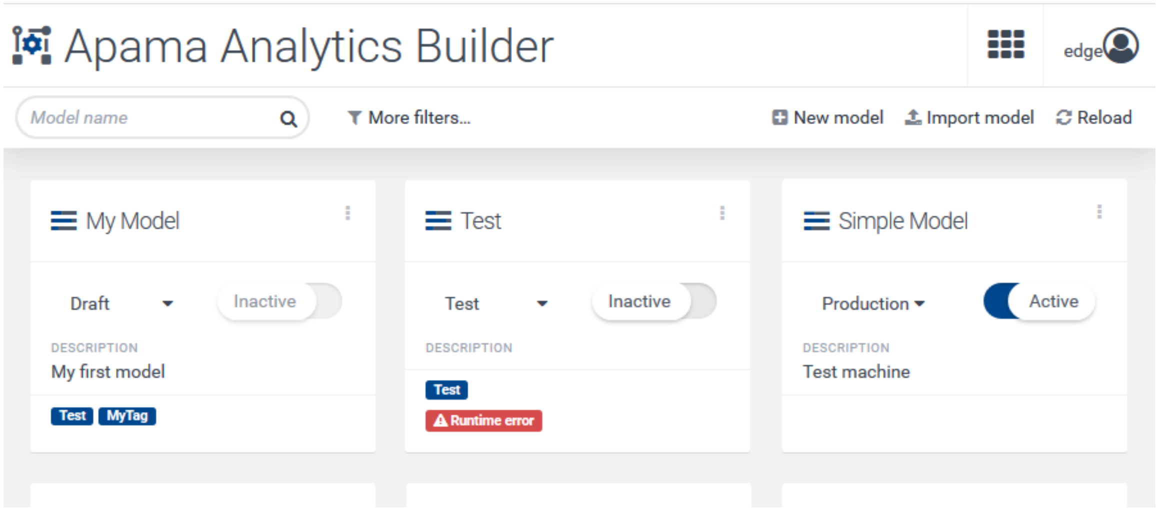
The model manager user interface

The model manager lists all available analytic models (for example, within the current Cumolocity IoT installation) as cards. Each card shows the mode (such as **Draft** or **Production**) and state (**Active** or **Inactive**) of a model. You add new models and manage the existing models from here.



Each card that is shown for a model has an actions menu (the three vertical dots that are shown at the top right of a model) which contains commands for managing the model (for example, to export or remove the model).

To edit a model, you can simply click on the card that is shown for the model (see also "Editing an existing model" on page 27). When you add a new model or edit an existing model, the model editor is invoked in which you define the blocks and wires that make up a model. See "Using the Model Editor" on page 31 for detailed information.

If one or more tags have been defined for a model, they are shown on the card for that model.

If you want to change the name, the description or the tags of an existing model, you have to do this in the model editor. See "Changing the name, description, and tags of a model" on page 33.

If you have a long list of cards, you can easily locate the model that you are looking for by entering its name in the **Model name** search box. Or you can enter part of the model name. For example, enter the word "test" to find all models that have this word in their names. The characters that you type in may be contained at any position within the model name. These search criteria are not case-sensitive. When search criteria are currently applied, **Clear search** is shown next to the search box; click this to clear the search and thus to show all available cards.

You can also reduce the number of shown cards by using a filter. See "Filtering the models" on page 25 for detailed information.

If ⚠ Runtime error is shown on the card of a deployed model, this model is no longer processing events. Move the mouse pointer over this message to display a tooltip with information on what went wrong.

See the Cumulocity documentation for detailed information on the items that are shown in the top bar (application switcher and user button).

Filtering the models

The model manager offers several ways to reduce the number of shown cards, thus letting you quickly locate the models that you are looking for.

Filtering also works in combination with a model name that you specify in the **Model name** search box which is explained in "The model manager user interface" on page 24.

To filter the models

1. In the toolbar of the model manager, click **More filters**.
2. In the resulting dialog, select one or more filters.

   You can filter the models according to the following criteria:

   - **Mode**

     You can show only the models that are in a specific mode. For example, if you only want to see the models that are in simulation and test mode, select the corresponding check boxes.

   - **Status**

     You can show only the models that are in either the Active or Inactive state. For example, if you only want to see active models, select the corresponding check box.

   - **Device**

     You can show only the models that use specific devices in their input blocks and output blocks. Open the **Filter by device name** drop-down list box, select one or more devices, and click **Apply**.

   - **Data point**

     You can show only the models that use specific data points, such as `c8y_TemperatureMeasurement`. This requires that at least one device has been selected in the **Filter by device name** drop-down list box. Open the **Filter by data points** drop-down list box, select one or more data points, and click **Apply**.

   - **Tags**

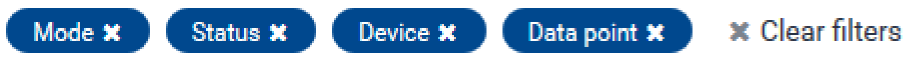
You can show only the models for which specific tags have been defined in the Model Configuration dialog box, which is shown when you add a new model or when you invoke that dialog box from the model editor (see also "Adding a new model" on page 26 and "Changing the name, description, and tags of a model" on page 33). Open the **Filter by tag** drop-down list box, select one or more tags, and click **Apply**.

All of the above-mentioned drop-down list boxes include a **Filter** search box that you can use to reduce the number of items that are offered for selection. You can enter a name or part of a name. For example, enter the word "test" to show only the items that have this word in their names. The characters that you type in may be contained at any position within the name. These filter criteria are not case-sensitive. Clicking the **All** check box selects all items that are currently shown in the drop-down list box, depending on the contents of the **Filter** search box.

You can combine several types of filters, for example, to show only active models in production mode that use a specific data point.

3. Click **Apply filters**.

   The toolbar of the model manager now shows the types of filters that are currently applied. For example:



   Click **Clear filters** in the toolbar if you want to clear all filters. Or to clear a specific filter, click on a filter icon in the toolbar, and deselect the filter in the resulting dialog box. Clicking **Reset filters** in that dialog box also clears all filters.

Adding a new model

When you add a new model, the model editor is invoked. See "Using the Model Editor" on page 31 for detailed information.

Note: The new model will only be listed in the model manager, when you save the model in the model editor. See also "Saving a model" on page 34.

To add a new model

1. In the toolbar of the model manager, click **New model**.
2. In the resulting Model Configuration dialog box, enter a unique model name.

   You can optionally enter a description for the model and one or more tags.

   Tags are helpful for filtering the models in the model manager to show only the models for which a specific tag has been defined (see also "Filtering the models" on page 25). To add a tag, you simply type its name and press Enter or the Tab key. The tag is then shown in a colored rectangle. To remove a tag, click on the ✕ that is shown in the rectangle. The dialog prevents you from entering duplicate tags for a model; if you enter such a tag name, the duplicate tag is not added and the original tag blinks one time.

3. Click **OK**.

   The model editor appears. See "Overview of steps for adding a model" on page 33 for a brief overview of how to add blocks and wires to the new model.

Editing an existing model

You can edit each model that is currently listed in the model manager.

If a model is in the Active state, editing will set the model to read-only mode. In this case, the model editor only allows you to view the contents of the model (for example, you can view the block properties). You can navigate and zoom the model as usual, but you cannot change anything. The save button in the model editor is therefore disabled.

To edit a model

- In the model manager, click the actions menu of the model that you want to edit (or view) and then click **Edit**.

  Or simply click the card that is shown for the model (but not on the toggle button for changing the state or the drop-down menu for changing the mode).

  If the model is in the Active state, a dialog appears informing you that you can only view the model. When you click **Continue**, the model editor appears and you can view the model, but you cannot change it.

  See "Using the Model Editor" on page 31 for further information.

Deploying a model

A model can have one of two states. The current state is always indicated on the toggle button that is shown for a model:

- **Active.** This state indicates that the model has been deployed.
- **Inactive.** This state indicates that the model is currently not deployed.

The inputs that a model receives and what happens to its outputs depends on the mode to which the model is set. Each model can be set to one of the following modes:

- **Draft.** The model is still under development. (New models are created in draft mode.)
- **Test.** When active, the model is deployed to the Apama correlator so that the measurements and events from the devices are processed. The output of the model is only stored (and recorded as an `Operation` or `Measurement` object of a "virtual device") and *not* sent back to the devices.
- **Simulation.** When active, the model uses historical input data (replayed from previously received data) and is deployed to the Apama correlator. The output of

the model is only stored (and recorded as an `Operation` or `Measurement` object of a "virtual device") and *not* sent back to the devices. To start a simulation, you must define the time range from which the input data is to be used. When all data from the time range has been replayed, the model is automatically undeployed from Apama and the model state is changed to Inactive. The timestamps of the historical data entries remain unchanged for easier comparison of simulation runs. See also "Model Simulation" on page 65.

- **Production.** When active, the model is deployed to the Apama correlator so that the measurements and events from the devices are processed. The output of the model is stored and sent back to the devices.

A model in draft mode can only be in the Inactive state. A model in test, simulation or production mode can be in either the Active or Inactive state.

When a model is imported by loading a JSON file, it is always imported as an inactive model.

To deploy a model

1. In the model manager, click the drop-down menu in the model that you want to deploy and select one of **Production**, **Test** or **Simulation**.
2. If you have selected simulation mode, click the calendar icon which is now shown, specify the time span that is to be used, and click **Apply**. See also "Simulation parameters" on page 66.
3. When the toggle button currently shows **Inactive**, click this button to change the state to **Active**. For simulation mode, you can only set the state to **Active** when a valid time range has been defined.

Undeploying a model

You can undeploy each model that is currently in production, test or simulation mode and for which the toggle button shows **Active**.

