FESTO

FluidSIM® 5

User's Guide

FluidSIM is a teaching tool for simulating pneumatics, hydraulics, electrics/electronics and digital technique. It can be used in combination with the Festo Didactic SE training hardware, but also independently. FluidSIM was developed as a joint venture between the University of Paderborn, Festo Didactic SE, Denkendorf, and Art Systems Software GmbH, Paderborn.

Contents

Welcome!

Chapter 1

Welcome to FluidSIM!

Thank you for purchasing the FluidSIM training software. This user's guide functions both as an introduction to FluidSIM and as a reference manual outlining the possibilities, concepts and operation of the software package. This guide is not designed for the teaching of training content in fluid engineering or electronics; if you require materials for that purpose, there are textbooks available from Festo Didactic SE.

FluidSIM permits the creation and simulation of circuits in the following fields:

— Electro-pneumatics/vacuum technology

— Electro-hydraulics/mobile hydraulics

— Electrical engineering/electronics

There are specialized versions of the program for each of these technologies, referred to in the following as FluidSIM-P, FluidSIM-H and FluidSIM-E respectively.

All three versions also contain components for drawing creation and simulation of:

— Digital technology

— GRAFCET

Some of the functions and components described in this manual may not be available, depending on which program versions you purchased. In places where the programming differences between the technologies are only minor, general examples are given, and the specific differences are mentioned. When specialized functions are explained, such as closed-loop control in pneumatics and in hydraulics, a separate chapter is devoted to each function.

For the first time you can link all technologies in FluidSIM in a single circuit or project. This means that if you have purchased all three technology versions, you can utilize pneumatic, hydraulics, control technology, electronics, digital technology etc. in any way you want

in a single technical system. FluidSIM ensures that you can only join connections which are also physically possible.

A major feature of FluidSIM is its close linkage between CAD functionality and simulation. On the one hand, FluidSIM allows DIN-compliant drawing of fluidic and electronic circuit diagrams; on the other hand, it is capable of using physical component descriptions to carry out a realistic, dynamic simulation of the drawn circuit. This practically eliminates the separation between drawing creation and simulation.

When developing FluidSIM, special emphasis was placed on making operation intuitive and easy to learn. This approach makes it possible for you to learn to design and simulate fluidic and electronic circuit diagrams in a very short time. To provide access to professional functions not present in this simple operating interface, FluidSIM also has an "Expert Mode" which can be switched on as needed.

FluidSIM-P was created by the "Knowledge-based Systems" workgroup at the University of Paderborn. FluidSIM-H is the result of cooperative research between the Instrumentation and Control department at Gerhard Mercator University in Duisburg, and Knowledge-based Systems at the University of Paderborn. On hand for mechanical engineering matters was Dr Ralf Lemmen. FluidSIM-E was developed as an entirely new module by Art Systems Software GmbH.

Planning and development of FluidSIM: Dr Daniel Curatolo, Dr Marcus Hoffmann and Dr Benno Stein.

Users of this software are encouraged to contribute tips, criticism, and suggestions for improvement of FluidSIM via email.

info@fluidsim.de

did@de.festo.com

You can also find the newest version on the following websites:

www.fluidsim.de

www.festo-didactic.de

Installation

Chapter 2

With your purchase of the full version of FluidSIM, you received one or more DVD-ROMs and possibly a license connector. The installation procedure is described in the following sections.

The full version of FluidSIM is available in two versions: a version that supports automatic Online activation, and the version with a license connector for insertion in a USB port.

2.1   Technical requirements

You need a computer running Windows XP (SP3), Windows Vista, Windows 7 or Windows 8.

If you intend to simulate complex circuits, a computer with dual processor is recommended. Stand-alone tablet PCs without a physically connected mouse are not ideal because creating drawings is impractical using only swipe and gesture control.

During simulation, most of the adjustable components can be controlled using a game controller as an alternative to the mouse. You can use any game controller which Windows recognizes and which appears in the Control Panel. You may need the matching device drivers for Windows.

Additional drivers may be necessary in order to link FluidSIM to external hardware. Compatible drivers for Festo's EasyPort can be found in the Support subfolder on the DVD. Communication with other applications via OPC requires special auxiliary modules, which are likewise located in the **Support** folder. For more details about OPC, see the section OPC and DDE communication with other applications.

2.2 Installation with program activation

We recommend activating the program via a PC connected to the internet. During installation, you will be prompted to activate FluidSIM. There are three ways of doing so:

— Online activation
This variant allows fully automatic activation if the installation PC has direct access to the internet.

— Indirect activation
In this case the PC on which FluidSIM is to be installed does not need to have direct internet access. Instead, the subsequent dialog window gives you an internet address and an individually generated license key. You can then generate a matching activation code by accessing the displayed internet address from any computer. You then enter that activation code in the field provided in the activation dialog box on the installation PC.

— Call Festo to receive your activation code
If you do not have an internet connection or if the internet connection fails, you can call our service staff on weekdays during standard office hours and they will provide you with your activation code.

2.2.1 Important information about online activation

During program activation, the individual features of your PC's hardware are linked to the product ID and used to generate an activation code which is valid only for that PC. If at some later time you intend to modify your PC substantially or want to use a new PC, you can transfer the license. To do so, you first have to deactivate the license on the original PC, by uninstalling the program. You can find the deinstallation procedure in the Control Panel in "Add or Remove Programs" or "Programs".

If the PC on which you installed FluidSIM is no longer functional or deactivation fails for some other reason, as an exception you can transfer the license without prior deactivation.

! Please note that this type of license transfer (without prior deactivation) is only possible a few times. Moreover, when you transfer a license to a modified or new PC, activation is no longer possible on the original PC. Once the license is transferred, you cannot activate FluidSIM on the original PC without a prior deactivation.

2.3 Installation with a license connector

Depending on whether you purchased a multiple or single user license, this special connector is either connected directly to the local user's computer or is on a *license server* at a central location in your network.

In the case of network licensing, the connector defines how many instances of FluidSIM can run simultaneously on the network. If you try to start more instances of FluidSIM than are permitted, you will see a corresponding error message. If the license server is down or the license connector is no longer present, you will be able to save any circuits you are working on before FluidSIM terminates. As soon as the license server becomes available again, you can resume your work.

! Detailed information on network installation of FluidSIM can be found in the installation guide included as a booklet in the product packaging, and also in electronic form as a PDF file in the "Doc" folder on the installation DVD.

2.4 Installing the full version from DVD-ROM

If you are using the software with a license connector, do not plug it in until you are prompted to do so by the installation program.

⟶ Switch on your computer and log on with administrator rights.

⟶ Insert the DVD-ROM.

Usually the installation program starts automatically. If it doesn't, please start it manually.

After a few seconds the start screen of the installation program appears. Here you can select whether you have received the version for online activation or a license connector with the FluidSIM package.

! Note that there are two versions of the license connector: The newer one is silver in color and has the product label "CodeMeter". If you have purchased FluidSIM as an update of an earlier version, you can also continue to use your existing green "WibuKey" connector if it has been reprogrammed accordingly.

For online activation, you do not need a license connector; instead you require your individual product ID which is printed on the back of the DVD case.

⟶ Follow the instructions of the installation program. If you are not sure how to answer any of the questions, simply click Next .

First steps

Chapter 3

3.1   Create a new circuit drawing

When you start FluidSIM, the system checks whether you have installed more than one technology (pneumatics, hydraulics, electronics). If you have, the selection window appears listing the available technologies. Here you specify which components and program functions you wish to use in this program session. This decision is especially important for network users because a license will be occupied for each technology until you exit FluidSIM. You can restart FluidSIM at any time and select a different combination.
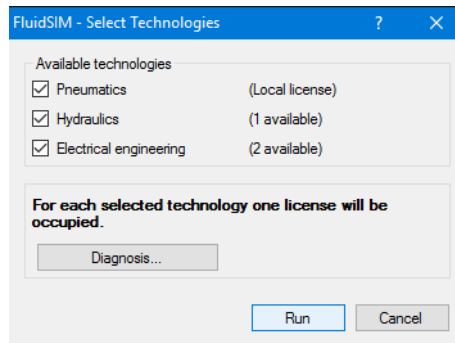
Figure 3/1: *Select Technologies* dialog window

Available technologies

The available technologies and the currently free licenses are displayed here.

FluidSIM remembers the last selection and suggests it when the program is next started. If you frequently use different combinations, you can create links which will allow you to start FluidSIM directly with the corresponding selection.

Next, the key concepts and terms are described which you will encounter when using FluidSIM.

⣿⣿⣿⟶ Start FluidSIM with the selection you require.

⣿⣿⣿⟶ In the menu File , select New / File... .

An empty circuit window opens in which you can insert symbols and connect them with lines. First you should set the drawing size.

⣿⣿⣿⟶ In the Page menu, select Drawing Size... .
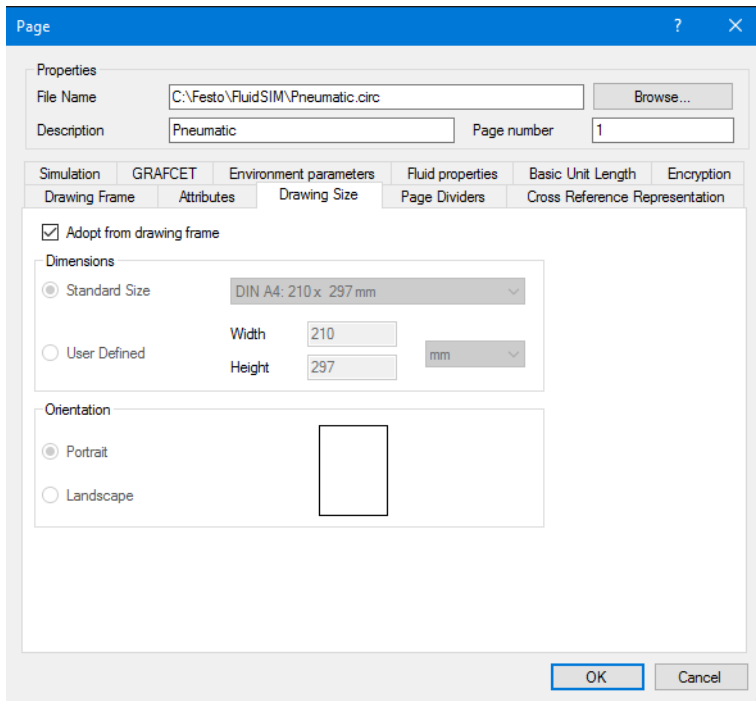
Figure 3/2: Page dialog window, *Drawing Size* tab: setting the drawing size

If you use a drawing frame, then FluidSIM can automatically adjust the paper size. If you wish to define the drawing size manually, then deactivate the "*Adopt from drawing frame*" option and select the dimensions and orientation you require for the drawing. If the drawing's dimensions are larger than your printer's printing area then you can distribute your drawing across several pages (tile).

To retain a better overview you can create attributes for every circuit drawing.

⌁⌁⌁▷ Click the "*Attributes*" tab.
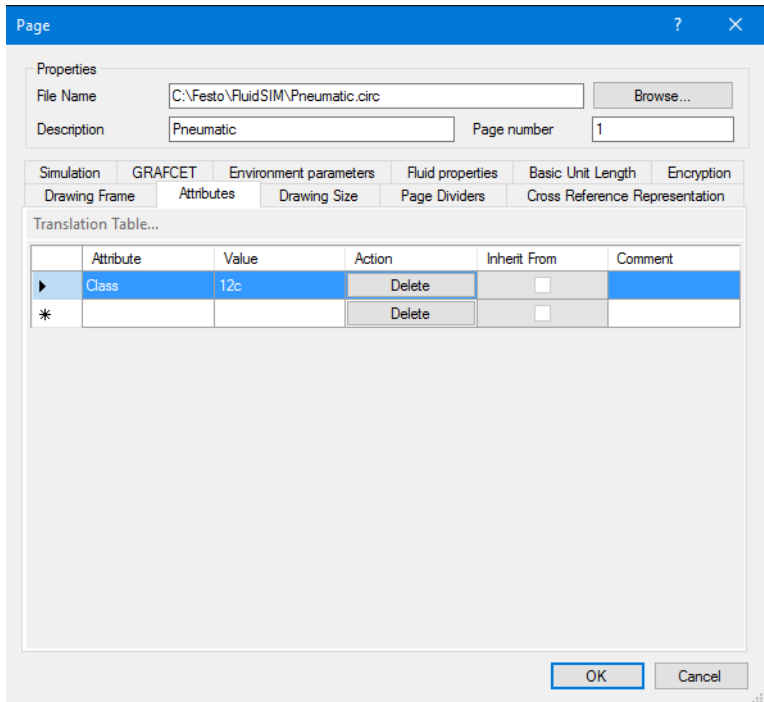
Figure 3/3: Page dialog window, *Attributes* tab: creating attributes

The attribute table allows you to save any desired data in the form of attribute value pairs. The associated placeholders (attributes with the same name) in the drawing frame are replaced by the values entered.

You can also access this dialog window directly by using the Page menu and the Properties... menu item.

3.2 Organize symbols, libraries and circuit diagrams

In order to support the organization of the different document types in FluidSIM all of the circuit files are assigned to one of three groups.

Symbols

Symbols are formal, abstract models providing a graphical representation of the function of a component or component group. This can consist of simple circuit symbols or entire circuits. Symbols can be inserted into their own circuits and linked between the connecting points. The insert can be performed either via the Insert menu or via drag and drop from a library window. Symbols can be compiled into library files with the **lib** file suffix.

Libraries

Libraries are hierarchically organized collections of symbols. In addition to the standard library, which users cannot modify, users can compile any desired number of their own libraries. You can find functions for organizing the libraries on the Library menu as well as on the context menu of the currently active library. To switch libraries use the tab in the upper margin of the library window. Library files have the **lib** file suffix.

Circuits

The default location for circuits is in the **FluidSIM** folder contained in the My Documents folder defined by the operating system. These have the **circ** file suffix.

Note: It is worthwhile to create a new sub-folder in the **FluidSIM** directory for every customer or every project.

3.3 Select unit system

Before creating the first circuit, it's advisable to select the preferred unit system.

⇢ Open the unit dialog via the menu Library / Setup units... .
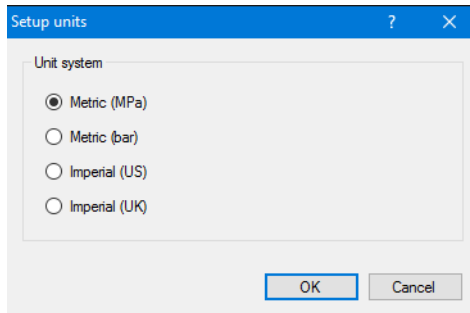
Figure 3/4: *Select unit system* dialog window

FluidSIM converts units automatically, when default library compo-
nents are inserted in the circuit. Units used in the provided demo
circuits are determined by this option. Units of already existing
circuit components are **not** influenced by selecting another unit.

3.4 Insert symbol from menu

To find a specific symbol you can either enter characteristic key
words in the *Find Symbol* dialog windows or navigate through the
hierarchical structure.

⤍ Where necessary open a new window and select the Find
Symbol Description... entry on the Insert menu.

The *Find Symbol* dialog window then opens. You can enter your
search terms in the "*Search*" input line. Separate the individual
search terms using commas or spaces. Neither the order of the
search terms nor upper nor lower case letters have any influence on
the search results.
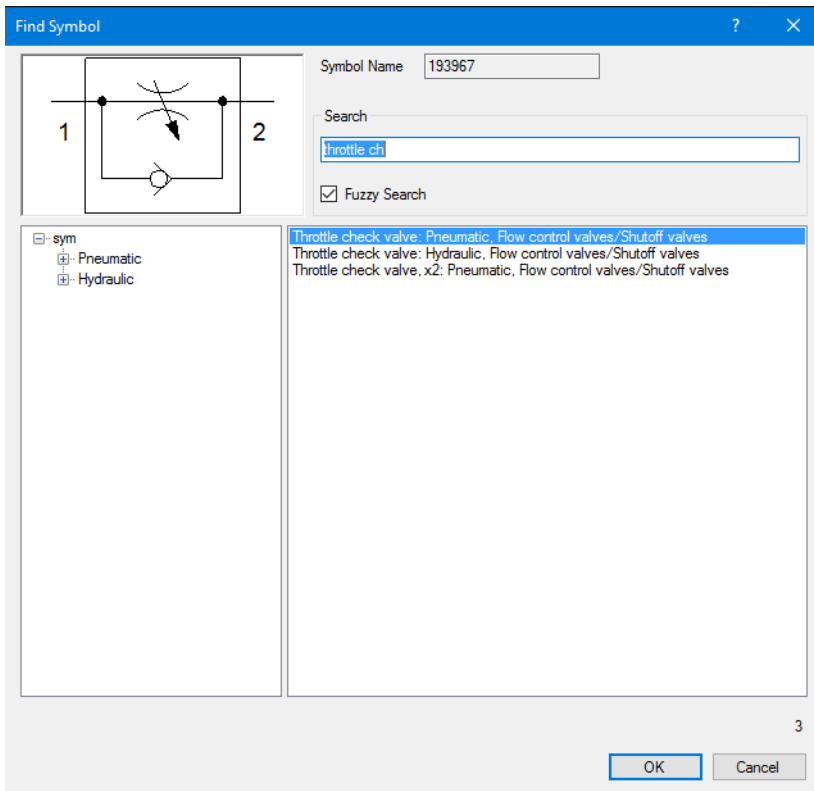
Figure 3/5: *Find Symbol* dialog window

You can see the symbols found in the two results lists. The library hierarchy is displayed on the left-hand side although only those branches appear which contain matching symbols. An alphabetical list of the search hits is displayed on the right-hand side. The symbol of the highlighted entry is shown in the preview. Once you have found the symbol that you were looking for, you can select it using the OK button or by double-clicking on the appropriate row in the results list. The symbol then "hangs" on the mouse pointer and is placed by left-clicking on the drawing area.

With the *Fuzzy Search* option you can activate a tolerance in order to achieve results despite minor typing errors or spelling variants.

3.5   Symbol libraries

FluidSIM is capable of managing multiple libraries, each of which is displayed in a tab in the library window. Libraries which cannot be modified in FluidSIM are labeled with a lock symbol 🔒 in the tab. This applies to standard library as well as to symbol folders which FluidSIM does not manage itself or for which the registered user does on possess write authorization.

Every library is displayed hierarchically. Every hierarchy level can by shown or hidden by clicking on the group name. Right-clicking in a library opens a context menu offering the following menu items for editing the library:

View | Defines the size of the symbols displayed. Small , Normal and Large are available.

Expand All | Opens all of the hierarchy levels.

Collapse All | Closes all of the hierarchy levels.

There are three types of library:

The standard library | This library is delivered with FluidSIM and cannot be modified.

Symbol folders | Circuit and symbol files saved on the disk can be used as libraries in FluidSIM. The files from the selected folder are added as a library via the Library menu and the Add Existing Symbol Folder... menu item. The library hierarchy corresponds exactly to the folder hierarchy. These libraries cannot be modified in FluidSIM. The files must be modified directly.

User libraries | You can create and subsequently edit new libraries via the Library menu and the Create New Library... menu item (see section

Create user library). Using drag and drop you can move the symbols and groups within the library as desired.

3.5.1 Create user library

In order to be able to access frequently used symbols (or circuits) more quickly multiple symbols can be compiled into libraries. Libraries are saved as files with the `lib` file suffix. You can create new libraries using the Library and the Create New Library... menu item. Right-clicking in the new library opens a context menu with which you can modify the library.

The following options are available:

Copy	Copies the selected symbols to the clipboard
Paste	Inserts the symbols into the library from the clipboard. These symbols can also be partial circuits.
Delete	Removes the selected symbols from the library.
Rename...	Edits the text which libraries display below the symbol.
Add Existing Symbols...	Opens a dialog window for selecting symbol files to be copied into the library as new symbols.
Copy to Other Library	Copies the selected symbols into another library. The available libraries are listed in a submenu. Only the currently open libraries are displayed here (appearing as tabs in the library window) which are not write-protects (recognizable as no lock symbol 🔒 is displayed).
New Sub-Folder...	Creates a new hierarchy level below the active group. The active group is the one belonging to the area below the mouse point and can be recognized by the dark blue coloring.
Remove Sub-Folder	Removes the hierarchy level which the mouse pointer is located in.

Rename Sub-Folder...   Enables you to rename the hierarchy level which the mouse pointer
                              is located in.

3.6   Circuit files

FluidSIM circuit files have the **circ** file suffix and are saved as
compressed XML files. An option in the *Save* tab under the Op-
tions... menu item from the Tools menu allows you to deactivate
this compression so that the circuit files can be viewed as plain
text. This can be useful for version management software, for
example.

However, please note that editing a **circ** file outside FluidSIM can
cause the file to become unreadable or corrupted upon re-import.

Library and project window

Chapter 4

4.1   Change window position

The library window is anchored on the left-hand side by default and the project window (when a project is open) is on the right-hand side.

To separate the window from the anchor move the mouse pointer to the upper margin. Click and hold the left mouse button. Move the window a small distance towards the center of the screen. Now release the left mouse button. Now you need to move the library window to the lower right and the project window to the lower left. Once a window has been separated from the anchor it can be moved freely.

To re-anchor the window move the mouse pointer to the upper margin. Click and hold the left mouse button. Move the window as far as possible to the right or the left. Now release the left mouse button. This window snaps into place. This enables you to anchor the library window to the right and the project window to the left, for example. You can also anchor both windows on the same side. In this case you can move the desired window into the foreground by clicking the associated tab.

4.2   Automatic show and hide

The tabs offer an additional, practical function: Automatically showing and hiding the library or project window. Click the associated vertical tab "*Library*" or "*Project*" at the edge of the window. This causes the window to be hidden providing a larger area for the drawing. In order to make the window visible again move the mouse pointer over the tab; the window opens once again. As soon as you have performed your operations in this window and move the mouse pointer to a circuit window the library window and / or

the project window are automatically hidden. To deactivate the
function click the associated tab again (this then appears de-
pressed).

Edit circuit

Chapter 5

5.1 Insert and arrange symbols

You can insert symbols into the symbol window being edited using the dialog window *Find Symbol* and by means of the libraries. You can also transfer objects from every other window by selecting them and dragging them to the desired window. Alternatively you can also utilize the clipboard by selecting the items, choosing the Copy menu item on the Edit menu, bringing the target window into the foreground and selecting the Paste menu item on the Edit menu. Using the mouse pointer to drag objects from one window to another copies them. Dragging the objects from one position to another within a window moves them. In order to copy within a window you need to hold down the Shift key while moving the mouse pointer. You can recognize operation by the shape of the mouse pointer. During a move-operation a cross with arrows ✛ appears, when copying a plus symbol ✛ also appears in the lower right-hand corner of the cross.

5.2 Connect connectors / ports

In order to connect two component connectors with a line move the mouse pointer to the component connector. You can recognize a connector by the small circle at the end of a symbol's connection line. As soon as you have touched the line the mouse pointer transforms into a crosshair ⊕.
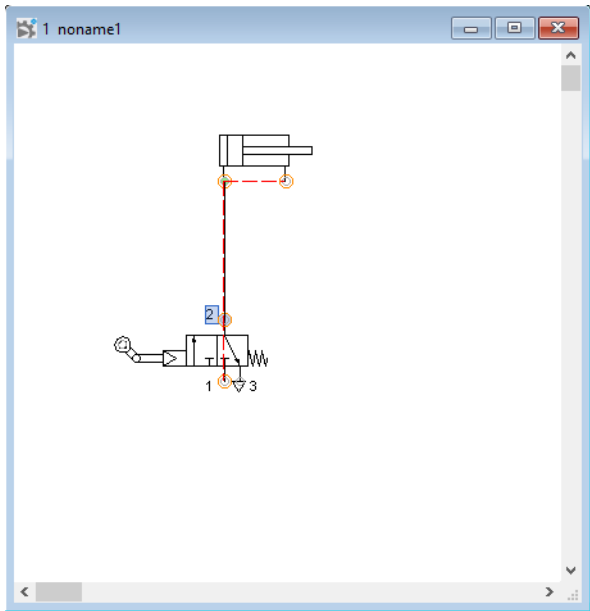
Figure 5/1: Mouse pointer as a crosshair over a component connector.

⌁→ Now press the left mouse button and move the mouse pointer to the connector which you wish to connect with the first.

You can recognize when you are over the connector by the shape of the mouse pointer ⊕. If the mouse pointer is over a connector which is already connected to a line then the prohibited sign ⊘ appears and no line can be connected.

⌁→ Release the mouse button once you have touched the second connector.

FluidSIM automatically lays a line between the two connectors.
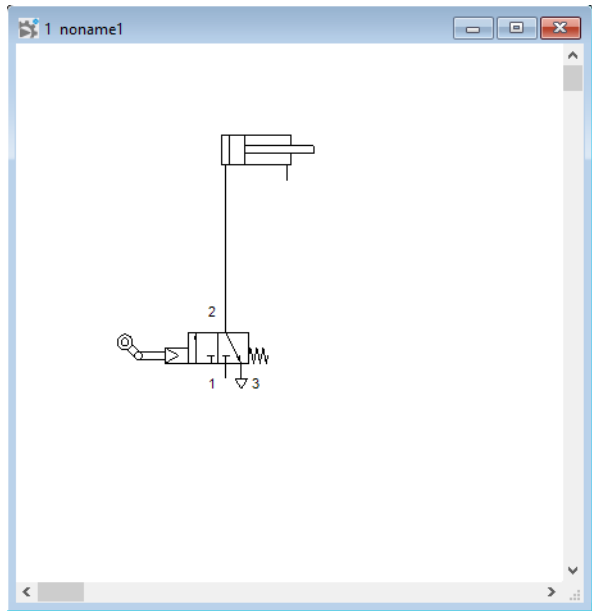
Figure 5/2: Line between two connectors

Support points can be set when dragging lines. To do so simply release the mouse button while dragging the line and click the desired points. The line is completed as soon as you click a second connector or the same point twice. You can cancel the action by pressing the Esc key or the right mouse button.

5.3 Automatically connect connectors

FluidSIM supports two methods of automatically connecting connectors. The first is to drop a symbol on an existing line. To be able to use this method, the symbol must have at least two connectors that precisely fit onto one or more existing lines and the lines that

will be produced must not cross the symbol. The following two
illustrations show this function.
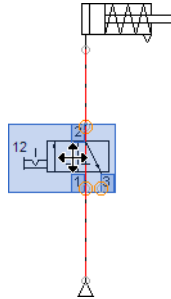
Figure 5/3: Circuit before the connectors are automatically con-
nected
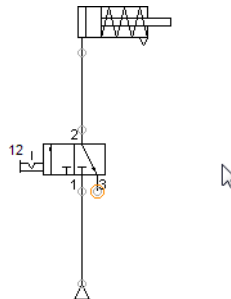
Figure 5/4: Circuit after the connectors are automatically connected

Another method of automatically connecting connectors is to
position symbols so that their connectors can be horizontally or
vertically connected with free connectors from other symbols. After
the symbol has been dropped the corresponding lines are automat-
ically drawn if they do not cross any symbols. The free connectors
can also be T distributors.

You can define how different objects' connectors are automatically
connected in the *Connector Links* tab under the Options... menu

item from the $\boxed{\text{Tools}}$ menu. The following two illustrations show this function.
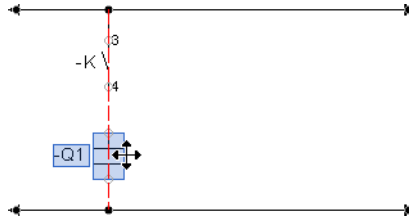
Figure 5/5: Circuit before the connectors are automatically connected
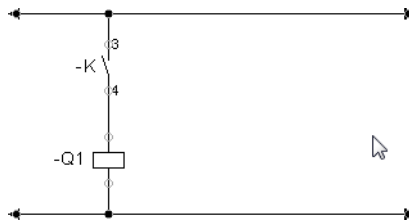
Figure 5/6: Circuit after the connectors are automatically connected

5.4 Insert T distributor

You do not need to utilize a special symbol in order to insert a T distributor. FluidSIM automatically inserts a T distributor when you lay a component connection on a line or lay a line segment to a connection. If you wish to connect two lines then you can also draw one line segment to another; FluidSIM then inserts two T distributors and connects these with a new line.

⤑ Move the mouse points to a connector and press the left mouse button.

As soon as you touch the line the mouse pointer transforms into a crosshair ⊕.

┈┈⟩ Release the mouse button once you have touched the desired point on the line.

FluidSIM inserts a T distributor and automatically lays a line.
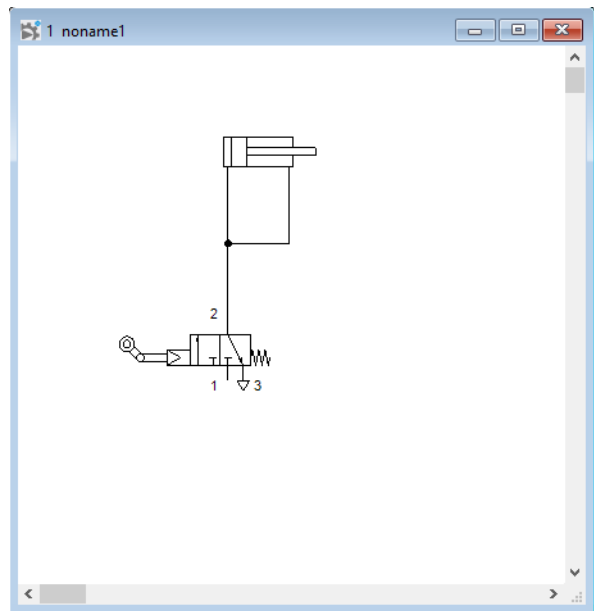
Figure 5/7: Line connection with inserted T distributor

Every T distributor can connect up to 4 lines with each other.

The default representation for the T distributor can be selected via the corresponding drop-down list T-Node ◆ ▾ on the toolbar.

You can customize the representation of the T distributor by dou-ble-clicking the T distributor or highlighting the T distributor and selecting the Properties... menu item from the Edit menu. The

"*Properties*" dialog window opens. Select the "*Representation*" tab.
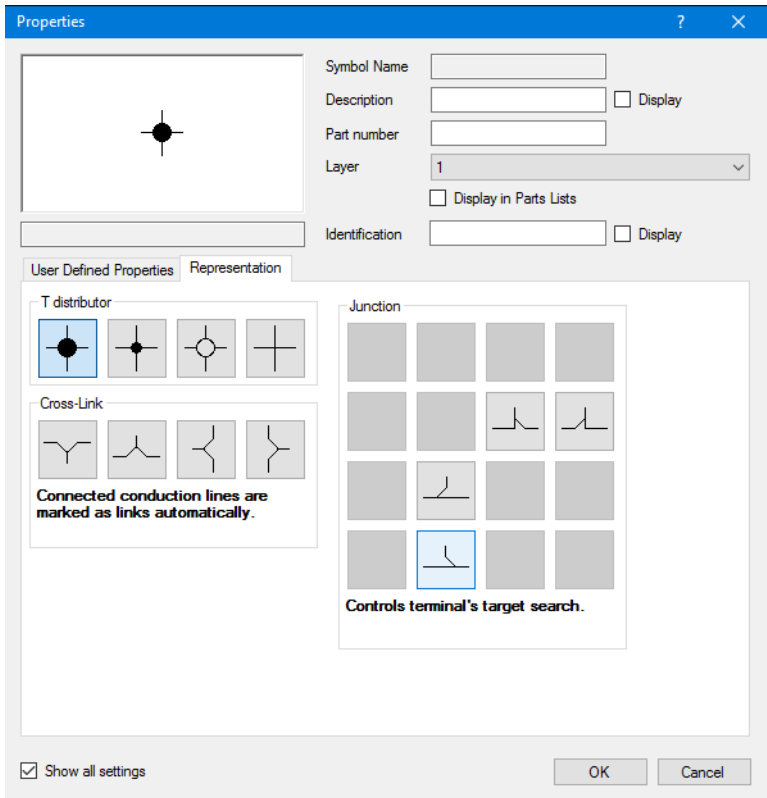
Figure 5/8: T distributor dialog window. Tab: *Representation*

T distributor   Defines the representation of the basic T distributor. Here you can select whether the distributor should be represented as a filled circle or a simple intersection.

Cross-Link   Defines that the T distributor should be represented as an electric link. This representation has a knock-on effect on the connected lines, which are automatically marked as links.

Junction

Defines that the T distributor should be represented as an electric junction. This representation has a knock-on effect on the terminals' target search. With a junction, the target in the direction of a straight line or right angle is found first and then the target via an angled branch.

5.5   Move lines

Once you have joined two connectors you can then adjust the length of the lines. You can move the line segments in parallel by moving the respective line segment. You can see when you have touched the line on the basis of the line-selection shape ⊣⊢ of the mouse pointer.

---⟩   Press the left mouse button and move the line segment orthogonally to the desired position.
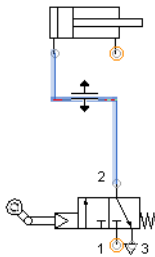
Figure 5/9: Moving a line segment

---⟩   Release the left mouse button; FluidSIM adjusts the adjoining line segments in such a way that they remain connected.

If you move a line segment with is directly connected to a component connector then FluidSIM may insert additional line segments in order to prevent gaps.

If you move a line segment that is horizontally or vertically connected with other line segments via T distributors then these line segments are moved together with the T distributors.
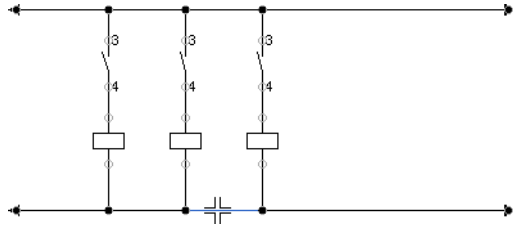
Figure 5/10: Moving multiple line segments
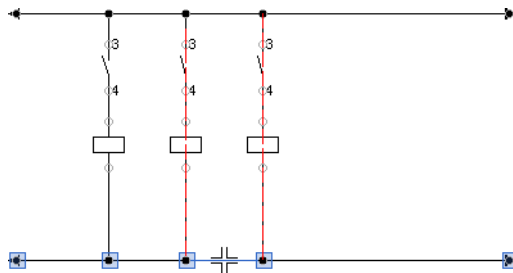
Figure 5/11: Moving multiple line segments

If you only want to move the individual line segment in the case described above then release the mouse button after you highlight the line segment. Click the segment again and move it while keeping the mouse button pressed.
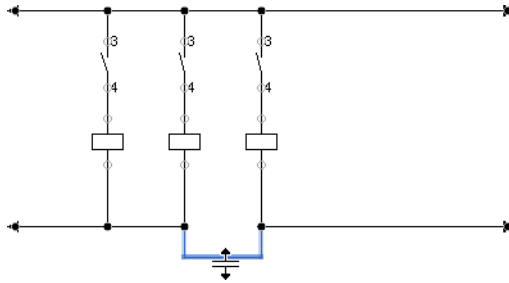
Figure 5/12: Moving an individual line segment

5.6 Direct connection via straight connection line

Normally connection lines in technical circuits are always drawn orthogonally. However, it can sometimes be desirable to create a direct connection between two connectors via a diagonal line. To achieve this, first connect the two connectors in the standard way. Then select any segment on the line and right-click to open the context menu. Select "*Straight connection line*" to create a direct connection.
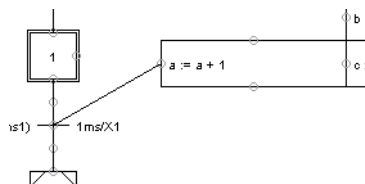
Figure 5/13: Direct connections between two connectors

To switch back to an orthogonal line, open the context menu again and select "*Orthogonal line segments*".

5.7   Define the characteristics of lines

Lines, like other symbols, can be assigned an identification and user-defined properties. You can find further information on this under Component attributes in the *Properties* dialog window.

You can also define the style, color and drawing layer of the lines by double-clicking a line segment or highlighting the line segment and selecting the | Properties... | menu item from the | Edit | menu. The *Line Properties* dialog window opens. Select the *Drawing Properties* tab in this window. The settings are applied to the entire line section as far as the next connector or T distributor.

Double-clicking a line segment or selecting a line segment and clicking on the menu item | Properties... | in the | Edit | menu, will open up the *Line Parameters* dialog.

Figure 5/14: *Line Parameters* dialog window: defining the properties of a pneumatic line

Layer

In this drop-down list, you define the Layer of the line. You can set the Layer by clicking the downward-pointing arrow to the right of the list and selecting a layer. Depending on the setting for drawing layers, the line might not be displayed or might not be able to be edited. In order to see the object or change its settings, you have to temporarily activate the drawing layers with menu item View Drawing Layers... .

Identification

Here you can assign an identification that uniquely identifies the line in the circuit diagram. The identification is shown as text in the circuit drawing if the "*Display*" option is selected.

Automatic designation	Optional, FluidSIM can assign reasonable designations to lines. The designation of a line if combined out of the designations of connected connectors as well as their components. Assuming connector 2 of component A1 is connected to connector 4 of component V3, the line designation would be A1:2/V3:4. When activated, the line designation updates automatically, whenever the designation of connected components changes.
Reverse Direction	The automatic line designation, as well as other evaluation tables, uses the source and target of a line or cable. The direction is initially determined by the connector the line is drawn from. Using the Reverse Direction option, the direction can be reversed afterwards.
Display in Parts Lists	Activate this option if you want the line to appear in the parts list.
Display in Tube Lists	Activate this option if you want the line to appear in the tube list.
	As with other graphic objects, you can select style, color and line-width for the lines. Select the *Drawing Properties* tab in the line properties dialog. The settings will be applied to the whole line segment until the next connector respectively T-junction.
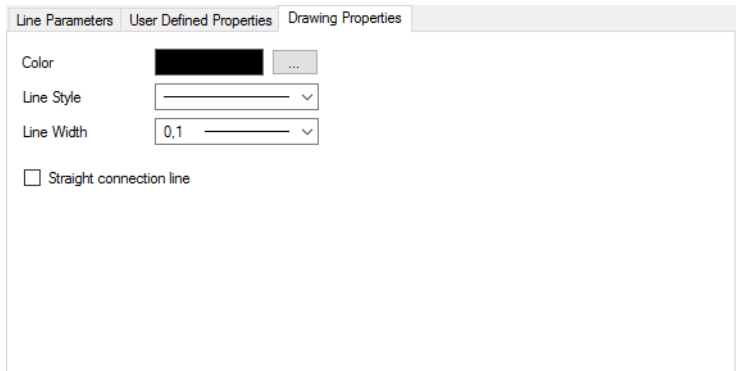
Figure 5/15: *Drawing Properties* dialog window: defining the properties of a line

Color	Sets the color of the line.
Line Style	Sets the line style of the line.
Line Width	Sets the line thickness of the line.
Straight connection line	Normally connection lines in technical circuits are always drawn orthogonally. However, it can sometimes be desirable to create a direct connection between two connectors.

Note: Working lines are typically displayed as solid lines, pilot lines as dashed lines.

Please note that the way the lines are displayed during the simulation depends on the physical status of the lines. The colors, line styles, and line thicknesses will vary according to pressure, flow, voltage, etc.. You can define how the lines are displayed during the simulation on the *Simulation* tab under Options... in the Tools menu. When you exit Simulation Mode, the lines once again appear the way you defined them in Edit Mode.

5.8 Delete line

To delete a line you can either highlight an associated line segment and press the Del key or select the Delete menu item from the Edit menu or highlight a component connector and press the Del key. In these cases it is the line rather than the connector itself that is deleted.

If you delete a T distributor which three or four lines are attached to then all of the lines are deleted. If, on the other hand, only two lines are connected then only the T distributor is deleted and the two lines combined into one.

5.9 Set the properties of the connectors

You can assign a component connector an identification and a blanking plug or silencer by double-clicking on the connector or by selecting the connector and choosing the Properties... menu item on the Edit menu. The *Connector* dialog window then opens.
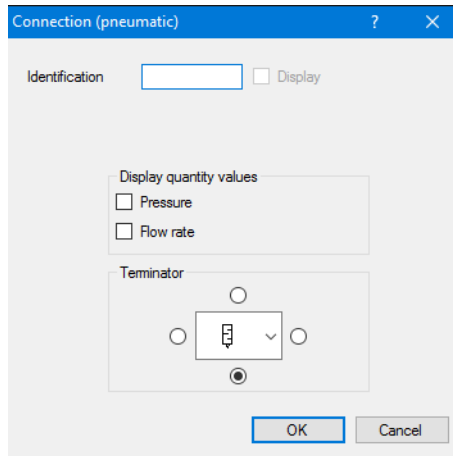
Figure 5/16: *Connector* dialog window: setting the properties of a connector

Identification

You can enter a text identifying this connector into the input line. If the *Display* option is activated then the identification is displayed in the circuit diagram.

Whether or not the identification is actually displayed depends on the option selected under Show Connector Descriptions .

Display quantity values

During the simulation, the calculated quantity values can be displayed not only with specialized measuring devices, but also directly at the connectors. For a quick overview, you can use View Quantity Values... to show all values at all connectors with a single click. As this is generally fairly confusing, you can also choose to view the quantity values at selected connectors only. For more details, see "Displaying quantity values".

Terminator

Open the symbol list containing connector terminators by clicking the button using the arrow. Select a suitable silencer or a blanking plug.

Note: Please note that this symbol list is only available if a line is not connected to the connector in question. If you wish to connect a

line to a sealed connector you first have to remove the blanking plug or silencer. To do this select the empty field in the symbol list with the connector terminators. The alignment of the connector terminator can be set via the radio buttons.

5.10 Configure a way valve

If you require a certain valve which you cannot find in the standard FluidSIM library you can create your own valve symbol with the help of the valve editor.

⤑   Insert a 5/n-way valve into a circuit window from the "Standard Symbols / Pneumatic Symbols / Valves / Configurable Way Valves" library (insert a hydraulic valve in case of FluidSIM-H).