When you undeploy a model, the model is stopped and no longer processes incoming data. Any state built up in the model is lost. For simulation mode, this means that the model is stopped before all historical data from the specified time range has been replayed.

To undeploy a model

- In the model manager, click the toggle button in the model that you want to undeploy so that **Inactive** is then shown on the button.

Copying a model

You can copy each model that is currently listed in the model manager.

When you copy a model, the copy gets the same name as the original model followed by the number sign (#) and a number. For example, when the name of the original model is "My Model", the name of the first copy is "My Model #1". The number in the model name is increased by one with each subsequent copy that you create. The copy gets the same description as the original model. It is recommended that you edit the copy and give the model a meaningful name and description.

To copy a model

- In the model manager, click the actions menu of the model that you want to copy and then click **Copy**.

  A card for the copied model is immediately shown in the model manager.

Exporting a model

You can export each model that is currently listed in the model manager. This is helpful, for example, if you want to transfer a model from the current Cumulocity IoT installation to a different installation. The model is saved in JSON format.

To export a model

- In the model manager, click the actions menu of the model that you want to export and then click **Export**.

  The resulting behavior depends on your browser. The model is usually exported to the download location of your browser.

Importing a model

You can import a model that has previously been exported (in JSON format). This is helpful, for example, if you want to import a model from a different Cumulocity IoT installation.

To import a model

1. In the toolbar of the model manager, click **Import model**.
2. In the resulting dialog box, navigate to the location where the model that you want to import is stored.
3. Select the model and click **Open**.

   A card for the imported model is shown in the model manager.

Removing a model

You can remove each model that is currently listed in the model manager. When you remove a model that is currently deployed, it is first undeployed and then removed.

To remove a model

1. In the model manager, click the actions menu of the model that you want to remove and then click **Remove**.
2. In the resulting dialog box, click **Remove** to confirm the removal.

Reloading all models

You can refresh the display to show any changes other users have made since the page loaded, or to see whether deployed models have entered a failed state.

To reload all models

- In the toolbar of the model manager, click **Reload**.

4 Using the Model Editor

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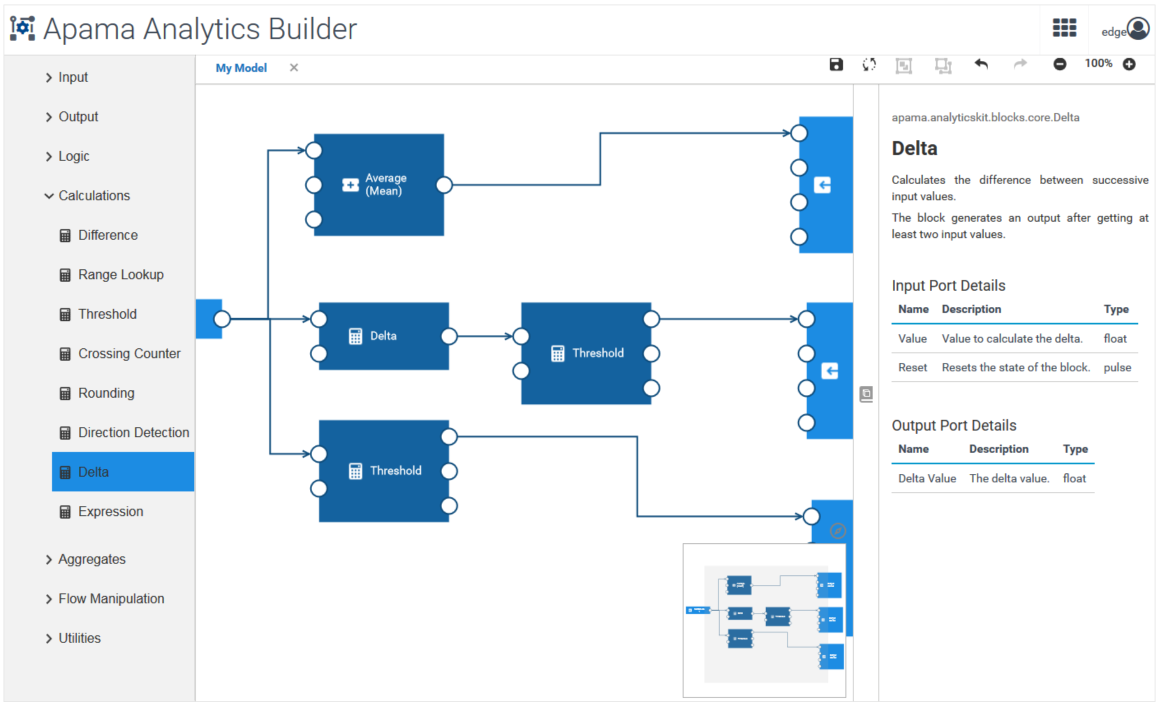
The model editor user interface

The model editor allows you to create analytic models graphically. It is invoked when you add or edit a model in the model manager. See also "Adding a new model" on page 26 and "Editing an existing model" on page 27.



apama.analyticskit.blocks.core.Delta

Delta

Calculates the difference between successive input values.

The block generates an output after getting at least two input values.

Input Port Details

Name	Description	Type
Value	Value to calculate the delta.	float
Reset	Resets the state of the block.	pulse

Output Port Details

Name	Description	Type
Delta Value	The delta value.	float

The palette on the left contains the blocks that you can add to your model. It has several expandable/collapsible categories for the different types of blocks.

The canvas in the middle is the area in which you "draw" your model. You drag the blocks from the palette onto the canvas, specify the parameters for the blocks, and wire the blocks together.

The overview area at bottom right of the canvas shows the entire model. This is helpful if your model is too large to fit on the currently visible area of the canvas. See also "Navigating large models" on page 46.

The documentation pane on the right allows you to view reference information for the currently selected block. See also "Viewing the documentation for a block" on page 36.

Caution: Changes are only saved when you click 💾 (see also "Saving a model" on page 34). The editor warns you if you attempt to navigate away from the editor and there are unsaved changes, however, you should always ensure that your changes are saved before disconnecting the browser from the network or suspending a laptop.

Working with models

Overview of steps for adding a model

This topic gives a brief overview of how to add and design a new model. For more detailed information, see the topics that are referenced in the steps below.

You add and design a model as follows:

1. In the model manager, click **New model**. Enter a model name in the resulting dialog box. See also "Adding a new model" on page 26.
2. In the model editor, drag the required blocks from the palette onto the canvas. See also "Adding a block" on page 35.
3. Refer to the block documentation as necessary. See also "Viewing the documentation for a block" on page 36.
4. Use the block parameter editor to specify the parameters of the block. See also "Editing the parameters of a block" on page 35.
5. Connect the appropriate blocks with wires. See also "Adding a wire between two blocks" on page 38.
6. Save your changes. See also "Saving a model" on page 34.

   Note: Only saved models are listed in the model manager. When you add a new model and then leave the model editor without saving the model, it will not be listed in the model manager, and all the edits you made will be lost.

7. Leave the model editor. This takes you back to the model manager. See also "Leaving the model editor" on page 34.
8. A newly added model is automatically set to draft mode in the model manager. If you want to test it, simulate it, or make it available in production, see "Deploying a model" on page 27.

For detailed background information, including restrictions, see "Wires and Blocks" on page 49.

Changing the name, description, and tags of a model

You can rename each model that you are currently editing in the model editor, and you can also change the description of each model.

You can also add or remove tags. Tags are helpful in the model manager, to show only the models for which a specific tag has been defined (see also "Filtering the models" on page 25).

To change the name, description, and tags of a model

1. In the model editor, click on the model name which is shown at the left of the toolbar.
2. In the resulting Model Configuration dialog box, specify a new unique name for the model, change the description, and/or change the tags.

   To add a tag, you simply type its name and press Enter or the Tab key. The tag is then shown in a colored rectangle. To remove a tag, click on the ✕ that is shown in the rectangle. The dialog prevents you from entering duplicate tags for a model; if you enter such a tag name, the duplicate tag is not added and the original tag blinks one time.
3. Click **OK**.

Saving a model

When you save a model in the model editor, it is stored in the Cumulocity inventory for your tenant, in JSON format.

Important: It may happen that you and another user are editing the same model at the same time. In this case, the changes that are saved last will be stored. So your changes might be overwritten by a later save by another user.

To save a model

- In the toolbar of the model editor, click 💾.

  This toolbar button is only enabled when changes have been applied to the model and when the model has been given a name.

Leaving the model editor

When you leave the model editor using the corresponding toolbar button, you are returned to the model manager. You can then, for example, edit a different model, or change the mode or state of the current model.

Caution: All unsaved changes are lost when you navigate to a different URL or close the browser window.

To leave the model editor

- In the toolbar of the model editor, click ✕ (shown to the right of the model name).

  In case there are still unsaved changes, you are asked whether to save or discard them.

Working with blocks and wires

Adding a block

The blocks in the palette are grouped into different categories. The blocks in the **Input** and **Output** categories represent devices that have been registered in Cumulocity's inventory (visualized in the Device Management application). Other categories contain blocks, for example, for adding logic to the model or for adding calculations.

When you move the mouse pointer over a block in the palette, a tooltip appears which briefly explains the purpose of the block. The tooltip also shows the entire name of the block; this is helpful, for example, with input and output blocks when the device name is not fully shown in the palette. Detailed information for each block is available in the documentation pane; see "Viewing the documentation for a block" on page 36.

To add a block

1. In the palette of the model editor, expand the category which contains the block that you want to add.
2. Drag the block from the palette and drop it onto a free space of the canvas.
3. Specify all required parameters for the block. See "Editing the parameters of a block" on page 35.

   Note: The block parameter editor is automatically shown when you add a block for which parameters need to be specified. It is not shown, however, if the block does require any parameters (such as the **OR** block).

Editing the parameters of a block

Most blocks (but not all) have parameters that you have to set according to your requirements.

The block parameter editor also contains commands for duplicating and deleting the currently selected block. See "Duplicating a block" on page 38 and "Deleting a block or wire" on page 39 for detailed information.

For the input and output blocks, you can globally replace the devices that are used. See "Replacing devices" on page 40 for detailed information.

To edit the parameters of a block

1. On the canvas of the model editor, click the block that you want to edit using the *left* mouse button.

   The block parameter editor appears, providing input fields for all parameters that can be specified for that block.

2. For some blocks (such as an input block or output block for a device), the block parameter editor shows a **Block Type** drop-down list box. Select the type of block that is appropriate for your requirements.

   Note: The following applies when you change the block type for a block that is already wired to one or more other blocks: if the new block type has different port names (for example, if the port name changes from **Value** to **Value 1**), the existing wires to/from the changed ports are removed. This is done because a changed port name would make the existing wiring invalid.

3. For some blocks (such as the **Range Lookup** block), the block parameter editor shows text boxes for specifying key-value pairs. If you need to specify more key-value pairs, click **Add row**. The key-value pair in the first row is processed first. You can drag a row to a different position using the ⇅ control that is shown next to that row, and you can delete a row that you do not need any more by clicking ✕ next to that row. Empty rows are automatically removed when you leave the block parameter editor.

4. Specify all required parameters.

   Detailed reference information for each block (and block type) is available from the documentation pane. See also "Viewing the documentation for a block" on page 36.

   Your input is kept in memory when you leave the block parameter editor (for example, when you click on another block or the canvas).

   Note: Keep in mind that your changes are only written to the inventory when you save the model. See also "Saving a model" on page 34.

Viewing the documentation for a block

The documentation pane allows you to view detailed information for the currently selected block. It shows the so-called *Block Reference* which provides documentation of a block's parameters, input ports and output ports. You can resize the documentation pane, and you can also toggle its display.

To view the documentation for a block

1. In the model editor, click the block for which you want to view the documentation. You can do this in the palette or on the canvas.

2. When a **Block Type** drop-down list box is shown in the block parameter editor, select the block type for which you want to view the documentation.

3. If the documentation pane is currently not shown, click the area that contains the ⧉ icon (shown at the right of the canvas) to display the documentation pane. Clicking that area again hides the documentation pane.

4. If you want to resize the documentation pane (for example, to make it larger), move the mouse pointer over the area that contains the ⧉ icon. When the mouse pointer changes to show the resize icon (←‖→), click and hold down the mouse button and drag the mouse to the left or right (to make the documentation pane wider or smaller).

Selecting blocks and wires

If you want to move, duplicate or delete one or more blocks that are currently shown on the canvas of the model editor, you first have to select the required blocks.

To select a single block on the canvas, you just need to click the block. With a block, the resulting behavior depends on the mouse button that you use:

- When you click the block using the *left* mouse button, the block is selected and the block parameter editor is shown (see also "Editing the parameters of a block" on page 35).
- When you click the block using the *right* mouse button, the block is selected only (the block parameter editor is not shown). This is helpful if the editor would be in the way, for example, when adding a wire to another block.

To select a single wire, you just need to click the wire (you can use either mouse button in this case).

To select several blocks and/or wires at the same time, do one of the following:

- Press Ctrl and click each block and/or wire that you want to select.
- Or to select an area containing several blocks and wires, click and hold down the mouse button over an empty space of the canvas and wait until the mouse pointer changes to a cross. Then drag the mouse to select the desired area. Release the mouse button when all required blocks and wires have been selected.
- Or to select all blocks and wires, press Ctrl+A.

To deselect your selection:

- Press Ctrl and click the currently selected block or wire.
- Or to deselect all selections, click an empty space of the canvas.

Moving a block

You can move each block that is currently shown on the canvas to different location. When one or more wires are attached to a block that is moved, the wires are also moved.

To move a block

- On the canvas of the model editor, click the block that you want to move, hold down the mouse button and drag the block to the new location.

- Or to move several blocks at the same time, select them as described in "Selecting blocks and wires" on page 37. Then click and hold down the mouse button and immediately drag the blocks to the new location (do not wait until the mouse pointer changes).

Duplicating a block

You can duplicate each block that is currently shown on the canvas. The original block and its copy will then both have the same parameters.

When you duplicate a single block, the attached wires are not automatically duplicated. Attached wires between two duplicated blocks, however, are automatically duplicated.

To duplicate a block

- On the canvas of the model editor, click the block that you want to duplicate and then do one of the following:
  - Click the **Duplicate** command which is shown at the bottom of the block parameter editor.
  - Or press Ctrl+C to copy the block, and then press Ctrl+V to paste the block.
  - Or press Ctrl and drag the block to be duplicated to the position at which you want to place the copy.
- Or to duplicate several blocks at the same time, select them as described in "Selecting blocks and wires" on page 37 and then proceed as described above. Exception: the **Duplicate** command is only available when you select a single block.

Adding a wire between two blocks

The blocks on the canvas can be wired together to indicate that the output from one block is used as the input for the other block.

The wires are attached to *ports*, that is, to the circles that are shown to the left and/or right of a block. Each block can have zero, one or more of the following:

- output ports (shown at the right side of a block)
- input ports (shown at the left side of a block)

To see the labels of the ports, click the block to select it. Or move the mouse pointer over a port to see the label in a tooltip.

See "Wires and Blocks" on page 49 for detailed information on the types of values that can be sent between two blocks, the processing order of wires, restrictions, and more.

To add a wire between two blocks

- On the canvas of the model editor, click the output port of the block that you want to connect and drag the mouse to the input port of another block.

Changing a wire

You can change the path that a wire takes to the block to which it is currently connected. And you can also rewire a block so that it is connected to a different block or to a different port of the same block.

Wires cannot create cycles. See "Wire restrictions" on page 58 for detailed information.

To change a wire

1. On the canvas of the model editor, click the wire that you want to change.

   This automatically selects the blocks to which the wire is currently attached so that you can see the port names.

2. To change the path that a wire takes between two blocks, drag one of the resize icons (■) that are now shown on the selected wire to a different position.

   Or to move the wire to a different port, drag the move icon (◆) that is now shown at the input or output port (a hand pointer is shown in this case) to a different port.

Deleting a block or wire

You can delete each block or wire that is currently shown on the canvas. When you delete a block, all wires that are attached to this block are automatically deleted.

To delete a block or wire

- On the canvas of the model editor, click the block or wire that you want to delete and press Del.

  In the case of a block, you can alternatively click the **Delete** command which is then shown at the bottom of the block parameter editor.

- Or to delete several blocks and/or wires at the same time, select them as described in "Selecting blocks and wires" on page 37 and then press Del.

Undoing and redoing an operation

You can undo and redo each change that has been applied to the canvas. For example, you can undo the deletion of blocks, undo changed parameter values, or undo the rerouting of a wire.

It is not possible to undo/redo the change to a model name or its description.

Note: To use the key combinations mentioned below, the canvas must have the focus. When the documentation pane or the palette currently has the focus, the change on the canvas is not undone/redone.

To undo or redo an operation

- To undo the last operation, click ↶ in the toolbar of the model editor.

  Or press Ctrl+Z.

- To redo the last operation, click ↷ in the toolbar of the model editor.

  Or press Ctrl+Y.

The above toolbar buttons are only enabled when there is an operation that can be undone or redone.

Replacing devices

You can search the input and output blocks for the devices that are used in the current model and replace them with other devices that are currently registered in Cumulocity's inventory (visualized in the Device Management application).

After you have replaced the devices, you need to verify that the measurements that are used by the input and output blocks of the current model still refer to the appropriate measurements. The Cumulocity fragment and series are not changed by the replacement, which may or may not apply to the newly defined device.

To replace devices

1. In the toolbar of the model editor, click ⟳. This toolbar button is only enabled when at least one device has been defined in the current model.
2. In the **Current device** drop-down list box of the resulting dialog box, select the device that you want to replace. All devices that are used in the model are available for selection.
3. In the **Replace with** drop-down list box, select the device that you want to use instead. All devices that are registered in Cumulocity's inventory are available for selection.
4. If you want to replace further devices, click **Add row**. This is only shown if more than one device has been defined in the current model.

   A new row is shown, containing additional **Current device** and **Replace with** drop-down list boxes, and you can now select one more device to be replaced. Any devices that you have previously selected for replacement are no longer offered for selection in the **Current device** drop-down list box.

   Repeat this step until all required devices have been selected for replacement. You can add as much rows as there are devices in the current model.

5. If you want to remove a row (for example, when you no longer want to replace the selected device), click ✕ next to that row. This is only available if the dialog box currently shows more than one row.
6. Click **Replace**.

Copying items to a different model

You can copy any items on the canvas (blocks, groups, and attached wires) and paste them in a different model. The prerequisite for this is that all is done in the same session. It will not work if you try to paste the items in a different tab or in a different browser.

Caution: There may be performance issues if you copy many input blocks and output blocks. This is because this operation requires access to Cumulocity's inventory service to get the information about the devices that are represented by these blocks.