To set the valve body and the actuation types of the way valves double-click the valve. The dialog window *Properties* then opens. Click the "*Configure Valve*" tab to access the valve editor.
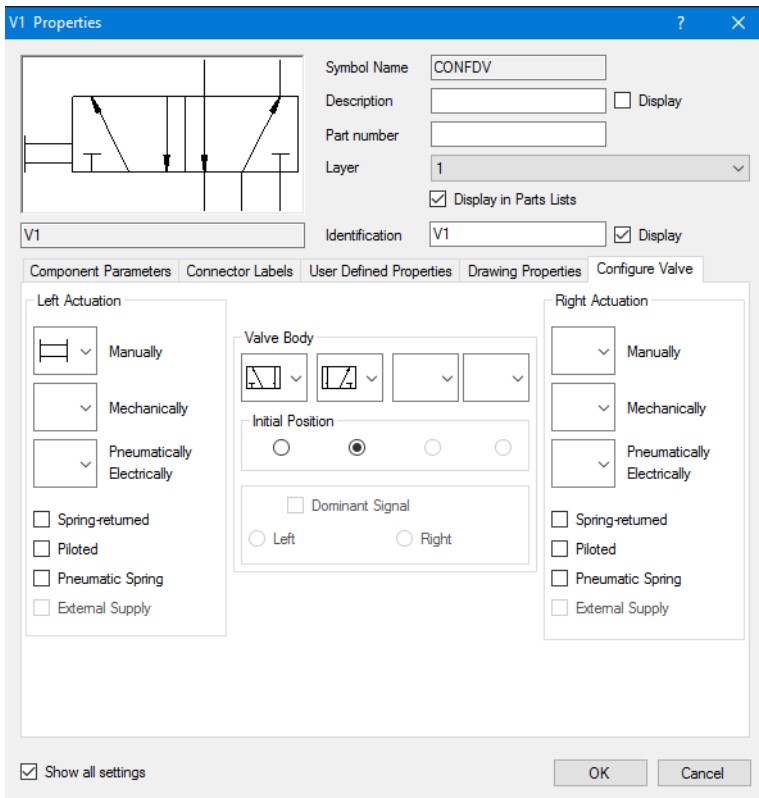
Figure 5/17: *Properties* dialog window: *Configure Valve* tab

Left Actuation – Right Actuation

You can select the actuation types of the valve from the "*Manually*", "*Mechanically*" and "*Pneumatically/Electrically*" ("*Hydraulically/Electrically*" resp.) categories for both sides of the valve. Click the button with the mouse pointer and select a symbol element. A valve can have multiple actuation types at the same time. If you do not want an actuation type from a category then select the empty field in the list. You can also define whether each side should have a spring return, pilot control, pneumatic spring or external supply.

Valve Body	A configurable valve can possess a maximum of four switching positions. One valve body can be selected for each switching position. Click the associate button with the mouse points to open the symbol elements list. Select a symbol element for each switching position. If you want to use less than four switching positions then select the empty field on the list for the positions not required.
Initial Position	Here you set which switching position the valve should use in the normal position. Note: When determining this setting, ensure that it does not conflict with a possible spring return.
Dominant Signal	This provides a graphical identification of whether the right or left signal should dominate in the event of equally strong signals.
External Supply	This creates an additional connector for connecting the external supply for the controller.

5.11 Configure cylinders

If you require a certain cylinder which you cannot find in the standard FluidSIM library you can create your own cylinder symbol with the help of the cylinder editor.

⤑ Insert a double-acting cylinder into a circuit window from the "Standard Symbols / Pneumatic Symbols / Pneumatic Drives / Configurable Cylinders" library. In the case of FluidSIM-H, select a hydraulic cylinder accordingly.

To configure the cylinder double-clock on the cylinder. The dialog window *Properties* then opens. Click the "*Configure Cylinder*" tab. This brings you to the cylinder editor.
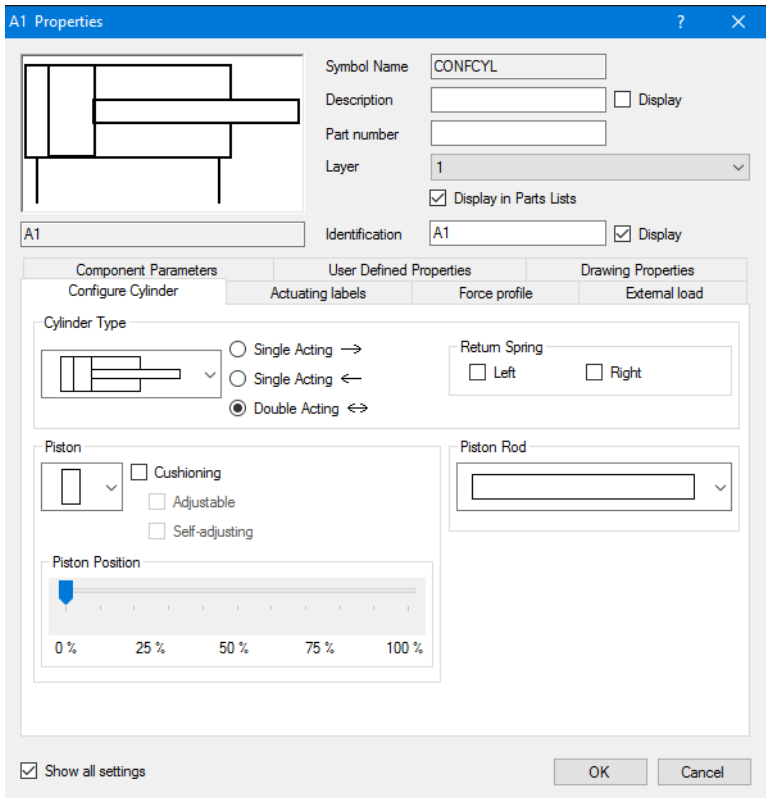
Figure 5/18: *Properties* dialog window: *Configure Cylinder* tab

Cylinder Type	Click the button with the mouse pointer to open the symbol elements list. Select a cylinder type. Set whether the cylinder should be single-acting or double-acting.
Return Spring	Specifies whether a spring for the return should be inserted into the right or left cylinder chamber.
Piston	Click the button with the mouse pointer and select a symbol element for the piston. Set whether the cylinder should possess end position cushioning and whether this should be adjustable.

Piston Rod	Click the button with the mouse pointer and select a symbol element for the piston rod.
Piston Position	Using the slider you can specify the relative piston position in 25 % steps. 0 % stands for the completely retracted and 100 % extended piston.

5.12 Group symbols

If you wish to combine multiple symbols into a group select these and choose the Group menu item on the Edit menu. Groups can also be nested, i.e. already grouped objects can be grouped again.

A group primarily serves as a drawing aid and does not represent any new components. Every element in a group is included in a parts list in exactly the same way as without being grouped. Double-clicking on a group element opens the dialog window *Properties* of group element clicked.

If you wish to combine multiple symbols into a new component with its own attributes create a macro object.

5.13 Create macro objects

If you wish to combine multiple symbols into a new component with its own attributes then highlight these and select the Create Macro Object menu item from the Edit menu. This creates a new macro object. Macro objects are included in the parts lists as independent components. The original symbols are removed from the parts lists. It is no longer possible to edit their component attributes.

5.14 Delete symbol groups and macro objects

To delete a group or a macro object select the group or the macro object and select the Ungroup/Break Off menu item from the Edit menu. This always deletes the outermost group. In order to delete nested groups you must repeat the operation.

5.15 Align symbols

To align objects with each other, select these and choose the desired orientation from the Align menu item on the Edit menu or click the appropriate button on the toolbar.

5.16 Mirror symbols

The symbols can be both horizontally and vertically mirrored. Select the desired mirror axis from the Mirror menu item on the Edit menu or click the appropriate button on the toolbar. If you select multiple objects at the same time then every object will be mirrored separately. If you wish the operation to use a common mirror axis then group the objects before the operation.

The geometrical properties can be entered directly via the "*Drawing Properties*" tab. Enter a minus sign in front of the corresponding scaling factor in order to mirror the symbol.

5.17 Rotate symbols

The symbols can be rotated in 90 degree steps or with the help of the mouse pointer. To rotate objects in 90 degree steps, select the desired angle from the Rotate menu item on the Edit menu or click the appropriate button on the toolbar. If you select multiple objects at the same time then every object will be rotated separately. If you wish the operation to use a common axis of rotation then group the objects before the operation.

You can also rotate symbols with the help of the mouse pointer by clicking and dragging the edge of the symbol. In order to do this FluidSIM must be in Enable Rotate mode. This mode can be activated or deactivated using the Enable Rotate menu item from the Edit menu or by clicking the corresponding button on the toolbar.

Note: Activating the Enable Scale mode deactivates the Enable Rotate mode and vice versa.

⤳   In Enable Rotate mode click the edge of the symbol and hold down the mouse button.
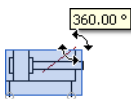
Figure 5/19: Rotate symbol

The current angle of rotation and guides are displayed.

⤳   Hold down the mouse button and move the mouse pointer until the desired angle of rotation is achieved. The angle changes in 15 degree steps.

Note: If you also press the Shift key then you can rotate the symbol steplessly.
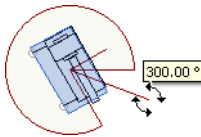
Figure 5/20: Rotate symbol

The angle of rotation can also be entered directly in the properties dialog window in the Drawing Properties tab.

Note that the *rotation of the drawing* has no effect on the simulation. If you want a load to be raised, for example, you need to enter the desired angle under "*Mounting angle*" in the component parameters.

5.18 Scale symbols

The component symbols can be scaled with the help of the mouse pointer. In order to do this FluidSIM must be in | Enable Scale | mode. This mode can be activated or deactivated using the | Enable Scale | menu item from the | Edit | menu or by clicking the corresponding button on the toolbar.

Note: Activating the | Enable Scale | mode deactivates the | Enable Rotate | mode and vice versa.

⤑ In | Enable Scale | mode click the edge or corner of the symbol and hold down the mouse button.
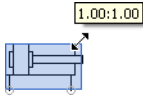
Figure 5/21: Scale symbol

The current scaling relationship to the current original size is displayed.

⟶ Hold down the mouse button and move the mouse pointer until the desired size is reached. The scaling relationship is changed in 0.25 steps. Note: If you also press the Shift key then you can scale the symbol steplessly.
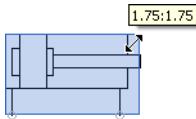
Figure 5/22: Scale symbol

You can simultaneously mirror the symbol by moving the mouse pointer over the middle of the symbol to the opposite side.
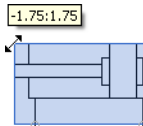
Figure 5/23: Mirror symbol

The scaling factor can also be entered directly in the *Properties* dialog window in the Drawing Properties tab.

Drawing frame

Chapter 6

In FluidSIM drawing frames are "circuit diagrams" which consists of a title block and the frame with the field divisions. They can also be displayed in other circuit diagrams. Existing CAD drawing frames can be imported using the DXF import menu item on the File menu. No order to make a drawing frame usable in different projects and circuit diagrams a number of texts in the title block must be editable. These texts are Author, Creation date, Project name, Page name and Page number, for example. In FluidSIM these are text components with *Attribute Link*.

6.1 Editable labels

Texts in the title block of a drawing frame are text components. You can use the imported texts or insert new text components at the desired positions. Editable texts are text components with *Attribute Link*. These texts are replaced by the corresponding attribute values of the project and the circuit.

⤏ Double-click a text component to open the *Properties* dialog window.

⤏ Enter the name of the attribute to be linked, e.g. "creator", in the text field and activate the "*Attribute Link*" option.

Note: You can also use an imported text as an attribute name.

The attribute name is utilized as a placeholder. These attributes are displayed in angle brackets in the "circuit diagram" with the drawing frame. These attributes are replaced by the corresponding attribute values when using the drawing frame in a project or circuit diagrams. Edit the attribute values in the *Properties* dialog window of the project or the circuit diagram. Clicking on a text component of the drawing frame opens the *Properties* dialog window of the project or the circuit which contains the attribute which the text component refers to.

6.2 Use a drawing frame

Drawing frames can be copied into a project and/or a circuit diagram. Insert the drawing frame via the *Properties* dialog window of a project or a circuit.

All of the objects belonging to a drawing frame are inserted into the circuit diagram as a copy. Changing the file with the drawing frame at a later date does not have any effect on the circuit diagram which the drawing frame was inserted into.

When copying the objects belonging to the drawing frame all of the attributes are generated with the drawing frame's text components refer to and which do not exist in the project or circuit.
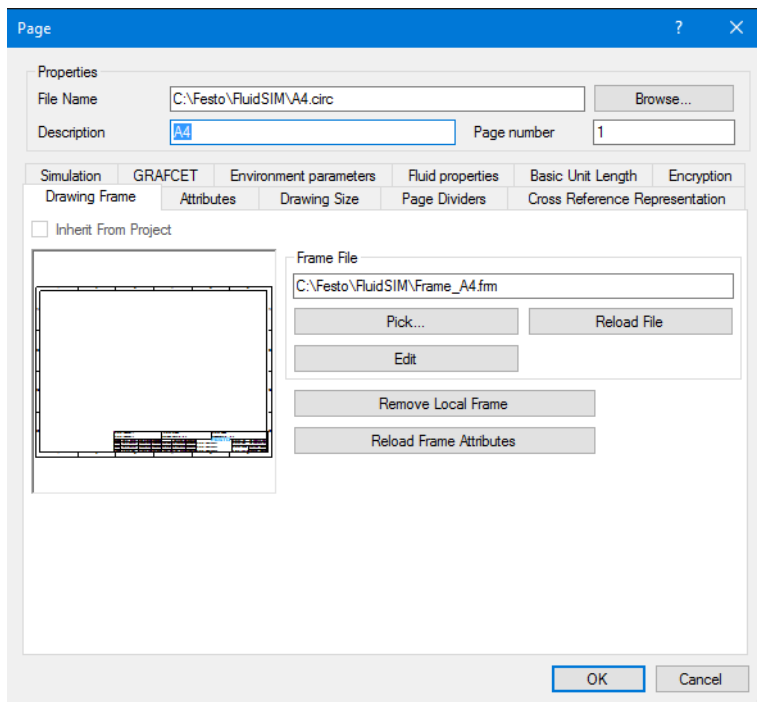
Figure 6/1: | Page | dialog window: inserting a drawing frame

Inherit From Project	If this option is activated then the drawing frame specified in the project is copied into the circuit. The path and the file used are displayed in the "*Frame File*" line.
Pick...	This button opens a dialog window in which an included frame can be selected. These frame files are located in the `frm` directory and are compiled in the project file `frames.prj`.
Reload File	Reloads the drawing frame and resets possible changes to the attributes and the page dividers.
Edit...	Opens the frame file for editing.
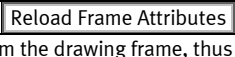
Remove Local Frame	Removes the drawing frame from the circuit. The drawing frame's attributes remain attributes of the project or circuit.
Reload Frame Attributes	When inserting a drawing frame the attributes of the text components of the drawing frame are listed. These attributes are saved with the project or the circuit drawing and can be edited and deleted. The Reload Frame Attributes button reloads all of the attributes from the drawing frame, thus updating the attribute list of the project or the circuit drawing.
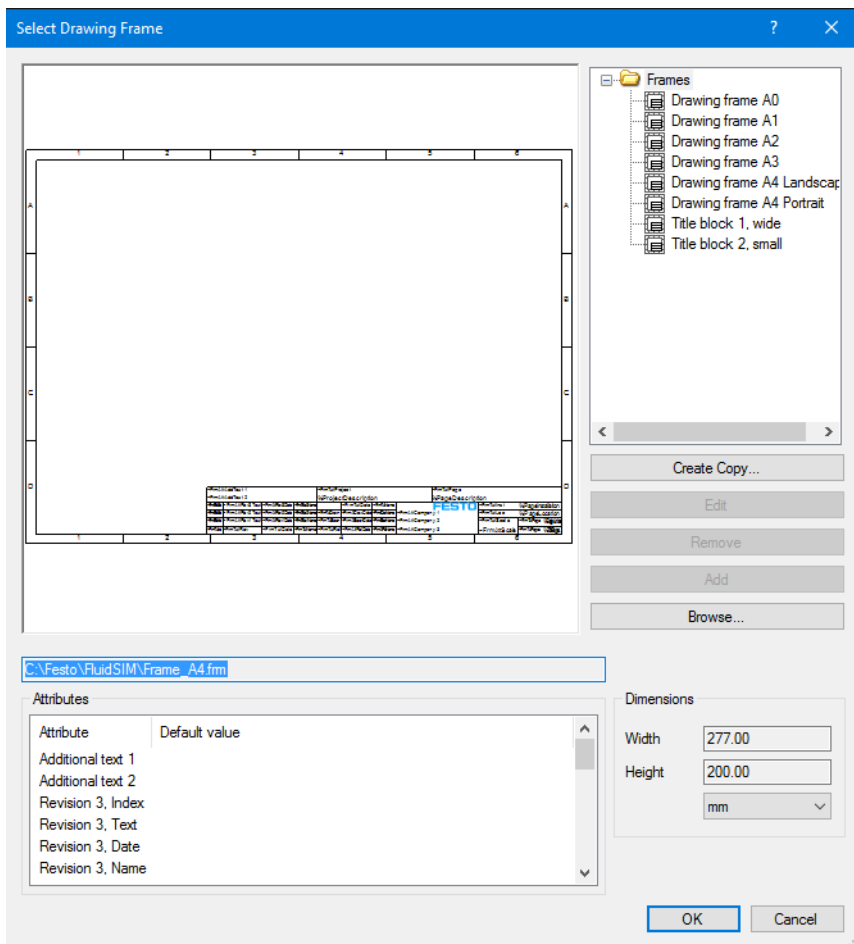
Figure 6/2: *Select Drawing Frame* dialog window

All of the available frame files are displayed as a tree on the right-hand side. The desired drawing frame can be selected in this tree. The drawing frame is then displayed in the preview. In addition the

"*Attributes*" list displays all of the attributes of the texts from the drawing frame which were defined as links.

Browse...   Opens a dialog window to select a circuit file to be used as a frame.

6.3   Drawing frame Editor

The drawing frame editor allows for the creation and modification of drawing frames.

The editor can be started from the property dialog of a project or a page. First, select a drawing frame in the "*Drawing Frame*" tab and open the frame for modification by clicking on Edit... .

Please note, that drawing frames, which were delivered in a version below 5.2a, can't be edited with the new editor.

6.3.1 Drawing Size
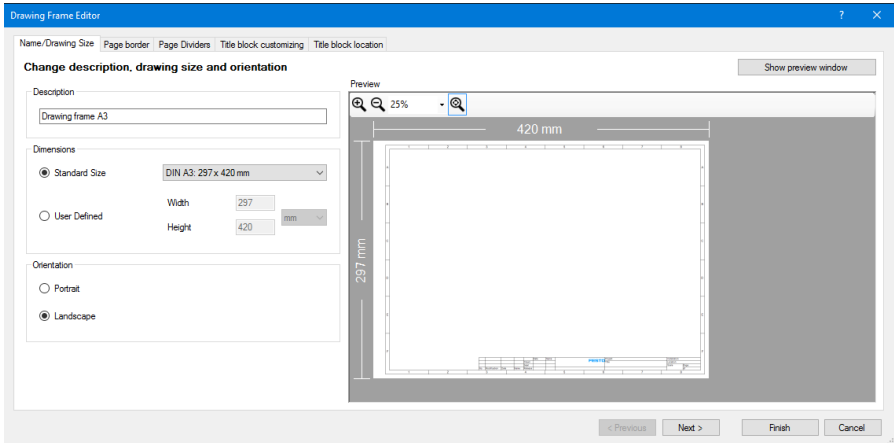
Figure 6/3: Tab *Drawing Size*

In this tab you can select a name for the drawing frame and change its size and orientation. In the upper area you can choose from predefined standard sizes or select your own, individual dimensions. Below, you can change the orientation of the drawing frame.

In the preview on the right side, the current dimensions are shown for illustration.

6.3.2 Page border
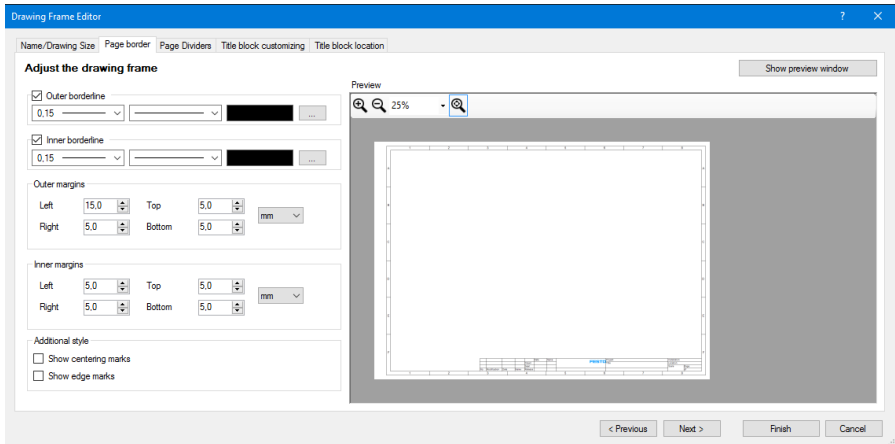
Figure 6/4: Tab *Page border*

This step allows you to configure the outer and inner border line according to your wishes.

In the upper part the properties linewidth, linestyle and color of the border line can be defined. If wanted, one or both lines can be deleted from the drawing frame by clicking the respective check boxes.

In the center part you can define the space between the outer border line and the border of the drawing space as well as the space between the inner border lines. All changes are visible in the preview on the right side immediately.

In the lower part you can decide to show additional markings in the drawing frame.

6.3.3 Page Dividers
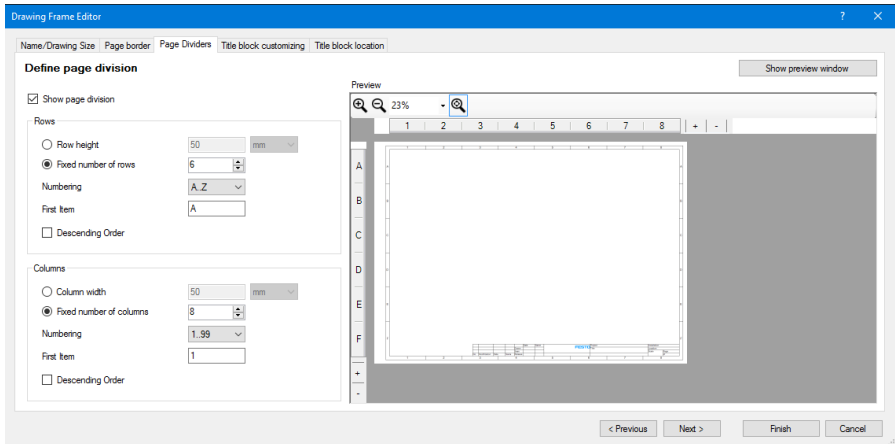
Figure 6/5: Tab *Page Dividers*

In this tab the page dividers can be set up.

In the upper left side, properties for the individual rows can be adjusted. The area below deals with the properties for the columns' designation.

The arrangement of columns and rows can either be defined by a fixed number or by choosing a particular height respectively width.

— If you specify a row height or column width concretely, the rows and columns will be inserted with the given width / height starting from the middle of the inner border. The last column or row on both sides of the drawing frame can turn out shorter than the specified width when using this way of arrangement. The following figure exemplarily shows the arrangement of columns on a DIN A4 sized drawing frame with landscape orientation and a specified column width of 50 mm.

33,5mm	50mm	50mm	50mm	50mm	33,5mm
1	2	3	4	5	6
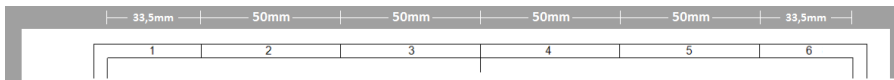
Figure 6/6: Example for column widths with predefined column widths

— If you otherwise specify a fixed number of rows or columns, the width / height of the inner border will be divided into the specified number of columns, which all have the same size. The following figure shows the arrangement of columns on the same DIN A4 drawing frame as before but with six columns.

44,5mm	44,5mm	44,5mm	44,5mm	44,5mm	44,5mm
1	2	3	4	5	6
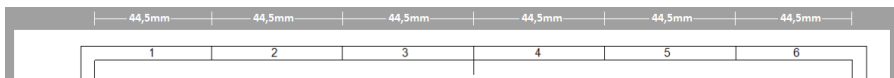
Figure 6/7: Example for column widths with predefined column count.

The numbering defines how the columns or rows are labeled. You can choose between a numeric labeling or an alphabetical labeling with upper- and lowercase letters. Use the *First Item* field to select, which number or letter should be used as start for the labeling.

By default the columns will be numbered from left to right and rows from top to bottom with ongoing numbering. Select the *Descending Order* check box, if you wish to reverse the order of numbering.

On the right side the current page dividers status is displayed along with additional controls to manually adjust the dividers. The shown controls correspond to the controls in the main program and can be used as well to manually set up the dividers. Given this case, the width and height of the arrangement equals the complete width / height of the inner border.

6.3.4 Title block customizing
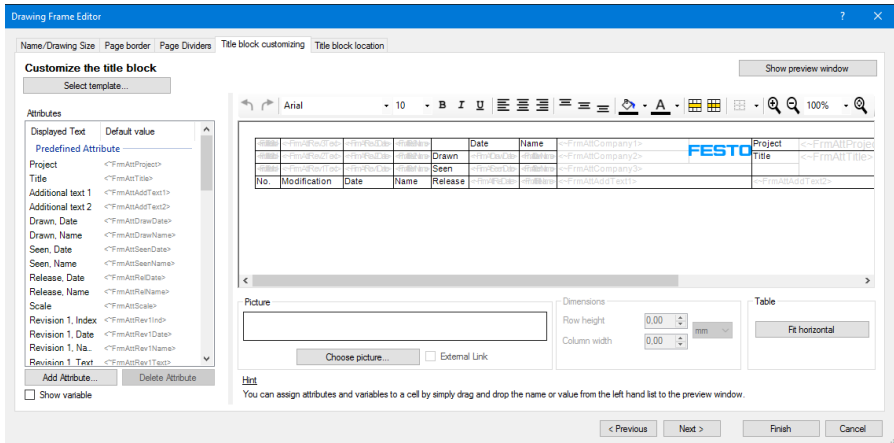
Figure 6/8: Tab *Title block customizing*

This tab allows for adjusting and arranging the title block to your needs.

General structure of the title block

The title block inside the drawing frame consists of a table with a specific number of columns and rows. In each individual cell can either contain a fixed text, an attribute link or an image.

Using the Select template... button at the top of the tab opens up a dialog, which allows for choosing a predefined title block to load.
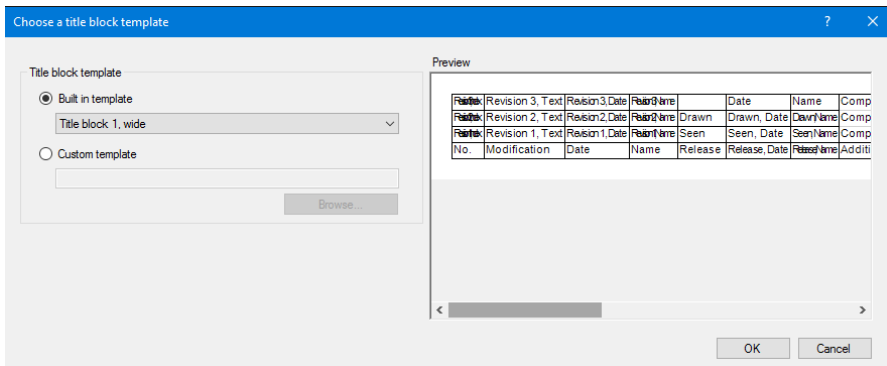
Figure 6/9: Dialog for choosing a title block

In this dialog you can choose a template for the title block. You can either use a predefined or an user-defined template. The selected title block will be shown in a preview on the right.

Selecting cells

Individual table cells can be selected by left-clicking on them. Selected cells will be displayed with a thicker blue border. The content of the selected cell, its cell properties as well as dimensions of the corresponding row and column are shown below the table.

You can select multiple cells by moving the cursor over additional cells while pressing the left mouse button. Alternatively, you can select the first cell and then select the last cell while keeping the Shift key pressed. Multiple, non-contiguous cells can be selected by holding the Ctrl key while clicking on the individual cells. The selected cells will be framed with a thicker blue border as well.

Adjusting the table structure.

You can change the current table's number of rows and columns by right-clicking on a table cell. A context menu for the current cell is shown. Using the menu items Insert and Delete , you can find commands for adding or removing rows and columns.

You can change a columns width or a rows height by moving the cursor to a cells border, pressing the right mouse button and moving the border. The selected cell will be changed in size and so will

the tables overall height / width. Holding down the $\boxed{\text{Ctrl}}$ key while moving the mouse will result in changing the cells size without changing the tables overall size.

Instead of changing the cell height or width by mouse, you can also directly input dimensions in the corresponding boxes under the table. Select a cell from the row / column you want to adjust and insert the values into the input fields.

Inside the table, multiple cells can be combined to a single connected cell. Such a connected cell spans multiple columns and / or rows.

To connect multiple cells, select them in the table and click on the menu item $\boxed{\text{Merge cells}}$ in the menu at the top. Cells can only be connected in a rectangular shape of neighboring cells. Connecting cells makes the new connected cell use the content and formatting of the cell in the upper left corner of the selection. To split up a connected cell use the menu item $\boxed{\text{Split cells}}$

Inserting a fixed text

By double-clicking a cell, you can input a fixed text for that cell. An input cursor is shown and allows to directly input a text. You can also press the F2 function key, to access the cells input mode.

Fixed texts are in language independent in general. That means, the text will be show as they've been inserted, independet from the language of the page or project. If you want to use a language-dependent text, you can use the predefined attribute texts, shown in the list on the left. Select a text and drag it into table cell. The cell will then show the internal place holder for the attribute text. For example, the internal placeholder for the attribute "*Project*" is "~FrmAttProject".

Text formatting

You can adjust a cells text formatting by using the menu bar on the top. Select a cell, which formatting you want to adjust. Click on one of the formatting options in the menu bar afterwards or select a value e.g. for font size.

Figure 6/10: Menu bar over the table display

Using the menu bar you can change the following formatting options:

— Font

— Font size

— Font style (B = bold; I = italic; U = underline)

— Horizontal alignment (left; centered; right)

— Vertical alignment (top; centered; bottom)

— Background color

— Font color

On selecting a cell, the values for font and font size for the current cell are shown in the menu bar, as well as for font style, vertical and horizontal alignment.

Insert images

To insert an image into a cell, select the cell and click the Choose picture... button below the table. Use the dialog to select an image. Supported image types are BMP, JPEG, PNG and GIF.

The path and filename of the selected image will be shown in the input field above the button and the image will be shown in the selected table cell. The image will be displayed in its original aspect ratio and will be adjusted in size to fit the cell. Either the maximum width or height of the cell will be used, depending on which leads to a larger image. If you want the image to be displayed larger, enlarge the images cell.

A freshly inserted image is bound to the cell by path and filename. This is indicated by the activated check box *External Link*. On every use of the drawing frame, the image is reloaded from this path. If the file is not available, a red X is shown instead of the image itself.

To embed the image in the drawing frame, deactivate the *External Link* check box. The file will then be embedded into the drawing frame and is always visible, independent from the previous file path. By embedding images into the drawing frame, the file size for the drawing frame, as well as any projects file size using the drawing frame, increases. Keep in mind, to use space-saving images preferably.

Adjust cell border lines

You can select the border lines of a cell by using the Borderlines button in the menu bar above the table. Select the cells you want to change the border lines for and click the small triangle on the right side of the control to see a drop-down menu of the available border lines.
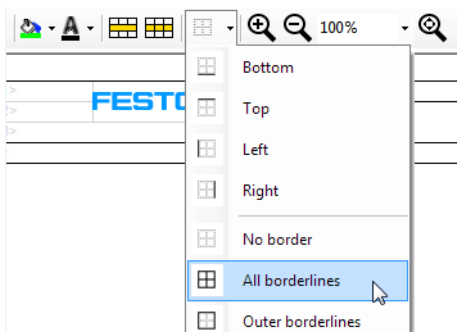
Figure 6/11: Border line selection

You can select a border line for the selected cell from this menu. By selecting No border, you can remove all border lines from the selected cells. Your choice will be applied to the control and can be applied to further cells by left-clicking the control when other cells are selected.

Frame attributes and variables

Additionally to the possibilities of fixed texts and images described earlier, the title block can also contain variable elements, whose values are determined later on using the drawing frame in a specific project or circuit. These elements can either be drawing frame attributes, which are maintained in the project or page properties or predefined variables, which get replaced by the corresponding value inside the circuit automatically.

Drawing frame attributes

Drawing frame attributes are special place holders, which can be selected in the title block and are replaced in the final circuit by the value of the corresponding attribute of the page or project, e.g. the project name, the page title or the approval date.

All available attributes are shown in the list on the left. You can find predefined attributes, predefined variables as well as user-defined attributes.

Each drawing frame attribute consists of two base components: The attributes labeling and a placeholder that will be replaced with the attributes value. The attributes labeling is located in the *Displayed Text* column, the placeholder is located in the *Default value* column. The placeholder is shown in angle brackets in a grey font, if no default value is defined.

To use an attribute in the drawing frame, select the placeholder from the *Default value* column and drag it to the desired cell while holding the left mouse button. On releasing the mouse, the selected place holder will be filled in. Inserting the placeholder into the table cell is sufficient to have the attribute appear in the property tab when using the drawing frame. From there you can select a value for the attribute, which will replace the place holder.

You can define default values for attributes in the drawing frame. Double-click on a place-holder and enter the desired default value. The default value will be shown instead of the place holder in the list, while the place holder is still displayed in the cells of the title block. On using the drawing frame, the default value will be applied to the drawing frame, but remains changeable at all times. By entering a default value, you also gain the possibility to check for the correct formatting of the text and the cells size.

If you want to insert the attributes labeling additional to the attributes value, select the label in the *Displayed Text* and drag it to the desired cell. Predefined attributes use special variables to be displayed language dependent, when using the drawing frame.

Complimentary to using predefined attributes and variables, you are able to define your won attributes. To add an attribute, click the Add Attribute... button and enter a name for the attribute. After-

wards the attribute is shown in the list and can be used as described above. In difference to predefined variables, user-defined variables will not be translated according to circuit or project language.

Variables

The attribute list contains the following predefined variables:

— Page number

— Description

— Installation

— Circuit

— Location

— File Name

— Full file path

— Full project path

— File modification date and time

— File modification date

— File modification time

— Total project pages

These variables are used in the same way as the drawing frame attributes described above. In difference to the drawing frame attributes, it is not possible to define a default value for variables, since they are replaced directly with the variables value when using the drawing frame.

6.3.5 Title block location
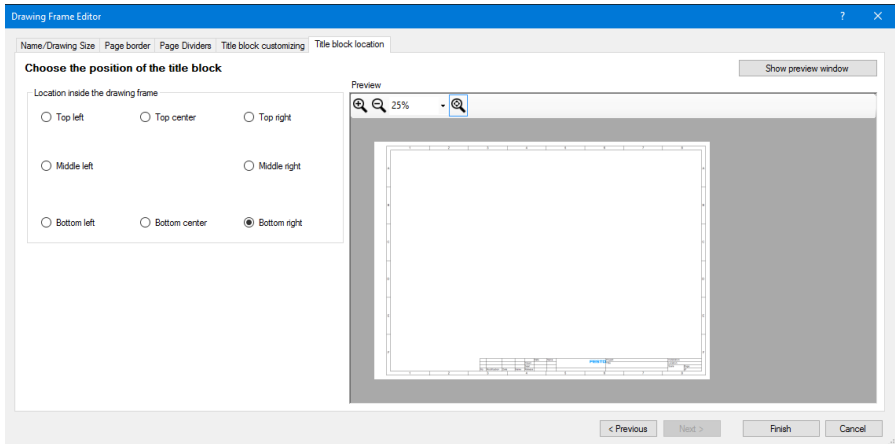
Figure 6/12: Tab *Title block location*

This tab allows changing the position of the title block inside the drawing frame.

Select the preferred position from the possible options. The title blocks changed position will be displayed in the preview on the right.

6.4   Page dividers

A circuit diagram or page can be logically divided into rows and columns, which can be labeled with numbers or letters. These page dividers are usually shown in the drawing frame and serve as a means of orientation within the page. Above all they allow the current paths (columns) of contacts to be specified in the contact images.

The graphical representation of the page dividers matches the logical page dividers in the drawing frames provided. The logical page dividers can be shown and hidden via the Show Page Dividers menu item from the View menu or via the button. They are displayed at the left-hand as well as the upper edge of the circuit window.

To be able to display and edit page dividers, you need to activate the Expert Mode option in the Options... menu.

If the page dividers are visible you can customize them using the mouse so that they match the graphical representation of the drawing frame, for example. This customization can be done in different ways:

→ Click and hold the mouse buttons in a column or row to move the entire column or row.
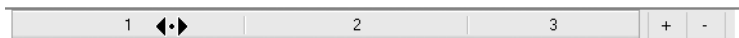
Figure 6/13:

→ Click and hold the mouse buttons at the outer margin of a column or row to move the margin of the column or row.

Figure 6/14:

The opposite margin is not moved and the columns or rows are resized proportionally.

→ Click and hold the mouse buttons at the margin of an inner division in a column or row to move the margin of the column or row.
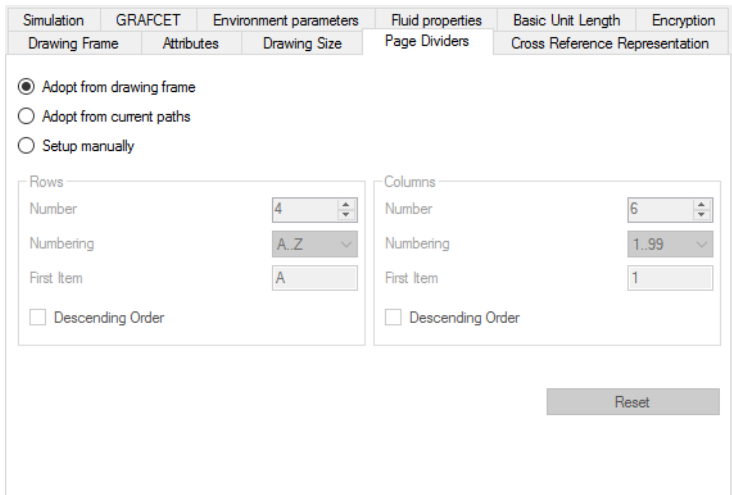
Figure 6/15:

In this case only the adjacent columns or rows are resized.

Columns and rows can be inserted and removed using the ⊞ and ⊟ buttons.

The label type and the number of rows and columns can be defined using the ⋯ button. The settings are saved as page properties. The following dialog window is opened:

Figure 6/16: Page dialog window, *Page Dividers* tab

Adopt from drawing frame   Selecting this option only makes senses for pages that do not represent drawing frames. This option must be deactivated if the current page represents a drawing frame that is to be inserted into other pages later.

If this option is activated then all settings that have been defined in the drawing frame will be adopted.

Adopt from current paths   When this option is activated, the page dividers are automatically derived from the current paths of the electrical circuit. You can show or hide automatic current path numbering via the " Display Current Path Numbering " menu.

Setup manually	Permits manual division of the rows and columns.
Rows	Defines the settings for the horizontal rows.
Columns	Defines the settings for the vertical columns.
Number	Defines the number of page dividers.
Numbering	Numbers, lowercase letters or uppercase letters can be used for numbering.
First Item	Defines the first numbering item. The numbering will be continued on analogously from this item.
Descending Order	Changes the numbering order.
Reset	Resets the page dividers to default values.

Additional tools for creating drawings

Chapter 7

7.1 Drawing tools

7.1.1 Grid

For arranging the symbols and laying the lines it is often practical to show a point or line grid. You can activate or deactivate the display of the grid using the Show Grid menu item from the View menu. You can also define further grid settings in the *General* tab under the Options... menu item from the Tools menu.

In order to simplify handling the connectors snap into place when they are close to a grid line. This makes it easier to find the precise position when moving the connectors.

Note: The grid snap function may not be desired as it prevents free positioning. In this case you can hold down the Ctrl key during the moving operation; this temporarily deactivates the grid snap function.

7.1.2 Alignment lines

Connectors between symbols should be exactly horizontal or vertical wherever possible. Then they can be connected with a straight line.

FluidSIM supports the exact positions firstly via the grid snap and secondly via automatically displaying red alignment lines while moving the selected objects.

·····➔ Open a circuit file which contains multiple objects. Select one
        of these and slowly move it back and forth above and next to
        other objects.

Observe the dashed red lines which appear when two or more
connectors lie above each other.
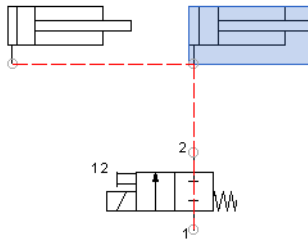
Figure 7/1: Automatically display the alignment lines

In order to simplify handling the connectors snap into place when
they are close to an alignment line. This makes it easier to find the
precise position when moving the connectors.

Note: The grid snap function may not be desired as it prevents free
positioning. In this case you can hold down the Ctrl key during
the moving operation; this temporarily deactivates the alignment
lines and the grid snap function.

7.1.3 Object snap

Various snap points can be activated for precise drawing. During a
drawing operation the mouse pointer snaps into place as soon as it
is close to a snap point. The following snap functions are available:

Snap to Grid

Snap to Connector

    ↙   Snap to End Point

    ↗   Snap to Mid Point

    ⊙   Snap to Center

    ✂   Snap to Intersection

Press and hold the Ctrl key during a drawing operation to temporarily deactivate the object snap function.

To be able to use object snap, you need to activate the Expert Mode option in the Options... menu.

7.1.4 Rulers

The rulers can be shown and hidden via View Show Rulers . They are displayed at the left-hand as well as the upper edge of the circuit window.

To be able to use the rulers, you need to activate the Expert Mode option in the Options... menu.

7.2 Drawing levels

FluidSIM supports 256 drawing levels which can be shown / hidden and locked / unlocked individually. In addition you can also define the color and line thickness for every drawing level. Using the Drawing Layers... menu item on the View menu you can set the properties of the individual layers and also insert a description.

Note: The drawing frame is located on layer "0" by default.
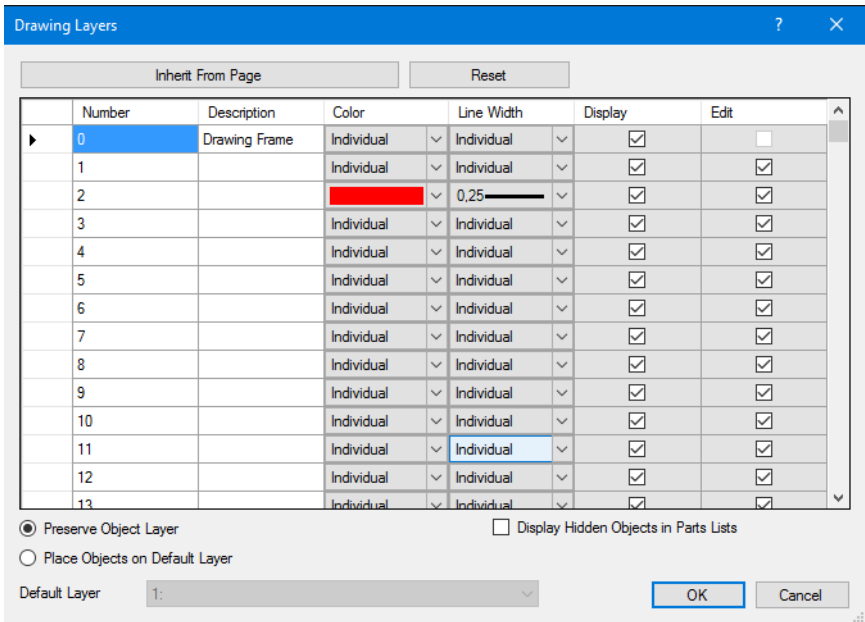
Figure 7/2: *Drawing Layers* dialog window

The drawing layer settings can be copied over as default settings from the current circuit using the Inherit From Page button.

You can select the drawing layer where newly inserted objects should be placed under "*Default Layer*". If you do not want the symbol layer to be changed when objects are inserted then select the "*Preserve Object Layer*" option.

Objects located on a drawing layer for which the "*Edit*" option is deactivated are visible but cannot be highlighted and therefore neither moved nor deleted. This enables you to lock a drawing frame, for example, if it was inserted manually and not via the *Properties* dialog window for the circuit or project. In order to still be able to edit objects on layers of this type you must activate the "*Edit*" option for the corresponding layer.

Drawing layers for which the "*Display*" option is deactivated are neither visible nor can they be edited.

7.3 Cross-references

Cross-references serve to link connected parts of a circuit drawing when the entire drawing is spread across multiple pages. This allows lines to be interrupted, for example, and continued on another page.

FluidSIM offers two types of cross-references. Paired cross-references consist of two cross-reference symbols that reference each other. The two cross-reference symbols are linked via a unique label that is entered for both symbols.

The option also exists to reference any object within a project from a cross-reference symbol. The cross-reference is unidirectional in this case: from the cross-reference to the target object. This allows several cross-references to reference the same object.

Both types enable you to jump directly from a cross-reference to the associated target. With the paired cross-reference the target is the corresponding cross-reference, otherwise an object.

You jump to the corresponding target either using the Jump to Target button in the properties dialog window for the cross-reference symbol or by highlighting the cross-reference and selecting the Jump to Target menu item from the context menu.

The circuit drawings involved must belong to the same project.

Open the *Cross-reference* dialog window from the Edit menu and the Properties... menu item. Alternatively you can open this dialog window by double-clicking the cross-reference symbol or using the Properties... context menu.
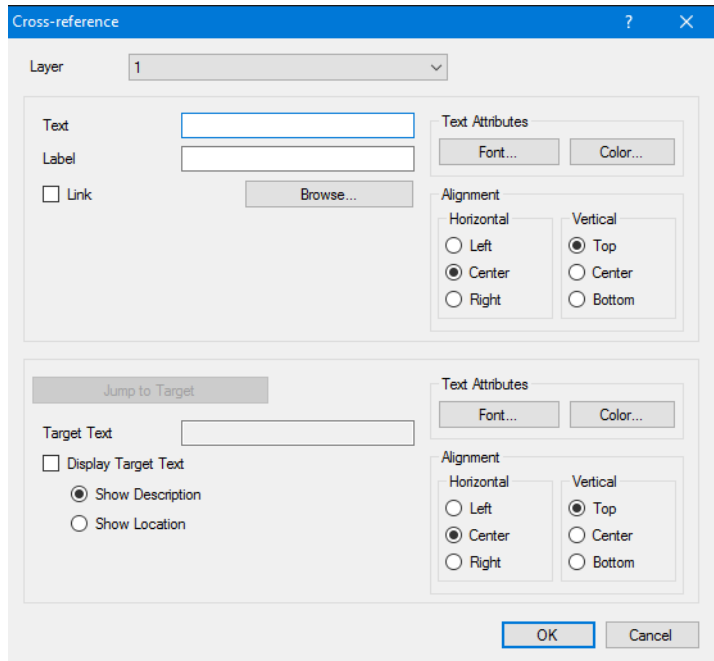
Figure 7/3: *Cross-reference* dialog window

Text	This text is displayed in the cross-reference
Label	Defines the labels via which the linked cross-references are identified.
Link	If this option is activated then the label entered constitutes a link to a target object. The cross-reference only works in the direction of the target object in this case. This option can be combined with the *Show Location* option to show the location of the target object.
Target Text	If the *Show Location* option is activated then the location of the target object will be displayed here. The representation of the location is defined in the *Cross Reference Representation* tab in the properties dialog window for the page or project.

If *Show Description* is activated then the text of the corresponding cross-reference is displayed for paired cross-references, otherwise the description of the target object is displayed.

Display Target Text

If this option is activated then the above-mentioned text from the *Target Text* field is displayed below the text for this cross-reference.

Jump to Target

Activating this button opens the circuit window containing the corresponding cross-reference. The associated symbol is indicated by an animation.

The font type, text color and alignment of the texts to be displayed can also be customized.

7.3.1 Create cross-references from symbols

You can generate a cross-reference from one or more symbols. To do so highlight the corresponding symbols and select the Edit ▸ Create Cross-reference menu item or the Create Cross-reference menu item from the context menu. The highlighted symbols are combined into a group that constitutes a cross-reference with two additional texts. One of these texts shows the label used and the other the target text for the cross-reference.

7.3.2 Cross-reference representation

The location of the target object can be shown in cross-references. How it is represented can be specified in the *Cross Reference Representation* tab in the properties dialog window for the circuit or project. The location can be composed from the "*Page number*", "*Page*", "*Page Column*", "*Page Row*" and "*Object Identification*" components. These reference the target object. Separators can be placed before and after each component. The default representation is:

| Page number. Page Column The description for the page and the page number are specified in the Properties dialog window for the circuit.

To be able to use the options for displaying cross-references, you need to activate the Expert Mode option in the Options... menu.

The page number is a predefined placeholder that can be used in text components and drawing frames among other things.

Figure 7/4: *Cross Reference Representation* tab

Inherit From Parent Node	Defines whether the representation rules for the parent node should be applied.
Example	A sample location that conforms to the specified rules is displayed here.
Reset	Resets the cross-reference representation to the default setting.

7.3.3 Manage cross-references

All paired cross-references in a project are listed in a dialog window that is opened using the `Project` `Manage Cross References...` menu item. Using this dialog you can jump to all paired cross-references in the project.

To be able to use the options for managing cross-references, you need to activate the `Expert Mode` option in the `Options...` menu.
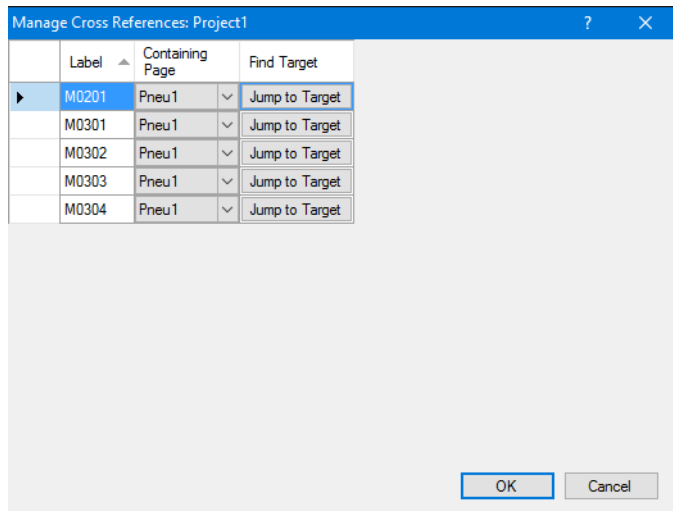
Figure 7/5: `Manage Cross References...` tab

Label	Contains the label for the corresponding cross-reference.
Containing Page	A page containing the cross-reference in question can be selected in the drop-down list.
Jump to Target	Using this button you can jump to the corresponding cross-reference.

7.4 Drawing functions and graphical elements

Graphical elements can be inserted into a circuit using the Draw menu or by activating the drawing function on the toolbar. In order to prevent you from unintentionally moving other symbols when drawing you enter a special mode for the drawing function in which you can only perform the selected drawing functions. After every drawing operation FluidSIM returns to the normal editing mode. To insert another drawing element you must select the associated menu item or the corresponding drawing function on the toolbar again.

Note: If you wish to draw several elements in a row without leaving the special drawing mode then you can select the menu item or the corresponding drawing function on the toolbar while holding down the Shift key. The drawing mode then remains active until the menu item or the drawing function is deactivated by selecting it again or another drawing function is selected without the Shift key being pressed.

The drawing functions toolbar contains the following buttons:

Switches to the normal editing mode.

Switches to the mode for drawing a line.

Switches to the mode for drawing a polyline.

Switches to the mode for drawing a rectangle.

Switches to the mode for drawing a circle.

Switches to the mode for drawing an ellipse.

Switches to the mode for drawing a text.

Switches to the mode for drawing an image.

Switches to the mode for drawing a conduction line. You can start by choosing whether you would like to draw a pneumatic, hydraulic, electric, digital, or GRAFCET conduction line.

▇▇▇ ▾	The graphical elements are drawn in the color shown.
——— ▾	The graphical elements are drawn in the line style shown.
0,1 ——— ▾	The graphical elements are drawn in the line thickness shown.
Start ⊢— ▾	The line beginnings are drawn with the symbol shown.
End →► ▾	The line ends are drawn with the symbol shown.

7.4.1 Interruption/Potential

If conduction lines extend over several pages then the line ends can be assigned interruptions. Interruptions can be used to define that a conduction line is only interrupted in the drawing and is continued somewhere else. An interruption can be assigned an identification and linked with another interruption. The location of the linked interruption can be displayed at the source interruption.

If an electric interruption is used with an electric line then this interruption is a potential. The use of electric potentials is described under Potentials and conduction lines.

You can insert an interruption into an existing line or position it freely in a circuit.

┈┈> Select the Interruption/Potential... menu item from the Insert menu.

A dialog window opens where you can make various settings for the interruption to be inserted.

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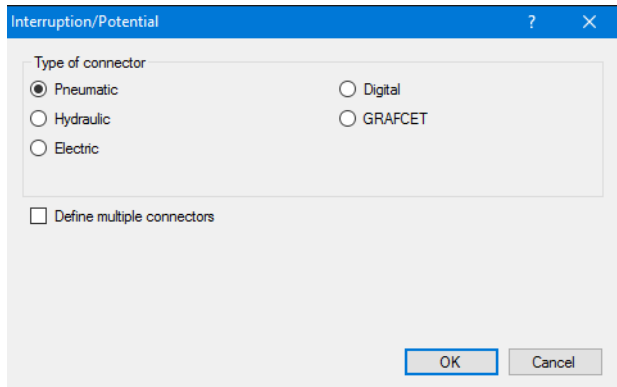
Figure 7/6: Interruption/Potential... dialog window

| Type of connector | Defines whether a fluidic or electric interruption (potential) is to be inserted. |

Type of connector   Defines whether a fluidic or electric interruption (potential) is to be inserted.

Define multiple connectors   Multiple interruptions can be set one after the other if this option is active. You can cancel the action by pressing the Esc key.

You can edit the properties for an interruption by double-clicking it. The following dialog window opens.
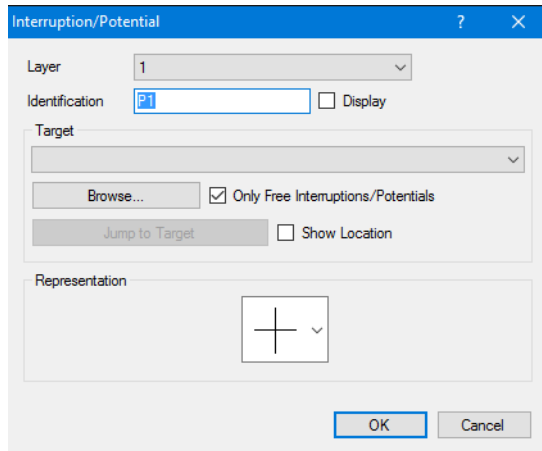
Figure 7/7: *Interruption/Potential* dialog window

Layer	Defines the drawing layer for the interruption.
Identification	Defines the identification for the interruption. The identification will be displayed in the circuit if the *Display* option is active.
Target	Interruptions can reference each other in pairs. The counterpart interruption can be selected from a list or entered directly in the list box. Browse... opens a dialog window where all interruptions are displayed in a tree and can be selected. Only interruptions that are not linked will be shown in the list if the *Only Free Interruptions/Potentials* option is active.
Jump to Target	If the interruption is linked with another interruption then this button can be used to jump to the counterpart interruption.
Show Location	If this option is activated and the interruption is linked with another interruption then the location of the counterpart interruption will be displayed as a page coordinate (e.g. page number/column).
Representation	A symbol that defines the representation of the interruption can be selected from a list. To illustrate the representation the relevant symbol always additionally shows the intersection of two lines.

7.4.2 Conduction line

A conduction line is drawn by defining two end points. A pneumatic or electric line of this type consists of two connectors with a line between them. Both connectors can be used as the starting point for further connections. The conduction lines can only be drawn horizontally or vertically.

You open a dialog window where you can make various settings for the line to be dragged using the Insert   Conduction Line... menu item or the ↦ button on the toolbar.
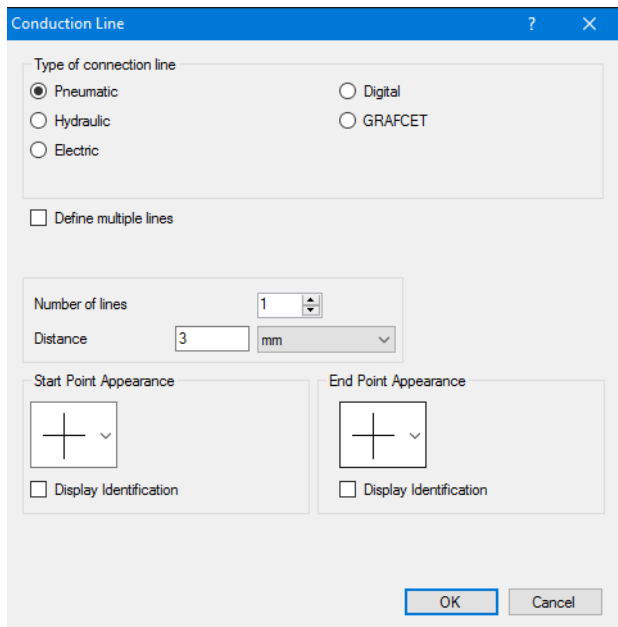
Figure 7/8: Conduction Line... dialog window

Type of connection line

Selects the conduction line type. The following are available: "*Pneumatic*" and "*Electric*".

Define multiple lines | Multiple conduction lines can be set one after the other if this option is active. You can cancel the action by pressing the ⎵Esc⎵ key.

If multiple conduction lines with the same distance between them are to be drawn horizontally or vertically then change the number in the "*Number of lines*" field. You specify the distance to be maintained between the lines using "*Distance*".

Under "*Start Point Appearance*" and "*End Point Appearance*" you can define the representation of the respective end point. If the "*Display Identification*" option is selected then the identification for the start point is displayed. In order to guarantee that the same identification is displayed for the start point and the end point, a text reference for the start point is displayed for the end point instead of its identification.

Interruptions are used as end points for conduction lines.

After confirming the dialog window you switch to a special mode where you define the end points of the line with two consecutive mouse clicks. Alternatively you can also draw a line by clicking and dragging.

An electric conduction line can constitute a potential line. This is described under Potentials and conduction lines.

7.4.3 Line

A line is drawn by defining two points. In contrast to a conduction line this line is purely a drawing element. As such it can be drawn with any desired angle but does not allow connections with pneumatic or electric connectors.

The line-specific properties can be defined in the *Drawing Properties* tab of the *Properties* dialog window for the line:

Figure 7/9: *Properties* dialog window for a line: *Drawing Properties* tab

Start Point	Defines the x/y coordinate of the start point.
End Point	Defines the x/y coordinate of the end point.
Scale	Defines the scaling in the x or y direction.
Rotation	Defines the angle of rotation in degrees.
Override Color	Defines the color of the drawing element.
Line Style	Defines the line style.
Line Width	Defines the line thickness.
Start Cap	Defines how the beginning of the line is displayed.
End Cap	Defines how the end of the line is displayed.
Background	

Sets the location of the drawing element to the background. This means that all of the circuit symbols are on top of this. For example symbols are not covered by filled drawing elements.

Foreground   Sets the location of the drawing element to the foreground. This means that all of the circuit symbols are underneath this. For example symbols are covered by filled drawing elements.

Reset   Reset the settings to the default values.

7.4.4 Polyline (set of connected lines)

A polyline (also called a set of connected lines or polygonal chain) is drawn by defining two or more points. Each mouse click sets a further vertex. The polyline is ended by clicking the same point twice.

The properties of the polyline can be defined in the *Drawing Properties* tab in the *Properties* dialog window:

Figure 7/10: *Properties* dialog window for a polyline: *Drawing Properties* tab

Position	Defines the coordinates of the upper left corner.
Scale	Defines the scaling in x or y direction.
Rotation	Defines the angle of rotation in degrees.
Color	Sets the color of the polyline.
Fill Area	Fills the polyline with the color listed. When the individual lines overlap, the resulting subareas are alternately shown filled and transparent, to allow for identifying the line course.
Hatching	Determines, that enclosed areas are crosshatched in the selected style. When the individual lines overlap, the resulting subareas are alternately shown crosshatched and transparent, to allow for identifying the line course.
Line Style	Defines the line style.

Line Width	Defines the line width.
Start Cap	Defines how the beginning of the line is displayed.
End Cap	Defines how the end of the line is displayed.
Background	Sets the location of the drawing element to the background. This means that all of the circuit symbols are on top of this. In particular it means that symbols are not covered by filled drawing elements, for example.
Foreground	Sets the location of the drawing element to the foreground. This means that all of the circuit symbols are underneath this. In particular it means that symbols are covered by filled drawing elements, for example.

To change the vertices of a polyline or to set new vertices switch to the "polyline editing mode" by selecting the Edit Edit Poly Line menu item or activating the button on the toolbar.

You can move the existing vertices by clicking and dragging. The mouse pointer changes to when you mouse over an existing vertex. If the mouse pointer is over a line without a vertex is displayed and a new vertex is inserted as soon as you click.

7.4.5 Rectangle

A rectangle is drawn by defining two diagonally opposite corner points.

The rectangle-specific properties can be defined in the *Drawing Properties* tab of the *Properties* dialog window for the rectangle:

Figure 7/11: *Properties* dialog window for a rectangle: *Drawing Properties* tab

Position	Defines the coordinates of the upper left corner.
Size	Defines width and height of the rectangle.
Scale	Defines the scaling in the x or y direction.
Rotation	Defines the angle of rotation in degrees.
Color	Sets the color of the rectangle.
Fill Area	Fills the rectangle with the color listed.
Hatching	Sets the hatch style of the rectangle.
Line Style	Defines the line style.
Line Width	Defines the line thickness.
Background	

Sets the location of the drawing element to the background. This means that all of the circuit symbols are on top of this. For example symbols are not covered by filled drawing elements.

Foreground

Sets the location of the drawing element to the foreground. This means that all of the circuit symbols are underneath this. For example symbols are covered by filled drawing elements.

7.4.6 Circle

A circle is drawn by defining a middle point and a radius. You can draw a circular arc by subsequently entering the beginning and final angles into the *Drawing Properties* tab in the *Properties* dialog window of the circle.

The circle-specific properties can be defined in the *Drawing Proper-ties* tab of the *Properties* dialog window for the circle:

Figure 7/12: *Properties* dialog window for a circle: *Drawing Proper-ties* tab

Position	Defines the coordinates of the upper left corner.
Size	Defines the radius for the circle. If values for *rx* and *ry* are different, an ellipse is created.
Scale	Defines the scaling in the x or y direction.
Arc	Defines the starting and final angles of a circular arc.
Rotation	Defines the angle of rotation in degrees.
Color	Sets the color of the circle.
Fill Area	Fills the circle with the color listed.
Hatching	Sets the hatch style of the circle.
Fill mode	Sets the fill mode of the circle.

Line Style	Defines the line style.
Line Width	Defines the line thickness.
Start Cap	Defines how the beginning of the line is displayed.
End Cap	Defines how the end of the line is displayed.
Background	Sets the location of the drawing element to the background. This means that all of the circuit symbols are on top of this. For example symbols are not covered by filled drawing elements.
Foreground	Sets the location of the drawing element to the foreground. This means that all of the circuit symbols are underneath this. For example symbols are covered by filled drawing elements.

7.4.7 Ellipse

An ellipse is drawn by defining a middle point and two radii with parallel axes. You can draw an ellipse by subsequently entering the beginning and final angles into the *Drawing Properties* tab in the *Properties* dialog window of the ellipse.

The ellipse-specific properties can be defined in the *Drawing Properties* tab of the *Properties* dialog window for the ellipse:

Figure 7/13: *Properties* dialog window for an ellipse: *Drawing Properties* tab

Position	Defines the coordinates of the upper left corner.
Size	Defines the radii for the ellipse. Using identical values for both *rx* and *ry* will result in a circle.
Scale	Defines the scaling in the x or y direction.
Arc	Defines the starting and final angles of an ellipse.
Rotation	Defines the angle of rotation in degrees.
Color	Sets the color of the ellipse.
Fill Area	Fills the ellipse with the color listed.
Hatching	Sets the hatch style of the ellipse.
Fill mode	Sets the fill mode of the ellipse.

Line Style	Defines the line style.
Line Width	Defines the line thickness.
Start Cap	Defines how the beginning of the line is displayed.
End Cap	Defines how the end of the line is displayed.
Background	Sets the location of the drawing element to the background. This means that all of the circuit symbols are on top of this. For example symbols are not covered by filled drawing elements.
Foreground	Sets the location of the drawing element to the foreground. This means that all of the circuit symbols are underneath this. For example symbols are covered by filled drawing elements.

7.4.8 Text

A text is inserted at the position of the mouse pointer by clicking. The dialog window *Properties* for entering the text and setting the attributes then opens.

7.4.9 Image

An image is inserted at the position of the mouse pointer by clicking. The dialog window for selecting an existing image file then opens.

Large background images can massively decrease the processing speed as the screen has to be re-drawn whenever symbols are moved or edited.

The image-specific properties can be defined in the *Drawing Properties* and *Picture* tabs of the *Properties* dialog window for the image:

Figure 7/14: *Properties* dialog window for an image: *Drawing Properties* tab

Position	Defines the coordinates of the upper left corner.
Scale	Defines the scaling in the x or y direction.
Rotation	Defines the angle of rotation in degrees.
Override Color	Defines the color of the drawing element.
Background	Sets the location of the drawing element to the background. This means that all of the circuit symbols are on top of this. For example symbols are not covered by filled drawing elements.
Foreground	Sets the location of the drawing element to the foreground. This means that all of the circuit symbols are underneath this. For example symbols are covered by filled drawing elements.
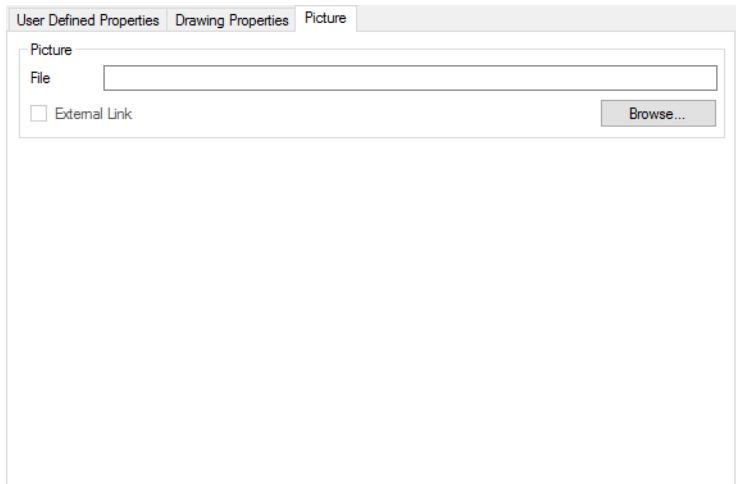
Figure 7/15: *Properties* dialog window for an image: *Picture* tab

File	Defines the image file for the image.
External Link	When this option is active FluidSIM only saves a link to the image file. However if this option is deactivated then the image is embedded in the circuit diagram. This is the preferable variant if you wish to pass on or archive the circuit diagram.

7.5   Check drawing

You can use Check Drawing in the Page menu to have FluidSIM check your drawing for possible drawing errors. FluidSIM displays the following messages where necessary:

— *Duplicated identification labels*

— *Unresolved link targets*

— *Superimposed objects*

- *Lines through connectors*

- *Open connectors*

- *Duplicated cross-reference labels*

- *Superimposed lines*

- *Cyclic object references*

- *Objects outside the drawing area*

- *Missing translations*

- *Ambiguous terminal strip references*

- *Unassigned cables*

- *Unassigned terminals*

- *Duplicated terminal references*

- *Two digital outputs are connected to each other.*

- *Digital loop detected.*

- *Connection errors found in the GRAFCET diagram.*

If messages are displayed then the corresponding objects are selected after confirmation in the dialog window.

Simulating with FluidSIM

Chapter 8

8.1 Simulation of existing circuits

FluidSIM comes supplied with a series of functional circuits. These include circuits used in training material, which are discussed in more detail in the various basic and advanced level workbooks from Festo Didactic SE.

You can find these sample circuits under Circuits for exercises (TP)... in the Didactics menu. The names of the folders match those of the corresponding workbooks from Festo Didactic SE. The sample circuits can be edited and simulated as desired. However, bear in mind that your modifications may alter the function of the circuit and consequently also the training material. We therefore recommend saving any modified sample circuits under a different name or in their own folder.

⤳ Open the circuit **demo1** and start the simulation via Execute Start or using the symbol ▶.

FluidSIM switches to *Simulation Mode* and starts the simulation of the circuit. In Simulation Mode, the mouse pointer changes into the hand symbol 🖐.

At the start of the simulation, FluidSIM first creates a physical model of the entire system. Construction of the model is usually a complex operation, which can take several seconds depending on the complexity of the circuit and the speed of the computer. Continuous calculation of the model using mathematical methods then follows. It cannot always be guaranteed that the subsequent dynamic simulation will take place in real time. The percentage of real time achieved is displayed by FluidSIM in the status bar at the lower edge of the screen.

The line animation display during the simulation can be customized in Options... .

The exact numerical values for the pressures, flow rates, voltages, and currents are displayed on the connected measuring devices. Section "Displaying quantity values" describes how you can display the numerical values for all or some quantity values in the circuit even without measuring devices.

! The simulation is based on physical models which were calibrated with the pneumatic, hydraulic, and electric components in the Festo Didactic SE equipment sets. The calculated values should therefore closely match the values recorded by your measurements. When comparing the two, please bear in mind that in practice, measurements can be subject to large fluctuations. The reasons for differences range from component tolerances and tube length, to air and oil temperatures.

The calculation of the quantity values also forms the basis for the exact, *real-time-proportional* animation of the cylinders.

Real-time-proportional guarantees the following property: If in reality a cylinder moves twice as fast as another one, for example, that will also occur in the animation. In other words, the real-time ratio is retained in the simulation.

Manually operated valves and switches can be switched by clicking them with the mouse:

⇢ Move the mouse pointer onto the left-hand switch.

The mouse pointer changes into a hand with pointing finger ⟲ indicating that the switch beneath can be flipped.

⇢ Click the switch.

When you click a manually operated switch, its real behavior is simulated. In our example, the clicked switch is closed and recalculation begins automatically. Following the calculation, the new pressure and flow values are displayed and the cylinders move into their initial positions.

! The switching of components is only possible while a simulation is running (▶) or when a simulation is paused (⏸).

If you wish to simulate another circuit, you do not need to close the currently loaded circuit. FluidSIM allows you to have multiple circuits open at the same time and to simulate them either separately from one another or as a total system within one project.

⌁⟶ Click ■ or ⎹Execute⎸ ⎹Stop⎸ to switch the currently active circuit from Simulation Mode to Edit Mode.

When you switch from Simulation Mode to Edit Mode, the non-adjustable components are automatically reset to their "normal" state. In other words, the switches are set to their initial position, the valves switch to their normal position, the cylinder pistons are set to the position *previously set* for them, and all calculated quantity values are deleted. Components used to adjust or harmonize the system on the other hand, such as flow control valves, pressure-reducing valves or potentiometers, retain the values set by the user during the simulation.

By clicking ▌▌ (alternatively: ⎹Execute⎸ ⎹Pause⎸) you can switch from Edit Mode to Simulation Mode without starting the simulation. This is useful if you want to switch any components before starting a simulation (e.g. to simulate a protection circuit where two switches need to be pressed at the same time).

8.2   The different simulation modes

In addition to the functions for simulating circuits as presented in the previous section (■ , ▶ , ▌▌) there are also the following supplementary functions:

◀◀ Simulation reset and restart

▌▶ Simulation in single step mode

▶▎ Simulation up to a state change

8.2.1 Reset and restart of the simulation

With ◀◀ or Execute   Reset , a running or paused simulation of a circuit is reset and the circuit is returned to its initial state. The simulation is then restarted immediately.

8.2.2 Single step mode

In single step mode, the simulation will stop after a small step. More exactly, clicking ▶ or Execute   Single Step starts the simulation for a short period of time (about 0.01-0.1 seconds of simulation time in the real system) before switching back into pause mode (❚❚).

You can switch into single step mode directly from an actively running simulation. This makes it easy to focus on key moments in the simulation.

8.2.3 Simulation to a state change

Clicking ▶❙ or Execute   Simulate until State Change causes the simulation to start and run until a state change happens; the simulation then pauses (❚❚). A state change happens when one of the following takes place:

1. A cylinder piston moves against a stop

2. A valve switches over or is actuated

3. A relay switches over

4. A switch is actuated

You can switch into state change mode directly from an actively running simulation.

8.3 Simulating circuits you create yourself

This section assumes that you are already familiar with the basic concepts involved in creating circuits. If necessary, read the section Create a new circuit drawing" first.

Circuit diagrams can be created and modified in Edit Mode only. You can identify Edit Mode by the mouse arrow pointer ⌖ .

8.3.1 Example with a pneumatic circuit

⋯⋙ Create the circuit shown in the figure.
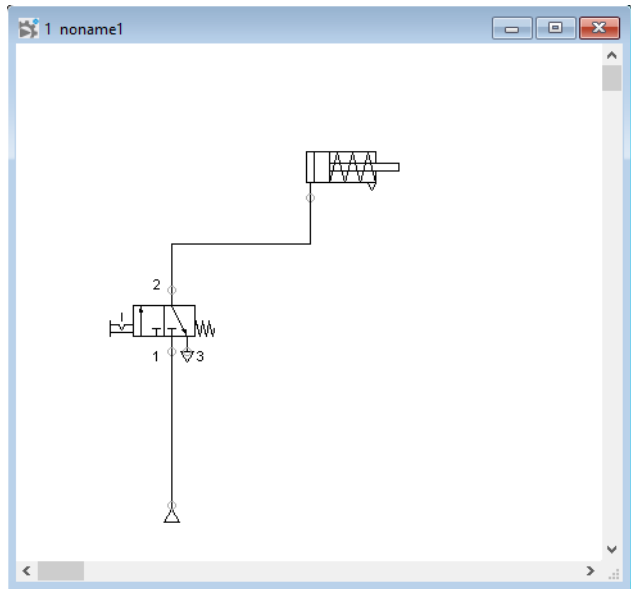
Figure 8/1: Simple pneumatic circuit

To define the valve's actuation type, double click the valve. The valve's property dialog opens.

┈┈> Go to the "*Configure Valve*" tab. Then, in the top drop-down list on the left side, select a manual actuation with detenting. On the right side, click the "*Spring-returned*" field.

If required, you can also set the standard nominal flow rate of the valve.

Close the dialog box with OK . As port "3" on the valve is only needed as an air outlet, set a silencer there.

┈┈> Double click the *port*.

A dialog box opens where you can select a *Terminator* by clicking the downward-pointing arrow to the right of the list and selecting the blanking plug or a silencer symbol.

⇢ Select the third symbol (the simple silencer) and close the dialog box.

The valve should now look like this:
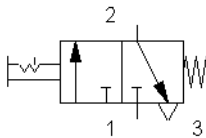
Figure 8/2: Manually operated 3/2-way valve

Now try to simulate this circuit.

⇢ Start the simulation with ▶ (or with Execute Start or with F9).

⇢ Move the mouse pointer onto the valve and click the valve with the pointing finger 👆.
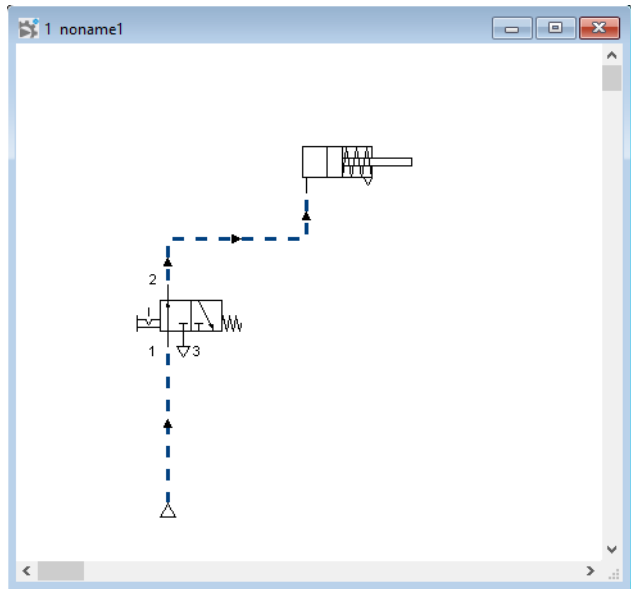
Figure 8/3: Simulated circuit

Once the cylinder has advanced, the pressure in the cylinder supply line must inevitably increase. This situation is detected by FluidSIM and the parameters are recalculated; the pressure at the compressed air supply increases to the set operating pressure.

┈┈> Click the valve to make the cylinder retract.

In complex circuits, or for the transmission of high switching forces, valves may also be activated indirectly. In the following we will replace the direct manual activation of the valve with indirect pneumatic activation.

┈┈> Activate Edit Mode with ■ (or with Execute   Stop or with F5).

┈┈> Select and delete the line that connects the cylinder and the valve.

┈┈> Drag another 3/n-way valve onto the drawing area and open the valve configuration dialog box by double clicking (or by Edit Properties...). "Construct" a pneumatic valve (normally closed), close the dialog box, put a silencer on port "3" again, and arrange the components as follows:
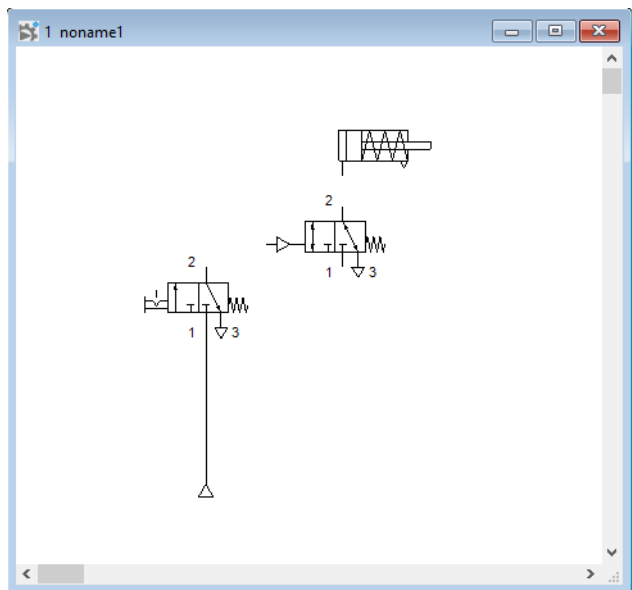
Figure 8/4: Circuit with unconnected components

┈┈> Connect the new valve's outlet port to the cylinder.

┈┈> Draw a line from the outlet port of the manually operated valve to the control port of the pneumatic valve.

┈┈> If necessary, drag the line segments until the drawing is arranged clearly.

The circuit should now look something like this:
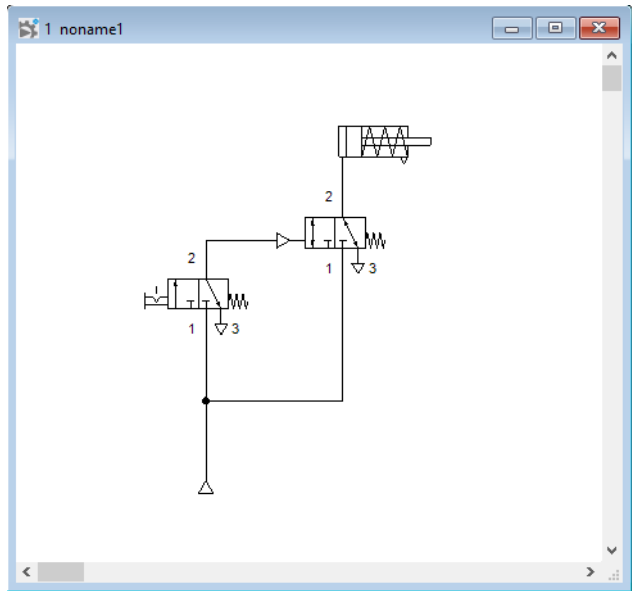
Figure 8/5: Circuit with indirect activation

----> Save this circuit with 🖫 (or with | File | | Save File |). FluidSIM
automatically opens the file selection box if the file did not al-
ready exist; you can enter a file name in that box.

----> Start the simulation with ▶ and click the manually operated
valve.

When you click a valve, the real behavior of the valve is simulated.
In our example, the clicked valve is switched over and recalculation
begins automatically. As a result, the indirectly activated pneumatic
valve is switched and the cylinder advances.

FluidSIM not only animates the switching of manually actuated
components, but nearly all components which have multiple states.

The following figure shows a 3/2-way valve in closed position and in open position:

Figure 8/6: Closed and open 3/2-way valve

When non-detenting components are clicked, they remain actuated as long as the mouse button is held down.

⟶ Stop the simulation and switch to Edit Mode. Select the state diagram from the component library and move it into the circuit window.

The state diagram records the quantity values for the most important components and displays them in graph form.

⟶ Move the state diagram to a free space in the circuit drawing and drag and drop the cylinder onto the diagram.

A dialog box opens where you can select the quantity values you are interested in. In this instance, only the position is of interest, so you can remove the check marks for the other values (velocity, acceleration).

⟶ Start the simulation and observe the diagram.

Figure 8/7: Circuit with state diagram for the cylinder

⤏ Set the simulation to " Pause " and move the mouse pointer onto the curve on the diagram.

If the mouse pointer rests on the diagram for a second, a box appears showing the exact values for time and the relevant quantity value. If you move the mouse along the curve, the display alters accordingly, updating the values as the mouse pointer moves.
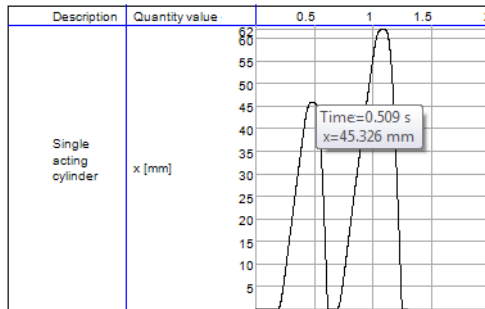
Figure 8/8: Display of the exact values in the state diagram

You can use multiple state diagrams in one window, and can also display multiple components in the same diagram. You can add a component to a state diagram by dragging it onto the diagram. A dialog will open, where you can select the quantity values to be logged and can assign different colors to them. Dragging onto the diagram again opens the dialog box again, allowing you to change your selection. If no quantity value is assigned to a component, it is not displayed in the diagram.

This concludes the example. Further editing and simulation concepts are described in the next section.

8.3.2 Example with a hydraulic circuit

⇢ Create the circuit shown in the figure.
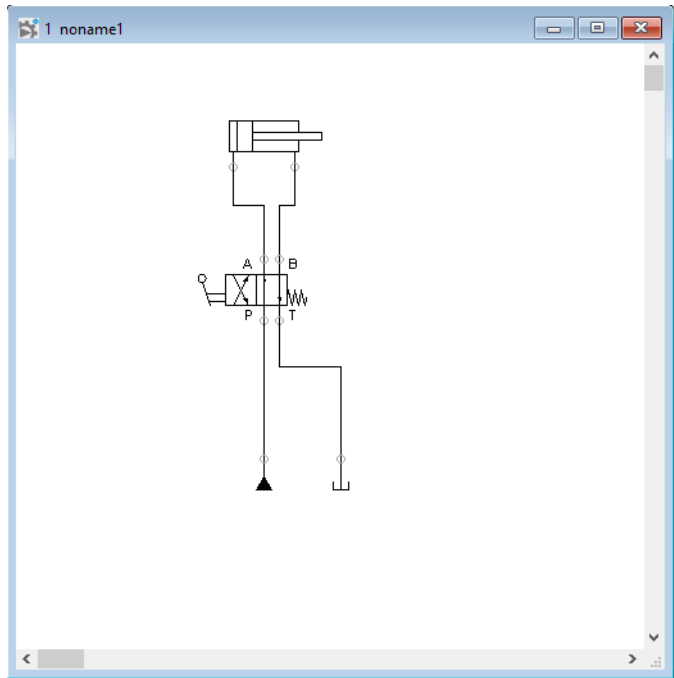
Figure 8/9: Simple hydraulic circuit

To define the valve's actuation type, double click the valve. valve's property dialog opens.