To copy items to a different model

1. On the canvas of the model editor, select all items that you want to copy and press Ctrl+C.

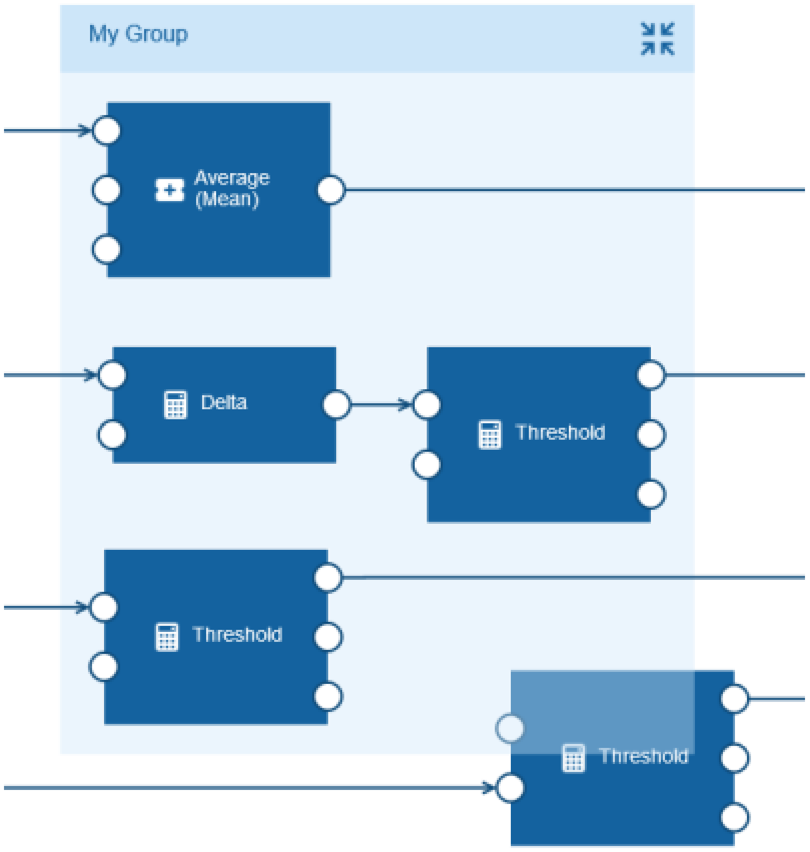
   This also works if the model is currently in read-only mode.
2. Leave the model editor. See also "Leaving the model editor" on page 34.
3. In the model manager, switch to the model into which you want to paste the copied items. This can be an existing model (see also "Editing an existing model" on page 27) or a new model that you first have to create (see also "Adding a new model" on page 26).
4. When the model editor is shown, press Ctrl+V to paste the copied items into the model.

Working with groups

What is a group?

You can arrange blocks and their attached wires in a group. A group is a special type of block which can be collapsed and expanded. When a group is expanded, you can change its contents in the same way as you would on the canvas, for example, you can add wires or edit the block properties. You can also add more blocks to the group or remove blocks from the group. When a group is collapsed, it occupies less space on the canvas, however, the blocks and wiring within the group are not visible in this case.

Groups are helpful if commonly required functionality needs to be made available in multiple places. You can give each group a name by which it can be identified. You can copy a group and paste it in either the same model or in a different model.



The size of the box that is shown for a group is determined by its contents. If you move a block within the group to a different position, the box size is automatically adapted (that is, the box is made larger or smaller). The same applies if you change the path that a wire takes to another block within the same group.

You move a group on the canvas in the same way as you move a block (see also "Moving a block" on page 37). When you move a group, the group is always shown on top of all other items on the canvas. As the group box is transparent, you can easily see which blocks belong to the group and which are just overlayed by the box.

It is not possible to nest groups.

Note: There is one exception when managing the contents of a group: When you copy one or more blocks that are contained in a group using Ctrl+C and Ctrl +V or if you use the **Duplicate** command in the block parameter editor, the copy is not added to the group. It is added to the canvas instead. However, when you press Ctrl and then drag the blocks to be duplicated, you can place the copy either within the group (this can be the same or a different group) or on the canvas. See also "Duplicating a block" on page 38.

Adding a group

You can add any blocks that are currently shown on the canvas (including the wires between the blocks) to a group.

To add a group

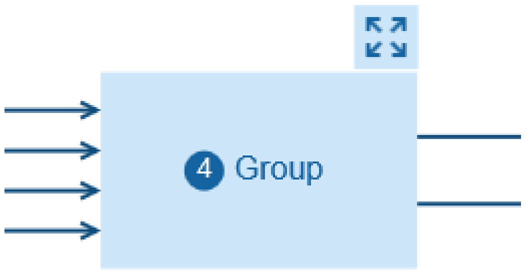
1. On the canvas of the model editor, select one or more blocks that you want to add to a group. You need not select wires; all existing wires are retained. See also "Selecting blocks and wires" on page 37.
2. In the toolbar of the model editor, click .

   Or press Ctrl+G.

Collapsing and expanding a group

If you need more space on the canvas and do not need the group contents to be visible, you can collapse the group.

When a group is collapsed, a number is shown on the collapsed group indicating the number of blocks in that group. For example:



If you want to make the group contents visible again (for example, to edit block properties or to add wires), you have to expand the group.

When you save the model, the state of each group (that is, whether it is currently collapsed or expanded) is stored. The next time you edit the model, its contents will be shown as after the last save.

To collapse or expand a group

- To collapse a group, click which is shown next to the group name.
- To expand a group, click which is shown above the top right of the collapsed group.

Renaming a group

When you add a group, its default name is "Group". You can rename each group and give it a unique name.

If a group name is longer than can be shown in the group label, move the mouse pointer over the group name to view the entire name in a tooltip.

It is not possible to have groups without names. If you delete a group name, the previous name is automatically used again.

To rename a group

1. In the model editor, select the group and then click on the group name. You can either do this when the group is collapsed or expanded (see also “Collapsing and expanding a group” on page 43). This selects the entire name for editing.
2. Specify a new group name and press Enter.

Moving blocks into a group

You can move one or more blocks from the canvas into an existing group. All existing wires are retained.

You can only move blocks into a group when its contents is visible, that is, when the group is currently expanded. See also “Collapsing and expanding a group” on page 43.

To move blocks into a group

1. Make sure that the group into which you want to move the blocks is not collapsed.
2. On the canvas of the model editor, select the blocks that you want to move into the group (see also “Selecting blocks and wires” on page 37). You need not select the wires between the blocks; they are automatically moved together with the blocks.
3. Do one of the following:
   - Drag the selection into the group and drop it there.
   - Or select the group into which you want to move the blocks. Then click in the toolbar of the model editor, or press Ctrl+G.

Removing blocks from a group

When you remove a block from a group, the block is moved to the canvas. It is not deleted. All existing wires are retained.

When the last item of a group has been removed, the group is automatically deleted. If you want to remove all items from a group at the same time, you can simply ungroup the entire group. See “Ungrouping a group” on page 45.

To remove blocks from a group

- To remove one or more blocks from a group at the same time:
  1. In the expanded group, select the blocks that you want to remove.
  2. In the toolbar of the model editor, click . Or press Ctrl+Shift+G.
- Or to remove a single block from a group:
  1. In the expanded group, select the block that you want to remove.
  2. Click the **Remove from Group** command which is then shown at the bottom of the block parameter editor.

Deleting blocks and wires from a group

You delete blocks and wires from a group in the same way as deleting them directly on the canvas. The only prerequisite is that the group is currently expanded. See "Deleting a block or wire" on page 39.

If the last item in a group is deleted, the group is automatically deleted.

Copying a group

You can copy each group that is currently shown on the canvas. The original group and its copy will then both have the same contents.

Wires coming in from blocks outside of the group or going from the group to blocks outside of the group are not copied.

You can also copy a group into a different model, see "Copying items to a different model" on page 41.

To copy a group

- On the canvas of the model editor, click the group that you want to copy (it does not matter whether the group is currently collapsed or expanded) and then do one of the following:
  - Press Ctrl+C to copy the group, and then press Ctrl+V to paste the group.
  - Or press Ctrl and drag the group to be copied to the position at which you want to place the copy.

Ungrouping a group

When you ungroup a group, the group is removed and all the blocks from that group are shown directly on the canvas. All attached wires are retained.

You can ungroup several groups at the same time. In this case, it is important that no block or wire is selected either within or without the selected groups, otherwise ungrouping is not possible.

To ungroup a group

1. On the canvas of the model editor, select one or more groups that you want to ungroup. It does not matter whether a group is currently collapsed or expanded.
2. In the toolbar of the model editor, click .

   Or press Ctrl+Shift+G.

Deleting a group

You can delete each group that is currently shown on the canvas.

Caution: When you delete a group, all blocks and wires within this group are also deleted.

To delete a group

- On the canvas of the model editor, click the group that you want to delete (it does not matter whether it is currently collapsed or expanded) and press Del.

Managing the canvas

Navigating large models

If your model is too large to fit onto the visible part of the canvas, you can use the mouse to drag the parts of the model into view that are currently outside of the window. You can do this either directly on the canvas or in the overview area. The overview area always shows the entire model. If the overview area is currently not shown, see "Showing and hiding the overview" on page 47.

To navigate in a large model

1. In the model editor, position the mouse over a free spot of the canvas (which does not contain a block or wire) or anywhere over the overview area.
2. Click and hold down the mouse button, and immediately drag the mouse into the desired direction. Release the mouse button when the required area is visible on the canvas.

   Note: When you hold down the mouse button for a longer time over a free spot of the canvas, the mouse pointer changes and you can select an area instead (for example, several blocks and attached wires). See also "Selecting blocks and wires" on page 37.

Showing and hiding the overview

The overview area, which shows the entire model, is shown at bottom right of the canvas. If you do not need the overview, you can hide it.

To show or hide the overview

- To hide the overview, click ⊘ which is shown directly above the overview area.
- To show the overview, click ⊘ at the bottom right of the canvas.

Zooming the canvas

The toolbar of the model editor indicates the current zoom percentage for the canvas. The zoom buttons in the toolbar allow you to

- zoom out, which makes everything on the canvas smaller so that more items can be shown, and to
- zoom in, which makes everything on the canvas larger, but less items can then be shown.