⤑ Go to the "*Configure Valve*" tab. Then, in the top drop-down list on the left side, select a manual actuation and the valve bodies "Crosswise" and "Parallel". Then on the right side, click the "*Spring-returned*" field.

If required, you can also set the hydraulic resistance of the valve.

Close the dialog box with OK .

The valve should now look like this:
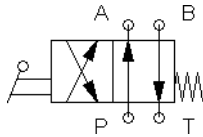
Figure 8/10: Manually operated 4/2-way valve

Now try to simulate this circuit.

⤑ Start the simulation with ▶ (or with Execute Start or with F9).

Then all pressures and flow rates are calculated, the lines are colored, and the cylinder advances:
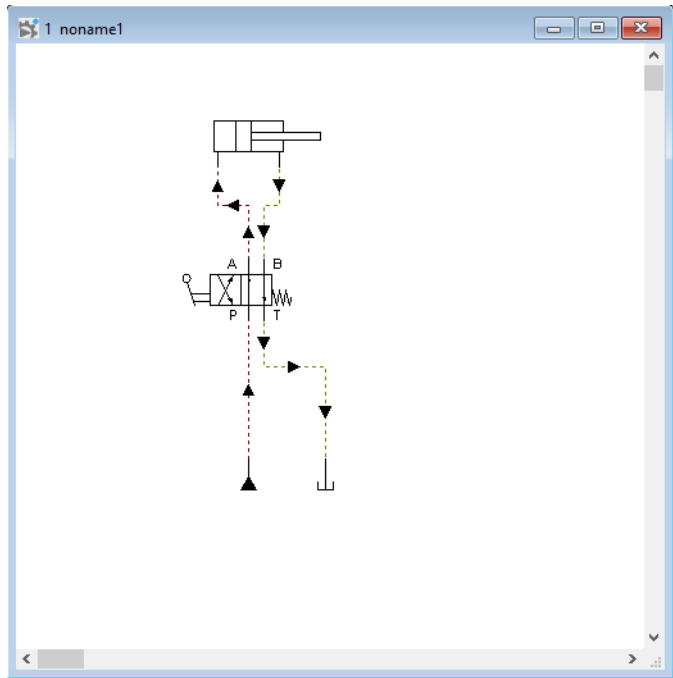
Figure 8/11: Simulated circuit

Once the cylinder has advanced, the pressure in the cylinder supply line should increase. This situation is detected by FluidSIM and the parameters are recalculated; the pressure on the pump side increases to the value predefined by the limit protection in the pump unit.

To limit the pressure to a lower value, you have to safeguard the pump unit with a pressure relief valve.

---> Activate Edit Mode with ■ (or with Execute Stop or with F5).

⋯⋯> Drag a pressure relief valve and a second tank onto the drawing area.

⋯⋯> If necessary, drag the line segments until the drawing is arranged clearly.

The circuit should now look something like this:
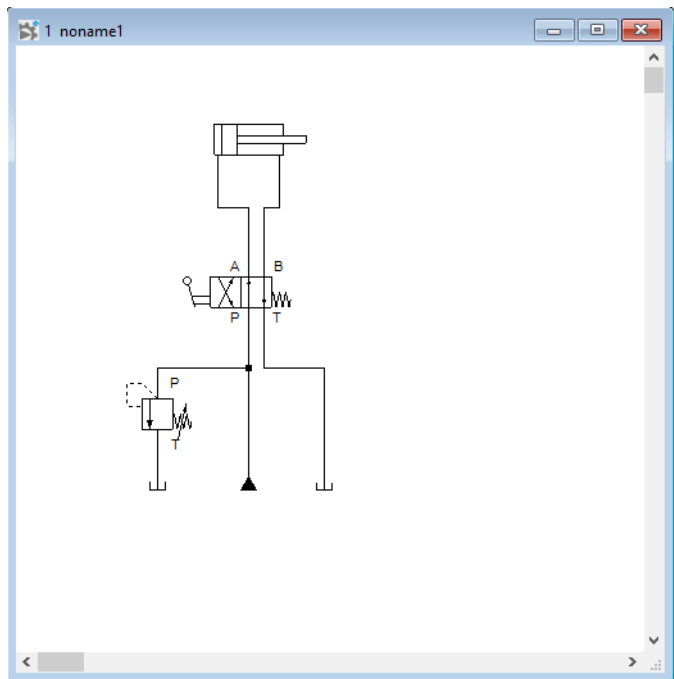
Figure 8/12: Circuit with pressure relief valve

⋯⋯> Save this circuit with 🖫 (or with File Save File). FluidSIM automatically opens the file selection box if the file did not already exist; you can enter a file name here.

⋯⋯> Start the simulation with ▶.

The cylinder advances. Once it reaches its stop, a new situation is created. This situation is detected by FluidSIM and the parameters are recalculated; the pressure relief valve opens, and the resulting distribution of pressure is shown:
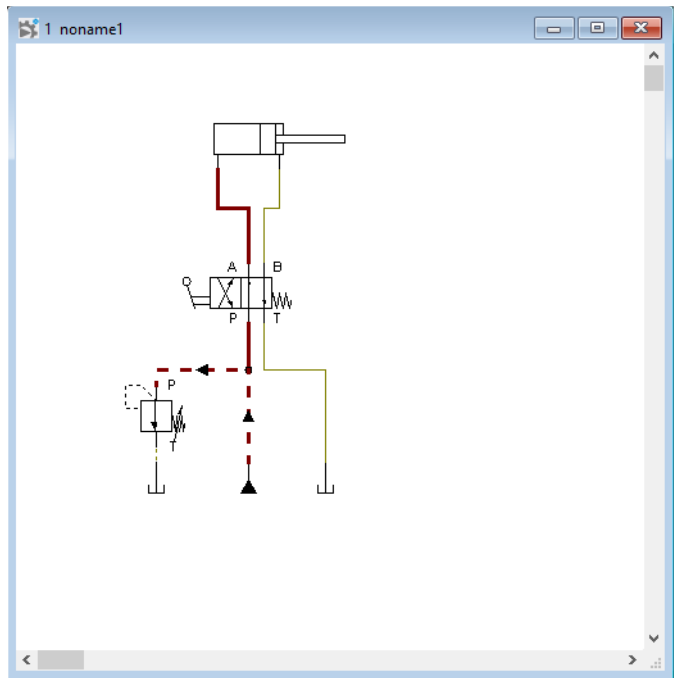
Figure 8/13: Circuit with open pressure relief valve

FluidSIM not only animates the switching of manually actuated components, but nearly all components which have multiple states.

The following figure shows a pressure relief valve in closed position and in open position:
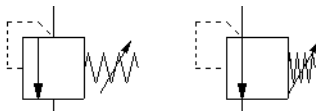
Figure 8/14: Closed and open pressure relief valve

Remember that manually operated valves and switches can be switched during Simulation Mode by clicking them with the mouse:

···⟩ Move the mouse pointer onto the left-hand side of the directional control valve.

The mouse pointer changes into a hand with pointing finger 🖑 indicating that the valve can be switched over.

···⟩ Click the left-hand side of the valve and hold down the mouse button.

When you click a valve with the mouse, the real behavior of the valve is simulated. In our example, the clicked valve is switched over and recalculation begins automatically. As a result, the pressure relief valve closes and the cylinder retracts. As soon as the cylinder reaches its left-hand stop, the pressure relief valve opens again.

! When non-detenting components are clicked, they remain actuated as long as the mouse button is held down.

···⟩ Stop the simulation and switch to Edit Mode. Select the state diagram from the component library and move it into the circuit window.

The state diagram records the quantity values for the most important components and displays them in graph form.

···⟩ Move the state diagram to a free space in the circuit drawing and drag and drop the cylinder onto the diagram.

A dialog box opens where you can select the quantity values you are interested in. In this instance, only the position is of interest, so

you can remove the check marks for the other values (velocity, acceleration).

⟶ Start the simulation and observe the diagram.

Figure 8/15: Circuit with state diagram for the cylinder

⟶ Set the simulation to " Pause " and move the mouse pointer onto the curve on the diagram.

If the mouse pointer rests on the diagram for a second, a box appears showing the exact values for time and the relevant quantity value. If you move the mouse along the curve, the display alters accordingly, updating the values as the mouse pointer moves.
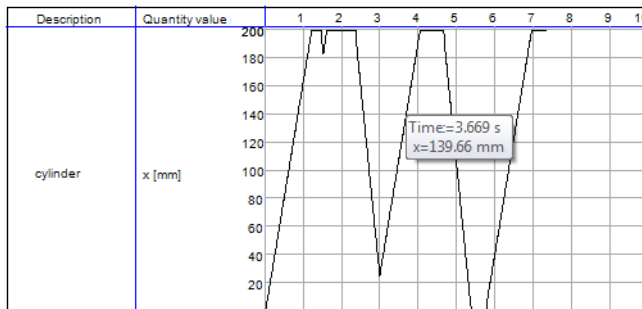
Figure 8/16: Display of the exact values in the state diagram

You can use multiple state diagrams in one window, and can also display multiple components in the same diagram. You can add a component to a state diagram by dragging it onto the diagram. A dialog will open, where you can select the quantity values to be logged and can assign different colors to them. Dragging onto the diagram again opens the dialog box again, allowing you to change your selection. If no quantity value is assigned to a component, it is not displayed in the diagram.

This concludes the example. Further editing and simulation concepts are described in the next section.

8.3.3 Example with an electronic circuit

⤏ Create the circuit shown in the figure.
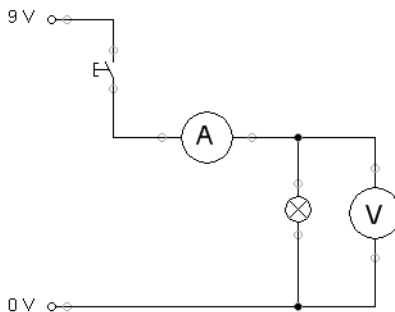
Figure 8/17: Simple electronic circuit

Now try to simulate this circuit.

⋯⋯→ Start the simulation with ▶ (or with Execute   Start or with
      F9).

Then all voltages and currents are calculated, and the potential
from the positive terminal of the electrical power source to the
pushbutton is colored.

⋯⋯→ Click the pushbutton and hold down the mouse button.

The current now flows through the pushbutton to the ground via
the ammeter and the light:
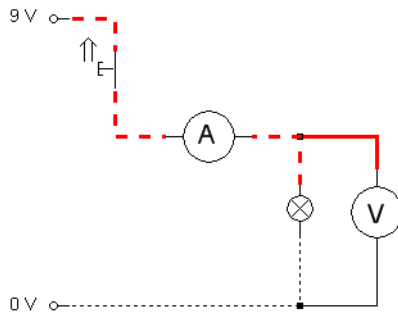
Figure 8/18: Simulated circuit

The values for current and voltage can be read on the measuring devices. So far, the circuit is a purely electric circuit, strictly speaking. Now let's add an electronic component: the diode.

⸺⟩ Stop the simulation and switch to Edit Mode. Modify the circuit as shown in the figure and start the simulation.

Ensure that the diode is installed as shown. When you actuate the pushbutton, you will see that the potential only reaches as far as the diode:
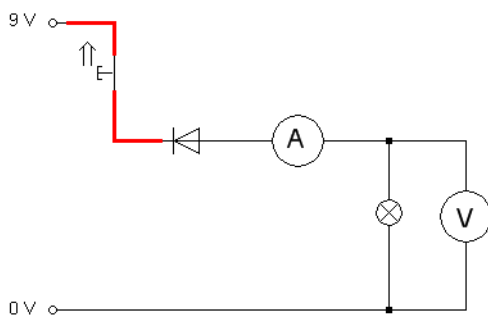
Figure 8/19: Diode installed in reverse direction

⤑   Remove the diode and install it the other way around.

In this case rotating or mirroring the diode is not enough because while that would turn the component around, it would not change the line connections. That means that the lines would run through the component and the drawing would look correct.

FluidSIM detects drawing errors of this kind, highlights the critical sections, and issues a warning:
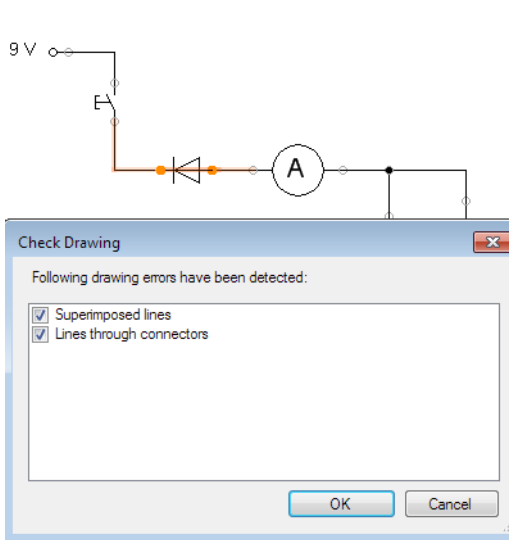
Figure 8/20: Warning of error in line layout

Once the diode is installed correctly, the current will flow through the diode and the light will light up:
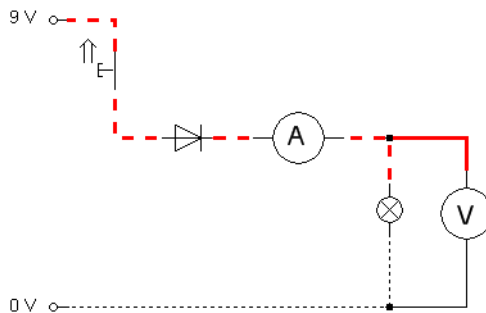
Figure 8/21: Diode installed in forward direction

In practice it is important in electronics to pay attention to the exact
currents and voltages. Electronic components are very sensitive
and can be destroyed quickly if subjected to excessive loads.

Next, the pushbutton will be replaced by a potentiometer.

⟶ Stop the simulation and switch to Edit Mode. Modify the circuit
   as shown.
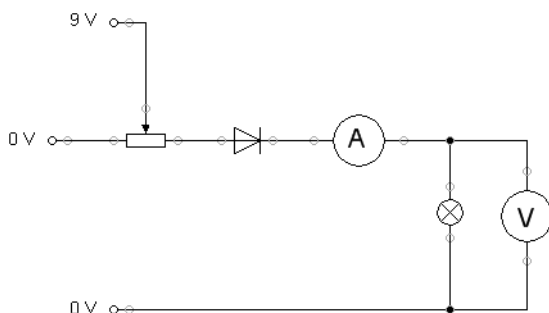
Figure 8/22: Simple circuit with a potentiometer

The potentiometer allows the resistance to be modified using a rotating or sliding controller. In FluidSIM you can click the potentiometer during the simulation and modify the resistance value as with a real potentiometer.

⤳ Start the simulation and display the amperages using View Quantity Values... . Alternatively, you can also press the I key repeatedly. Now click the potentiometer and watch how the current flow changes.

⤳ Stop the simulation and switch to Edit Mode. Select the state diagram from the component library and move it into the circuit window.

The state diagram records the quantity values for the most important components and displays them in graph form.

⤳ Move the state diagram to a free space in the circuit drawing and drag and drop the ammeter onto the diagram.

A dialog box opens where you can select the quantity values you are interested in. In this instance, only the amperage is of interest.

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⤳ Start the simulation, vary the resistance value of the potenti-
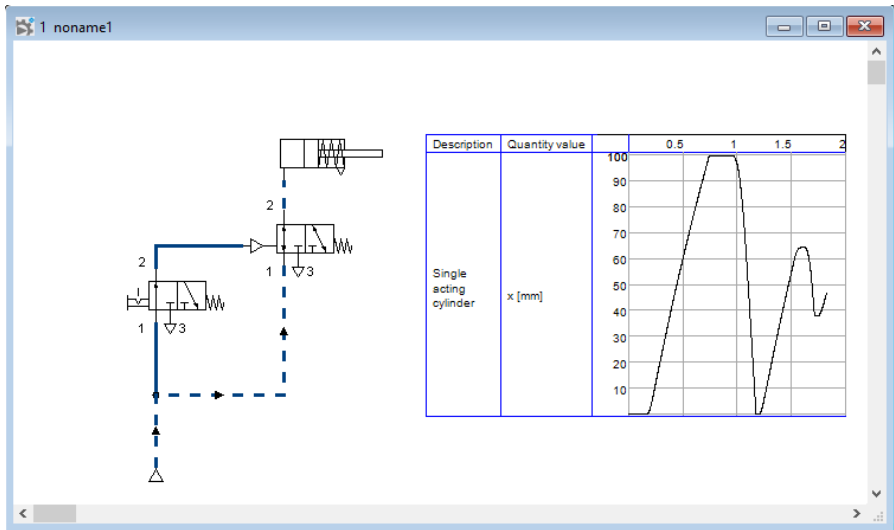ometer, and observe the diagram.
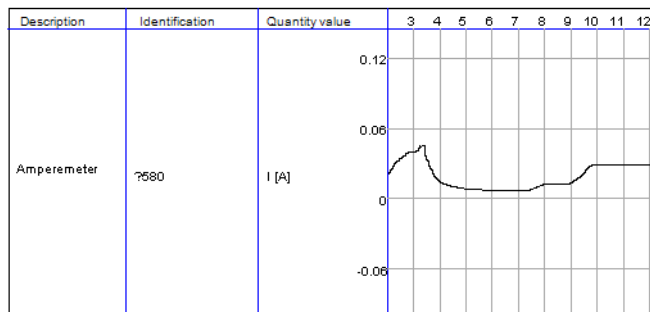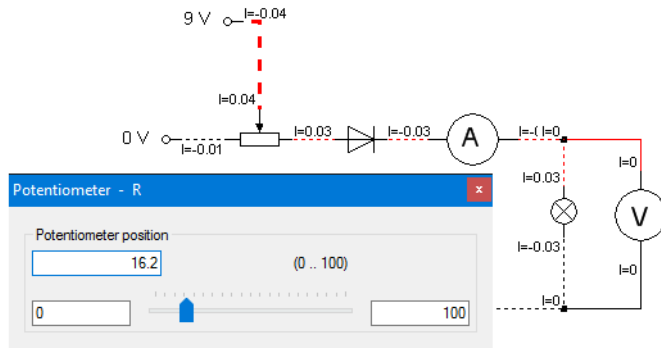
Figure 8/23: Circuit with state diagram for the ammeter

⤳ Set the simulation to " Pause " and move the mouse pointer
onto the curve on the diagram.

If you move the mouse along the curve, the display alters accord-
ingly, updating the values as the mouse pointer moves. If you move

the mouse along the curve, the display alters accordingly, updating the values as the mouse pointer moves.

| Description	Identification	Quantity value	8 9 10 11 12 13 14 15 16 17
Amperemeter	?580	I [A]	

Time=10.805 s
I=0.035 A
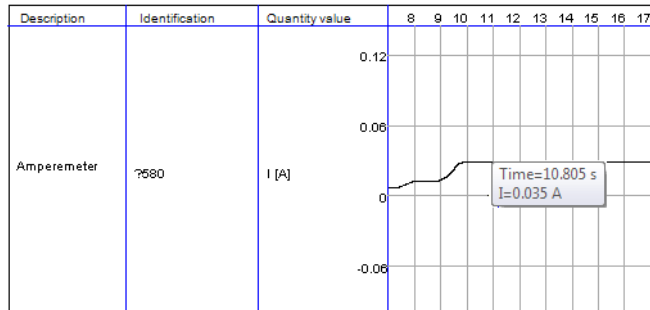
Figure 8/24: Display of the exact values in the state diagram

You can use multiple state diagrams in one window, and can also display multiple components in the same diagram. You can add a component to a state diagram by dragging it onto the diagram. A dialog will open, where you can select the quantity values to be logged and can assign different colors to them. Dragging onto the diagram again opens the dialog box again, allowing you to change your selection. If no quantity value is assigned to a component, it is not displayed in the diagram.

This concludes the example. Further editing and simulation concepts are described in the next section.

Advanced concepts in simulating and creating circuits

Chapter 9

This section describes advanced concepts and functions for simulation and circuit creation in FluidSIM.

9.1 Adjusting the component parameters

Most of the symbols in FluidSIM's component library are basic symbols representing various different versions of a component. You can use the properties dialog box to customize the component's parameters, size, characteristic curves etc..
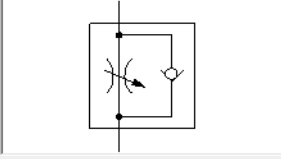
In Expert Mode there are sometimes many more parameters available, depending on the component. These allow you to modify, for example, spring forces, friction, or effective area. These parameters are hidden in the standard mode. To avoid having to switch Expert Mode on and off continuously, you can use the "*Show all settings*" option to temporarily display all parameters or to hide the advanced settings.

⤏ Drag a one-way flow control valve (throttle check valve) onto the drawing area and open the properties dialog box by double clicking.

You can access the adjustable parameters on the "*Component Parameters*" tab.

Figure 9/1: Adjustable parameters of the one-way flow control valve

Show designation	Shows the designations of the parameters displayed using the *Display* option.
Show variable	Shows the variables of the parameters displayed using the *Display* option.
Show Unit	Shows the units of measurement of the parameters displayed using the *Display* option.

Display   Check this box if you want that parameter to be displayed in the circuit.

Variable   Clicking this button takes you to a dialog box with assignment options for accessing the parameter in GRAFCETs or for controlling it with a game controller.

⇢ In the *Opening level* row, click the button for variable assignment.

Figure 9/2: Variable and controller assignment of a parameter

Predefined variable

This is the standard, complete variable name. It is made up of the identification entered by you and the internal parameter name. You can use this variable name to access the parameter in GRAFCETs in order to query it or modify its value.

User-defined alias

If you do not like the predefined variable name, you can enter your own name for it here. Note that this alias has to be unique across the entire page or project. FluidSIM issues a warning if an alias name is entered twice.

Controller assignment	As described in the "Adjusting component parameters during the simulation" section, many component parameters can be altered with the mouse during the simulation. FluidSIM also offers the option of controlling parameters via connected game controllers (e.g. Microsoft Xbox controller). This is especially practical when you need to modify several parameters at the same time during a simulation.
Axis	Here you can define which axis you want to use to control the parameter during the simulation. To assign an axis, simply click in the field and briefly actuate the desired controller axis. FluidSIM then enters the desired axis.
Dead-zone	This value determines how much movement of the controller axis is required to trigger a signal. This prevents unintended modification of values from very small movements of the fingers.
Range	Sometimes you may wish to use the game controller to control only a certain range. This can be necessary above all because the control levers on most controllers spring back to their zero position automatically as soon as they are released. Using the mouse together with the straight line on the graph, you can interactively determine how the controller position relates to the parameter.

! Controller assignment is not available for the simulation variables calculated by FluidSIM (piston positions, velocities, pressures, flow rates, etc.) because these variables only permit read access. Similarly, these variables cannot be assigned in GRAFCETs. FluidSIM displays a warning if an attempt is made to modify a simulation variable.

Simulation variables therefore have only the option of variable assignment.
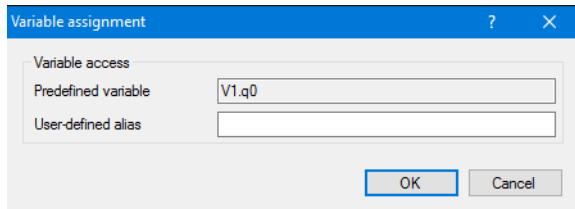
Figure 9/3: Variable assignment of a simulation parameter

9.2   Special settings for cylinders

To adapt a cylinder, drag a representative cylinder into the circuit and open the properties dialog box. It contains settings that you can use to determine the appearance and function of the component. See section "Configure cylinders" for the basic functions for configuring the cylinder properties.

9.2.1 Cylinder friction and cylinder mass

If the options "*Show all settings*" and "*Enter manually*" are selected, you can specify parameters defining a velocity-dependent characteristic curve and the mass moved by the cylinder. If you select "*Calculate automatically*", an heuristic is applied which calculates the settings on the basis of the cylinder dimensions.

Clicking an input field in the "*Cylinder friction*" section activates a "..." button that can be used to open a dialog box containing a graph displaying the cylinder friction as a function of the cylinder velocity.
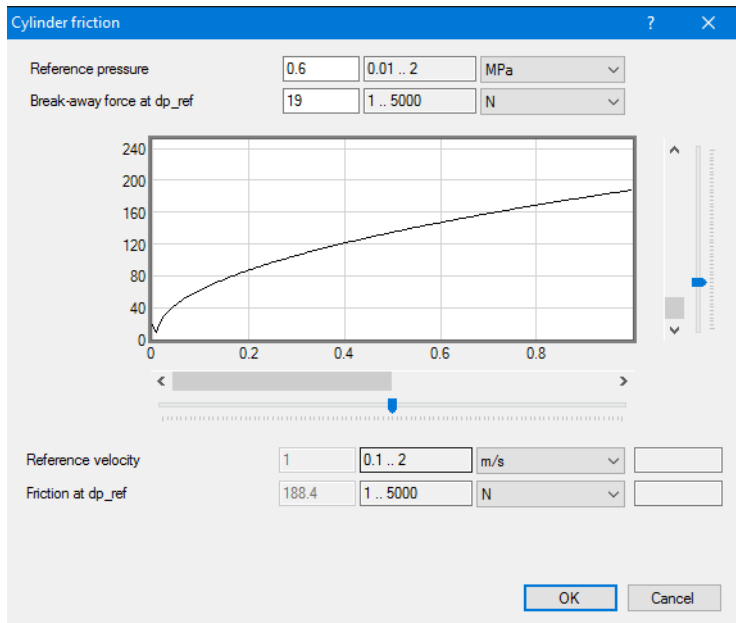
Figure 9/4: Friction curve of a pneumatic cylinder

9.2.2 External load and friction

Figure 9/5: External load on the cylinder

Moving mass

Enter here the mass of the load that you want the cylinder to move. The mass of the cylinder piston and piston rod is calculated automatically by FluidSIM from the entered cylinder dimensions, so the mass entered here refers only to the external load. In particular, an entry of "0" does not mean that the moving parts in the cylinder have no mass.

Friction

The static friction and sliding friction define the friction of the moving load on a surface. The internal friction in the cylinder is calculated automatically by FluidSIM from the entered cylinder

dimensions. If the load is lifted or pulled without coming into contact with a surface, enter "0" for both values. In practice it is very difficult to arrive at reliable values for friction. FluidSIM therefore offers set friction coefficients for some combinations of materials, to provide a rough guide. If you compare other tables of friction values, you will notice that the specifications (usually measured in experiments) vary greatly from table to table. You should therefore be cautious when interpreting the results of simulations influenced by friction. Nonetheless, varying the friction values does allow you to see clearly the physical effects of static and sliding friction. Note also that the mounting angle influences the friction force from the moved load. You can adjust the mounting angle on the "*Component Parameters*" tab.

9.2.3 Force profile
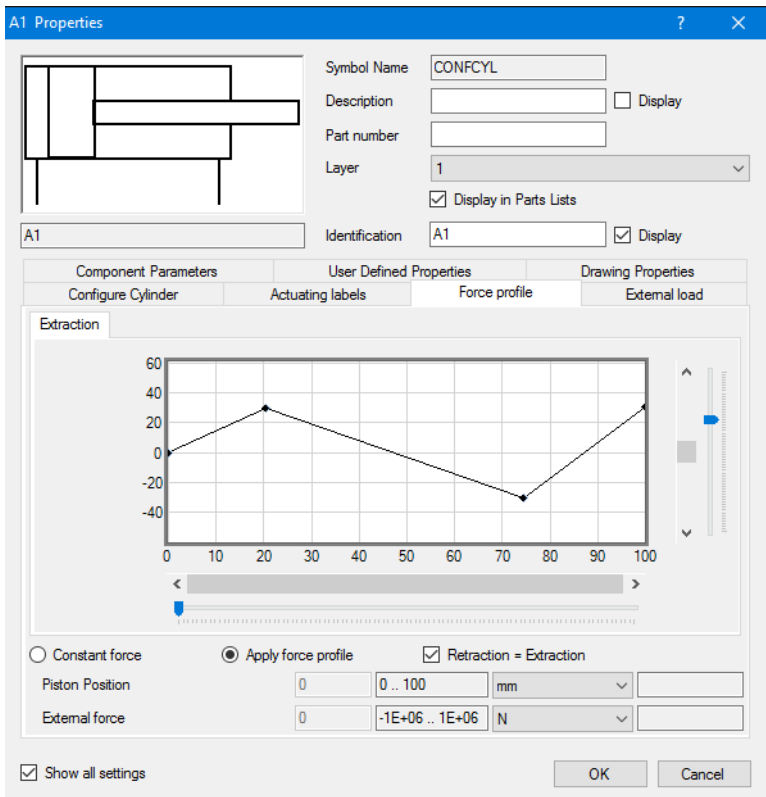
Figure 9/6: Force profile of the cylinder

Constant force

If you want a constant force to be applied over the entire range of cylinder movement, select this option and enter a force.

Apply force profile

Select this option if you want the force to change depending on the cylinder's position. By clicking the mouse in the graph field, you can interactively set reference points which will be interpolated to

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form a line. Alternatively, you can select an existing reference point and numerically enter the two values in the input fields for the piston position and the corresponding force.
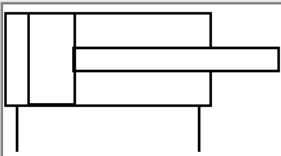
You can use the sliders to adjust the displayed value ranges for position and force. As the force on the y-axis covers an especially wide numerical range, it is advisable to start by restricting that interval so that the shape of the curve can be seen clearly.

Retraction = Extraction

Select this option if you want to apply the same force profile for advancing and retraction. Otherwise, remove the checkmark and enter separate force profiles on the tabs "*Extraction*" and "*Retraction*".

9.2.4 Actuating labels

Figure 9/7: Actuating labels on the cylinder

Here you can create new actuating labels or modify existing ones. This dialog box is identical to the one that opens when you double click an distance rule.

Displacement encoder	In addition to the actuating labels you can also enter a special label for a continuous displacement encoder or select from the list of counterparts already present in the project.

9.3 Special settings for directional control valves

To adapt a directional control valve, drag a representative cylinder into the circuit and open the properties dialog box. It contains settings that you can use to determine the appearance and function of the component. See section "Configure a way valve" for the basic functions for configuring the valve properties.

9.3.1 Hydraulic resistance

For hydraulic valves, you can adjust the hydraulic resistance. In practice the hydraulic resistance is often given by a curve or a pair of values (pressure drop/flow rate). In the field "*Hydraulic resistance*" you can either enter a specific value or alternatively click the "..." button. That takes you to a dialog box where you can define the parabola either by interactively clicking in the graph field or by entering a pair of values.
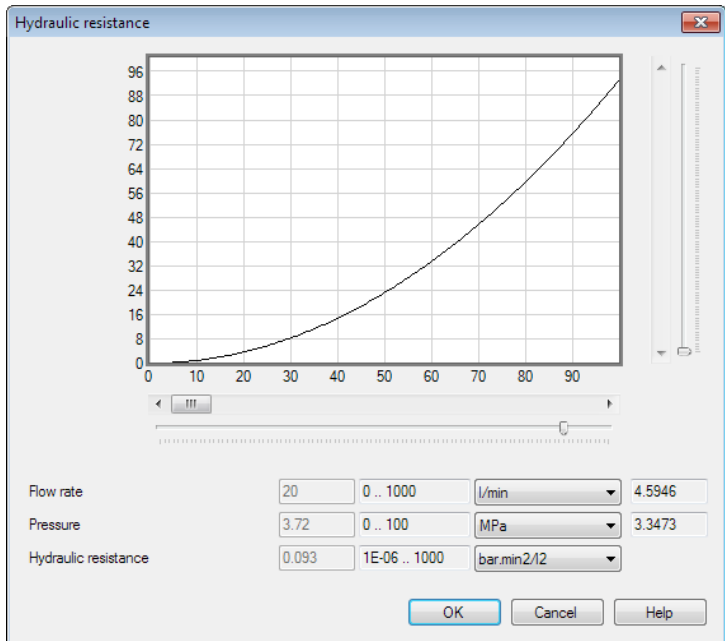
Figure 9/8: Hydraulic resistance curve

Starting in Version 5 of FluidSIM, it is possible to define fluid properties (e.g. density and viscosity) for a circuit or a project. For compatibility reasons an oil of type HLP 22 is used as a base for calculations when defining the hydraulic resistance. If another fluid is defined in "*Fluid type*", the hydraulic resistance is internally converted based on this medium.

9.4 Additional simulation functions

This section describes additional functions for the simulation of circuit diagrams.

9.4.1 Simultaneous actuation of several components

So that you can actuate multiple pushbuttons or spring-returned valves at the same time, you can put them in a permanently actuated state. You can permanently actuate a pushbutton (or valve with manual actuation) by clicking it with the mouse while pressing the Shift key. You can release this permanent actuation by clicking once on the component.

Sometimes it may be necessary for multiple actuated objects to be released at the same time. In that case, when clicking the object, hold down the Ctrl key instead of the Shift key. The switched components then remain in the actuated state until you release the Ctrl key again, at which time all the objects actuated in this way return to their initial position simultaneously.

For more complex switching operations or continuous adjustments, we recommend using a game controller. For more details, see "Adjusting the component parameters".

9.4.2 Simulation of individual pages and entire projects

In FluidSIM it is possible for multiple circuits to be open at the same time. Circuits whose pages belong to a project are simulated as an entire system. This is practical if, for example, you want to create the hydraulic or pneumatic part and the electrical part on separate pages. You can also divide large drawings across multiple pages and define the line connections using interruption points. When a circuit belonging to a project is simulated, all the other pages of the project switch into Simulation Mode as well when the simulation is started. While the simulation is running, it is therefore not possible to edit any pages belonging to the open project.

In contrast, if pages that do not belong to the project are edited or simulated, the editing or simulation always applies only to the

currently active circuit window. In such cases, it is therefore possible to simulate one circuit while editing another.

9.5   Displaying quantity values

The numerical values for all or some quantity values in a circuit can be displayed even without measuring devices.

⤏   In the | View | menu, click | Quantity Values... | to open the dialog box for the display of quantity values:

Figure 9/9: Dialog box for adjusting the quantity values display

Here you can define how every quantity value listed ("*Velocity*", "*Pressure*", etc.) will be displayed.

For the display of pressure values, flow rates, and forces, you can choose between different units of measurement. These settings take effect when quantity values are displayed at connectors and components and on state diagrams.

None   Do not display any values for this quantity value.

Individual   Display values only at connection points previously selected by the user.

All	Display all values for this quantity value.
Display measurement units	Activate this option if you also want the unit of measurement to be displayed for the quantity values.

> **!** You can use the key in the "*Shortcut*" column to switch between the display types " None ", " Individual " and " All " for that particular quantity value without having to open the dialog box.
>
> Proceed as follows to select connection points for the display of individual quantity values:
>
> ┄┄⟩ Open a circuit.
>
> ┄┄⟩ In Edit Mode, double click a component connector, or select the menu item Edit Properties... .
>
> The dialog box for the connector's settings then opens. In the "*Display quantity values*" field, you can choose which quantity values are to be displayed at that connector when the " Individual " option is activated for that parameter in the dialog box for quantity values display.

9.5.1 Display of direction of quantity values in FluidSIM

Vectorial quantity values are characterized by their quantity and their direction. In circuit diagrams, the direction is displayed at the component connectors by a mathematical sign ("+" = into a component, "−" = out of a component). If the amount of the quantity value is close to zero, the exact numerical value is not displayed. Instead, "› 0" is displayed for a small positive value and "‹ 0" for a small negative value.

In the case of fluidic flows, the direction is also indicated by an arrow in the middle of the line segment. The visual impression is reinforced by conveyor-belt-style animation of the lines.

9.5.2 Reference arrows

To indicate directions, such as the direction of current and voltage on measuring instruments, so-called "reference arrows" can be shown or hidden using the menu option [View] [Show Reference Arrow]. In electrical engineering, the reference arrows always refer to the technical direction of current.

The arrows indicate the direction from the higher potential to the lower. If a negative value is displayed on a measuring instrument, the direction of current is the opposite of the arrow.

Figure 9/10: Reference arrows for a voltmeter and an ammeter

9.6   Virtual measuring instruments

Measuring instruments can be installed in the circuit diagram as symbols, displaying the corresponding values during the simulation. Just as in reality, the measuring instruments in FluidSIM have physical characteristics that affect the variables being measured. For example, an ammeter has an electrical resistance. The value measured is therefore not exactly the same as the value that would exist without the measuring instrument installed. In FluidSIM, the position of the measuring instruments cannot be modified during the simulation.

Virtual measuring instruments, on the other hand, can be installed and moved both in Edit Mode and in Simulation Mode. They do not have a physical model of their own, but instead directly utilize the simulation values calculated at the connectors of the symbols. As a consequence, unlike a real measuring instrument, they do not influence the variable being measured.

Virtual measuring instruments can be inserted into the circuit diagram via the menu option Diagnosis . Alternatively, you can use the corresponding symbol in the diagnosis toolbar. To simplify their use, virtual measuring instruments for the most important measured variables (voltage, current, pressure, and flow rate) are provided in both the menu and the toolbar.

9.6.1 Inserting virtual measuring instruments

⤑ Use the menu Diagnosis or the diagnosis toolbar to select a virtual measuring instrument and position it by left-clicking on a free location in the circuit diagram.
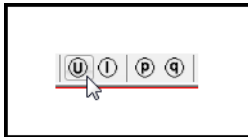
Figure 9/11:
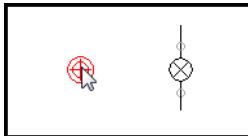
Figure 9/12:

You then automatically enter a mode in which you can move the measuring tip.
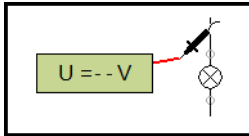
Figure 9/13:

When the mouse pointer is moved over a valid measuring position (connector or line), it switches to a crosshair. If the measuring tip is dropped onto a line, it will lock onto the nearest connector.
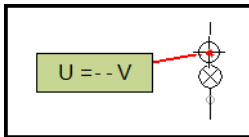
Figure 9/14:

Clicking again drops the measuring tip there and you can then drop the second measuring tip for the voltage measurement.
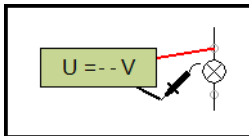
Figure 9/15:

The measuring cables are displayed and the measurement can be carried out during the simulation.
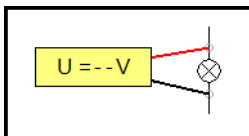
Figure 9/16:

Press the ESC key to cancel the placement of the measuring tips.

A positive value is displayed if the potential (or pressure) is higher at the red measuring tip than at the black measuring tip, or if the flow direction is from the red measuring tip to the black one.

9.6.2 Deleting virtual measuring instruments

In Edit Mode, you can delete virtual measuring instruments by selecting them and then pressing the Del key, or via the menu Edit Delete , or by right-clicking to access the context menu.

In Simulation Mode, you cannot select symbols by clicking them with the mouse. Deletion is then only possible via the context menu.

9.6.3 Measurements of currents and flow rates

In FluidSIM, currents and flow rates are calculated in the connectors of the symbols. Consequently only one measuring tip is required when measuring currents and flow rates. Nevertheless, two measuring cables are displayed, as would be used in reality.
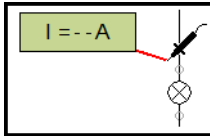
Figure 9/17: You drop only one measuring tip
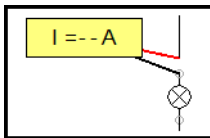
Figure 9/18: Display of two measuring cables

9.6.4 Properties dialog window

At any time, you can use the Properties dialog window of the virtual measuring instrument to modify the choice of measured variable and the position of measuring tips. Each specific virtual measuring instrument corresponds to a universal measuring instrument for which the measured variable is selected in advance.

The Properties dialog window is adapted dynamically according to the measuring mode selected. The number of measuring tips required depends on the measured variable. For example, only one measuring tip is required for a pressure measurement, but two for a voltage measurement.
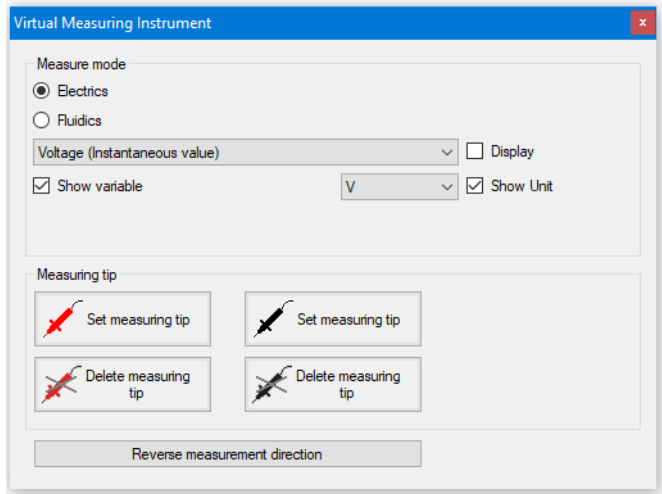
Figure 9/19:

Electrics	Restricts the measured variables available for selection accordingly.
Fluidics	Restricts the measured variables available for selection accordingly.
Display	Displays the description of the variable measured in the virtual measuring instrument.
Show variable	Displays a symbol in the virtual measuring instrument that corresponds to the measured variable selected, e.g. "U" for voltage.
Show Unit	Displays the unit of the selected measured variable in the virtual measuring instrument.
Set measuring tip	By pressing this button you can set the corresponding measuring tip again. Which measuring tips are available depends on the measured variable selected.
Delete measuring tip	

Pressing this button deletes the corresponding measuring tip. Which measuring tips are available depends on the measured variable selected.