Note: When you use the key combinations mentioned below, the currently selected area defines what is to be zoomed. When the canvas has the focus (for example, when you have just selected a block or wire), only the content of the canvas is zoomed. When the documentation pane or the palette currently has the focus, the browser's zoom functionality is used and all of the browser content is zoomed (and the zoom percentage in the toolbar remains unchanged).

To zoom the canvas

- To zoom out, click ⊖ in the toolbar of the model editor.

  Or press Ctrl and the minus key.
- To zoom in, click ⊕ in the toolbar of the model editor.

  Or press Ctrl and the plus key.

5 Wires and Blocks

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Values sent on a wire

Blocks within a model are connected from block outputs to block inputs with wires.

Note: These block outputs and inputs are also called *output ports* and *input ports*. See also "Adding a wire between two blocks" on page 38.

Wires allow blocks to pass signals and values between blocks. The value sent on a wire is one of the following types, according to the block output from which it is connected:

Type	Description
`boolean`	A true or false value. A boolean value stays true or false until changed.
`float`	A numeric value, which can be fractional (and processed using fixed precision). A float value maintains its current value until changed.
`string`	A textual value. A string value maintains its current value until changed.
`pulse`	A signal of a point in time. Pulses are only active momentarily. Unlike the above types, they only represent a single instance in time. See also "The pulse type" on page 56.
`any`	A value that may be any of the above types. See also "The any type" on page 56.

The type of a wire depends on the output to which it is connected. This can be viewed in the block reference. Similarly, the type (or supported types) of a block's input can be viewed in the block reference.

Value types

The following types are referred to as *value types*:

- `boolean`
- `string`
- `float`
- `any` when used to hold a `boolean`, `string` or `float` value

Value types are useful for modeling measurements such as sensor values, which may be read intermittently, or sampled. In between readings, the physical property being measured (such as temperature) will still have some value, as it is a continuous property. For practical reasons, a sensor may not give a continuous stream of output but instead a periodic sampling, or provide new readings only if the value being measured has changed (within whatever measurement resolution the sensor provides). Between sample points, blocks will use the most recent value, as that is the most up to date value being provided. In general, blocks assume that a value stays at whatever the most recent reading of that value is until a new value is received.

For example, consider a pair of temperature sensors. One provides a reading every 10 seconds regardless, while another only provides a new reading if the value has changed by 0.5 degrees. If we connect these to a **Difference** block, then we may have inputs as shown in the following table, with the corresponding result from the **Difference** block's **Absolute Difference** output:

Time	Sensor 1 (reads every 10s)	Sensor 2 (output if changed by 0.5)	Difference block: Absolute Difference output
10:00:00	20.0		
10:00:03		22.0	2
10:00:10	20.0		2
10:00:20	20.0		2
10:00:23		22.5	2.5
10:00:28		23.0	3
10:00:30	21.1		1.9
10:00:35		23.5	2.4
10:00:40	22.8	24.0	1.2

Note that two inputs (to different input nodes of the block) to the same block with the same timestamp only generate a single output. For each wire within a model (and each input block), there can only be a single value for a given point in time. An input block cannot generate more than one output for the same timestamp. If it receives multiple events at the same time, then it is undefined which of the events is picked.

In general, blocks will not consider there to be any significance to a wire receiving the same `boolean`, `float` or `string` value as before. Most blocks will not change behavior.

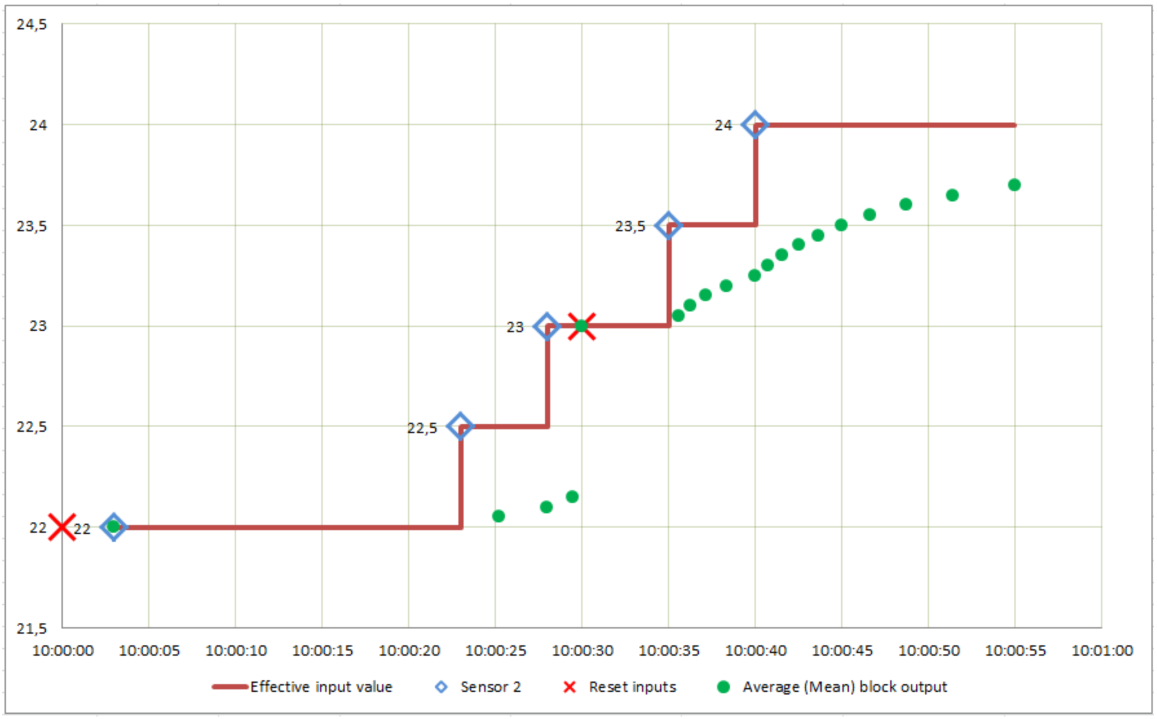
This is true for any arithmetic blocks, such as the **Difference** block in the example above: the output is still 2 on the repeated readings from sensor 1. There are some exceptions, such as the **Missing Data** block when the **Ignore Repeated Inputs** check box is not selected (`false`).

If a single block has a numeric value input and pulse signals such as reset, the absence of a new value when a pulse signal occurs means that the value is treated as having the same value still. Thus, when an **Average (Mean)** block is reset, its output will be equal to the most recently received input (assuming it has received an input since the model has started). In the example below, the **Average (Mean)** block's duration has not been set, while the output threshold is set to 0.05; this means the block will generate new output even if there is no new input (see "Common block inputs and parameters" on page 59).

Time	Reset signal	Sensor 2	Average (Mean) block output	Notes
10:00:00	Reset			No output. There has been no input value yet.
10:00:03		22.0	22.00	With no history, the output value is the input value.
10:00:23		22.5		All of the values up to this point have been 22, so the average value is still 22 (thus, no new output is generated).
10:00:25.22			22.05	Average of 20 seconds at value 22 and 2.22 seconds at value 22.5.
10:00:28		23.0	22.10	Average of 20 seconds at value 22 and 5 seconds at value 22.5.
10:00:30	Reset		23.00	The input is still 23 (we just have not received a new event), and reset only discards the history. With no history, the output value is the input value.
10:00:35		23.5		

Time	Reset signal	Sensor 2	Average (Mean) block output	Notes
10:00:35.56			23.05	Average at various points in time, when the output changes by 0.05.
10:00:36.25			23.10	
10:00:37.14			23.15	
10:00:38.33			23.20	
10:00:40		24.0	23.25	Average of 5 seconds at value 23 (from reset at :30 to :35) and 5 seconds at value 23.5 (from :35 to :40).

The following graph illustrates the inputs to the **Average (Mean)** block and the output of this block:



Note how the effective input value is unchanged until a new measurement input occurs, and the **Average (Mean)** block operates on this effective value (the red line in the above graph). When reset, the block outputs the current effective input, which at the second reset at 10:00:30 is 23. Note that when the **Output Threshold** parameter is set, new outputs can be generated even if no new input occurs, and will asymptotically approach the last input value. Note that this behavior differs from Apama queries or stream queries.

If the **Average (Mean)** block was configured with a window of 10 seconds, then the window would apply as illustrated below:

Time	Reset signal	Sensor 2	Effective input value	Average (Mean) block output	Values in window history	Notes
10:00:00	Reset					
10:00:03		22	22	22.00		First value after start: the window is empty, so the **Average (Mean)** block uses the input value for the output.
10:00:23		22.5	22.5		22	
10:00:23 - 10:00:28			22.5	increasing from 22.00 to 22.20	22, 22.5	Proportion of window that is 22 or 22.5 changes over time, thus the output changes.
10:00:28		23	23	22.25	22, 22.5	
10:00:28 - 10:00:30			23	increasing from 22.25 to 22.40	22, 22.5, 23	
10:00:30	Reset		23	23.00		Window is reset and thus now empty; the current (effective) input is 23, so the **Average (Mean)** block uses that for the output.
10:00:35		23.5	23.5		23	

Time	Reset signal	Sensor 2	Effective input value	Average (Mean) block output	Values in window history	Notes
10:00:35 - 10:00:40			23.5	increasing from 23.00 to 23.20	23, 23.5	
10:00:40		24	24	23.25	23, 23.5	Window is now full (10 seconds since reset).
10:00:40 - 10:00:45			24	increasing from 23.25 to 23.75	23, 23.5, 24	
10:00:45			24	23.75	23.5, 24	Value 23 is now finally expired from the window (this was the effective input until 10:00:35, which is 10 seconds ago).
10:00:45 - 10:00:50			24	increasing from 23.75 to 24	23.5, 24	
10:00:50			24	24	24	Value 23.5 is now finally expired from the window (this was the effective input until 10:00:40, which is 10 seconds ago). The window now contains 10 seconds worth of measurements, all with value 24.