Reverse measurement direction

The measurement direction depends on the order in which the measuring tips were set. In the case of measured variables that require only one measuring tip in FluidSIM (such as current), the measurement direction selected automatically may not be the direction desired. You can use this button to swap the measuring cables afterward, thus reversing the measurement direction.

9.6.5 Setting measuring tips again and deleting them

In both Edit Mode and Simulation Mode, you can use the Properties dialog window to set the measuring tips of virtual measuring instruments again or move them. In Edit Mode, you can open the dialog window by double-clicking or via the menu Edit Properties... .

In the Simulation Mode, a single click will open the dialog window, and you can also move the measuring tips directly by drag and drop, without going through the dialog window.

9.7   Displaying state diagrams

The state diagram records the quantity values for the most important components and displays them in graph form. Quantity values or output variables all those values calculated by FluidSIM during the simulation or set by the user, such as: position, velocity, acceleration, force, switching position, pressure, flow rate, opening level, revolutions/rpm, voltage, current, digital state, etc.

You can use multiple state diagrams in one window, and can also display multiple components in the same diagram. You can add a component to a state diagram by dragging it onto the diagram. A

selection dialog box will open, where you can select the quantity values to be logged and can assign different colors to them. Dragging onto the diagram again opens the dialog box again, allowing you to change your selection.

⤑ In Edit Mode, double click a state diagram, or select the menu item Edit Properties... .

The following dialog box will open:
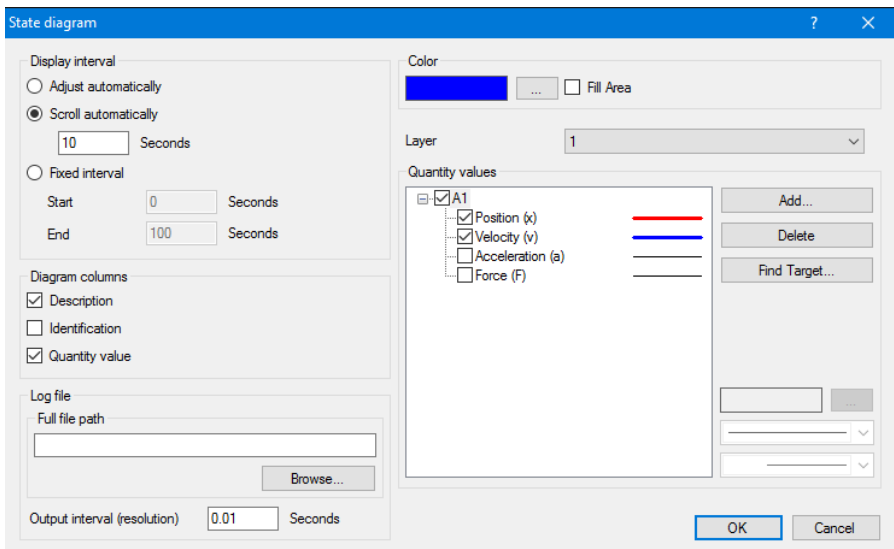
Figure 9/20: Dialog box for the state diagram

Display interval

Here you can enter the start and end times of the interval during which you want the quantity values to be logged. You do not necessarily need to know before starting the simulation the times at which the important events will occur; you can always change the display interval as desired after the simulation because FluidSIM always logs all values internally for the entire simulation period. If you select the "*Adjust automatically*" field, the entered limits are ignored and the time axis is scaled so that the entire simulation time is displayed. Activate the "*Scroll automatically*" field if you

	want the diagram to display the last n seconds. In this case, the time axis will be displaced toward the left-hand side once the simulation period exceeds the defined time window. In the input field, you can specify the number of seconds to be displayed in the time window.
Diagram columns	Here you can select which columns you want to be displayed at the left-hand side of the diagram. You can choose the columns "*Description*", "*Identification*", and "*Quantity value*" in any combination.
Log file	If you wish, FluidSIM can create a log file of the quantity values. Activate this option by entering the full path for the file in the input field and select a suitable time increment. Please note that entering very small increments may result in a very large volume of data. You may need to reduce the simulation time or increase the time increment.
Color	Defines the color of the diagram.
Fill Area	Defines whether the entire area is filled with the chosen color or just the border of the diagram.
Layer	In this drop-down list, you define the Layer of the diagram. You can set the Layer by clicking the downward-pointing arrow to the right of the list and selecting a layer. Depending on the setting for drawing layers, the diagram might not be displayed or might not be able to be edited. In order to see the object or change its settings, you have to temporarily activate the drawing layers with menu item View Drawing Layers... .
Quantity values	This list contains all the quantity values displayed in the diagram. Every component is listed together with its identification, and all its output variables are listed below it. Every variable can be selected and deselected with a checkmark. Once you have marked a variable, you can use the buttons at lower right to define the color, line style, and line thickness for it. You can use Add to select the components you want. Delete deletes the marked component together with its quantity values, and Find Target... takes you to the relevant component in the circuit.

9.8 Coupling hydraulics, pneumatics, electrics and mechanics

All three available technology versions, FluidSIM-P, FluidSIM-H and FluidSIM-E, allow you to create basic electrical circuits. In the pneumatics and hydraulics versions, they are used primarily to control the fluidic components. Because these simple electrical components are simulated completely with full physical accuracy, just as much as the electronic components are, they can be used and interchanged across all FluidSIM versions and can be combined with the electronic components in FluidSIM-E.

The following figure shows a small example:
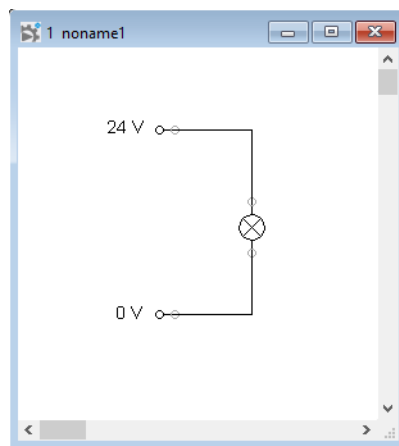
Figure 9/21: Simple electrical circuit

⋯⋯⟩ Create this circuit on your computer.

⋯⋯⟩ Start the simulation and observe that the indicator light lights up.

There are electrical components that link electrical circuits with pneumatic or hydraulic circuits. These include switches that are

operated pneumatically or hydraulically, and solenoids for the control of valves.

As the electrical circuit is drawn separately from the fluidic circuit, you need a way of creating a definite link between electrical components (e.g. a valve solenoid) and fluidic components (e.g. a certain valve position). One way of doing this is with so-called *labels*.

A label has a specific name and can be assigned to a component. If two components have labels with the same name, they are connected even if there is no visible line drawn between them.

You can enter the name for a label in a dialog box which you open either by double clicking the component or by selecting the component and clicking Edit Properties... . With electrically operated valves (solenoid actuated), the labels are entered on the left and the right by double clicking the appropriate "connector", as opposed to clicking in the middle of the component.

The following example illustrates how labels are used in FluidSIM.

⇝ Activate Edit Mode with ■ or with Execute Stop .

⇝ Expand the circuit as shown in the following figure:

Figure 9/22: Simple electro-pneumatic circuit

So that the valve can be controlled by the solenoid, these components need to be linked using labels.

⤑ Double click the valve solenoid or select the solenoid and click Edit Properties... .

The following dialog box appears:
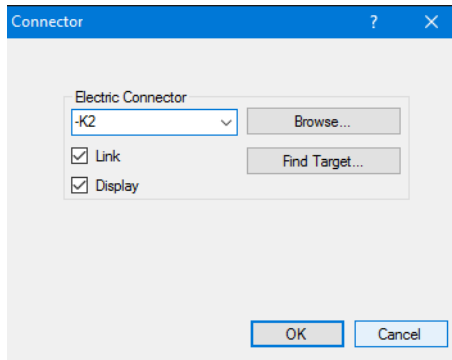
Figure 9/23: Dialog box for the valve solenoid

Identification

This text field is for entering a label name. A label name can be up to 32 characters long and can contain numerals and special characters as well as letters.

⋯⋯⟩ Enter a name (e.g. "Y1") for this label.

⋯⋯⟩ Double click the outside of the solenoid on the valve to open the dialog box for the label name.

⋯⋯⟩ Enter the same label name there as for the solenoid ("Y1").

The solenoid is now connected to the valve.

In reality, the valve solenoid would not be activated directly via the switch but via an intermediate relay. This is left out here for the sake of simplicity.

⋯⋯⟩ Start the simulation.

The electrical current and the pressure and flow distribution are calculated, and the resulting pressures are shown in color.

If you want to view the exact values for the quantity values, you can activate them in the dialog box accessible via View Quantity Values... . The activated quantity values are shown at the compo-

nent connection points. For more detailed information about this, see "Displaying quantity values".

⤑ Operate the electrical switch.

The valve then switches over and the cylinder advances:
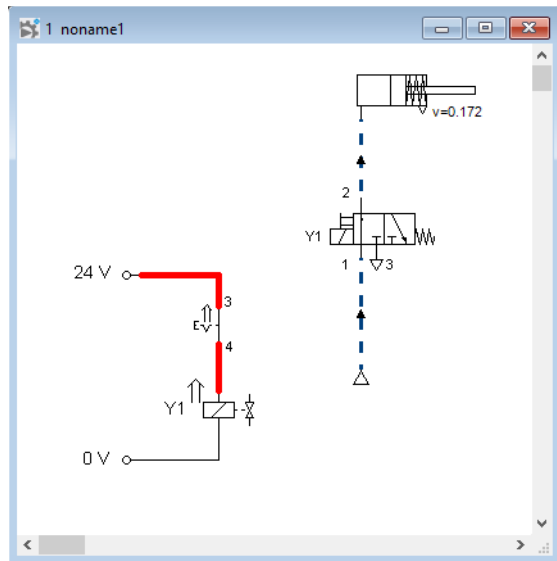
Figure 9/24: Simulation of the electro-pneumatic circuit

In addition to manual actuation or electrical control, some valves can also be switched over *mechanically* by the piston rod of a cylinder or by a permanent magnet on the piston. Mechanical linkages like this are created in the same way as those with electrical components: The connection is established by applying a label to the cylinder's distance rule and another to the mechanical "connector" on the valve.

⤑ Drag a configurable valve into a circuit window and specify a mechanical actuation (e.g. the stem).

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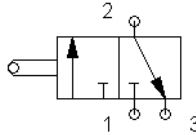
Figure 9/25: Valve with mechanical actuation

┄┄→ Double click the end of the stem.
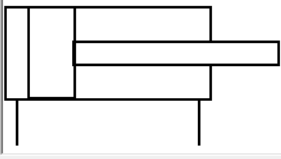
A dialog box will open in which you can enter a label. If you enter the same label on the cylinder's distance rule, the valve will be actuated mechanically when the cylinder's piston rod reaches the specified position.

A special instance of this type of linkage is the connection of a cylinder to a displacement encoder. You can use such connections to construct closed-loop control systems in combination with proportional valves, for example. Further information about proportional control systems can be found in section "Open-loop and closed-loop control by using continuous valves".

┄┄→ Double click a cylinder.

A dialog box will open in which you can adjust the cylinder's properties. Go to the "*Actuating labels*" tab.

Figure 9/26: Cylinder configuration dialog box

⤳ Enter a label under "*Displacement encoder*".

⤳ Add the displacement encoder from the component library to the circuit and double click to open the properties dialog box. Enter the same label there as you entered for the cylinder.
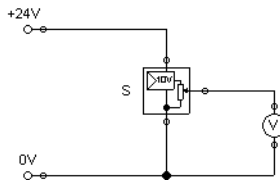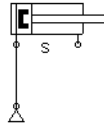
Figure 9/27: Linking the displacement encoder to the cylinder

The displacement encoder returns a voltage at its output which is proportional to the piston position of the linked cylinder. When the cylinder is fully retracted, this voltage will be the set minimum; when the cylinder is fully advanced, it will be set maximum.

9.8.1 Display styles for labels

As with component designations, it is often desirable to surround labels with a rectangular frame. You can select this in the basic settings for fluidic and electrical labels in the Options... menu. However, you can also set the frame for specific texts to be different from the standard frame. To do so, double click the specific text:
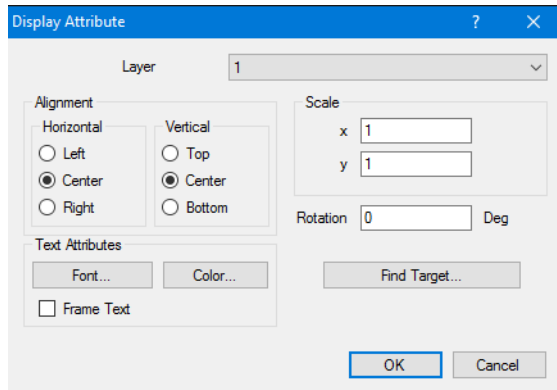
Figure 9/28: Dialog box for setting the text frame

Under *Text Attributes* you can set the option *Frame Text*.

FluidSIM automatically positions the labels so that they appear at an appropriate position near the component or connector. However, you can also move the labels using the mouse or the keyboard. To do so, click the label and drag it to the desired position. To modify the position with the keyboard, select the label (or the associated connector) and move the label using the cursor keys.

If you have inadvertently moved a label text so far that you cannot tell which component it belongs to, you can double click the label to open the properties dialog box and then activate the associated component with Find Target... .

9.9 Operating switches

This section describes how switches can be actuated by cylinders, relays, pressure, or by other switches.

9.9.1 Switches at cylinders

Limit switches, proximity switches, and mechanically actuated valves can be activated by the piston of the cylinder. To make this possible, first you have to place a distance rule on the cylinder so that the switches can be positioned.

⸺⧐ Drag the cylinder onto the drawing area and open its properties by double clicking. Go to the "*Actuating labels*" tab and enter a label along with the start and end positions.

When you close the dialog box, the distance rule will appear automatically *above* the cylinder. You can move or copy the distance rule from one cylinder to another. When the distance rule comes close to a cylinder, it slots automatically into the correct position.

The correct position for a distance rule depends on the cylinder type. Distance rules can be positioned over the cylinder housing, in front of the cylinder housing (next to the advanced piston rod) or in both positions at the same time:
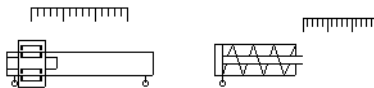
Figure 9/29: Examples of distance rule positions

To modify the labels or positions or to add more, you can either open the properties for the associated cylinder or enter these details directly on the distance rule.

⸺⧐ Double click the distance rule.

The following dialog box appears:

Figure 9/30: Dialog box for the distance rule

Label

The text fields in the left-hand column are used to enter the label names of proximity switches or limit switches in the electrical circuit that you want the cylinder piston to actuate.

Position

The text fields in the right-hand columns define the exact start and end positions of the switches on the cylinder.

⟶ Enter "Y1" as the label in the first row and enter 35 for both the start and end positions, and close the dialog box by clicking "OK".

A dash with the label name will appear immediately at the corresponding position under the distance rule:
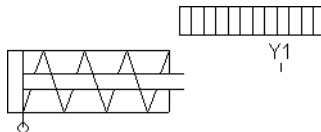
Figure 9/31: Cylinder with distance rule

This means that this cylinder will activate the switch or valve labeled "Y1" once its piston has moved 35 mm, assuming that the same label was entered on the switch in the electrical part of the circuit or on the mechanical "connector" of the valve.

Once the cylinder in the above example passes the 35 mm position, the switch will drop out again. If you want the actuation to be maintained over a longer distance, enter the start and end positions accordingly in the dialog box.

To place labels on electrical switches, double click the component. Valves with mechanical actuation have a special connector for this purpose, which may be on the end of the stem or in the center of the roller, for example. If there is already a label on the component or connector, you can also double click the label directly and then click Find Target... to open the corresponding dialog box for editing the label.

9.9.2 Relays

A relay or solenoid can be used to actuate multiple switches or contacts simultaneously. It is of course necessary to link the relay to the relevant switches. Therefore in FluidSIM, relays too have labels, which can be used to define an association with switches in the usual way. When you double click a relay, the dialog box for the label name will open.

The following figure shows an electrical circuit diagram in which a relay simultaneously actuates two break switches and two make switches:
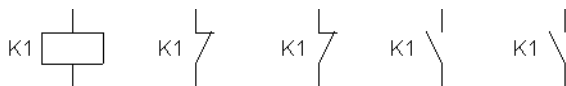
Figure 9/32: Relay with linked switches

In addition to the simple relay, there are also relays with switch-on delay, relays with switch-off delay, and counting relays. They ensure that the linked switches are not actuated until a defined time or number of pulses is reached. With these relays too, double clicking will open the corresponding dialog boxes for entering the values.

9.9.3 Coupling mechanical switches

The mechanical linkage of mechanical (manually operated) switches is accomplished in FluidSIM by assigning a label. If multiple mechanical switches have the same label, actuating one of them will cause all the identically labeled switches to be actuated with it.

9.9.4 Automatic switch altering

FluidSIM identifies delay switches, limit switches, and pressure switches by their method of installation and by their labels and automatically adds the corresponding symbol to the switch in the electrical circuit: ⌐ for switch-on delayed, ⌐ for off-delayed, ⌐ for mechanical actuated switches and ⌐ for pressure switches. In the case of switches actuated by the cylinder piston, you can choose how they are displayed in the properties dialog box for the closer, opener, and changeover:
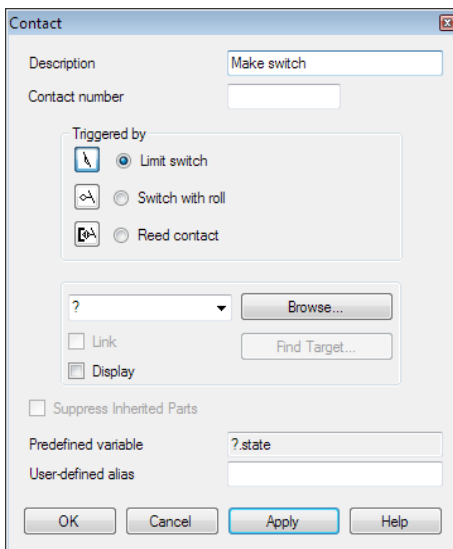
Figure 9/33: Dialog box for general electrical switches

This means that special symbols do not need to be used for these switches in FluidSIM. The simple switch symbols can be used instead:

Figure 9/34: Simple switch symbols

9.10 Adjusting component parameters during the simulation

Most components have parameters that can be adjusted in Edit Mode. Some of these components have already been discussed in earlier sections.

You can open the dialog box for adjusting the parameters by double clicking or with Edit   Properties... .

Several components can be adjusted during the simulation in the same way as they would be in reality. For example, the operating pressure of the compressed air supply, the delivery rate of the pump, the opening level of the throttle valve, or the resistance of the potentiometer can be altered continuously. To do this, you do not need to open the properties dialog box and then close it with OK ; all you need to do is click once on the component to open a window with sliders. Your changes take effect on the simulation immediately. As soon as you click another component or an empty space in the window, the dialog window with the sliders disappears automatically.

In Simulation Mode, when you move the mouse over a component that allows such real-time adjustments, the mouse pointer changes into the slider symbol .
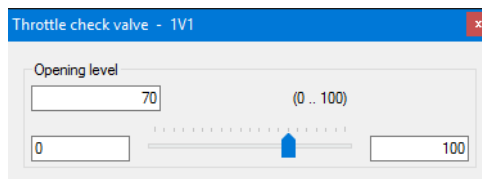
Figure 9/35: Adjusting the opening level during the simulation

For precision adjustment, some sliders allow you to select the control range. However, you can also enter the numeric value directly as a number in the input field.

Most parameters can also be controlled using a game controller. For details, see "Adjusting the component parameters".

9.11 Settings for simulation

In the $\boxed{\text{Options...}}$ menu, basic parameters and options for the simulation can be set under Simulation, Environment parameters, Fluid properties, and Sound.

Note that these settings are only used if no others are defined in the page or project properties. Newly created pages and projects are preset with the standard values set under $\boxed{\text{Options...}}$.

9.12 Use of the EasyPort-hardware

FluidSIM can directly address EasyPorts connected to the serial ports of the PC. No additional drivers or auxiliary programs are required. These days, however, serial ports are rare outside industrial environments. To use the EasyPort via a USB cable, you may require drivers that you will find on the installation DVD and which you can also download online from Festo Didactic SE.

The EasyPort hardware is linked to the components in FluidSIM via special electrical input/output components, which each have either eight digital inputs/outputs or two analog outputs/four analog inputs.

The EasyPort hardware can also be addressed using DDE and OPC communication. This allows you to control even remote EasyPort modules that are not connected locally (e.g. via a network connection). However, if the EasyPort modules are connected directly to the simulating PC, it is recommended to set up the direct connection.

⤑ Drag a digital input or output component from the component library into a circuit window and open the properties dialog box by double clicking or via the menu item $\boxed{\text{Edit}}$ $\boxed{\text{Properties...}}$.

The following dialog box will open:
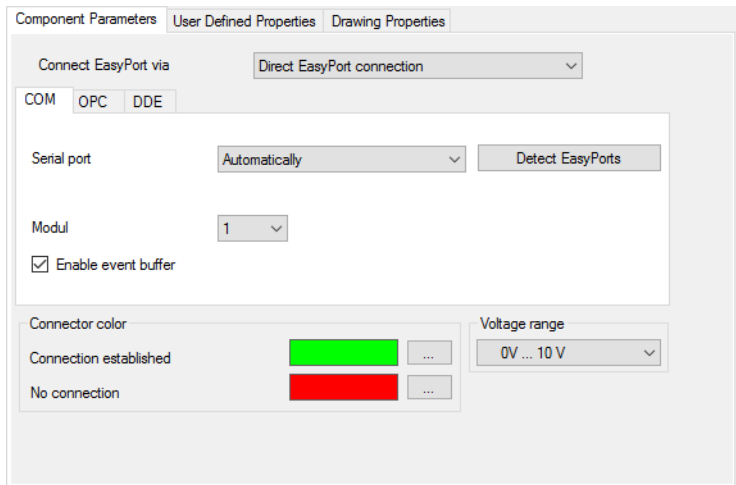
Figure 9/36: Dialog box for the EasyPort components

Direct EasyPort connection

Here you can set the serial port by which the hardware is connected to the PC, which EasyPort module and port number is assigned to the input/output component. If you do not know the exact number of the serial port, leave the setting as "*Automatically*". FluidSIM then searches all COM ports for connected EasyPorts.

Older EasyPorts are fitted as standard with only a serial port, of the kind used for many years on PCs and also in industrial applications. Modern PCs and especially portable computers, however, increasingly do not feature this connection. Nonetheless the serial port interface can be retrofitted easily using an inexpensive USB-to-serial converter, allowing the EasyPort to be connected and operated anyway. The converter's software does this by setting up a virtual COM port, which is assigned a number higher than the physically existing ports (usually COM 5). The hardware can be addressed in the usual way via this virtual port.

Connector color

Defines the color of the connection indicators for the input/output component when the EasyPort connection is active and when the connection is not present or is disrupted.

Voltage range

With the analog interface components, you can select the voltage range. This can be either from 0V to 10V or from -10V to 10V.

!

If FluidSIM does not find any EasyPort hardware at the start of the simulation, a corresponding warning is issued. You can start the simulation anyway, but if you do so FluidSIM will not make any further attempts to find EasyPorts until the simulation is closed and restarted. If, on the other hand, the connection is terminated while the simulation is running (e.g. by inadvertently pulling out the connecting cable), the simulation will continue to run without the EasyPort link, but FluidSIM will attempt to restore the connection. As soon as the hardware is once again available at the set port, the connection is restored and the simulation continues with EasyPort communication.

9.13 OPC and DDE communication with other applications

FluidSIM is capable of exchanging data with other applications, allowing it to work together with a PLC, for example. A prerequisite for this link is that the other application has an "OPC interface" or a "DDE interface". The link is established using the same interface components as for the use of FluidSIM with the EasyPort.

⤳ Drag an input or output component from the component library into a circuit window and open the properties dialog box by double clicking or via the menu item Edit Properties... .

The following dialog box will open:
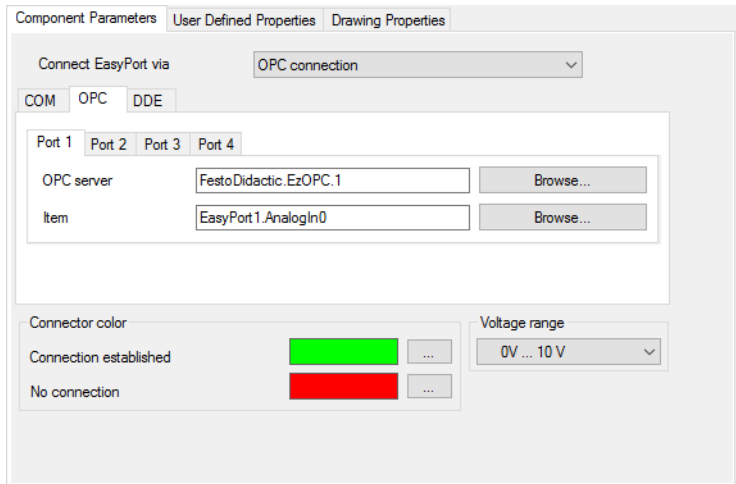
Figure 9/37: Dialog box for the OPC components

⟶ In the "*Connect EasyPort via*" list, select the "*OPC connection*" option.

OPC server

Enter the OPC server here or press the | Pick... | button and select it from the list.

Item

Enter the data item here or press the | Pick... | button and select it from the list.

> ❗ In order to establish communication via a DDE interface, first ensure that the DDE interface is active. You can do this with the global option under DDE Connection.

⟶ In the "*Connect EasyPort via*" list, select the "*DDE connection*" option.
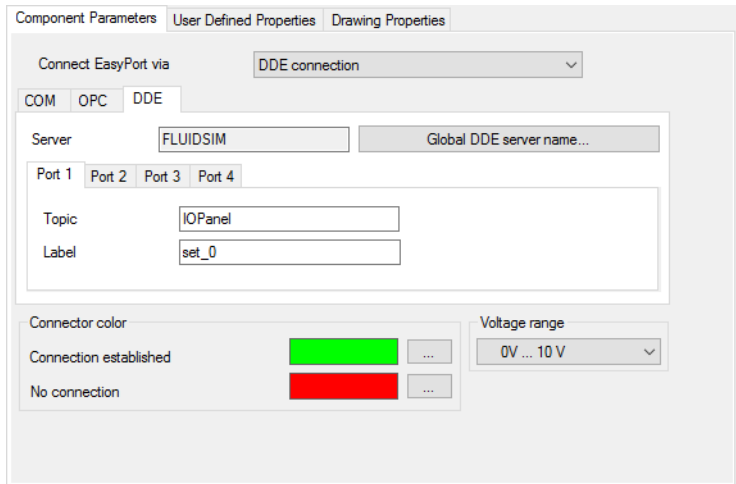
Figure 9/38: Dialog box for the DDE components

Server

This is the server name that FluidSIM uses when it registers in the system as a DDE server. As the server name is a global setting, it cannot be changed directly in this dialog box. Pressing the Global DDE server name... button takes you to the options dialog box where you can change the server name for the entire system.

Topic

Here, enter the "topic" via which you would like to address the components.

Label

Here, enter the label or the "item" via which you would like to address the components.

9.14 Open-loop and closed-loop control by using continuous valves

In addition to simple directional control valves, which only have discrete switching positions, FluidSIM also offers some continuous

valves. These are characterized by their ability to adopt a continuous range of intermediate positions. Like electrically actuated directional control valves, these components are controlled via a proportional amplifier or via a valve solenoid. These valves, however, are represented by special symbols:
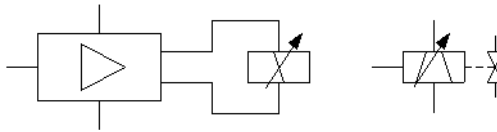
Figure 9/39: Proportional valve solenoid and amplifier

The separate proportional valve solenoid is used for position-controlled continuous valves where the control and amplifier component is built into the valve.

If you inadvertently use a label to link a directional control valve to a proportional valve solenoid, or a proportional valve to a simple valve solenoid, FluidSIM issues a warning.

The following two sections provide a brief introduction to the options for *open-loop control* and *closed-loop control* with FluidSIM.

The term "open-loop control" means that an *output variable* changes as a function of an *input variable*. In this specific case, the voltage on the proportional valve solenoid or amplifier represents an input variable. The valve piston of the proportional valve is shifted in a particular direction to a greater or lesser distance as a function of the value (and the direction) of the electrical current caused by that voltage (by means of an amplifier). This piston displacement is the output variable. If the pressure at the valve port is constant, the flow rate can be controlled in this way. If, on the other hand, the flow rate is constant, the pressure drop will change as a function of the opening level, determined by the valve position.

The term "closed-loop control" is used when the output variable (or a quantity value affected by it) is used in turn as the input variable. It is also quite possible for multiple output variables (and quantity values dependent on them) to be combined together with addition-

al input variables, using a calculation rule. A classic example is *position control*, where a cylinder needs to move to a certain position. The valve is activated electrically so that the cylinder moves. The cylinder's position (resulting from the movement caused by the valve setting) is used in turn as an input variable, to determine the deviation between the cylinder's position and its setpoint position. Once the cylinder has reached its target position, the deviation is 0 and the valve returns to its mid-position (closed position). The cylinder thus comes to a halt. If inertia or external disruption causes the cylinder to move past its target, the valve switches over to the other side, reversing the flow direction, and the cylinder moves back. This is the simplest form of closed-loop control, known as "P control" (proportional control).

9.14.1 Open-loop control in pneumatics

In order to understand how the continuous components function, please construct the following circuit (power supply, function generator, voltmeter, proportional valve solenoid, regulating valve):
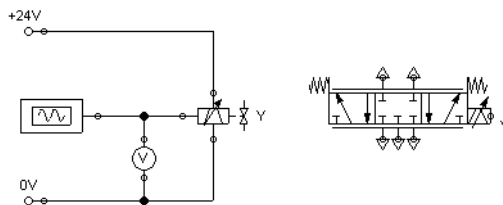
Figure 9/40: Simple open-loop control of the regulating valve

Do not forget to fit silencers on the valve's five pneumatic ports, in order to prevent warnings from FluidSIM.

⤑ Start the simulation and observe the regulating valve.

The function generator generates a signal between 0 and 10 volts. This varying voltage is converted by a proportional amplifier in the

valve into a corresponding current that actuates the proportional valve solenoid, so that the valve connected to it is shifted to either side to the maximum extent according to the signal voltage applied.

To switch over the valve to a lesser extent, the valve requires a lesser maximum voltage. You can set that by opening the properties dialog box for the function generator, by double clicking.

Component Parameters					
☐ Show designation		☑ Show variable		☑ Show Unit	
Designation	Value	Range	Unit	Display	Variable
Signal type	Sine			☐	
Frequency	1	0.01 .. 1E+05	Hz	☐	f...
Amplitude	5	0 .. 400	V	☐	U_S...
y offset	5	-100 .. 100	V	☐	U_offset...
Min. Voltage	-30	-400 .. 400	V	☐	U_cut_min...
Max. Voltage	30	-400 .. 400	V	☐	U_cut_max...
Simulated values					
Designation	Value	Range	Unit	Display	Variable
Voltage			V	☐	U...

Figure 9/41: Properties dialog box for the function generator

⤳ Enter 2 as the "*Amplitude*", close the dialog box, and restart the simulation.

The voltage will now vary between 3 and 7 volts. As a result, the valve will still shift symmetrically, but with less displacement from the mid-position.

⤳ Open the function generator properties again and set 3 as the y offset.

The function generator now supplies a voltage between 1 and 5 volts, with the valve moving further to the left than to the right.

⸺⟩ Open the function generator properties again and set "*Constant*" as the signal type.

! The sliders of the function generator for "*Frequency*" and "*Amplitude*" have no function when the signal type is set to "*Constant*". This allows us to use it to simulate a manually adjustable potentiometer.

⸺⟩ Start the simulation and click the function generator (with a *single* click).

A window opens showing the sliders of the function generator.
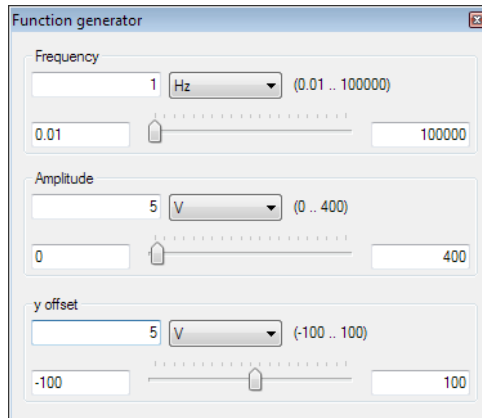
Figure 9/42: Adjusting the function generator during the simulation

⸺⟩ Change the y offset very gradually, while observing how the valve moves as a function of the slider setting.

9.14.2 Open-loop control in hydraulics

In order to understand how the continuous components function, please construct the following circuit (power supply, function

generator, voltmeter, proportional valve solenoid, regulating valve):
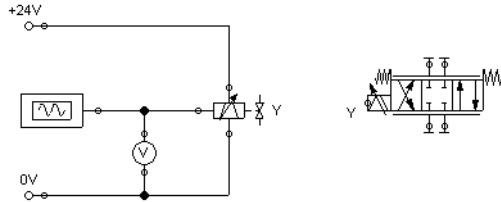
Figure 9/43: Simple open-loop control of the regulating valve

Do not forget to fit blanking plugs on the valve's four hydraulic ports, in order to prevent warnings from FluidSIM.

⤏ Start the simulation and observe the regulating valve.

The function generator generates a signal between -10 and 10 volts. This varying voltage is converted by a proportional amplifier in the valve into a corresponding current that actuates the proportional valve solenoid, so that the valve connected to it is shifted to either side to the maximum extent according to the signal voltage applied.

To switch over the valve to a lesser extent, the valve requires a lesser maximum voltage. You can set that by opening the properties dialog box for the function generator by double clicking.

Figure 9/44: Properties dialog box for the function generator

⋯⋯⟩ Enter 4 as the "*Amplitude*", close the dialog box, and restart the simulation.

The voltage will now vary between -4 and 4 volts. As a result, the valve will still shift symmetrically, but with less displacement from the mid-position.

⋯⋯⟩ Open the function generator properties again and set 2 as the y offset.

The function generator now supplies a voltage between -2 and 6 volts, with the valve moving further to the left than to the right.

⋯⋯⟩ Open the function generator properties again and set "*Constant*" as the signal type.

The sliders of the function generator for "*Frequency*" and "*Amplitude*" have no function when the signal type is set to "*Constant*". This allows us to use it to simulate a manually adjustable potentiometer.

⸺⸽ Start the simulation and click the function generator (with a *single* click).

A window opens showing the sliders of the function generator.
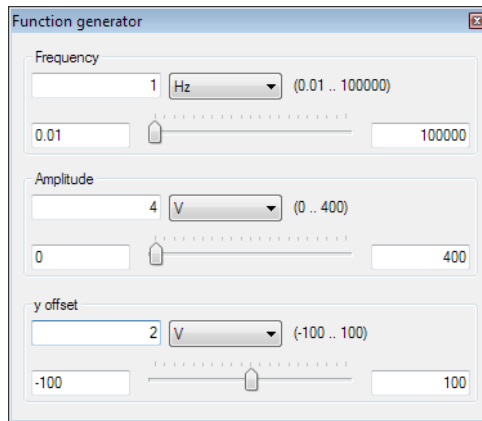
Figure 9/45: Adjusting the function generator during the simulation

⸺⸽ Change the y offset very gradually, while observing how the valve moves as a function of the slider setting.

9.14.3 Closed-loop control in pneumatics

Your task now is to set up a simple system of closed-loop position control. To do so, modify the circuit as shown in the following figure. Remember that you need to remove the silencers on the valve ports before you can drag lines. Instead of the function generator, it is now the displacement encoder that supplies the input voltage for the proportional valve solenoid. So you can apply the label to the cylinder, open its properties dialog box, go to the "*Configure Cylinder*" tab and set the "*Sensing*" option.
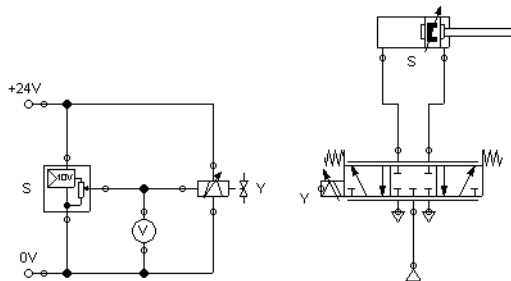
Figure 9/46: Simple closed-loop position control

! Note that the regulating valve is mirrored horizontally in this example.

⤍ Start the simulation and observe that the cylinder stops once it has traveled half the distance.

Now we want to expand the circuit so that the cylinder can move to any position we set on a slider during the simulation, as quickly as possible but still accurately. This is done using a PID controller.

⤍ Construct the following circuit and set the parameter values for the PID controller as shown.

! Note that the regulating valve is mirrored from its position in the example above.
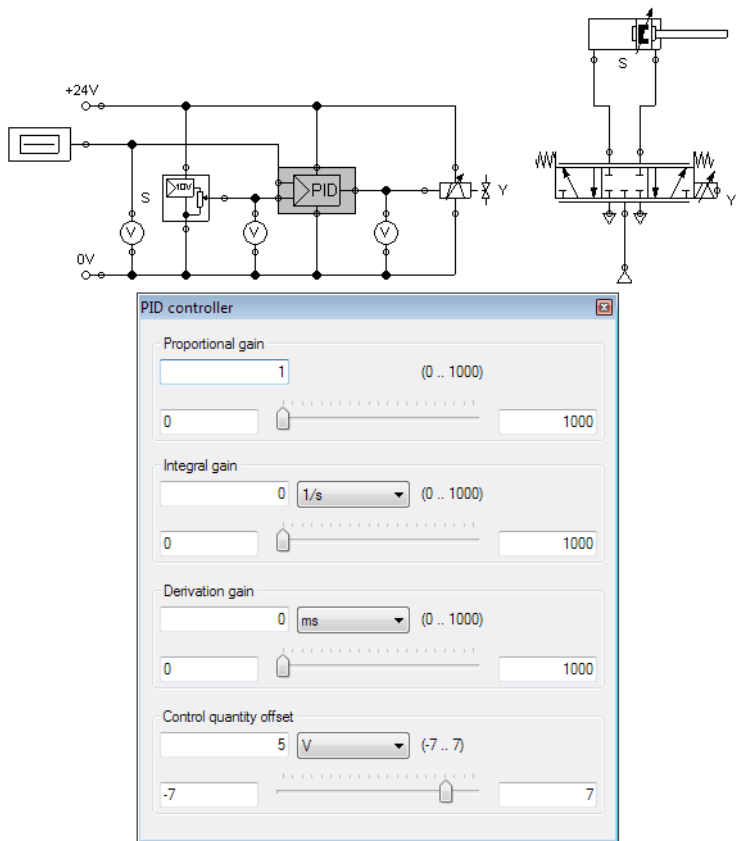
Figure 9/47: Position control with PID controller

┈┈> Start the simulation and slowly move the y offset of the function generator between 0 and 10.

The cylinder moves until it reaches its setpoint position, where it stops. The cylinder's target position is proportional to the voltage set on the function generator, with 0 V equating to "fully retracted" and 10 V meaning "fully advanced." The value 5 thus represents

the cylinder piston's mid-position. It does not matter what position the cylinder starts from; it will always stop at the specified target position.

⤏ Vary the initial piston position and observe how the cylinder reaches its setpoint position every time without fail.

To study the closed-loop control procedure more closely, let's examine the cylinder's displacement and velocity up to its setpoint position. You can do this by adding a state diagram, adjusting it to a suitable size, and dragging the cylinder onto the diagram. A dialog box will open where you should select the two quantity values "*Position*" and "*Velocity*".

Pneumatics are fast. So you can more clearly observe the effects described below, set the stroke of the cylinder to 5000 mm.

⤏ Set the y offset of the function generator to 5 and the start position of the cylinder to 0 and start the simulation.

The cylinder advances to the middle, losing velocity continuously until it comes to a stop.

Designation	Quantity value	0	1	2	3	4	5	6	7	8	9	10

S — Displacement mm
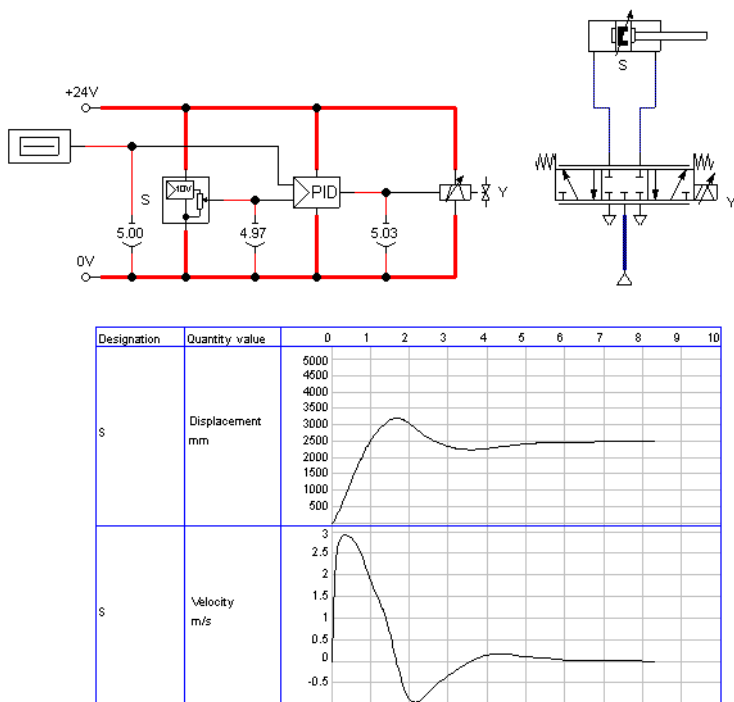
S — Velocity m/s

Figure 9/48: Position displacement and change in velocity during closed-loop control

It is often desirable for the cylinder to move at maximum velocity until it reaches its setpoint position and then to stop as suddenly as possible. You can do this by amplifying the position signal of the displacement encoder, which will accelerate the switchover of the regulating valve. This makes use of the fact that the PID controller limits the output voltage for the proportional valve solenoid to 10 V.