In the above, note how the current value only appears in the window (that is, contributing to the output value) after the measurement is received. At the point the measurement is received, it has zero weighting compared to the previous history. The sensor's value remains the effective input until is replaced with a newer value. For example, the block has an effective input value of 23.5 from 10:00:35 to 10:00:40, and the value 23.5 is thus only finally expired from the window at 10:00:50. When the window is empty, the effective input is used as the output instead, as the window is zero-length.

The pulse type

In contrast to value types, the `pulse` type represents a single point in time. This may be a result of a user pressing a momentary-action button, a state transition of a device, a sensor detecting a person walking through a door, a heartbeat event to denote a remote device is still alive, or a state transition of a block within a model.

Typically, blocks act upon every pulse sent to one of their inputs. Pulses are commonly used to trigger an output from a model using an output block, or used to reset the state of blocks within a model.

Pulses are active momentarily. In some regards, they are similar to a boolean value which is automatically reset to `false` after a model has processed a value.

Repeated pulses are typically significant, though they may not necessarily result in any change, depending on how they are being used. For example, repeatedly resetting an **Average (Mean)** block while its input value is unchanged will result in the output value remaining the same.

The any type

The `any` type is used on blocks which pass through a value of any type (for example, a **Time Delay** block or a **Gate** block).

Values of the `any` type can represent a value type or a `pulse` type.

Type conversions

It is legal to connect a block output to a block input if they are the same type. Most other connections are also permissible, which result in the conversions as described in the table below. An ✗ indicates that a connection is not legal; trying to deploy a model with such a wiring connection will fail.

		From block with output type				
		pulse	**boolean**	**float**	**string**	**any**
Connect to	**pulse**	✓	pulse occurs	pulse occurs	pulse occurs	pulse occurs

		From block with output type				
		pulse	**boolean**	**float**	**string**	**any**
input of type			when output changes to true	when output changes value	when output changes value	when output changes value (excluding changes to false)
	boolean	true when the pulse has occurred, otherwise false	✓	true if non-zero	true if not an empty string	true if value non-zero/ empty
	float	✗	0 for false, 1 for true	✓	✗	✗
	string	✗	"true" or "false"	number converted to a string (may be in scientific notation)	✓	string value (may be in scientific notation)
	any	✓	✓	✓	✓	✓

Only conversions that will always succeed are allowed. String values are not converted to float values; while the input conversion may work sometimes, it cannot be guaranteed to always work.

In many cases, you need not worry about type conversions and where a wire makes sense. Any type conversion that is needed happens automatically.

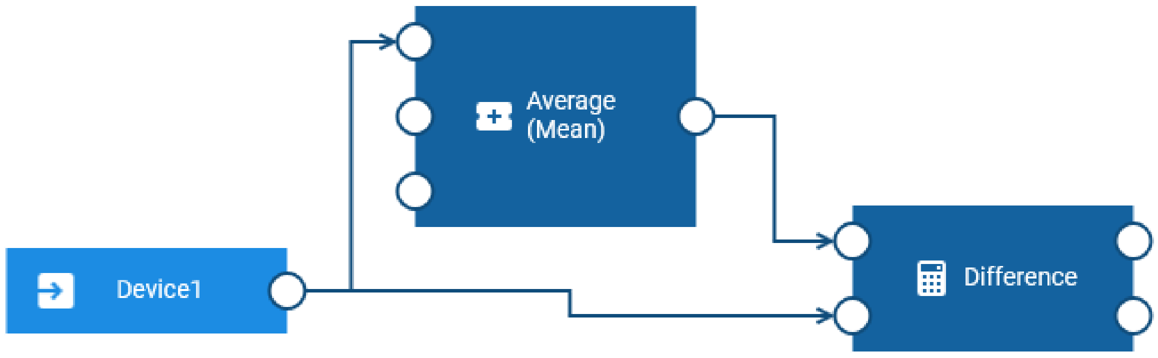
Some blocks accept different types of inputs, and may change their output type or behavior depending on the input types. For example, the logical **OR** block can operate on either boolean or pulse inputs, and its output is the same as its input types.

In some cases, it is desirable to force a value to be interpreted as a specific type, in which case a converter block can be used to force a conversion to a specific type. For example, the **Pulse** block can convert boolean or float values to pulses, according to the conversions above. This means: for boolean, generate a pulse when the boolean value changes to true; for float, generate a pulse when the value changes. Thus, connecting two float outputs to an **OR** block directly will generate a boolean output which is true when either of the float outputs is non-zero. Alternatively, connecting two float outputs each to a **Pulse** block and from them to the inputs of an **OR** block, will send a pulse whenever either float output changes value.

Processing order of wires

Where a block has multiple inputs connected, all of these inputs are calculated before the block performs any calculations based on the inputs. It may be that the inputs for a block occur out of step with each other (such as in the example for two temperature sensors in "Value types" on page 50), in which case a block uses the latest value for value type inputs.

Where a single value is sent on two or more paths which both lead to the same block, the block performs calculations based on the latest value for both paths. This ensures consistent behavior when multiple paths to a single block exist. For example:



When the device measurement is received, the **Average (Mean)** block calculation is completed to generate an average before the **Difference** block computes the difference between the value and its average.

Wire restrictions

While a block's output can be connected to multiple other blocks, a block's input can only have a single connection.

It is also legal to leave a block's input or output unconnected if that is not required (the **Average (Mean)** block in the example that is given in "Processing order of wires" on page 58 does not have anything connected to its **Sample** or **Reset** inputs).

Wires cannot create cycles. This means, the output of a block cannot be connected to

- the input of the same block, or to
- the input of any block that is connected directly or indirectly to one of the source block's inputs.

For example, there are three blocks: Block1, Block2 and Block3. A model would contain a cycle in the following cases:

- The output of Block1 is connected to the input of Block2, and the output of Block2 is connected to the input of Block1.
- The output of Block1 is connected to the input of Block2, the output of Block2 is connected to the input of Block3, and the output of Block3 is connected back to the input of Block1.

There are many possible connections which may lead to cycles in the model. The model editor, however, prevents you from creating cycles.

Block inputs and outputs

Many blocks have inputs or outputs that do not have to be used.

Some blocks generate several different outputs, and a model may only require some of the outputs available.

Some blocks have inputs, especially inputs of the `pulse` type, which do not have to be used. Leaving these not connected to anything is fine, and the operation associated with those inputs (such as **Reset**, see "Common block inputs and parameters" on page 59) will never be triggered.

Blocks can, when needed, detect which inputs are connected. For example, the **AND** block has five inputs, but it only requires the inputs that are connected to be `true` to generate a `true` output.

Common block inputs and parameters

The inputs listed below are the names of common input ports that are shown on the left side of a block.

- **Value** input

  Most calculation blocks have one main input which is called **Value**. This is the value on which the block performs its main calculation.

- **Value 1** and **Value 2** inputs

  Blocks may have a number of similar inputs, which may be labelled **Value 1**, **Value 2**, and so on. You can find such inputs with the **Difference** block (see also the example in

"Value types" on page 50) or with the **AND** and **OR** logic blocks. Typically, there is nothing significant as to which input is used.

- **Reset** input

  Blocks that maintain some internal state may also have a **Reset** input, which is typically a `pulse` type. This does not have to be connected, but can be used to explicitly control on which range of readings a block should perform a calculation. For example, a model that monitors vehicle journeys may reset on the engine starting, which signifies the beginning of a journey. See also "Value types" on page 50 for an example that illustrates the **Reset** input.

- **Sample** input and **Output Threshold** parameter

  Blocks typically re-calculate their output when a new input is received. Some blocks may also generate output at some point after receiving an input, either because of time delay parameters set (for example, with the **Missing Data** or **Time Delay** blocks), or because their output may change over time even if the input value is constant. For example, the **Integral** block with a positive input generates an ever-increasing output until its window is full (or indefinitely if no duration has been set, when the block is calculating the integral over an unbounded window).

  As with real-world sensors, it is not practical to create a continuously changing output. As well as generating an output if their input value changes, such blocks may also have a **Sample** input which triggers the block to re-evaluate and generate a new output, even if the input has not received any new value and the output has not changed by a significant amount. This is useful if there is a specific point in time when the output of the block should be calculated, as its output is going to be used at a later point in the model.

  Alternatively, such blocks may have an **Output Threshold** parameter, which is used to control how frequently the output is re-calculated. When set, the block determines when its output will change by the output threshold, and when that occurs, even if it is not as a result of any new input value, the block generates an output value.

  The **Output Threshold** should be set taking into account what error margins will exist on the input value (real-world physical sensors have some limited precision and accuracy in the property they are measuring), and what precision is required in the output.

  Take care to avoid **Output Threshold** values that are too large or too small. If the values are too large, the block does not generate a new output when needed (unless the **Sample** input is used). If the values are too small, the block limits how frequently it generates output; you can configure this by editing the Configuration.mon file and modifying the value set for the `MINIMUM_WAIT_TIME_SECS` constant (see also "Configuring model timeouts" on page 75). The scale of appropriate values varies depending on what the magnitude of the input value is. If **Output Threshold** is not set, then the block only generates new outputs if it receives an input (this may be appropriate if it is receiving frequent inputs on the value, or if the **Sample** input is being used).

Input blocks and event timing

Input blocks make data from external sources (such as Cumulocity IoT measurements) available to the model. Many data sources have timestamps on each piece of data, which reports the time that a measurement or event actually occurred. There may be delays in transmitting the data to the Apama system for processing, leading to events being received by Apama out of order.

For data sources that have timestamps associated with a piece of data, the input block can handle events received out of order. In order to do this, the input blocks hold all received events in a re-order buffer and delay processing them until a predefined delay time after their source timestamp. By delaying the processing of the event relative to the source timestamp, the input block allows events to be re-ordered. The key parameter to this process is the amount of time by which the events are delayed. You can configure this by editing the Configuration.mon file and modifying the value set for the `TIMEDELAY_SECS` constant; this is the time in seconds by which the input blocks delay inputs.

The input blocks assume that while events may be delivered out of order, they are received by Apama within the `TIMEDELAY_SECS` value. If an event is received after a delay of more than `TIMEDELAY_SECS` (that is, the difference between the timestamp in the event and the time on the system running Apama), then it is dropped. Thus, if the `TIMEDELAY_SECS` value is set too low, then a small delay may result in Apama dropping an event, which can lead to erroneous results. The higher the `TIMEDELAY_SECS` value is, the larger is the delay before an event is processed. Thus, it is important to pick a suitable value for `TIMEDELAY_SECS` to match the environment for events being delivered into Apama.

The correlator logs the number of dropped events periodically (every `LOGGING_THROTTLE_SECS`) to the correlator's log file, which can be found in /opt/softwareag/cumulocity-apama-rules/deploy/logs/correlator_defaultCorrelator.log.

For more information, see "Configuring model timeouts" on page 75.

Connections between models

You can connect multiple models together using output blocks and input blocks. A model that contains an output block such as **Output Measurement** (for Cumulocity `Measurement` objects) will generate a series of events, and this can be consumed by a suitable input block (such as **Device Measurement Input**) in another model.

Input and output blocks identify a series of events by specifying a *key* for the series of events. This key can be made up of multiple block parameters, and identifies that series of events distinct from other series of events through the same block type. For example:

- For `Measurement` object input and outputs, the *key* would be the device, the fragment, the series, and the measurement type. The **Units** parameter specified in an output block is not considered part of the key (it is for information only) and is not required to match the parameters of the measurement input block.

- For `Event` objects, the *key* would be the device and the event type.

When one model has an output block generating a series of events for a given *key* and a second model has an input block consuming from that same series of events (that is, with the same *key* parameters), then this forms a connection from the first model to the second. When the first model triggers the output block, this causes the second model to be evaluated with a new input on its input block.

Similar to the processing order of wires within a model (see also "Processing order of wires" on page 58), the following applies when an output block in one model generates a series of events that an input block in another model consumes:

- A single model can send the same events to more than one other model. This means, it is possible to have a single model perform some common pre-processing, such as unit conversion or calculating an average (with the **Average (Mean)** block), and that value to be used by multiple other models.
- Models are executed in order with respect to the connections between models so that the source of a connection is always evaluated before the target of a connection. If a model has connections from multiple blocks all triggered from the same initial event, then they will all evaluate first, and the receiving model will evaluate with all of the inputs once.

Similar to the wire restrictions within a model (see also "Wire restrictions" on page 58), there are restrictions on how output blocks and input blocks can be used to connect models together:

- Only one block across all models is permitted to generate a series of events for a given *key*.
- No cycles can be created between models. A model that receives events via an input block from another model cannot include an output block that generates events that the other model would consume. This applies even if one of the models contains two separate parts, such that there is no actual cycle in terms of wires and connections between models.

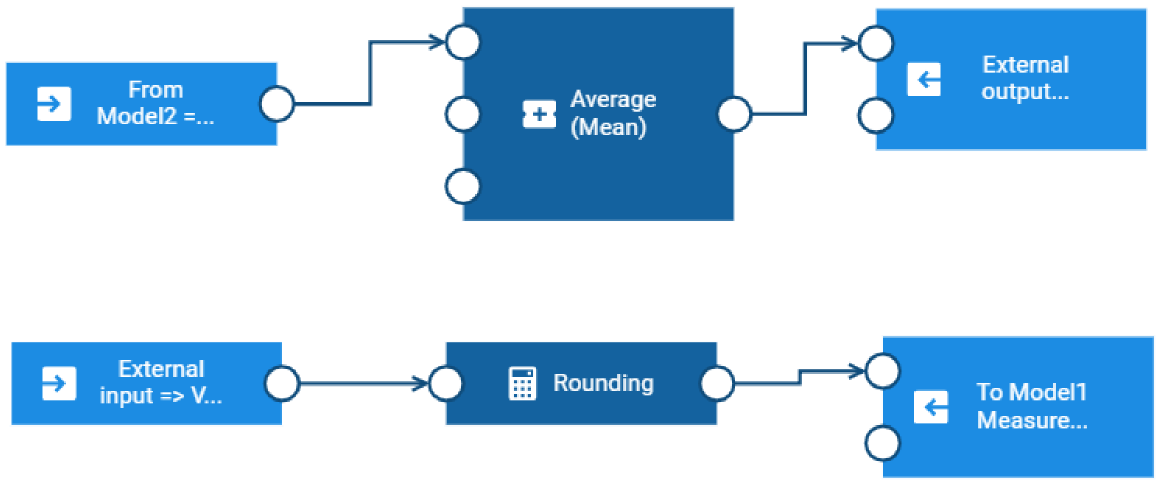
Any model that does not meet these restrictions when used in combination with the already activated models will cause an error on trying to activate it. This will count for the last element in a cycle of models. For such errors, the problem may be in interactions between models rather than a problem specific to a single model, but existing models that have already been activated will not automatically be deactivated. For example, if multiple models all generate the same series of events (with the same *key*), then the first model to be activated can be deployed, but all subsequent models will report an error upon trying to activate them.

For example, there are three models: Model1, Model2, and Model3. A cycle may exist if:

- An output block of Model1 produces a series of events that is consumed by an input block in Model2, and Model2 contains an output block that generates a second series of events, and

- Model3 contains an input block that consumes a series of events from Model2, and Model3 also contains an output block that generates a series of events used by an input block in Model1.

Note that only activating any two of these models can be done without error. If activated in order, only Model3 would have an error. But if Model1 or Model2 were deactivated, then Model3 could be activated. The error will occur even if one of the models does not contain a link from the input block that is part of the chain to the output block that forms part of the chain, such as the example for Model3 below: the events from Model2 do not form a cycle to the **To Model1 Measurement** output block, but they count as a cycle as they are both in the same model. (In this case, the issue could be resolved by splitting that model into two models, thus removing the cycle).



Fragment properties on wires

Wires have a primary value that is of the type of the wire: one of `float`, `boolean`, `string` or `pulse`.

In addition to this, some blocks may provide other "fragments" of information alongside the value. These are named properties on the value. They may be other pieces of information provided from an input block, such as the unit in which a measurement is measured, or some extra contextual information for a data source.

Most blocks only operate on the primary value from their input wires, but some blocks can make use of these fragment properties values and extract them into separate output ports (for an example, see the **Extract Property** block). This gives more flexibility in processing more complex data from external sources.

6 Model Simulation

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About simulation mode

You can deploy a model in simulation mode to run it against historical input data (such as Cumulocity IoT measurements). This allows testing the behavior of a newly developed model against historical data or fine-tuning an existing model. Or it allows testing a model against a set of historical data with known properties.

You use the model manager to deploy a model in simulation mode. See "Deploying a model" on page 27 for more details.

When a model is deployed in simulation mode, it uses data from virtual devices. Thus, a simulated model can run alongside other non-simulated models without interfering with them.

A simulated model runs as if it is running at the time of the historical data. The input data are processed in the order of their historical time. The simulated model also uses the historical time for the timestamps of the generated output.

When running a simulation, historical data is replayed into the Apama correlator from the Cumulocity database. If there is a significant delay in the data being queried from the database or high load in the system, this can lead to dropping the input in exceptional circumstances. A simulated model processes input data at normal speed. For example, if the historical data entries are separated by one second, they are processed one second apart. This means that simulating a model with one hour of historical data will take approximately one hour of simulation time.

Simulation parameters

To deploy a model in simulation mode, you have to provide values for two parameters in the model manager: start time and end time. These values determine the time range for which historical data is to be sent into the simulated model.

- **Start time**

  The start time from which historical data is to be sent into the model.

- **End time**

  The end time until which historical data is to be sent into the model.

Sending of data into the simulated model is stopped when all historical data from the specified time range has been sent.

Monitoring dropped inputs

The simulated model may drop delayed input events in exceptional cases. The number of input events dropped across all the models is exposed as a user status with the name `user-analytics-oldEventsDropped`. See also "Monitoring dropped events" on page 73.

7 Monitoring and Configuration

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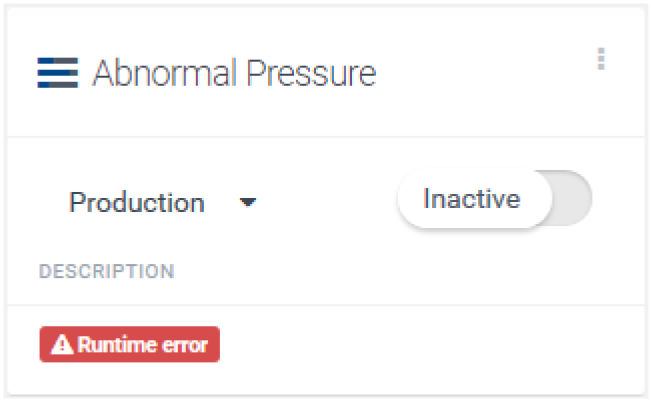
Monitoring

You can monitor the current status of each model in the model manager. The card for a model shows the current mode for this model (such as production mode) and whether it is in the Active (deployed) or Inactive state.