┅┅> Set the "*Proportional gain*" of the PID controller to 3 and start the simulation.
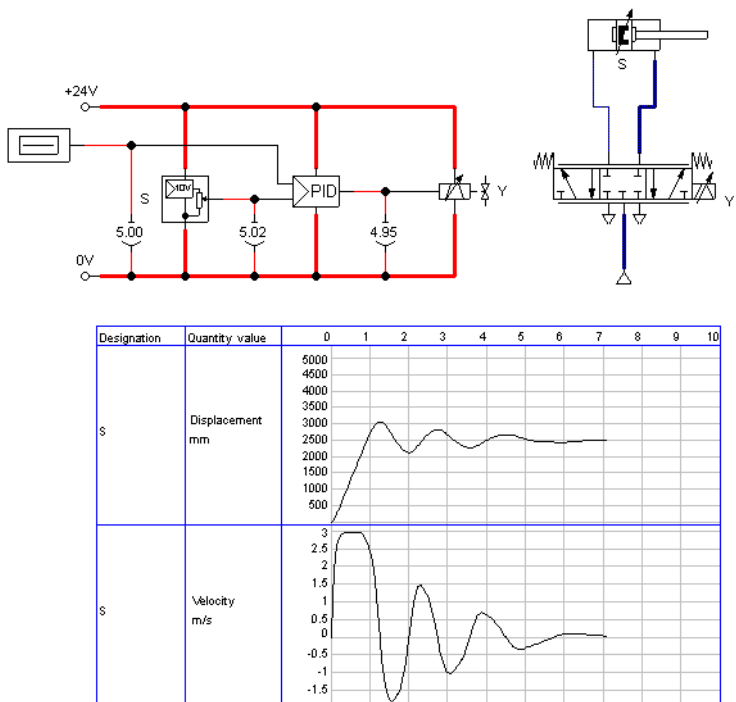
Figure 9/49: Position displacement and change in velocity with amplified input signal

You can see clearly that the cylinder now moves at a constant velocity for a long distance. It then brakes sharply and comes finally to a stop.

However, you can see that the cylinder piston moves clearly beyond its target, due to its inertia and the compressibility of the air, and moves back and forth several times before finally coming to rest. These oscillations around the setpoint position are typical for this kind of simple closed-loop control. In practice, you would try to reduce these oscillations by tweaking the parameters of the PID or loop controller. However, at this stage we will stop at the simple

basic principles, and refer you to the literature on proportional and closed-loop systems for further reading.

9.14.4 Closed-loop control in hydraulics

Your task now is to set up a simple system of closed-loop position control. To do so, modify the circuit as shown in the following figure. Remember that you need to remove the blanking plugs on the valve ports before you can drag lines. Instead of the function generator, it is now the displacement encoder that supplies the input voltage for the proportional valve solenoid. So you can apply the label to the cylinder, open its properties dialog box, go to the "*Configure Cylinder*" tab and set the "*Sensing*" option.
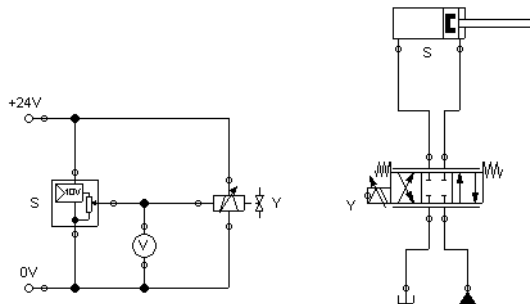
Figure 9/50: Simple closed-loop position control

⤏ Start the simulation and observe how the cylinder retracts and the valve moves further and further into its closed position.

This makes the cylinder slower and slower until it is fully retracted. Strictly speaking this is not really position control, because the cylinder would have stopped when it reached its physical stop anyway. So now let's change the relationship in the displacement encoder between the piston position and the output voltage. For example, if we want the cylinder to stop in the middle, the valve

must be in its closed position at the exact time when the cylinder reaches that position. As the output voltage is proportional to the piston position, it is easy to calculate how the voltages at the two limits (cylinder retracted/cylinder advanced) need to be selected in order for the voltage to be 0 V halfway through the cylinder stroke:

Component Parameters	User Defined Properties	Drawing Properties				

☐ Show designation ☑ Show variable ☑ Show Unit

Designation	Value	Range	Unit		Display	Variable
Voltage (Cylinder retracted)	0	-10 .. 10	V	∨	☐	U1...
Voltage (Cylinder extracted)	10	-10 .. 10	V	∨	☐	U2...
Minimum voltage	13	0.1 .. 300	V	∨	☐	U_min...
Resistance	100	1 .. 1E+04	Ohm	∨	☐	R...

Simulated values

Designation	Value	Range	Unit		Display	Variable
Voltage (out)			V	∨	☐	U_out...

Figure 9/51: Adjusting the voltage limits for the displacement encoder

⤙⤙⤐ Start the simulation and observe that the cylinder stops once it has traveled half the distance.

Now we want to expand the circuit so that the cylinder can move to any position we set on a slider during the simulation, as quickly as possible but still accurately. This is done using a PID controller.

⤙⤙⤐ Construct the following circuit and set the parameter values for the PID controller as shown.

Note that the pump unit and the tank are mirrored from their positions in the example above.

Figure 9/52: Position control with PID controller

⤑ Start the simulation and slowly move the y offset of the function generator between -10 and 10.

The cylinder moves until it reaches its setpoint position, where it stops. The cylinder's target position is proportional to the voltage set on the function generator, with -10 V equating to "fully retract-

ed" and 10 V meaning "fully advanced." The value 0 thus represents the cylinder piston's mid-position. It does not matter what position the cylinder starts from; it will always stop at the specified target position.

⟶ Vary the initial piston position and observe how the cylinder reaches its setpoint position every time without fail.

To study the closed-loop control procedure more closely, let's examine the cylinder's displacement and velocity up to its setpoint position. You can do this by adding a state diagram, adjusting it to a suitable size, and dragging the cylinder onto the diagram. A dialog box will open where you should select the two quantity values "*Position*" and "*Velocity*".

⟶ Set the y offset of the function generator to 0 and the start position of the cylinder to 0 and start the simulation.

The cylinder advances to the middle, losing velocity continuously until it comes to a stop.
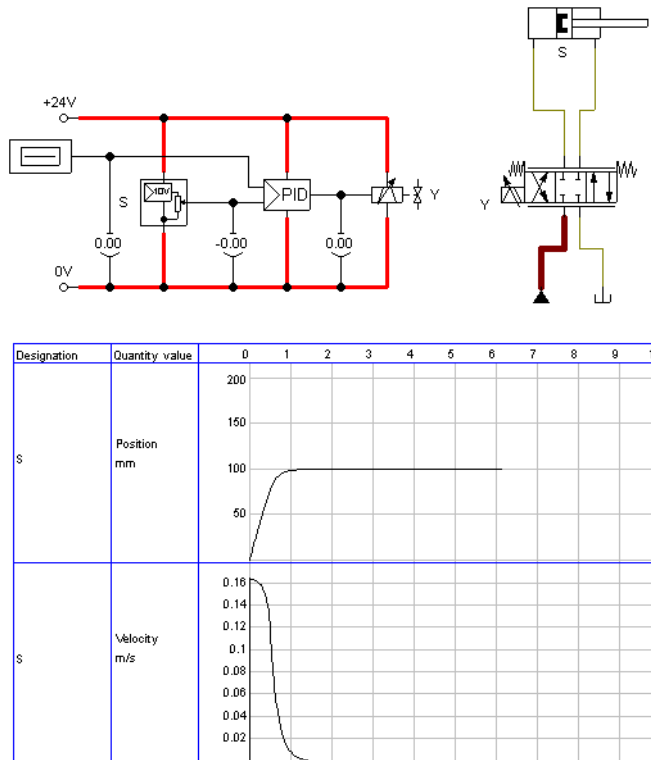
Figure 9/53: Position displacement and change in velocity during closed-loop control

It is often desirable for the cylinder to move at maximum velocity until it reaches its setpoint position and then to stop as suddenly as possible. You can do this by amplifying the position signal of the displacement encoder, which will accelerate the switchover of the regulating valve. This makes use of the fact that the PID controller limits the output voltage for the proportional valve solenoid to 10 V.

⋯⋯> Set the "*Proportional gain*" of the PID controller to 10 and start the simulation.
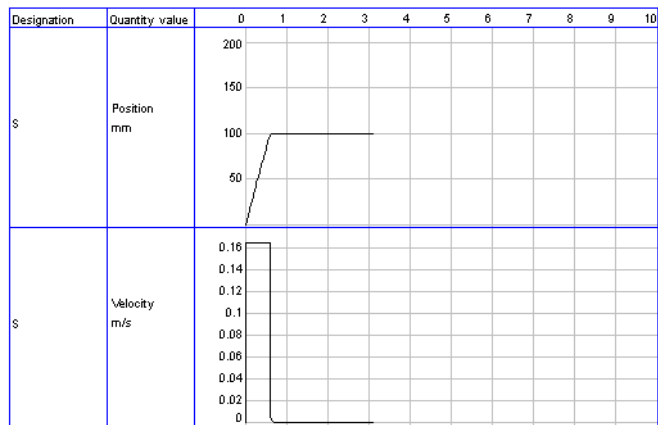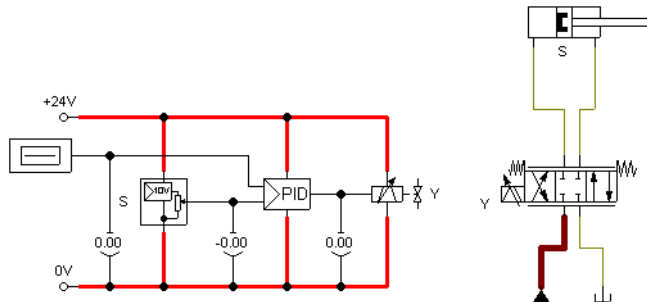
Figure 9/54: Position displacement and change in velocity with amplified input signal

You can see clearly that the cylinder now moves at a constant velocity for a long distance. It then brakes sharply and comes quickly to a stop.

If the cylinder had to move a load, its inertia would cause it to move slightly beyond its target and it would have to move back and forth

several times before coming to rest. These oscillations around the setpoint position are typical for this kind of simple closed-loop control. In practice, you would try to reduce these oscillations by tweaking the parameters of the PID or loop controller. However, at this stage we will stop at the simple basic principles, and refer you to the literature on proportional and closed-loop systems for further reading.

9.15 Use of the oscilloscope in electronics

For graphic display of the physical simulation variables, the state diagram is available. However, for visual representation of high-frequency and periodic signals, an oscilloscope is better. FluidSIM has such an oscilloscope in its electronics library, which can be installed in electrical circuits and connected like other measuring devices (e.g. voltmeter und ammeter). Any number of oscilloscopes can be installed and used at the same time.

⸱⸱⸱⸲ Create a circuit comprising a function generator and an oscilloscope.

Figure 9/55: Simple circuit with function generator and oscilloscope

⸱⸱⸱⸲ Set the function generator to the sine function and the frequency to 1 kHz. Now start the simulation and click the oscilloscope.

A dialog window opens with a display modeled on a real oscilloscope.

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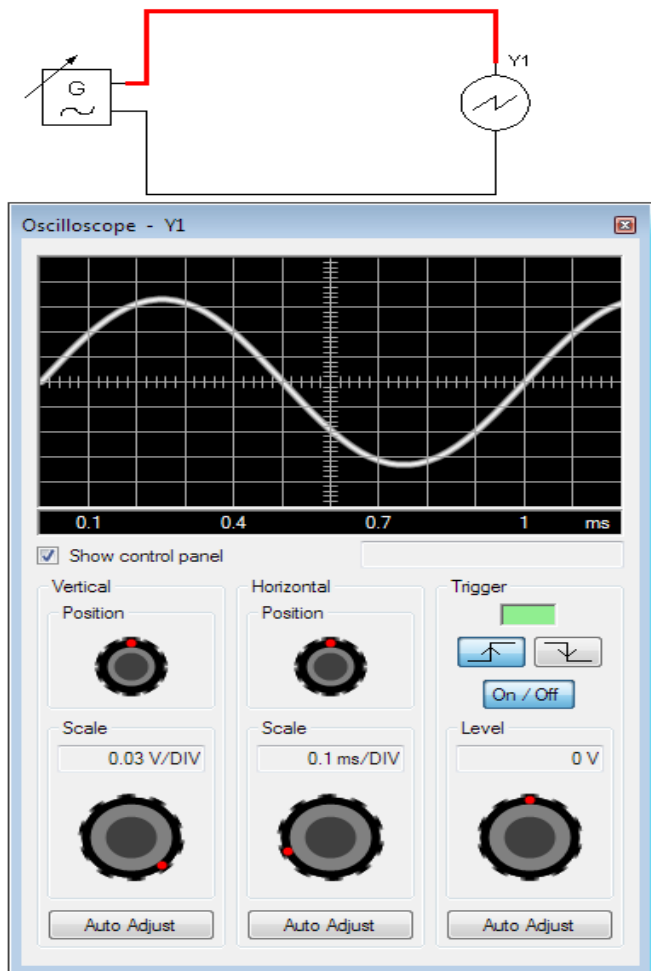
Figure 9/56: Modeling of a real oscilloscope

⤑ Turn the various dials and observe how the displayed curve changes.

9.16 Simulation of rotating machines

A complete mathematical model and very accurate values for the machine's characteristic data are required in order to ensure correct physical simulation of a rotating electric machine. Characteristic data include, for example, resistance and inductance of the stator and rotor windings, the number of pole pairs and idling speed without load.

However, these values are not included in the manufacturer's specifications or on the rating plates of common electric motors. The values specified there describe the status of the motor at nominal load. These usually include mechanical output power and motor speed at a specified voltage, amperage and line frequency.

However, these data alone do not permit physically correct simulation of an electric motor. The machine's above mentioned "inner" values are required.

And thus FluidSIM attempts to ascertain these required inner values on the basis of the specified performance data in different ways, especially in light of the fact that for some machines these parameters are not easy to measure. And thus there's no need for you, as a user, to get involved with the complicated internal layout of a machine, and all you have to do is enter the machine's performance data, for example from the rating plate, after which the machine can be simulated.

In the case of electric machines with a simple layout, above all DC motors due to their engineering design, the characteristic data can be readily derived from the performance data and directly calculated. Idling speed is additionally required in order to be able to obtain unambiguous values.

But things are not that simple in the case of machines with more complex designs such as asynchronous AC motors, capacitor motors and synchronous motors. Here it's much more difficult to arrive

at the characteristic parameters on the basis of the machine's specified performance data. The physical relationships which are taken advantage of in order to generate rotary motion in these motors are so complex, that the machine's inner values cannot be calculated directly from the nominal values.

For this reason, FluidSIM attempts to ascertain the characteristic data on the basis of various heuristic estimates and, to some extent, dynamic simulations, so that they are matched as well as possible to the entered performance data. These calculations are executed in the background after the machine's parameters have been entered or changed. When estimating the characteristic data, FluidSIM always attempts to select data in such a way as to ensure that the machine's specified performance data are approached as closely as possible, and that the machine's specified performance represents its maximum performance.

The fact that the inner values can only be approximated and not precisely calculated results in the following effects in the simulation:

— Under certain circumstances it might not be possible to start the simulation immediately.
After entering the parameters of a rotating electric machine, it may take a moment before the simulation can be started. This is because the machine's characteristic data are calculated in the background after the parameters have been entered (e.g. winding resistance). The simulation cannot be started until these parameters have been determined. These data are always determined once only after parameter values have been entered or changed. As long as the parameters are not changed, there's no need to repeat the calculation.

— Changed performance data in the simulation
FluidSIM always attempts to ascertain the characteristic parameters which best suit the attributes based on the entered performance data. If you use the performance data of an actual machine, this should usually work. But even if the entered performance data do not correspond to an actual machine, FluidSIM nevertheless attempts to find values for the characteristic data so that a simulation can be run for the machine. However, in this case some of the performance data in the simulation might not correspond with the entered data. Flow of current through the machine, for example, serves as an addi-

tional degree of freedom for the calculation of the characteristic data, which may deviate from the value in the simulation entered by you. If FluidSIM doesn't find any appropriate parameters based on the user entries, a similar machine is calculated which corresponds at least to the most important attributes. If this works, the symbol is identified in gray in order to indicate that not all of the entries have been used. The parameters which could not be taken into consideration are displayed in the component's characteristics dialog box. The affected entry fields are identified there in color.

— The simulation cannot be run with the selected parameters. After entering the parameters, the characteristic data of the electric machine are determined in the background. During this process the program might discover that a given component cannot be physically implemented with the entered data. In this case the respective symbol is identified in the circuit diagram and a corresponding error text is displayed. If this is the case, check to make sure that you have entered all of the parameters from the manufacturer's specifications or the rating plate correctly. The parameters which might be incorrect are displayed in the component's characteristics dialog box. The affected entry fields are identified there in color.

The goal of the process run by FluidSIM is to provide you with a correct physical simulation of electric machines without requiring you to be precisely familiar with the details.

GRAFCET

Chapter 10

This chapter provides an introduction to creating and simulating GRAFCET plans with FluidSIM. See norm DIN EN 60848 for the complete specification of the GRAFCET description language. Festo Didactic provides a range of training documentation for more detailed introductions to GRAFCET.

Unlike an SPS programming language, such as Sequential Function Chart (SFC), GRAFCET is a graphic description language that describes the logical behavior and operation of a control system or a process - regardless of the technical software and hardware implementation. FluidSIM can be used to both create and simulate GRAFCET plans. The term GRAFCET is also used as a synonym for a GRAFCET plan. It should be obvious from the context whether the word GRAFCET refers to the plan or the language.

A GRAFCET essentially describes two aspects of a control system, according to specified rules: the actions (commands) to be carried out and the sequence of execution. The elementary components of a GRAFCET are steps, actions and transitions and can be used in the same way as pneumatic or electrical components. To achieve a uniform operating concept, the GRAFCET elements feature connections that can be used to link them to each other (as with all other FluidSIM components).

10.1 The various GRAFCET modes

FluidSIM accommodates various GRAFCET training aims by means of three modes, which differ in terms of the degree of interaction they provide between GRAFCET on the one hand and the pneumatic, hydraulic, and/or electrical circuits on the other hand.

10.1.1 Drawing only (GrafEdit)

The simplest mode, also referred to as "GrafEdit" in the following sections, allows you to draw GRAFCET diagrams. Simulation or animation of a GRAFCET is not possible in this mode. You can draw a GRAFCET together with a fluidic or electrical circuit on one page or on a separate page within a project. However, in this mode the GRAFCET has no effect on circuit function, and the component states are not transmitted to the GRAFCET. The GRAFCET is a drawing only, with no action. This mode can be useful in practice in order to prepare the draft circuit conceptually with a GRAFCET and to verify it without the assistance of FluidSIM.

10.1.2 Observation (GrafView)

In this mode (also called "GrafView"), a GRAFCET can be drawn as described above, but unlike the simple GrafEdit mode, the conditions in GRAFCET objects can linked directly to variables in a corresponding circuit (see section "Access to variables of circuit components"). The GRAFCET can only have *read access* to the circuit elements. The GRAFCET observes the circuit during the simulation and is processed and visually presented according to the conditions in transitions and actions.

This mode is practical for simple checking of whether the intended function of the GRAFCET sequence matches the simulated system characteristics. In this mode, the processing of the actions of the GRAFCET has no effect on the other circuit elements. Control of the circuit is therefore not possible.

10.1.3 Control (GrafControl)

The "GrafControl" mode expands the GrafView mode by not only allowing *read access* to the fluidic and/or electrical circuit ele-

ments, but also permitting the GRAFCET actions to actively modify the values of those elements. This means GRAFCET cannot only take the place of an additional control, but can also initiate user actions. For example, pressing a pushbutton or switching over a manually operated valve can be simulated. This opens up a wide range of control possibilities because the GRAFCET can query all component parameters and also modify them when required. This includes the initiation of switching operations, the adjustment of flow control valves, and the modification of electrical resistances.

10.2 Setting the GRAFCET mode

Like the other simulation settings, the GRAFCET mode can be set for a single page, for an entire project node, and also in the global settings. For example, you can set the global GRAFCET settings under Tools Options... , *GRAFCET* tab and you can set the page-specific GRAFCET settings under Page Properties... , *GRAFCET* tab.

So it is always clear which GRAFCET mode is active, FluidSIM in Simulation Mode applies a colored border to pages containing a GRAFCET. A gray frame shows that the GRAFCET is not simulated, i.e. that GrafEdit mode is active. A blue frame indicates the GrafView mode, in which the GRAFCET can read simulation parameters. Finally, the red frame shows that the GRAFCET is in GrafControl mode, meaning that it has both *read* and *write* access to the component parameters.

10.3 GRAFCET elements

The following sections describe the individual elements offered by FluidSIM to allow creation of GRAFCET plans that comply with the GRAFCET standard.

10.3.1 Steps

Steps are either active or inactive and can be linked by actions. The actions of active steps are executed. The sequence of a GRAFCET is described by the transitions from a previous to a subsequent step. Steps and transitions have to alternate in the plan.

The creation and simulation of GRAFCETs in FluidSIM is illustrated in the following using simple examples.

---〉 Drag a step into a newly created circuit diagram.

Figure 10/1: Simple step

Each step has to be assigned a name. All newly created steps are consecutively numbered automatically. If a step is to be active at the start of the sequence control, it is marked as the initial step.

---〉 Open the step's dialog box by double clicking it or via the menu item Edit Properties... and select "*Initial step*" as the type.
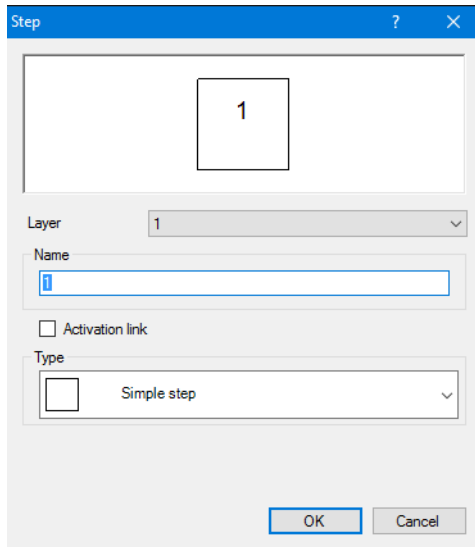
Figure 10/2: Step

Figure 10/3: Initial step

⤑   Start simulation with ▶ or via the menu (Execute | Start).

Figure 10/4: Active step

Active steps are marked with a point. Additionally, active steps are framed in green.

10.3.2 Actions

To execute commands, you can link any number of actions to a step. Actions do not have to be directly linked to a step; you can also link them to each other. To make it easier to create the drawing, it is enough to place actions next to each other, without having to draw connecting lines. If the connections for the elements overlap each other, they are automatically connected.
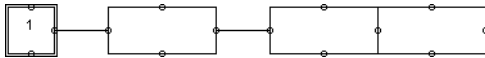
Figure 10/5: Actions

Actions can be defined by a textual description or by setting (or changing) variable values. If you want to simulate a GRAFCET with FluidSIM, the variable values are taken into account in the simulation. When displaying a GRAFCET graphically, you can decide whether the variable name or the descriptive text is shown in an action. If you want to display the description, you can set the checkmark next to " *Display description instead of formula*" in the action's properties dialogue (see example: `Grafcet/Grafcet18.ct`). At `View` `GRAFCET...`, you can specify whether the descriptions are displayed instead of the formulae for all GRAFCET components.

There are two types of action: continuously effective and stored effective actions. For a continuously effective action, its associated variable is set to the Boolean value (logical value) "TRUE" (1), provided that the step connected to the action is active. If the step is inactive, the value is set to "FALSE" (0). This way of setting a variable is referred to as "assignation" in the GRAFCET specifications.

For a stored effective action, the set value of the variable remains unchanged until it is changed by another action. This way of setting a variable is referred to as "allocation" in the GRAFCET specifications.

At the start of a sequence, all the variable values are initialized with "0".

⇢ Create the following GRAFCET. Select the action "Simple action" in the properties dialogue and enter "A " under "*Variable/output*". Then start the simulation.
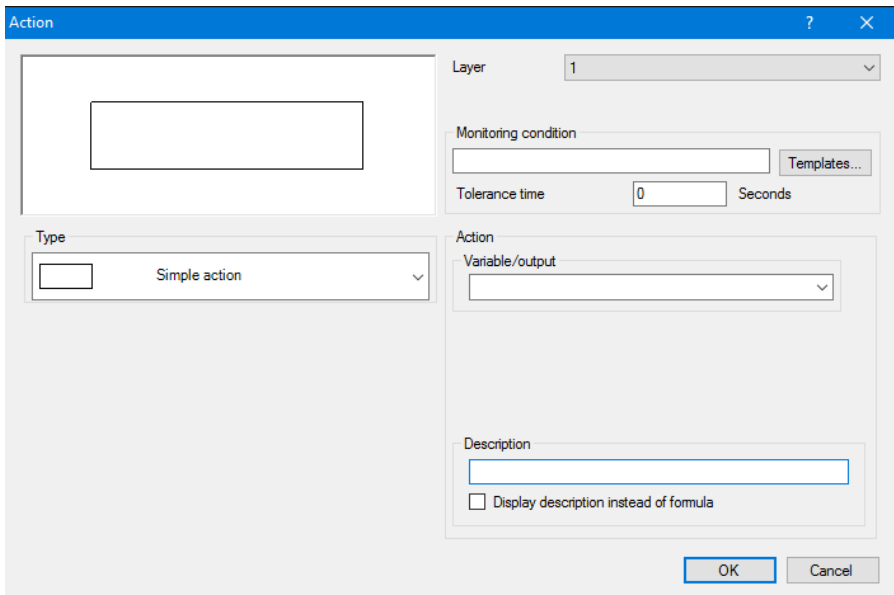
Figure 10/6: *Action* dialog window

Figure 10/7: Executed action

Step "1" is active and the action connected to the step is executed. Variable "A" is set to "1". The value of an action variable is shown during simulation in brackets after the variable's name.

10.3.3 Transitions

Transitions are used to describe the sequence of a control system. To do this, add the following information to GRAFCET:
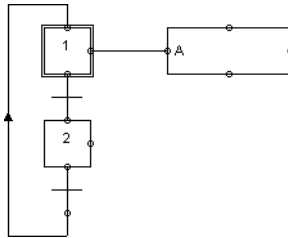
Figure 10/8: GRAFCET

⸱⸱⸱⸱⸱⸳ Select "2" as the name of the second (simple) step. The transition conditions that specify when the system moves from one step to the next are still missing. A transition is considered released once all the immediately preceding steps are active. A transition is triggered once it has been released and its condition has the value "1". A transition with the value "1" is displayed in green in FluidSIM. You can show a descriptive text instead of the formula, as with the actions.

A Boolean value is automatically generated for each step. The name begins with an "X", followed by the name of the step. In the example here, the variables "X1" and "X2" are generated. The value of a step variable is "1" if the step is active; otherwise it is "0".

Transition conditions can be time-dependent. These have the following form:

t1 s / "term" / t2 s

Where t1 and t2 have to be replaced by numbers and "term" by a Boolean term ("s" = seconds, "ms" = milliseconds).

The transition condition becomes true ("1") t1 seconds after "term" has changed its value from "0" to "1". This is called a "rising edge". The transition condition becomes false again ("0") t2 seconds after "term" has changed its value from "1" to "0". This is called a "falling edge".

The short form t1 s / "term" is also allowed. The system then assumes that t2 is 0 seconds.

⋯⋯➔ Enter the transition conditions into the transitions' properties dialogue as shown and then start the simulation.
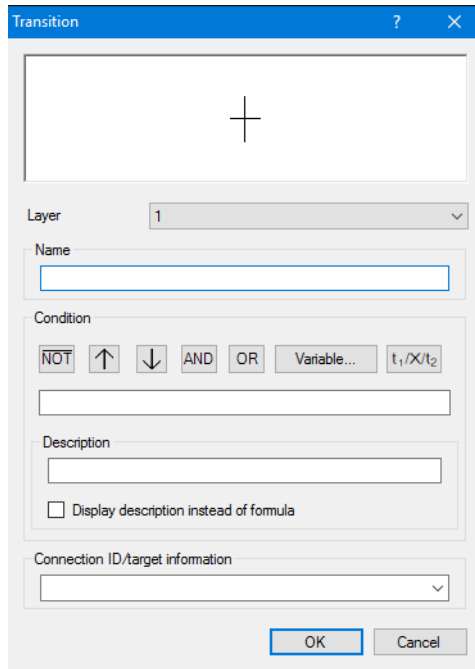
Figure 10/9: *Transition* dialog window
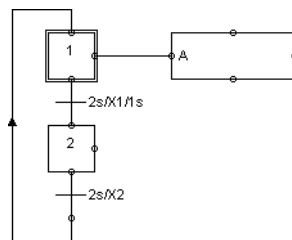
Figure 10/10: GRAFCET

The following cycle runs through:
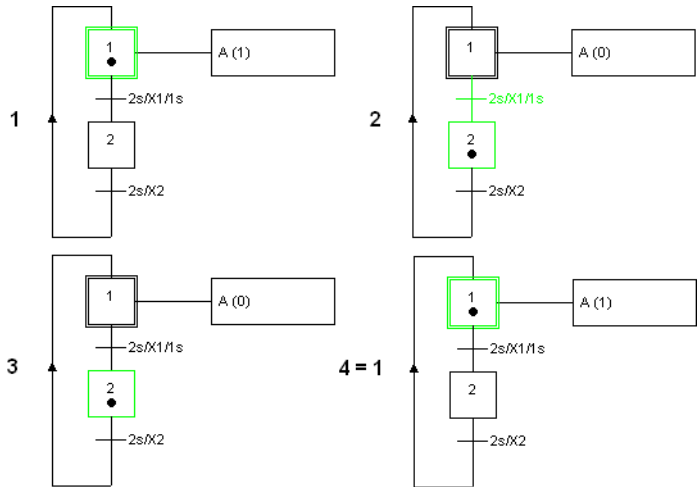
Figure 10/11: GRAFCET cycle

10.3.4 Stored effective actions (allocations)

In the next example, a counter is to be implemented. This works using a stored effective action (allocation) and an action on an event.

To do this, add the following information to GRAFCET:

⤏ Select "Action on activation" for the action of the second step, "C" as the variable and "C + 1" as the allocation. "C" will work as a counter. For the second action of the first step, select "*Action on event*", "B" as the variable with the allocation. "1" and "[C>2]" as the condition/event. Then start the simulation.
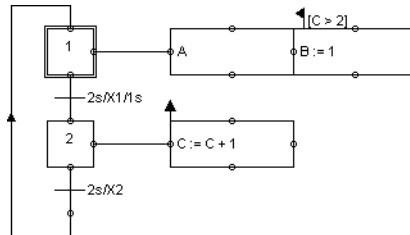
Figure 10/12: GRAFCET

Each time step "2" is activated, "C" is raised by one. As soon as "C" has the value "3" and step "1" is activated, "B" receives value "1".
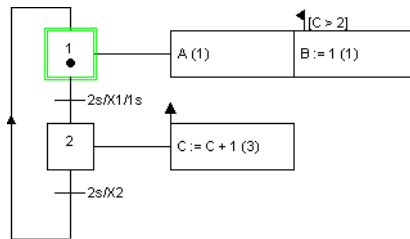
Figure 10/13: GRAFCET simulation

10.3.5 GRAFCET-PLC component

The GRAFCET-PLC component is a control device based on a PLC, the characteristics of which are described by a related GRAFCET. The GRAFCET is simulated in isolation regardless of the set GRAFCET mode, meaning that it has no direct access to the variables of other circuit components. The GRAFCET can only access the input and output variables of the related GRAFCET-PLC component.
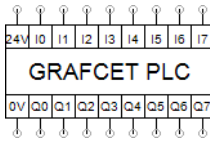
Figure 10/14: GRAFCET-PLC component

A GRAFCET-PLC component needs to be assigned to a GRAFCET. This is normally the GRAFCET on the same page. However, you can also specify a separate page in the project where the related GRAFCET is located.

You can open the properties dialog box by double clicking. You can access the adjustable parameters on the "*Component Parameters*" tab.

Figure 10/15: Adjustable parameters of the GRAFCET-PLC component

Related pages | The GRAFCET plans on the specified pages will be assigned to the GRAFCET-PLC component. If you do not specify any related pages, the GRAFCET assigned will be the one on the same page as the GRAFCET-PLC component.

Inputs

This list defines the names of the input variables that can be evaluated by the conditions of the related GRAFCET. Specifying a name is optional. The input variable names "I0" to "I7" are created automatically. The value of an input variable is set to "1" when a voltage of at least 24 volts is applied to the corresponding electrical connection and the GRAFCET-PLC component is connected to a power supply.

Outputs

This list defines the names of the output variables whose values can be set by the actions of the related GRAFCET. Specifying a name is optional. The output variable names "Q0" to "Q7" are created automatically. A voltage of 24 volts is generated at the electrical connection corresponding to an output variable if that output variable has a value not equal to "0" and the GRAFCET-PLC component is connected to a power supply. In any other situation, a voltage of 0 volts is generated.

The following simple example illustrates the use of the GRAFCET PLC component.
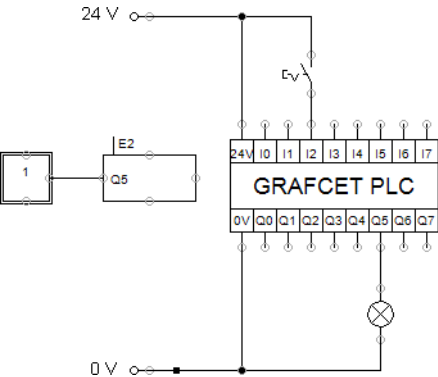
Figure 10/16: GRAFCET with its related PLC component

In the properties dialog box for the GRAFCET PLC component, the alias "E2" is entered for the input "I2". The output "Q5" was not given an alias. As soon as the electrical switch is closed, there is a potential at the input of "I2"; this potential causes the GRAFCET variable "I2" (and thereby also the alias "E2") to change its value from "0" to "1". As a consequence of this, the condition in the

action becomes true ("1") and the value of variable "Q5" is set to "1". This in turn leads to a potential being created at the output of "Q5" and the indicator light lights up.
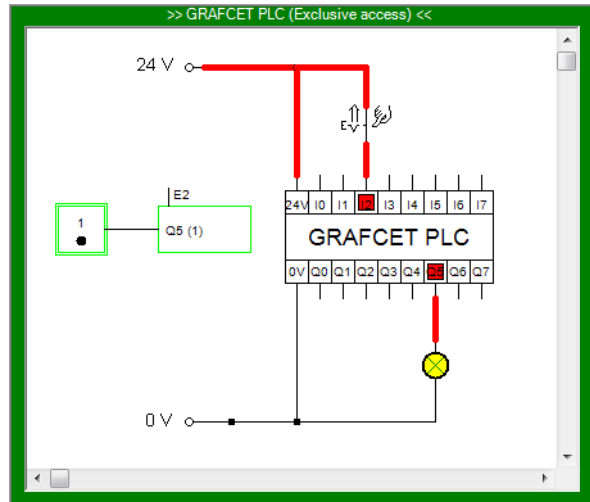
Figure 10/17: GRAFCET simulation

If a GRAFCET is connected to a GRAFCET-PLC component, the GRAFCET can only access the inputs and outputs of that related PLC component. As the GRAFCET and PLC component may be on separate pages, a frame around the GRAFCET during simulation indicates that it is in this restricted PLC mode.

As soon as the switch is opened again, the following situation arises:
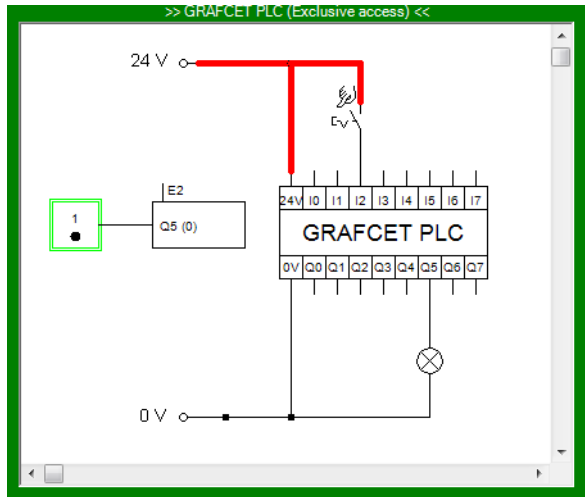
Figure 10/18: GRAFCET simulation

10.4 Access to variables of circuit components

If the set GRAFCET mode permits it, GRAFCET elements can directly access the variables of circuit components, with the "GrafView" mode allowing only read access and the "GrafControl" mode allowing both read and write access to the circuit variables. Also, to permit this access, every variable used in GRAFCET needs to be identifiable by a unique name. You can see the predefined name for every variable in the component parameters dialog box. Clicking the name of a variable opens another dialog box where you can specify a user-defined alias. This alias is used like a global variable and can be addressed directly in a GRAFCET.
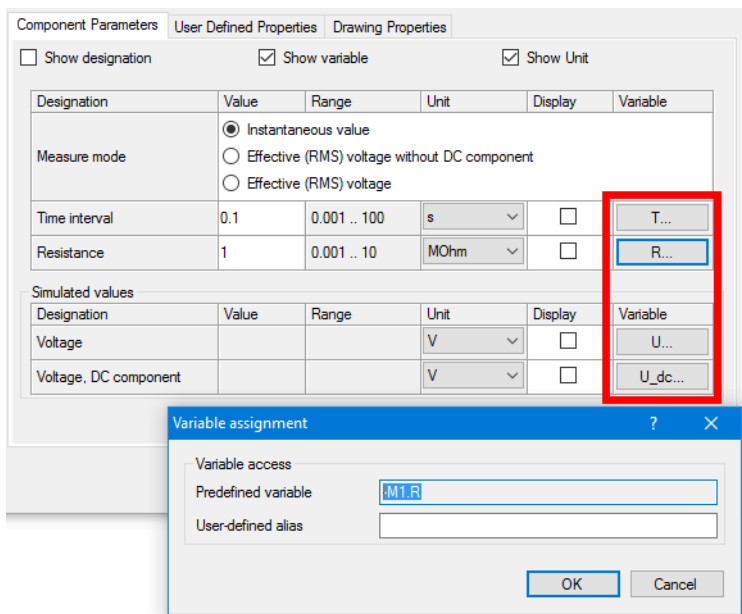
Figure 10/19: Variables of a voltmeter

Read access to the variables listed in the component dialog box is permitted. The complete variable name that can be used in a GRAFCET is made up of the component identification, a dot "." as a separator, and the variable designation. The complete variable name of the voltage of a voltmeter "-M1" is therefore "-M1.U", for example. Alternatively, the user-defined alias can be used.

The complete variable name of the actuated state of a manually operated switch "-S" is "-S.state". For the sake of simplicity, an alias with the switch's identification is created automatically. In this example, therefore, "-S" can be used directly in a GRAFCET instead of "-S.state".

In the "GrafControl" GRAFCET mode, write access is possible only to those variables which can actually be modified interactively during the simulation. With a voltmeter, for example, the resistance

can be specified only in Edit Mode. It cannot be modified during the simulation.

The following circuit (`Grafcet/Grafcet19.circ`) illustrates access to circuit variables.
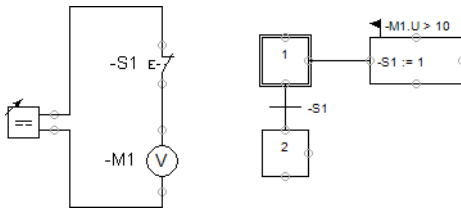
Figure 10/20: Access to circuit variables

The "GrafControl" GRAFCET mode is set in the circuit properties, otherwise the action could not act directly on the circuit. The condition checks if the voltage of voltmeter "-M1" is greater than 10 volts. The complete variable name of the voltage is "-M1.U" as described above, and is displayed on the action in the circuit. Once the simulation starts, the voltage can be increased interactively in the function generator. If the voltage exceeds 10 volts, the action becomes active.
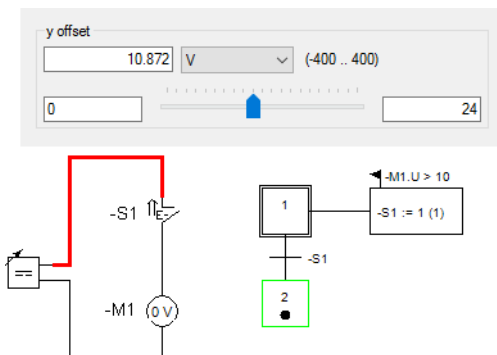
Figure 10/21: Access to circuit variables

The variable "-S1" is set, which is an (automatic) alias of "-S1.state". This sets the state of switch "-S1" to "1" (actuated) and the switch opens.

10.5 Monitoring with GRAFCET actions

A GRAFCET can be used to monitor the proper functioning of a fluidic or electrical circuit. The monitoring functionality in FluidSIM allows you to check whether GRAFCET actions executed in a circuit resulted in the desired behavior. This is done by evaluating so-called *monitoring conditions* in the active actions during the simulation. If a monitoring condition is violated, meaning that its value is "0" (FALSE), the corresponding action is marked with a color and the violation of the condition is tolerated for a defined time. Once that time is exceeded, the monitoring is categorized as failed.