If a model failed to deploy or failed while running, Runtime error is shown on the card for the model. To find out whether a model has failed while processing data, reload all models in the model manager to show their latest states. See also "Reloading all models" on page 30.

Monitoring periodic status

In addition to the status that is shown on the card for a model, periodic Cumulocity status operations are published to a Cumulocity device that has the default name `c8y_EdgeGateway`.

Each operation has the following parameters:

Parameter	Description
`models_running`	Information about deployed models that are running.
`models_failed`	Information about deployed models that have failed.
`apama_status`	The Apama correlator status metrics. Many status names correspond to the key names in Apama's REST API. The values are returned by the `getValues()` action of the `com.apama.correlator.EngineStatus` event and exposed via the REST API.

Model status

Following information is published for each deployed model that is currently running or has failed:

Name	Description
`mode`	The mode of the deployed model. It is `SIMULATION` for models deployed in simulation mode. Otherwise, it is `PRODUCTION`.
`modeProperties`	Any mode-specific properties of the model. This includes the start and end time of the simulation for models running in the `SIMULATION` mode.
`numModelEvaluations`	The total number of times the model has been evaluated since it was deployed.
`numBlockEvaluations`	The total number of times that the blocks have been evaluated in the model since it was deployed. This is the sum of the count of evaluation for each block in the model.
`avgBlockEvaluations`	The average number of blocks that have been evaluated per model evaluation.
`numOutputGenerated`	The total number of outputs generated by the model since it was deployed.

This information about each model provides insight into the performance or working of models. For example, a model with a much larger number of `numBlockEvaluations` than another model might indicate that it is consuming most resources even though it might have low `numModelEvaluations`. Similarly, it can be used to find out whether a model is producing output at the expected rate relative to the number of times it is evaluated.

The following is an example of Cumulocity's published status operation data:

```
{
    "creationTime": "2018-07-23T21:48:54.620+02:00",
    "deviceId": "6518",
    "deviceName": "c8y_EdgeGateway",
    "id": "8579",
    "self": "https://myown.iot.com/devicecontrol/operations/8579",
    "status": "PENDING",
    "models_running": {
        "Package Tracking": {
            "mode": "SIMULATION",
            "modeProperties":{"startTime":1533160604, "endTime":1533160614},
            "numModelEvaluations": 68,
            "numBlockEvaluations": 967,
            "avgBlockEvaluations": 14.2,
            "numOutputGenerated": 50
        }
    },
    "models_failed": {
        "Build Pipeline ": {
            "mode": "PRODUCTION",
            "numModelEvaluations": 214,
            "numBlockEvaluations": 671,
            "avgBlockEvaluations": 3.13,
            "numOutputGenerated": 4
        }
    },
    "apama_status": {
        "user-analytics-oldEventsDropped": "1",
        "numJavaApplications": "1",
        "numMonitors": "27",
        "user-httpServer.eventsTowardsHost": "1646",
        "numFastTracked": "183",
        "user-httpServer.authenticationFailures": "4",
        "numContexts": "5",
        "slowestReceiverQueueSize": "0",
        "numQueuedFastTrack": "0",
        "mostBackedUpInputContext": "<none>",
        "user-httpServer.failedRequests": "4",
        "slowestReceiver": "<none>",
        "numInputQueuedInput": "0",
        "user-httpServer.staticFileRequests": "0",
        "numReceived": "1690",
        "user-httpServer.failedRequests.marginal": "1",
        "numEmits": "1687",
        "numOutEventsUnAcked": "1",
        "user-httpServer.authenticationFailures.marginal": "1",
        "user-httpServer.status": "ONLINE",
        "numProcesses": "48",
        "numEventTypes": "228",
        "virtualMemorySize": "3177968",
        "numQueuedInput": "0",
        "numConsumers": "3",
        "numOutEventsQueued": "1",
        "uptime": "1383561",
        "numListeners": "207",
        "numOutEventsSent": "1686",
        "mostBackedUpICQueueSize": "0",
        "numSnapshots": "0",
        "mostBackedUpICLatency": "0",
        "numProcessed": "1940",
        "numSubListeners": "207"
    }
}
```

You can monitor the status using Apama's REST API or the Management interface which is an EPL plug-in. See the following topics in the Apama product documentation for further information:

- "Managing and Monitoring over REST" in *Deploying and Managing Apama Applications,* and
- "Using the Management interface" in *Developing Apama Applications*.

Monitoring dropped events

When a model receives an event, it may be dropped if the correlator delivers or processes it too late. See "Input blocks and event timing" on page 61.

The total number of dropped events across all models is periodically published as part of the status operation. The count of the number of dropped events is available as a user-defined status value with the name `user-analytics-oldEventsDropped` in the `apama_status` parameter of the status operation. See also "Monitoring periodic status" on page 70 for details about the operation.

All dropped input events are also sent to channel `AnalyticsDroppedEvents`, allowing you to implement your own monitoring of the dropped events. A dropped input event sent to the channel `AnalyticsDroppedEvents` is packaged inside an event of type `apama.analyticskit.DroppedEvent`. This allows you to extract the original dropped event and perform any analysis on it, for example, categorizing number of dropped events per device. Examples of some of the mechanisms you can employ include:

- Use the `engine_receive` tool to display the dropped events. See *Deploying and Managing Apama Applications* in the Apama documentation for information on how to use this tool to receive events from a correlator.
- Write EPL to receive dropped events by subscribing to the dropped event channel and performing analysis on it to find out from which devices events are most likely to be dropped.
- Write EPL to publish statistics about dropped events to a dashboard for visual monitoring.
- Write custom CEP rules and upload them to Cumulocity to publish statistics about dropped events as measurements or operations. See the *User guide* at "http://cumulocity.com/guides/" for information on how to use the Administration application to manage applications.

Monitoring the model life-cycle

Life-cycle messages are written to the correlator log file whenever a model is created or deleted, or when it fails. The log messages may look as follows:

```
Model "Build Pipeline" with PRODUCTION mode has started.

Model "Build Pipeline" with PRODUCTION mode has ended.

Model "Build Pipeline" with PRODUCTION mode has failed with an error:
IllegalArgumentException - Error while validating parameters for the
block "toggle" of type "apama.analyticskit.blocks.core.Toggle":
The "Set Delay" must be finite and positive: -1.
```

Be default, the log file is located at /opt/softwareag/cumulocity-apama-rules/deploy/logs/correlator_defaultCorrelator.log, but this may change depending on your configuration.

The reporting behavior can be changed to perform more operations for life-cycle events. See "Configuring model life-cycle reporting" on page 75.

Configuration

You can configure various parameters for monitoring or model processing by editing the configuration files that are mentioned in the topics below. These configurations are global and affect every deployed model.

Important: After editing a configuration file (StatusConstants.mon and/or Configuration.mon), you have to restart the correlator for the configuration changes to take effect.

Configuring status reporting

You can configure the frequency and the device name for the status operations by editing the constants of the `apama.analyticskit.cumulocity.StatusConstants` event in the StatusConstants.mon file. This file is located in the /usr/edge/properties/apama/support/cumulocity/ directory.

You can modify the values of the following constants:

Constant	Description
`MATCH_STRING`	The name of the Cumulocity device to which the status operations are to be published. The default name is `c8y_EdgeGateway`.
`PERIOD`	The frequency in seconds at which the status is to be published. The default value is 60 seconds.
`SEND_TYPE`	How the status is to be published. The default value is `OPERATION`, meaning that the status is published as a Cumulocity operation. You can change this to `EVENT` to publish the status as a Cumulocity event.
`EVENT_TYPE`	The event type if the status is published as a Cumulocity event. The default type is `apama_status`.
`EVENT_TEXT`	The event text if the status is published as a Cumulocity event. The default text is `Apama Status`.

Configuring model timeouts

You can configure time-related properties for the models by editing the constants of the `apama.analyticskit.Configuration` event in the Configuration.mon file. By default, this file is located in the /usr/edge/properties/apama/framework/monitors directory, but this may change depending on your configuration.

You can modify the values of the following constants:

Constant	Description
`TIMEDELAY_SECS`	The maximum delay in seconds before the input block considers an event to be old. The default value is 1 second. See also "Input blocks and event timing" on page 61.
`LOGGING_THROTTLE_SECS`	Logging throttling in seconds. Periodic log messages (for example, those reporting changes in the number of events being dropped by the input block) will not appear more frequently than defined by this constant. The default value is 1 second. See also "Input blocks and event timing" on page 61.
`MINIMUM_WAIT_TIME_SECS`	The minimum wait time in seconds. Some blocks can generate output automatically, based on the rate of change of the output. This sets a lower limit on the time between such outputs. See also "Common block inputs and parameters" on page 59.

Configuring model life-cycle reporting

A message is written to the correlator log file whenever a model is created or deleted, or when it fails. This behavior can be changed by updating the corresponding life-cycle actions of the `apama.analyticskit.Configuration` event in the Configuration.mon file. By default, this file is located in the /usr/edge/properties/apama/framework/ monitors directory, but this may change depending on your configuration.

You can modify the following actions for custom reporting of the model life-cycle:

Action	Description
`onModelStart`	This action is called with the model details whenever a model is created. It logs a message by default.

Action	Description
`onModelEnd`	This action is called with the model details whenever a model is deleted. It logs a message by default.
`onModelFailure`	This action is called with a failure reason whenever a model fails during creation or at runtime. It logs a message by default.

Some examples of the reporting you can implement are:

- Sending life-cycle events to a dashboard to visualize currently running or failed models.
- Sending Cumulocity operations to a standard device.
- Sending life-cycle events for downstream monitoring and taking action if a model fails unexpectedly.