The settings for monitoring can be set along with the choice of GRAFCET mode (see "Setting the GRAFCET mode").
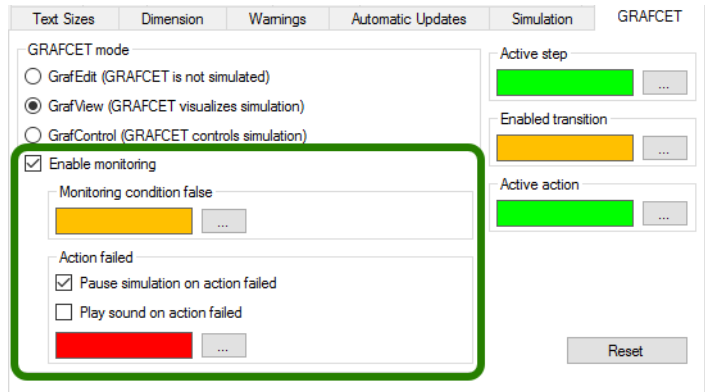
Figure 10/22: Settings for GRAFCET monitoring

Enable monitoring	Here you can define whether you want the monitoring to be carried out during the simulation.
Monitoring condition false	If the monitoring condition of an active action is violated, the action is marked in the color specified.
Action failed	Once a monitoring condition fails, or in other words, once the tolerance time is exceeded, the corresponding action is marked in the color specified.
Pause simulation on action failed	If this option is activated, the simulation switches to pause mode when a monitoring condition fails.
Play sound on action failed	If this option is activated, an audio signal is sounded when a monitoring condition fails.

The following example is designed to illustrate the use of GRAFCET monitoring (`Grafcet/Grafcet21_Hyd.circ` or `Grafcet/Grafcet21_Pneu.circ`).
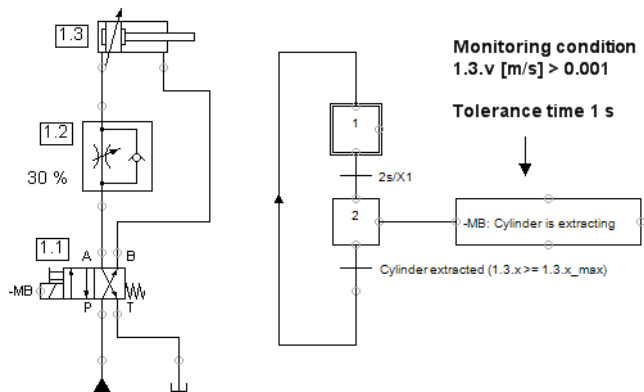
Figure 10/23: Circuit diagram with GRAFCET monitoring

The single action in the GRAFCET activates the solenoid valve directly. This should cause the cylinder piston to advance. A monitoring condition in the action will be used to check if the cylinder actually did advance. A small positive velocity indicates the advancing of the piston.

To formulate the monitoring condition, open the properties dialog box for the action by double clicking.
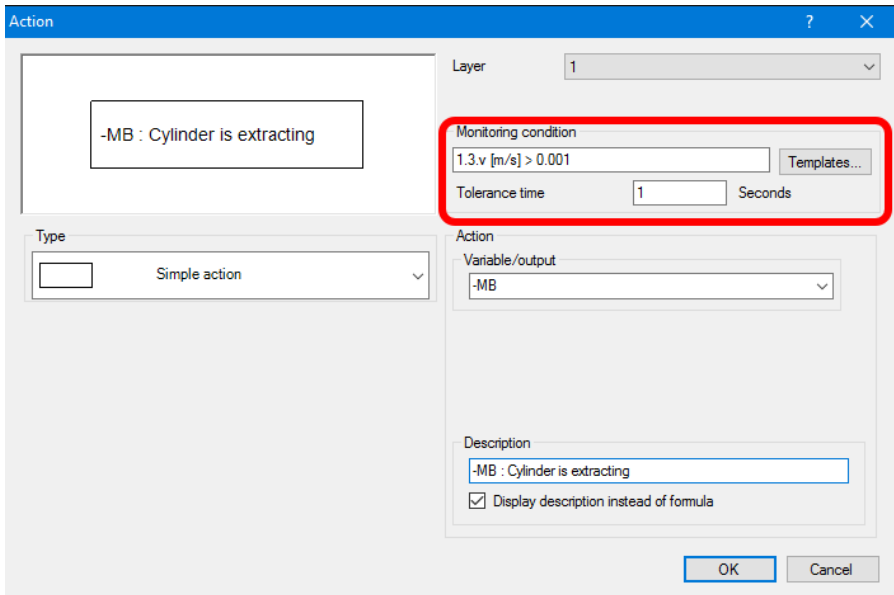
Figure 10/24: Specifying the monitoring condition

Monitoring condition

The monitoring condition is entered in this field. Circuit variables can be assigned to a unit of measurement by writing the desired unit in square brackets after the variable. This is "1.3.v [m/s]" in the example shown.

Tolerance time

In this field you enter the time period after which a violated condition is categorized as failed.

The "*Templates*" button opens a dialog box where a condition can be compiled interactively.

Figure 10/25: Template of a monitoring condition

Monitoring condition	You can use the two drop-down lists to select a template of a monitoring condition.
Component	Here you can specify the identification of the component to which the monitoring condition will refer. You can use the " Browse... " button to select the component from an additional selection dialog box.
Variables / Units	Here the variables and units are listed which are used in the selected template.
Parameter	Parameters can be adjusted in some templates. For example, in the template "Cylinder is in interval", you can specify the limits x1 and x2 of the interval.

Condition formula

The condition generated from the template is shown as a formula in this field. This formula is transferred into the input field for the monitoring condition.

Start the simulation and observe how the GRAFCET controls the circuit and advances and retracts the cylinder piston.
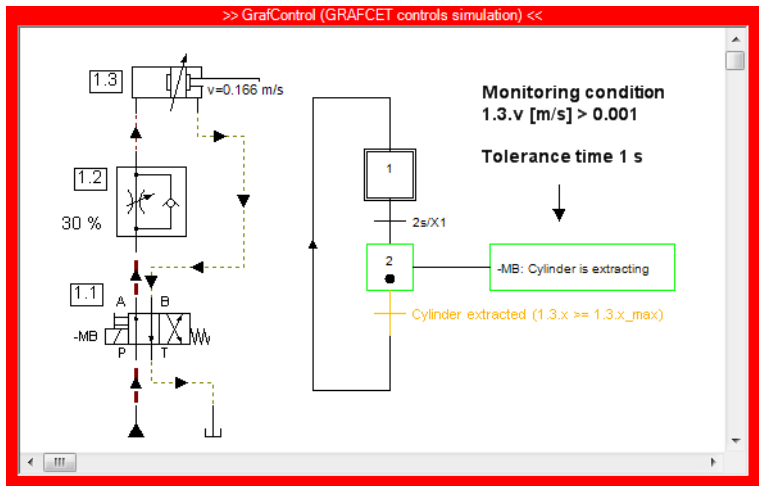
Figure 10/26: Simulation with GRAFCET monitoring

Now close the one-way flow control valve. The solenoid valve still switches over as a result of the GRAFCET action, but the cylinder cannot advance now. The monitoring condition of the action is now violated and the action is marked in yellow to indicate this violation.
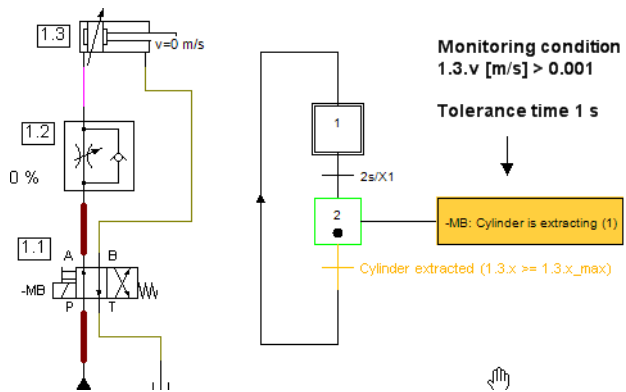
Figure 10/27: Simulation with GRAFCET monitoring

After the set tolerance time of one second, the violated condition is categorized as failed, the action is marked red, and the simulation goes into pause mode.
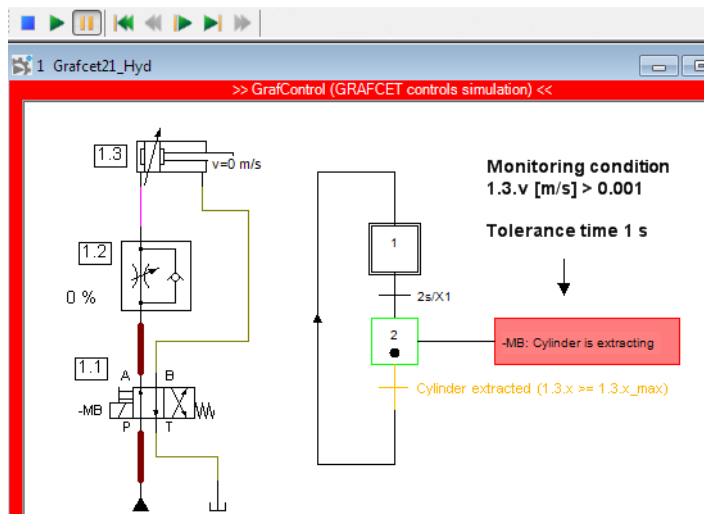
Figure 10/28: Simulation with GRAFCET monitoring

10.6 Quick reference for the FluidSIM-relevant GRAFCET concepts

The next sections introduce all GRAFCET concepts that are related to FluidSIM.

10.6.1 Initialization

All the variables in a GRAFCET are preset with the value "0" at the start of the simulation.

10.6.2 Sequence rules

— A transition is considered released once all the immediately preceding steps are active. A transition is triggered once it has been released and its condition has the value "1". A transition with the value "1" is shown in green in FluidSIM, regardless of whether the step linked to it is active or inactive.

— The relevant transition is triggered at the same time and does not take any time.

— Since triggering a transition does not take any time, a step can be activated and deactivated at the same time (even across various intermediate steps). An active step remains active in this situation. A loop of steps is only run through once at one point in time (see example: `Grafcet/Grafcet06.ct`).

10.6.3 Sequence selection

A step can branch off into various partial sequences. In the GRAFCET specifications, these partial sequences have to be exclusive. Since this can generally only be checked during the sequence, this exclusivity is not required in FluidSIM (see example: `Grafcet/Grafcet07.ct`).

10.6.4 Synchronization

The GRAFCET synchronization component can be used to implement synchronizations (see example: `Grafcet/Grafcet08.ct`).

10.6.5 Transient sequence / unstable step / virtual triggering

As described in Sequence rules, triggering a transition does not take any time. As a consequence of this, multiple consecutive steps can be activated at the same point in time one after the other. This sequence is called transient (continuous).

The intermediate steps in the sequence chain are referred to as unstable. The continuously effective actions connected to them are not displayed in the simulation. The allocations in the stored effective actions are carried out. Triggering the intermediate steps and their associated transitions is called virtual triggering (see example: `Grafcet/Grafcet06.ct`).

10.6.6 Determining the values of GRAFCET variables

Variables of continuously effective actions (allocations) receive the value "1" if the corresponding action is linked to an active step and any action condition present has the value "1".

Variables of stored effective actions (assignation) are changed if the corresponding action is linked to an active step and the relevant action event occurs (e.g. action on event or on activation).

FluidSIM does not check whether the two types of variable identification contradict each other for a variable. If this case occurs, the variable value is determined by an internal calculation, which the user cannot predict (see example: `Grafcet/Grafcet09.ct`).

10.6.7 Checking the entries

FluidSIM checks the validity of entries for conditions and assignations. If this kind of term does not match the specifications, the

term in question is displayed in red. The simulation is only released once all the terms are valid.

10.6.8 Admissible characters for steps and variables

Steps and variables cannot contain any spaces. Function names that can be used in a GRAFCET expression are not permitted.

There are no limitations for the descriptions that can be shown for conditions and actions, because these are only displayed and are not used for simulation.

10.6.9 Variable names

There are four different types of variables. All variables can be used in conditions and assignations.

Action Variables

Action variables are available throughout GRAFCET and can be set in actions (see example: `Grafcet/Grafcet10.ct`).

Step Variables

Step variables are inserted automatically for each step and have the value "1" when and only when the corresponding step is active. Step variables have the form X + "step name". If, for example, the step name is "12", then the associated variable is "X12". Step names are only ever valid within a partial GRAFCET or within the global GRAFCET. This means that the same step name can be used in different partial GRAFCETs. In order to be able to address step variables across partial GRAFCETs in FluidSIM, the step variable has to be preceded by the partial GRAFCET name. Example: Partial GRAFCET "1" contains step "2" and is meant to be addressed in the global GRAFCET. Within the global GRAFCET, the step variable name "G1.X2" has to be used. Within partial GRAFCET "1", "X2" is enough (see example: `Grafcet/Grafcet11.ct`). Variables of macro-steps have the form XM + "step name", macro inputs have XE + "step name" and macro outputs have XS + "step name" (see example: `Grafcet/Grafcet15.ct`).

Partial GRAFCET Variables	Partial GRAFCET variables are automatically inserted for each partial GRAFCET and have the value "1" when and only when at least one step in the corresponding partial GRAFCET is active. Partial GRAFCET variables have the form XG + "partial GRAFCET name". If, for example, the partial GRAFCET name is "1", the associated variable is "XG1" (see example: `Grafcet/Grafcet12.ct`).
Variables of circuit components	The variables of circuit components can be used in GRAFCETs as input and output variables (see "Access to variables of circuit components").

10.6.10 Functions and formula entry

A range of functions can be used in conditions and assignations. These functions are displayed according to the GRAFCET specifications (e.g. upwards arrow for rising edge). Entering GRAFCET-specific functions is supported by the buttons in the dialogues with the relevant labels:

— "+" (logical OR)

— "*" (logical AND)

— "NOT" (logical NOT)

— "RE" (rising edge)

— "FE" (falling edge)

— "s / / s" (delay)

— "s /" (delay, short form)

— "NOT(s /)" (time limit)

If the functions "NOT", "RE" or "FE" refer to a term, the term has to be placed in brackets.

Examples:

NOT a

NOT (a + b)

RE X1

RE (X1 * X2)

The following additional mathematical functions are available:

— abs (absolute amount)

— sign (algebraic sign: +1, 0, -2)

— max (maximum of two numbers)

— min (minimum of two numbers)

— ^ (to the power of, e.g. a^3)

— sqrt (square root)

— exp (to the power of constant "e")

— log (natural logarithm)

— sin (sine)

— cos (cosine)

10.6.11 Delays / time limits

Delays have the following form (see example:
`Grafcet/Grafcet03.ct`):

"Time in seconds" s / "Boolean term" / "time in seconds"

or

"Time in seconds" s / "Boolean term"

Examples:

1 s / X1 / 2s 3s/X3

Time limits have the following form:

NOT ("time in seconds" s / "Boolean term")

Example: NOT(6s/X28)

In addition to "s" for seconds, the following units of time can also be used.

— d (days)

— h (hours)

— m (minutes)

— s (seconds)

— ms (milliseconds)

Time specifications can also be combined, e.g. "2s500ms" for 2.5 seconds.

10.6.12   Boolean value of an assertion

In GRAFCET, you can use Boolean values to calculate an assertion, for example: a counter "C" should be larger than 6 and step "X1" should be activated. "C" is larger than "6" can be calculated as with a variable. To do this, the assertion has to be set in square brackets. So in this example:

[C › 6] * X1

If a Boolean assertion is positioned on its own in a condition, then you can omit the square brackets in FluidSIM, for example C › 6 instead of [C › 6]. (See example:**Grafcet/Grafcet13.ct**)

10.6.13 Target information

If you want to interrupt an operative connection from a transition to a step, you can enter the name of the target step in the transition's properties dialogue (see example: `Grafcet/Grafcet14.circ`).

10.6.14 Partial GRAFCETs

Partial GRAFCETs can be used to separate a GRAFCET into different hierarchy levels. This function is most often used for enclosing steps and compulsory commands. The name of a partial GRAFCET is always preceded by a "G".

In order to determine partial GRAFCETs in FluidSIM, the partial GRAFCET frame has to be placed over the relevant GRAFCET part and you have to assign a name in the properties dialogue. The preceding "G" is not part of the name that you have to enter; it is added automatically by FluidSIM and shown at the bottom left of the partial GRAFCET frame. You can alter the size of the partial GRAFCET frame by dragging its edges with the mouse (see example: `Grafcet/Grafcet11.ct`). It is important that all the elements of the partial GRAFCET are located entirely within the relevant frame and that there are no "foreign" elements overlapping the frame.

10.6.15 Macro-steps

Macro-steps can be specified using a step's properties dialogue. The preceding "M" is not a part of the name that you have to enter; it is added automatically by FluidSIM. You can specify macro inputs and macro outputs in the same way. The preceding "E" and "S" in these cases are not part of the name either and are automatically added by FluidSIM (see example: `Grafcet/Grafcet15.circ`).

10.6.16   Compulsory commands

Compulsory commands can be used to control partial GRAFCETs regardless of their normal sequence. There is an entry mask to help you enter these commands in FluidSIM. There are four types of compulsory command. They are shown here using four examples (see example: `grafcet/Grafcet16.circ`).

G12 {8, 9, 11}

Setting a specific situation. This example activates steps 8, 9 and 11 of partial GRAFCET 12.

G12 {*}

Freezing a partial GRAFCET. In this example, the current situation for partial GRAFCET 12 is maintained as it is. No further transitions are triggered.

G12

Setting a blank situation. All steps in partial GRAFCET 12 are deactivated in this example.

G12 {INIT}

Setting the initial situation. In this example, the steps in partial GRAFCET 12 that are marked as initial steps are activated.

10.6.17   Enclosing step

Enclosing steps can be specified using a step's properties dialogue. You can either enter the enclosed partial GRAFCETs directly or select them from a list. You have to separate individual partial GRAFCETs with a comma or a blank space.

During simulation, the name of the enclosing step is shown at the top left of the partial GRAFCET frame, as soon as the step is activated (see example: `Grafcet/Grafcet17.ct`).

You have to set the "*Activation link*" field in the properties dialogue for steps within the enclosed partial GRAFCET that you wish to activate when the enclosing step is activated.

10.6.18   Action when a transition is triggered

An action on triggering is a stored effective action which is executed when the transition connected to the action is triggered. The action is usually connected to the transition by a straight line (see example **Grafcet/Grafcet20.circ**).

Dimension

Chapter 11

FluidSIM allows both automatic and manual dimensioning.

11.1 Draw dimension

The buttons

⊢⊣ | Horizontal |

⊥ | Vertical |

⤢ | Align |

◿ | Angular |

⤙ | Flag |
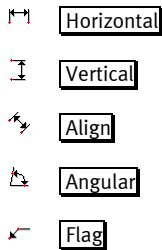
activate the corresponding mode for drawing the dimension arrows. Alternatively you can also access the dimensioning functions in the | Draw | menu under | Dimension |.

Horizontal, vertical and diagonal dimensioning is done by defining two points for the distance as well as then clicking to position the dimension text. Angular dimensioning requires the center point to be defined as well as two points for the angle. The fourth click in turn defines the position of the dimension text. The | Flag | dimension function can also be used for general labeling of important points in the circuit. Two points for a line with any pitch and a final click for the text are needed for this.

11.2 Settings for the dimension

Figure 11/1: *Dimension* dialog window

Layer	Defines the drawing layer for the dimension.
Automatic Dimensioning	Activates or deactivates automatic adaptation of the dimension when the dimension length is changed.
Length	If the *Automatic Dimensioning* option is deactivated you can enter any number that will be displayed as the length dimension. A unit can also be selected. *Show Unit* defines whether the unit should be displayed.
Decimals	Defines the number of decimal places.
Factor	Determines the factor by which the real length is multiplied for the displayed value. This is necessary if you are creating a drawing with a scale other than 1:1.
Color	Defines the color for the dimension.

Line Style   Defines the line style for the dimension.

Line Width   Defines the line width for the dimension.
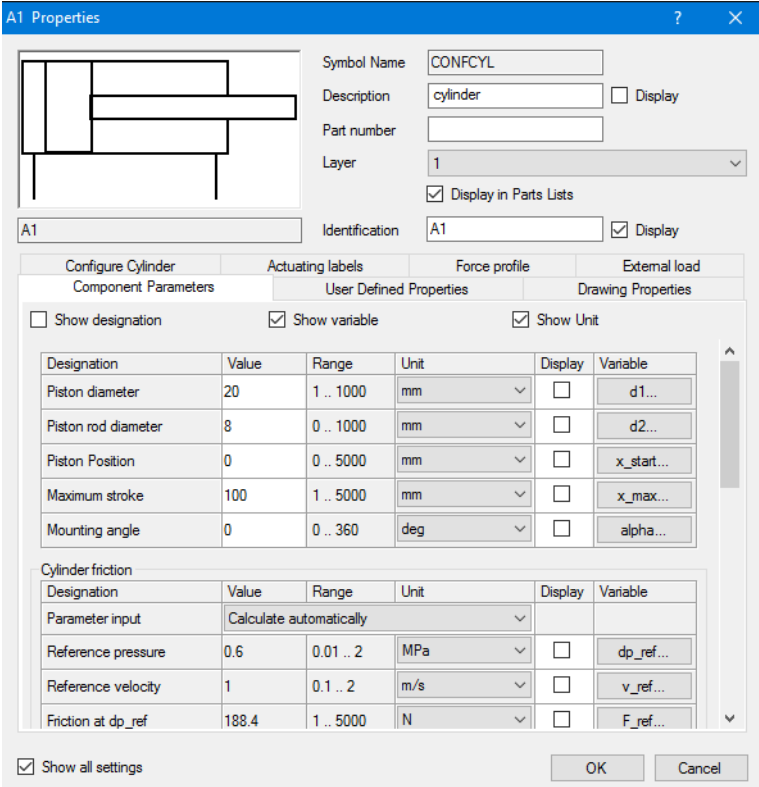
                              Dimensions, like all other objects in FluidSIM, can be moved, rotat-
                              ed, mirrored and scaled. The display value of the dimension is
                              automatically adapted during scaling if the *Automatic Dimension-
                              ing* option is activated.

Component attributes

Chapter 12

The FluidSIM circuit symbols largely correspond to the components in the equipment sets from Festo Didactic SE. The parameters of the components are also entered accordingly in FluidSIM. Open the *Properties* dialog window for a component by double clicking a symbol or by opening the Edit menu and selecting Properties... .

12.1 Component attributes in the *Properties* dialog window

Figure 12/1: *Properties* dialog window for a component:

The properties of a component are saved in attribute value pairs. The attributes are divided into different groups. The first group contains the general properties:

Figure 12/2: Detail from the *Properties* dialog window for a component: General properties

Symbol Name	Displays the name of the circuit symbol. The symbol name is mapped to appropriate products in the Festo product catalog. Users cannot edit the symbol name.
Description	Contains a more detailed description or the complete name of the circuit symbol where applicable. Users can edit this. The identification is shown as text in the circuit drawing if the "*Display*" option is selected.
Part number	The part number uniquely identifies a product within parts lists.
Layer	In this selection list you define the drawing layer for the symbol. Depending on the setting for the drawing layer it may not be possible to display or edit the symbol. In order to make the symbol visible or change the settings you have to temporarily activate the drawing layer on the Drawing Layers... menu item from the View menu.
Identification	Here you can assign an identification that uniquely identifies the component in the circuit diagram. The identification is shown as text in the circuit drawing if the "*Display*" option is selected. Note: FluidSIM automatically assigns a unique identification when inserting or copying circuit symbols. An automatically assigned identification text begins with a question mark and can be edited by the user (FluidSIM shows a warning if you are assigning an identification that already exists).
Display in Parts Lists	Deactivate this option if you do not want the symbol to appear in the parts list.

12.2 User Defined Properties

You can enter your own component attributes in the "*User Defined Properties*" tab.

Figure 12/3: Detail from the *Properties* dialog window for a compo-
nent: *User Defined Properties* tab

In order to edit an entry the corresponding row must be selected by
clicking on it. Clicking on the table cell to be modified again then
enables you to edit the entry in the cell.

A row can be deleted by first clicking the row to highlight it. The
highlighted row can then be deleted using the Del key.

You can add any desired attributes by filling out the empty cells on
the last row.

12.3 Drawing Properties

You can enter a number of drawing properties that influence how the symbols are displayed in the circuit diagram in the "*Drawing Properties*" tab.

Figure 12/4: Detail from the *Properties* dialog window for a component: *Drawing Properties* tab

Position	Defines the coordinates of the upper left corner.
Scale	Defines the scaling in the x or y direction. The scaling factor can also be defined with the help of the mouse pointer. This is described in the "Scale symbols" section.
Rotation	Defines the angle of rotation in degrees. The angle of rotation can also be defined with the help of the mouse pointer. This is described in the "Rotate symbols" section.
Override Color	If this option is activated then another color can be selected for the symbol.

Reset   Resets the geometrical settings to the default values: Scaling to 1,
                             rotation to 0 and "*Override Color*" deactivated.

12.4 Main and secondary components

As described under Component attributes in the *Properties* dialog
window, the FluidSIM circuit symbols largely correspond to the
components in the Festo product catalog. These symbols are called
main components. However there are also secondary components,
which do not correspond to components in the Festo product cata-
log. These secondary components are usually symbolic representa-
tions of a partial aspect of an associated main component.

All product properties are stored in the main component. The
secondary components only have a description and a reference to
the associated main component. In electrical engineering in par-
ticular, components such as relays are divided into main and sec-
ondary components where the coil is the main component and the
contacts are the secondary components.

12.5 Linking main and secondary components

Main and secondary components are linked using the symbol for
the secondary component. The circuit diagram detail shows a relay
comprising a coil as the main component and two contacts as the
secondary components. The contacts are to be linked with the coil.
This information is evaluated when displaying the contact image.
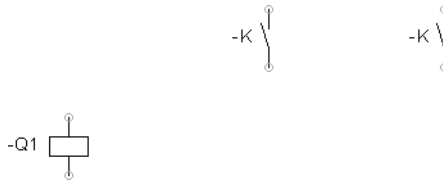
Figure 12/5: Relay comprising coil with two contacts

The symbol identifications are the defaults used in FluidSIM. The symbols are not linked together yet.

⸱⸱⸱⸱> Open the corresponding properties dialog window by double-clicking a contact.

Figure 12/6: Properties dialog window for a contact

Description   Defines a description for the secondary component. In the case of a contact, this is shown in the terminal diagram.

Contact number	You can enter a contact number here, which can, optional, be shown with the designation. To show the contact number by default, activate the corresponding option in General.
Triggered by	FluidSIM recognizes delay switches, limit switches, and pressure switches by the nature of their usage and by their labels and supplies the corresponding symbol for the switch in the electrical circuit The representation of switches that are actuated by cylinders can be determined by selecting the corresponding switch type in the component's properties dialog.
Main Component	A compatible main component can be selected from a list. The main component identification can also be entered directly as text.
Browse...	Opens a dialog that shows all compatible main components as a tree in accordance with the object hierarchy.
Link	If this box is checked then the secondary component is logically linked with the main component. If the main component is then renamed, the link is retained and the identification of the linked secondary component is adapted as appropriate to the main component identification.
Find Target...	If the secondary component is logically linked with a main component, a search can be performed for the associated main component using this button.
Display	If this box is checked then the main component's identification is shown as the identification for the secondary component.

⋯⋯⟩ Select "Q1" from the list of compatible main components. Proceed in the same way for the second contact.

Selecting from the list of compatible main components automatically establishes the logical links between the contacts and the coil. The circuit diagram should now look as follows:
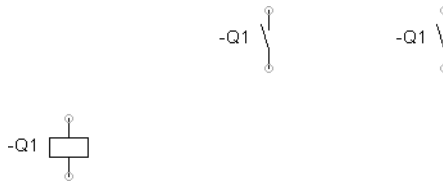
Figure 12/7: Relay comprising coil with two contacts

If you now change the coil identification to "Q2", the logical links mean that the identifications at the contacts will also be automatically changed to "Q2".

Examples of this are relays with the coil as the main component and the contacts as secondary components as well as electromagnetic directional control valves with the pneumatic symbol as the main component and the valve solenoids as secondary components in the electrical part of the circuit diagram.

12.6 Link solenoid valves and solenoid coils

The coils belonging to solenoid valves are usually displayed separately in the electrical part of a circuit diagram. The link between a solenoid valve and the associated coils is defined at the solenoid valve symbol.

The following circuit diagram shows a solenoid valve and the symbols for two separate solenoid coils. No link has been established yet between the solenoid valve and the coils.
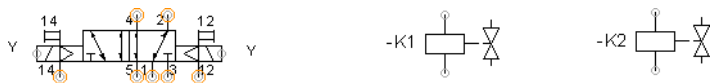
Figure 12/8: Solenoid valve and two separate coils

There are two ways of establishing a link between a solenoid valve and a coil. The first is using the properties dialog window for the solenoid valve.

⋯⋯⋋ Open the appropriate properties dialog window by double-clicking the solenoid valve and select the *Connector Labels* tab.
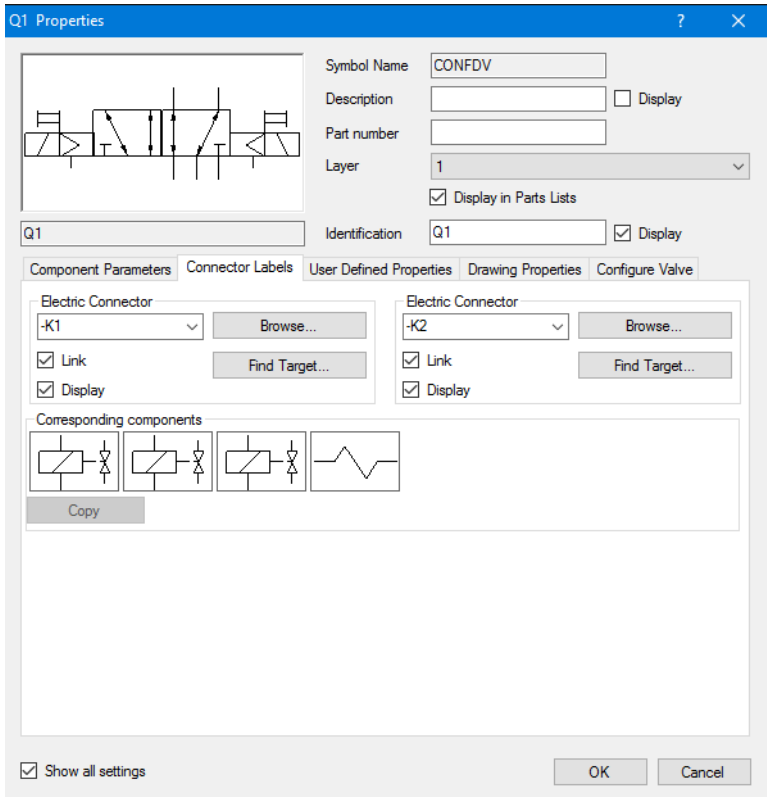
Figure 12/9: *Properties* dialog window, *Connector Labels* tab

This tab shows all of the solenoid valve's connectors. Connectors refer, among other things, to the logical connection options for the solenoid coils. The input fields of the left-hand electric connector are described below. The descriptions apply analogously to the right-hand connector and other types of logical connectors.

Electric Connector (Left)	The identification for the left-hand solenoid coil can be entered in this list box or selected from a list. When you click in this field the corresponding connector is highlighted in the preview. This helps to locate the connector, particularly when dealing with turned or mirrored symbols.
Browse...	Opens a dialog that shows all compatible solenoid coils as a tree in accordance with the object hierarchy.
Link	If this box is checked then the solenoid coil is logically linked with the connector at the solenoid valve. If the solenoid coil is renamed the link is retained and the identifications of the coils at the solenoid valve are changed to match the coil identifications.
Find Target...	If the connector at the solenoid valve is logically linked with a coil a search can be performed for the associated coil using this button.
Display	If this box is checked the coil's identification is shown as the identification for the solenoid valve connector.
Corresponding components	Provided that the valve if electrical actuated, this list contains all components, which can be combined with this valve connector in the electrical part of the circuit. You can select the object you want to use and copy it to the clipboard to insert it into the circuit directly. Of course, you can also select the corresponding valve solenoid from the component library later.

⤑ Select "-K1" from the list of compatible solenoid coils.
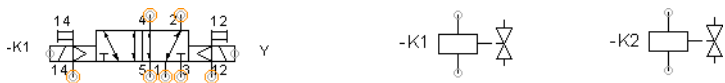
Figure 12/10: Left connector linked with coil "-K1"

The second way of linking a solenoid valve with a coil is to double-click the solenoid valve's connector directly. The coil connectors are represented like pneumatic connectors within the solenoid valve by means of small circles.

⤑ Double-click the right connector of the solenoid valve.

A dialog window whose fields correspond to the entries for a con-
nector in the *Connector Labels* tab of the *Properties* dialog window.
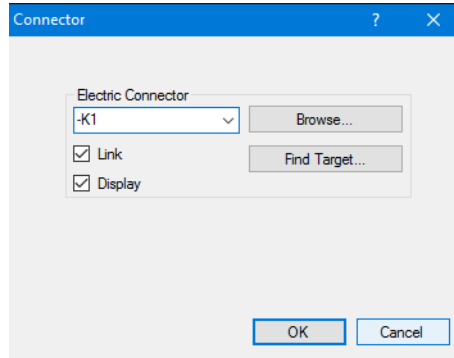
Figure 12/11: *Connector* dialog window

⤑ Select "-K2" from the list of compatible solenoid coils.

The (electric) connectors of the solenoid valve are now linked with
the solenoid coils.
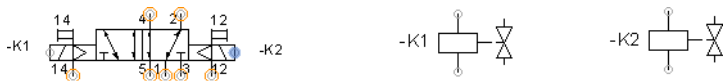
Figure 12/12: Link solenoid valve and solenoid coils

12.7 Attributes of the text components

In FluidSIM text components serve, firstly, to insert comments and
labels and, secondly, can be defined by the labels and accessories
without displaying a symbol. Open the dialog window *Properties* of
the text component by double-clicking on a text or via the Proper-
ties... menu item on the Edit menu.
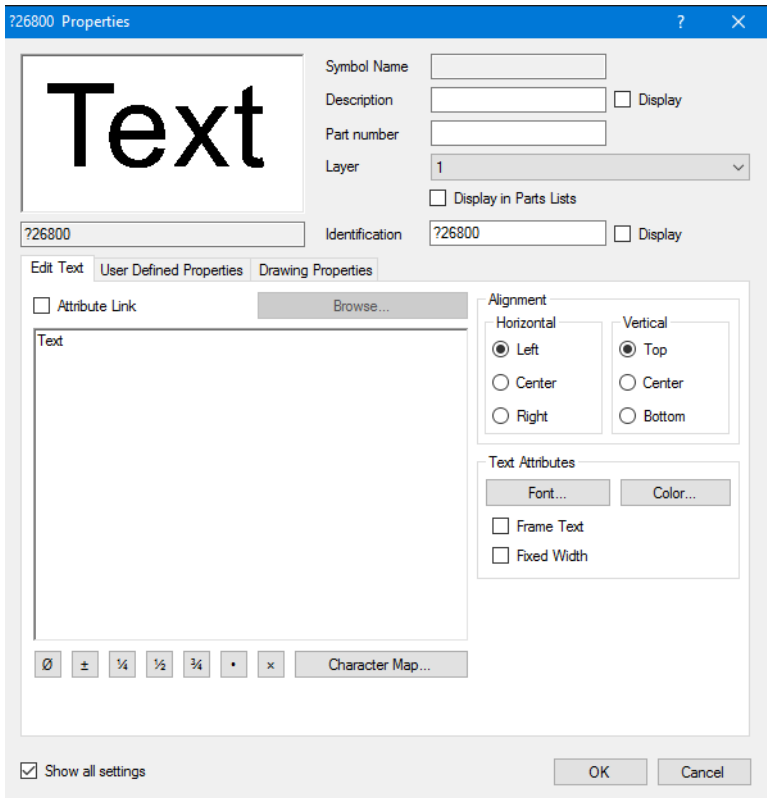
Figure 12/13: *Properties* dialog window for a text component:

A text component possesses all of the attributes of a standard component. The text properties are located on the "*Edit Text*" tab.
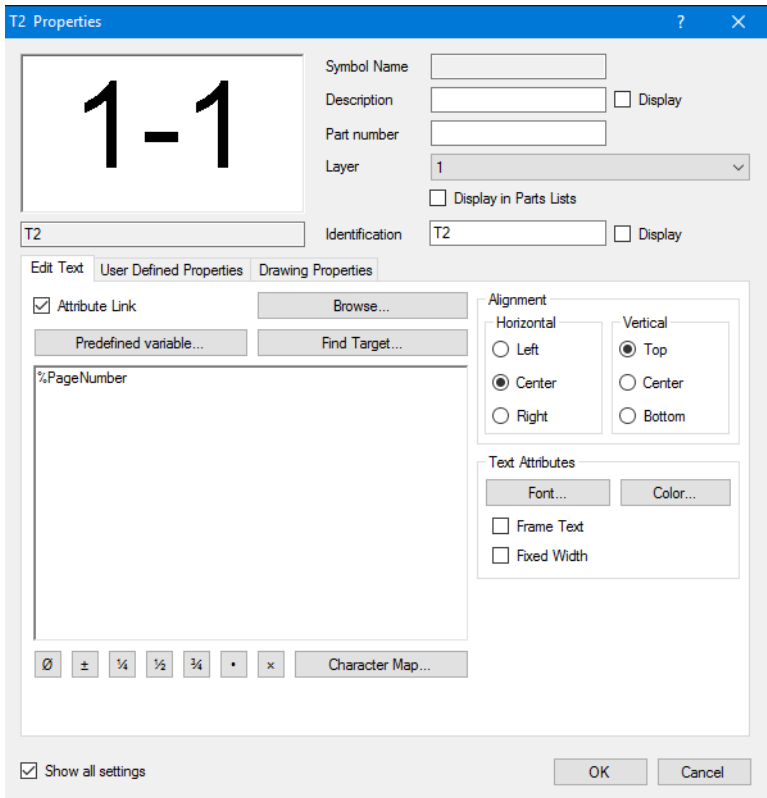
Figure 12/14: Detail from the *Properties* dialog window for a text component: *Edit Text* tab

Edit Text

Enter your text into the input field on the left-hand side. You can also enter text with multiple lines. Press the ⸢Enter⸥ key to create a line break.

Alignment

Defines the horizontal or the vertical alignment of the text within the text field.

Font...	Defines the text font.
Color...	Defines the text color.
Frame Text	Draws a frame around the text field.
Fixed Width	By default, FluidSIM adjusts the width of the textbox corresponding to the content. When using tables it might be useful if the space, which is reserved for the text, is fixed. Activating this option will swage the text in the given box, when it would usually require more space.
Attribute Link	If this option is activated a text that identifies a link to an attribute is displayed instead of the text entered. The value of the selected attribute is displayed in the circuit diagram. You can find a detailed description of this function under Link text components with attributes. A predefined placeholder such as the page number can also be selected using the Predefined variable... button.

12.8 Link text components with attributes

Text components can also display attributes of other components, values of predefined placeholders, attributes of a circuit or the project. The text component must be linked to the corresponding attribute for this. The linked attribute is defined in the input field of the "*Edit Text*" tab in the *Properties* dialog window for the text component. The activated *Attribute Link* option defines that the text in the text field should not be displayed but rather interpreted as a link.

Example:

Assuming that your project is called "Project1" and possesses the "Supplier" attribute with the value "Festo". You project contains the "Circuit1" circuit and you would like to display the value of the "Supplier" attribute, in this example namely the value "Festo", in this circuit diagram.

⤙⤐ Insert a text component into the circuit drawing by selecting the text element on the drawing elements toolbar and then left-clicking the circuit drawing. The *Properties* dialog window for the text component then opens.

Note: You can open the dialog window of an existing text component by double-clicking it or using the Edit menu and the Prop-erties... menu item.

⤙⤐ Activate the *Attribute Link* option and then click the Browse... button.

A window opens displaying the hierarchy of all of the available attributes. Please note that only those objects are listed that have an identification assigned by the user. Identifications beginning with a question mark "?" are not listed. These are identifications that have been automatically assigned by FluidSIM. The desired attribute is located under "*Attribute Tree*" - "Project1" - "Supplier".
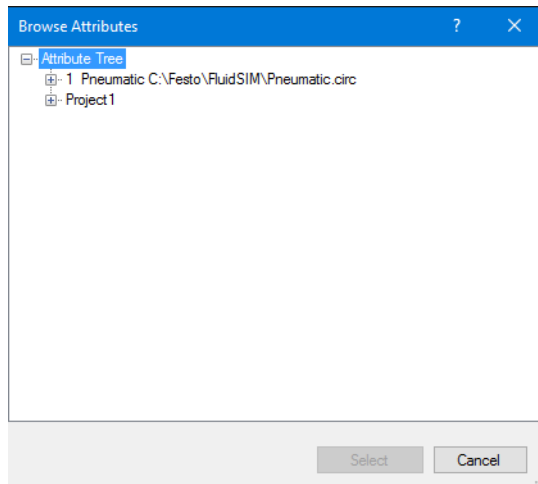
Figure 12/15: *Browse Attributes* dialog window

⤙⤐ Select "Supplier" and then click the Select button.

The "Project1.Supplier" value is displayed in the input field and "Festo" in the preview. The complete and unique name of the attribute contains all of the hierarchy levels beginning at the project. The individual layers in the name are separated by a full stop. It is also possible to enter only the attribute name into the input field. In this example: "Supplier". The hierarchy is then searched from the bottom up for the attribute, beginning with the text components. If the attribute searched for is not found in that component then the circuit and then the project are searched for the attribute.

If the attribute is not found then the attribute name is displayed in the circuit diagram in angle brackets. The missing attribute can be created at a later point in time. The link is then created automatically.

The concept of linking text components with attributes is also utilized for labeling von drawing frames.

12.9 Text components with specified links

Text components are automatically generated for displayable component attributes and connector labels which are linked to the corresponding attributes. Open the *Display Attribute* dialog window with which you can adjust how the text is displayed by double-clicking on the text component or via the Properties… menu item on the Edit menu.
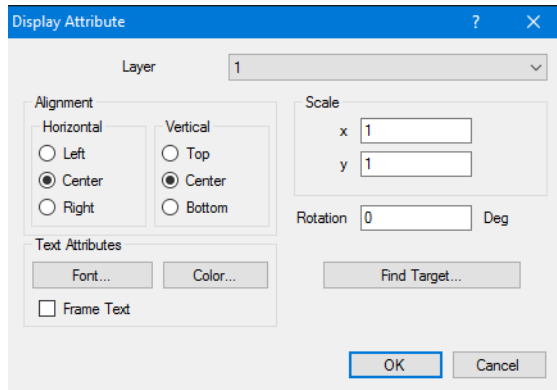
Figure 12/16: *Display Attribute* dialog window

Alignment	Defines the horizontal or the vertical alignment of the text within the text field.
Scale	Defines the scaling factor of the text in the x or y direction.
	Note: You can also change the text size by selecting another font size in the font type dialog window. You open this dialog window using the Font... button under *Text Attributes*.
Rotation	Defines text's angle of rotation in degrees.
Font...	Defines the text font.
Color...	Defines the text color.
Frame Text	Draws a frame around the text field.
Find Target...	The target of a linked text is the attribute which the text refers to. This button opens the *Properties* dialog window of the object which contains this attribute.

12.10 Change the properties of multiple objects simultaneously

If multiple objects are selected, choosing the [Properties...] menu item on the [Edit] menu opens a dialog window with a limited selection of properties. It only contains those properties which meaningfully relate to all of the selected objects. This enables you to change the font for multiple texts in a single operation, for example. The more different object types (symbols, connectors, drawing elements, texts, etc.) that are selected, the less common properties are available.

The following tabs are available for the common properties depending on the objects highlighted.

12.10.1 Drawing Properties

The dialog elements available within a tab depend on the objects highlighted.
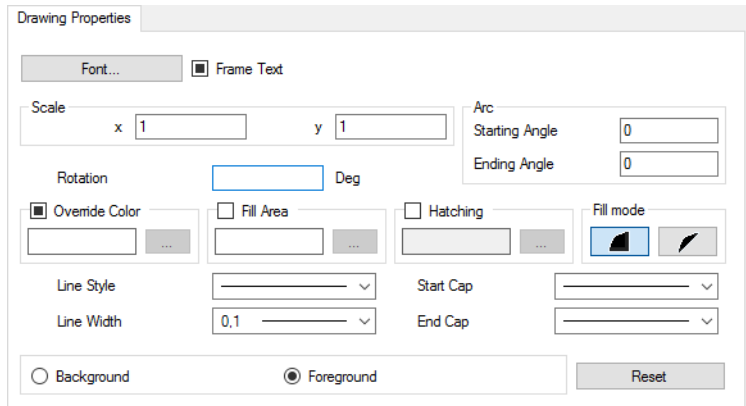
Figure 12/17: *Properties* dialog window, *Drawing Properties* tab: several highlighted objects

Font...	Defines the font type of the text.
Frame Text	Draws a frame around the text field.
Scale	Defines the scaling factor of the text in the x or y direction.
Rotation	Defines the angle of rotation of the text field in degrees.
Override Color	Defines the color of the drawing element.
Line Style	Defines the line style.
Line Width	Defines the line width.
Start Cap	Defines how the beginning of the line is displayed.
End Cap	Defines how the end of the line is displayed.
Background	Sets the location of the drawing element to the background. This means that all of the circuit symbols are on top of this. In particular this means that symbols are not covered by filled drawing elements, for example.

Foreground	Sets the location of the drawing element to the foreground. This means that all of the circuit symbols are underneath this. In particular it means that symbols are covered by filled drawing elements, for example.
Reset	Reset the settings to the default values.

12.10.2 Main Component
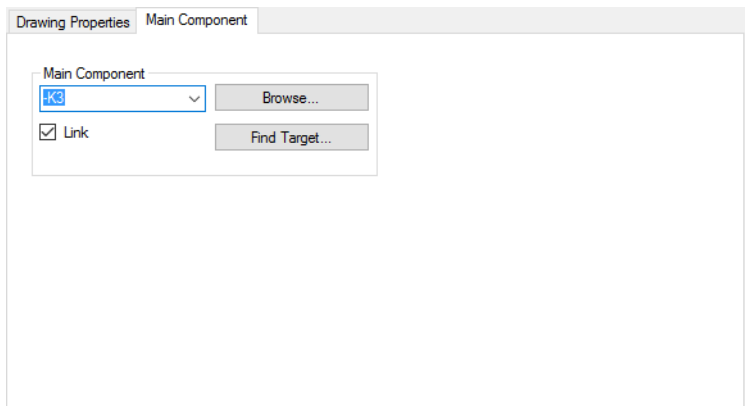
Figure 12/18: *Properties* dialog window, *Drawing Properties* tab: several highlighted objects

Main Component	A compatible main component can be selected from a list. The main component identification can also be entered directly as text.
Browse...	Opens a dialog that shows all compatible main components as a tree in accordance with the object hierarchy.
Link	If this box is checked then the secondary component is logically linked with the main component. If the main component is then renamed, the link is retained and the identification of the linked secondary component is adapted as appropriate to the main component identification.

Find Target...   If the secondary component is logically linked with a main compo-
                                 nent, a search can be performed for the associated main compo-
                                 nent using this button.

Failure models and failure configuration

Chapter 13

Just as you can select component parameters, you can also select predefined failure models for the simulation for a range of components. This makes it possible to simulate circuit diagrams with defective components. The possible failure models are saved with the components and cannot be modified or expanded by the user. Failure models can be defined using failure configurations.

13.1 Failure configurations

A failure configuration is a selection of failures that can be grouped together under one name. A number of configurations can be saved with a circuit diagram or a project. During a simulation, it is possible for teaching purposes to use virtual measuring instruments to find a failure and to repair it with the repair tool. There is a range of options that can be used to set how the repair can be carried out and what feedback the students receive.

The failure configurations are saved together with the circuit diagram or project.

You can use the menu Diagnosis Manage failure configurations... to manage the individual configurations and general settings. The following dialog window opens.
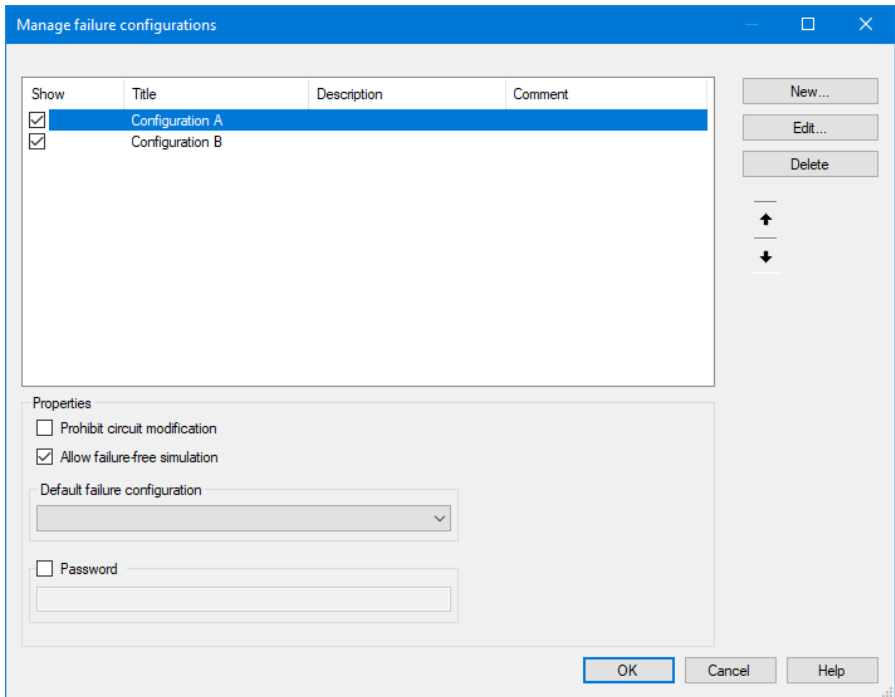
Figure 13/1:

List of failure configurations	Contains the defined failure configurations. Each configuration includes a selection of failures and options that define the type of repairs possible. The titles of the configurations are displayed in a list in the toolbar if the *Display* option is selected. The list can be sorted using the failure symbols.
New...	Creates a new configuration and opens the dialog window containing the configuration settings. Every configuration must be given a title.
Edit...	Opens the dialog window containing the settings for the selected configuration.

Delete	Deletes the selected configuration.
Prohibit circuit modification	Prevents the circuit diagram from being modified when this failure configuration is selected. Please note that this setting only takes effect the next time the circuit diagram is opened.
Allow failure-free simulation	Defines whether only the specified failure configurations can be simulated or if a failure-free simulation can be carried out as well. If this option is active, the failure-free simulation can be selected by selecting the entry "-" from the list of failure configurations in the toolbar.
Default failure configuration	Defines the configuration that is selected when a circuit diagram or project is loaded.
Password	Defines the password that needs to be entered before failure configuration management can be opened. If the password is not entered, the user can only select a failure configuration and simulate it.

When you select ⏍New...⏍ or ⏍Edit...⏍ the following dialog window opens, where you can manage a particular failure configuration.
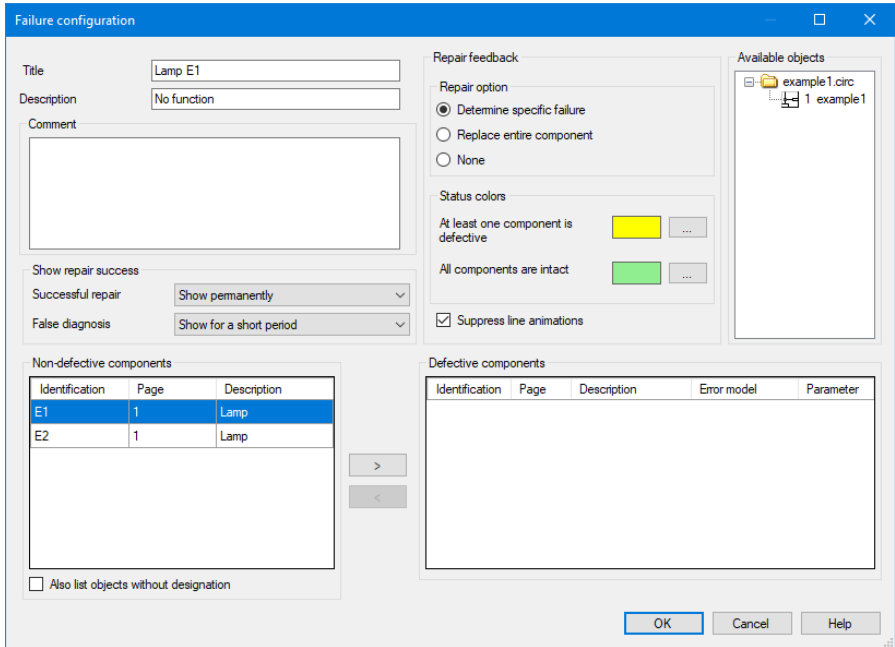
Figure 13/2:

Title	The title of the configuration is displayed in a list in the toolbar. Every configuration must be given a unique title.
Description	The description is displayed during the simulation together with the title along the top edge of the window.
Comment	The comment can be used to describe the configuration in more detail. It is used only in this dialog window and in the selection dialog window.

Various options can be used to set how a repair can be carried out and how feedback should be provided when repair is completed.

Repair option – - – Determine specific failure	When the user attempts a repair, a list of possible failures opens. The selected component will only be repaired if the selected failure matches the saved failure.
Repair option – - – Replace entire component	The user attempts a repair with a single click, without having to select a specific failure. This equates to a complete replacement of the component.
Repair option – - – None	If this option is selected, repair of defective components is not possible.
	When a failure configuration is used during a simulation, a status line is displayed at the top edge of the window. This line contains the title and description of the selected configuration. The status line also has a color which varies depending on the following options.
Status colors – - – At least one component is defective	The status line is highlighted in the color specified until all the defective components have been repaired.
Status colors – - – All components are intact	The status line is highlighted in the color specified when all the defective components have been repaired.

! If you do not want to visibly indicate that a repair has been completed, select the same color for both options.

Suppress line animations	Ordinarily, the user should use measuring instruments to analyze which components are defective. In FluidSIM, pressures and electrical potentials are normally indicated during the simulation by colors, which could render the use of measuring instruments superfluous under some circumstances. This option can be used to switch off the line animations.
	Every time the user attempts to repair an individual component, a symbol can be used to indicate whether the attempted repair was successful. A successful repair is marked by a green "OK" check mark and a false diagnosis is marked by a red "X" symbol. The duration of the marking can be set with the following options.
Show permanently	The marking is displayed permanently.
Show for a short period	The marking is displayed only for a few seconds and is then hidden again.

Do not show	The attempted repair is not marked at all.

The two lists, *Non-defective components* and *Defective components*, list the components of the circuits selected via the tree shown under *Available objects*. You can use the arrow buttons to move the components between the two lists.

The *Defective components* list contains the components of the failure configuration to which a specific failure can be assigned. This is done via a drop-down list in each row. If a failure requires additional parameters, the values can be set via the *Parameter* button.

Also list objects without designation	If this option is active, all the components are listed in the *Non-defective components* list. For greater clarity, normally only components with designations are listed.

13.2 Create failure configuration

In the following, a simple example is used to show how a failure configuration can be created. The following circuit diagram is used in the example.
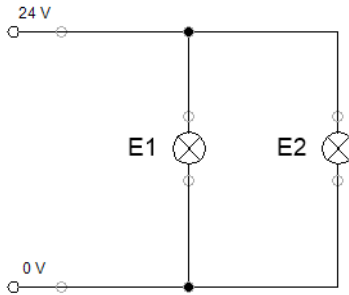
Figure 13/3:

⤏ Use the menu Diagnosis Manage failure configurations... to open the dialog window for managing the failure configuration.
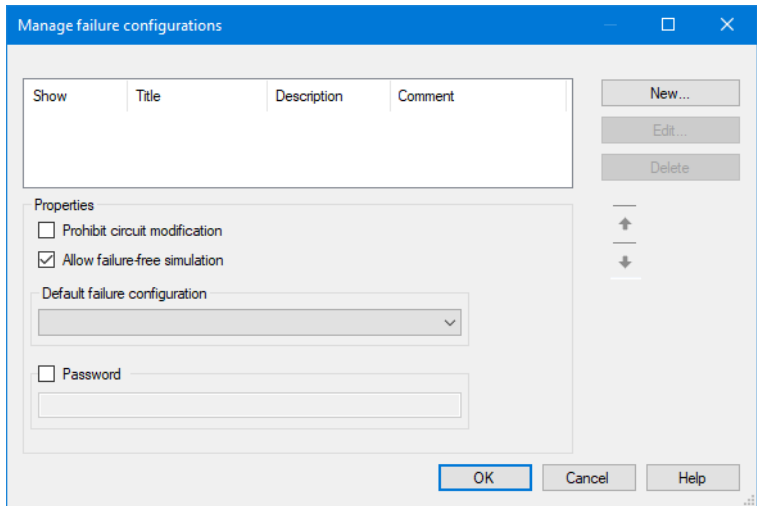
Figure 13/4:

The dialog window contains the general options for all failure configurations for this circuit diagram. For example, deselect *Allow*

failure-free simulation if you only want to simulate the failure configurations you have defined.

┈┈> Use the New... button to create a new failure configuration. The following dialog window then opens.

Figure 13/5:

┈┈> Enter a title and description.

The title of the selected configuration is displayed in the toolbar.
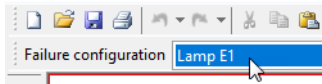
Figure 13/6:

   To make it easier for you to find the components in the displayed lists, you should previously assign designations to them. The *Non-defective components* list is preset to display only the components with designations.

⋯⋯> Select the lamp E1 and use the **"›"** button to move it into the *Defective components* list.
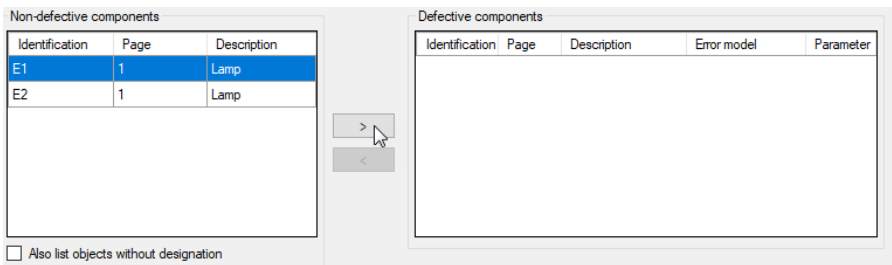
Figure 13/7:

⋯⋯> From the failure model list, select the failure *Filament blown*.
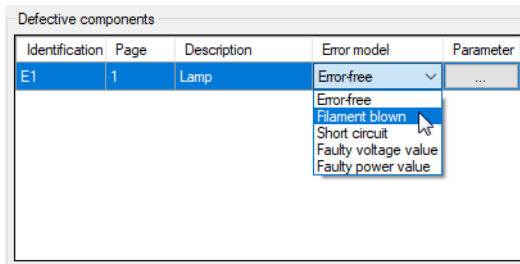
Figure 13/8:

·····> Close the dialog window with OK and create a second
configuration for the circuit diagram. This time you want the fil-
aments of both lamps to be blown.
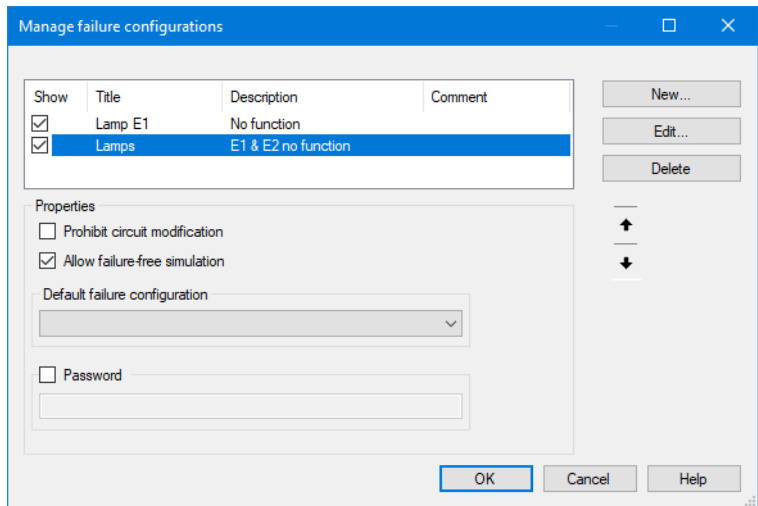
Figure 13/9: Circuit diagram with two failure configurations
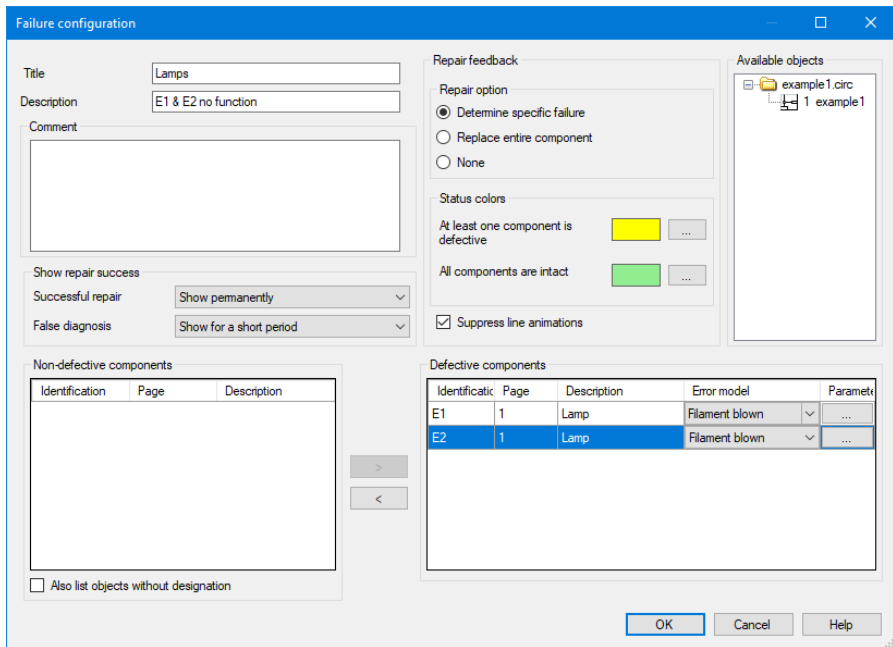
Figure 13/10: Second failure configuration of the circuit diagram

The failure configurations are saved with the circuit diagram.

⚬⚬⚬> Start the simulation with the first failure configuration.
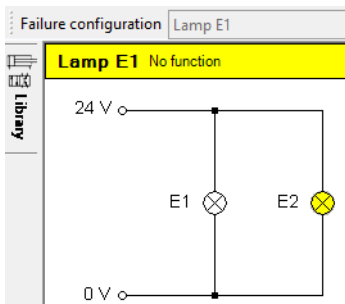
Figure 13/11:

In the presetting, the line animation is switched off so that the user is not given any clues about which components could be defective.

The title and description of the selected failure configuration are displayed at the top edge of the window. In the presetting, this information is given a yellow background if there are still defective components in the circuit diagram and a green background once all the components are repaired. The presettings can be modified in the Properties dialog window of the failure configuration. How components are repaired is described in the next section.

13.3 Carry out repairs

The modeled circuit diagram has two failure configurations. In the first configuration, only the lamp E1 does not light up; in the second configuration, neither of the two lamps lights up. How to create the failure configurations is described in the previous section.
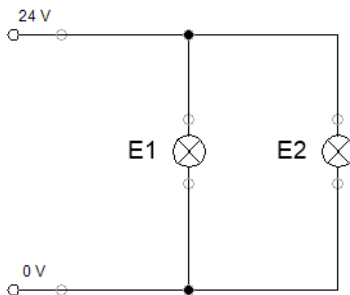
Figure 13/12:

If the diagnosis toolbar is not shown, you can display it again using the menu Diagnosis Show Diagnosis tool strip .

⋯⋯> From the list of failure configurations in the diagnosis toolbar, select the second failure and start the simulation.
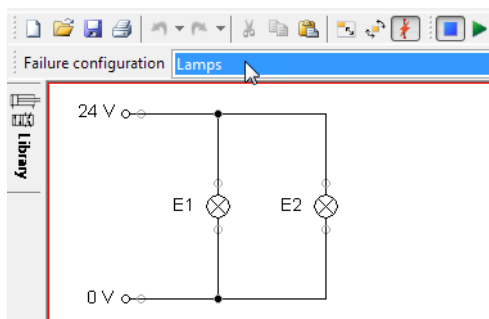
Figure 13/13:

The line animation is switched off in this configuration so that the user is not given any direct clues about which components could be defective.

The title and description of the selected failure configuration are displayed at the top edge of the window. The settings in the failure

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configuration specified that this information will have a yellow background until all the components have been repaired.
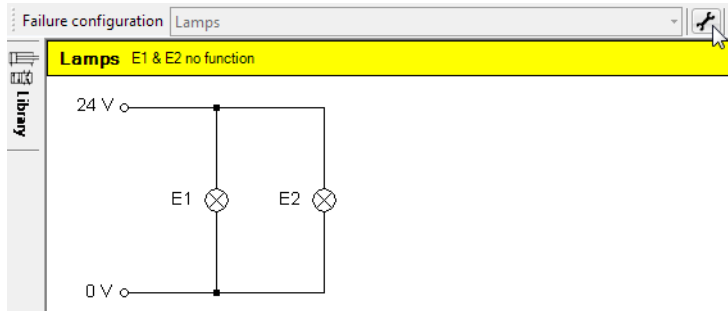
Figure 13/14:

⤑ Click the repair symbol in the diagnosis toolbar. The mouse pointer then changes.
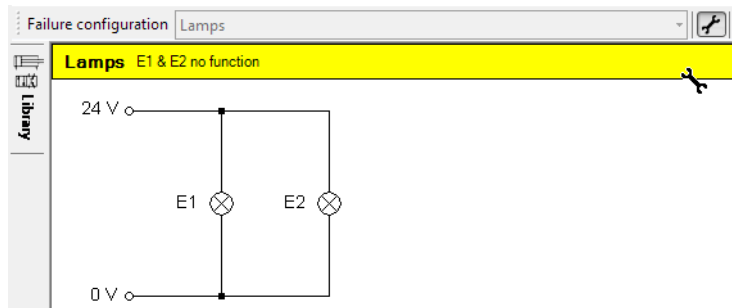
Figure 13/15:

⤑ Click a line or component you suspect to be defective, e.g. the line after the power supply.
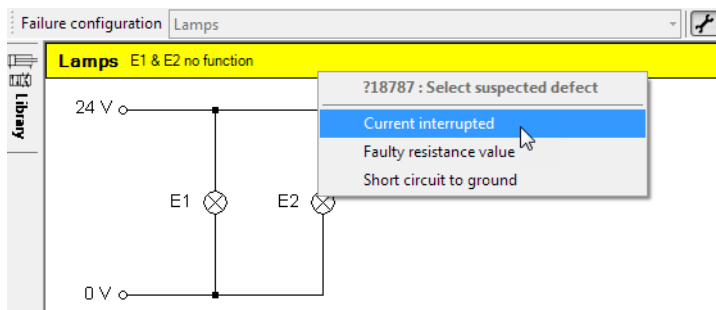
Figure 13/16:

The settings in the failure configuration require you to select the specific failure. In the example, the flow of current might be interrupted. This hypothesis is false, as indicated by a red "X" symbol. The "X" symbol is hidden again after a few seconds. In the failure configuration, you can specify whether an "X" symbol should be displayed as feedback and whether or not it should be hidden again.
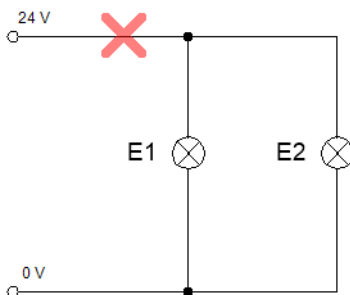
Figure 13/17:

! A repair attempt should be a specific and conscious action. This is why the repair mode is closed after each attempt.

⇢ Click the repair symbol again for the lamp E1 and this time select *Filament blown* as the suspected failure.
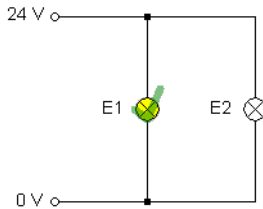
Figure 13/18:

This time the hypothesis is correct and the feedback displayed is a green "OK" a check mark. The yellow color of the title does not change because not all the defective components have been repaired yet. This feedback behavior can also be modified in the failure configuration.

⋯⋯⋗   Click the repair symbol again for the lamp E2 and select "Filament burnt out" as the suspected failure.
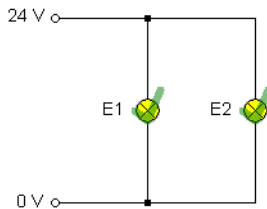
Figure 13/19:

Again, this suspicion is correct. This time the color of the title turns green, which indicates that all the components in the circuit diagram have been repaired.

Parts list management and analyses

Chapter 14

Various analyses can be inserted into a circuit diagram using the Insert menu item. Alternatively you can also use the ⚙ button on the toolbar. The following dialog window opens.
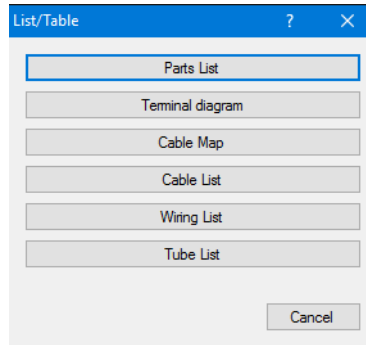
Figure 14/1: List/Table... dialog window

The following analyses can be inserted into the circuit diagram using this dialog: Parts List , Terminal diagram , Cable Map , Cable List , Wiring List and Tube List .

The use of parts lists is described below. The use and function of the other analyses are described in the corresponding chapters.

FluidSIM creates parts lists that are automatically updated in the background while the circuits are being edited.

If a parts list has been added to a circuit diagram as described above it can be used like a symbol. The use of parts lists as a special page type is described under Display parts list.

You can customize the appearance of the parts list under " Properties... " in the "*Appearance*" tab. You can see the effects of the settings straight away in the preview on the right-hand side.

If the "*Lines per Page*" option is selected you can specify the number of lines to be displayed per page. The relevant pages will also be output when the circuit diagram is printed. Buttons for navigation are displayed underneath the page if the list is split across multiple pages.
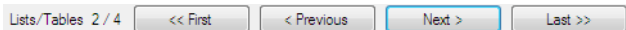
Figure 14/2: Buttons for navigating through lists

14.1 Display parts list

We recommend setting up one file specifically for the parts list in a project. If you wish to create a circuit drawing without creating a project you can switch the view for this circuit to the parts list view. Selecting the Parts List menu item from the View menu enables you to switch from the circuit view to the parts list view. Conversely, selecting the Circuit Diagram menu item from the View menu enables you to switch from the parts list view to the circuit view.

A parts list is displayed as a table in the window. You can edit the following options for editing the table:

— Attributes which the user can edit can be entered directly into the corresponding table field.

— Clicking on the column header sorts the rows on the basis of the column clicked. Clicking on the head of the same column again reverses the sorting order.

— You can adjust the column width by dragging the edges of a column header.

— You can change the order of the columns by dragging and dropping a column header in another position.

14.2 Find components from the parts on the circuit diagram

FluidSIM enables you to easily find components on the parts list in the circuit diagram and vice versa.
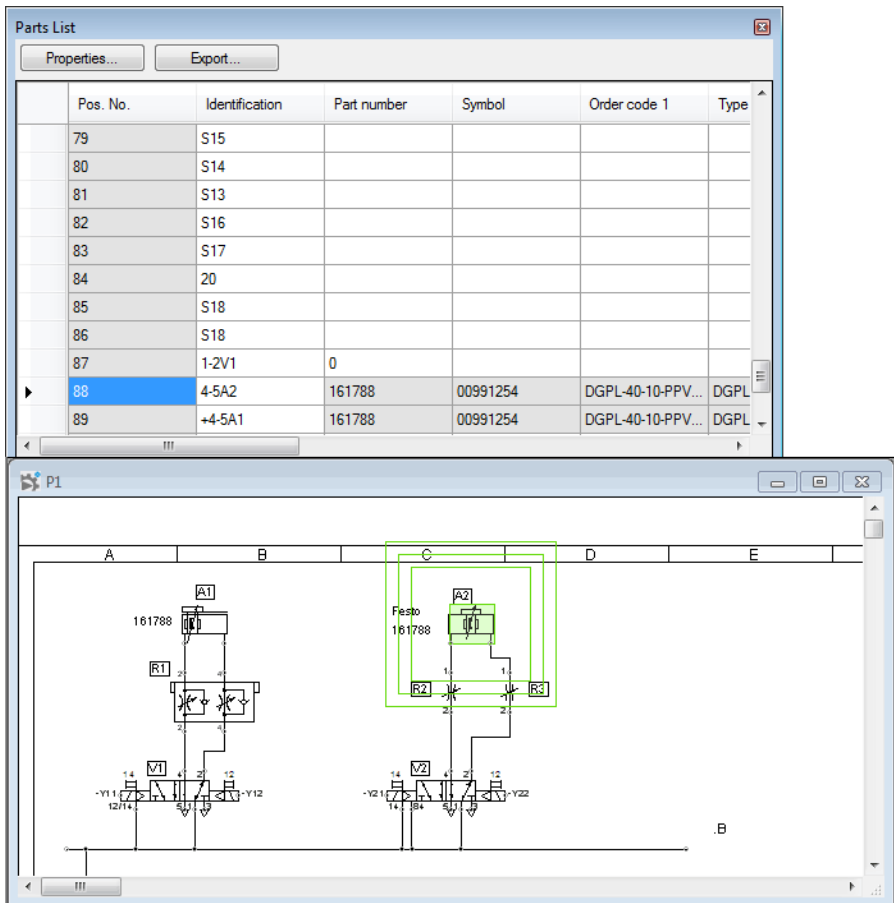
Figure 14/3: Finding components from the parts list

You have the following options:

— Clicking on the Find… button on the "*Find Target*" parts list column switches to the circuit diagram display and an animation identifies the corresponding components. If the same cir-

cuit diagram is already open in another window than the parts list view remains in the active window. The already opened window containing the circuit diagram is moved into the foreground and an animation identifies the corresponding circuit diagram symbol.

— When you click a cell in the parts list table an animation identifies the corresponding component in all of the opened windows displaying the circuit diagram.

— If you click a column header in the parts list table then both the entire column of the parts list as well as the corresponding components in the associated circuit diagram windows are selected.

— If you click a component in a circuit diagram then both this component and the corresponding row in the open parts lists are selected.

14.3 Set parts list properties

In the parts list view clicking on the ⟨ Properties... ⟩ button opens the *Parts List Properties* dialog window.
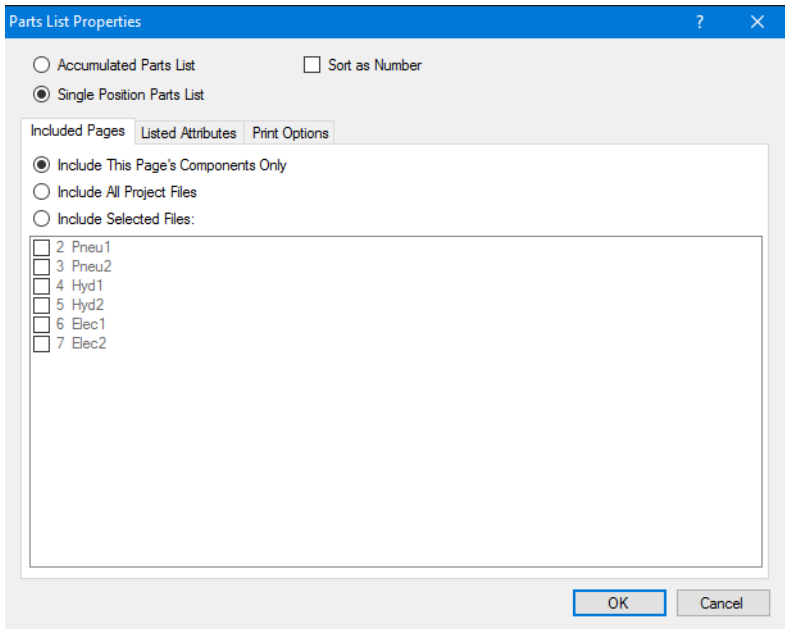
Figure 14/4: *Parts List Properties* dialog window: *Included Pages* tab

Accumulated Parts List	Compiles the components with the same attributes.
Single Position Parts List	Lists all of the components individually
Sort as Number	Interprets the column contents as numbers, so that "10" appears after "2", for example.
Include This Page's Components Only	Only lists the components of the corresponding circuit diagram.
Include All Project Files	Lists all of the components of the active project.
Include Selected Files:	Lists all of the components of the selected circuit diagrams belonging to the active project.
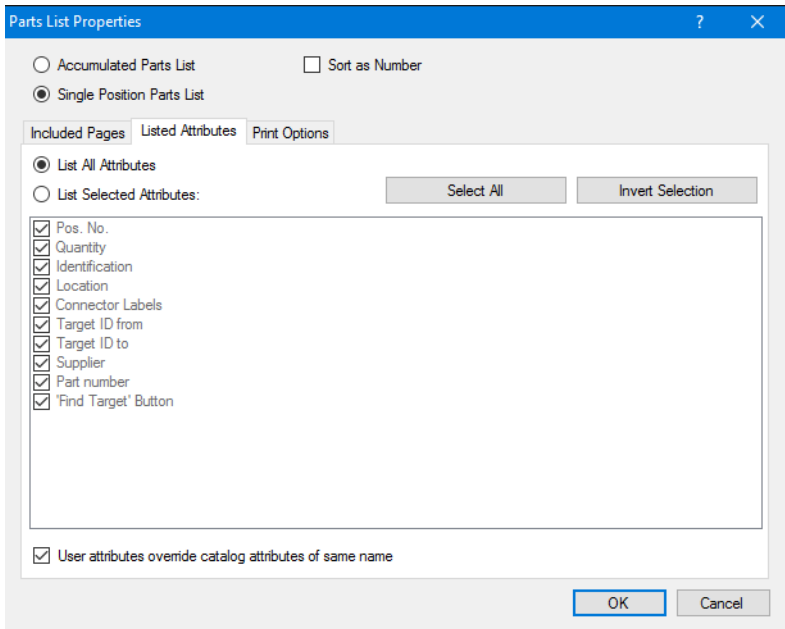
Figure 14/5: *Parts List Properties* dialog window: *Listed Attributes* tab

List All Attributes   Lists all of the component attributes within a parts list row.

List Selected Attributes: Only lists selected component attributes within a parts list row.
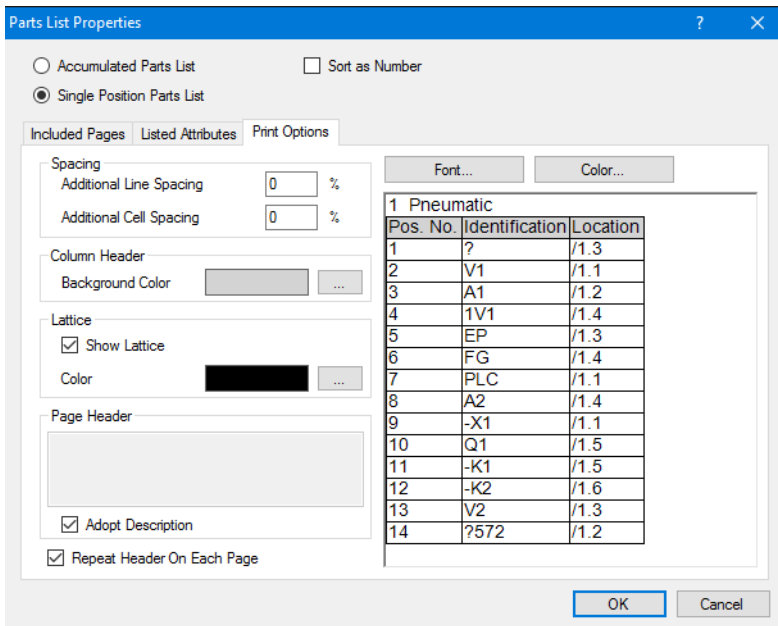
Figure 14/6: *Parts List Properties* dialog window: *Print Options* tab

Page Header

You can enter an additional text for the header row. Using the "*Adopt Description*" option, the page's description will be used.

Repeat Header On Each Page

If the parts list won't fit on a page completely when printing, additional pages will be printed automatically. By request, the column headers can be repeated on each site.

In this tab you can adjust the appearance of the parts list printout. In the preview on the right-hand side you can immediately see the effects of the adjustments. You can find information regarding printing a parts list in the "Print circuit diagram and parts list" section.

14.4 Export parts list

You can export the parts list as a text file.,

┈┈→ Click the Export... button in the parts list view.

A dialog window for selecting a file or entering a new file name appears. After you have entered a file and left the dialog field you can define the following format settings for the export in the *Parts List Export* dialog window:
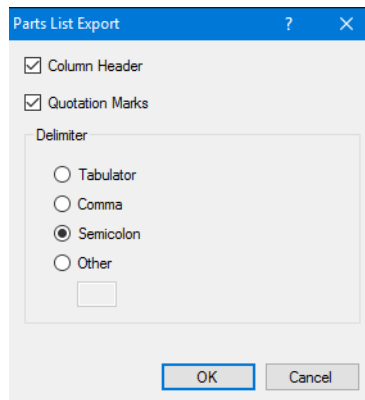
Figure 14/7: *Parts List Export* dialog window

Column Header

If this option is selected then the names of the attributes appear in the first row of the text file.

Quotation Marks

Select this option to set the field elements in quotation marks.

Delimiter

The selected separator is used to separate the columns.

14.5 Insert tube list

You can insert a tube list into a circuit diagram.

⟶   In the Insert menu, select Tube List to insert a tube list into
the circuit diagram. Alternatively you can click the ▦ button.
In the selection dialog box that opens, select Tube List .

The mouse pointer changes to a crosshair. Click the position in the
circuit diagram where you want to insert the tube list. A dialog
window then opens where you can select the associated tubing and
customize the appearance.
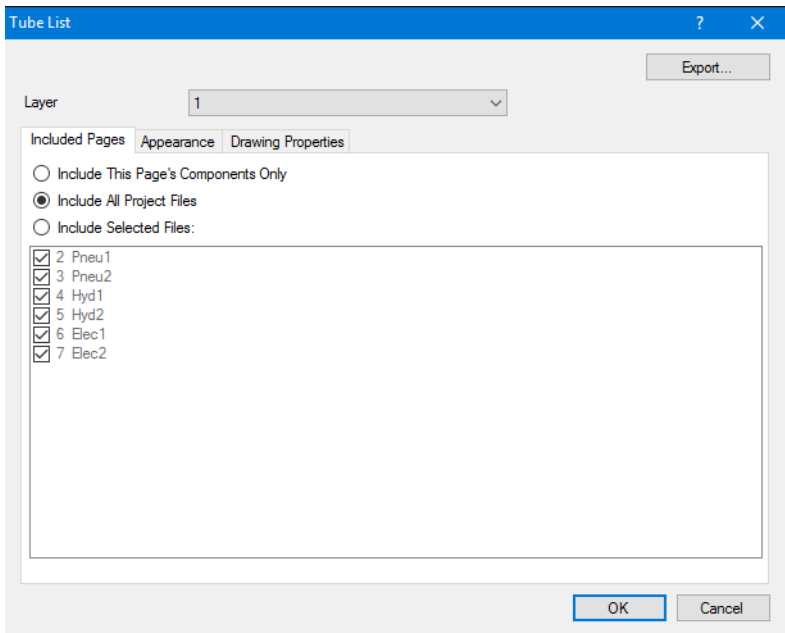
Figure 14/8: Tube List dialog window, *Included Pages* tab

Include This Page's Components Only	Lists only the tubes in the associated circuit.
Include All Project Files	Lists all tubes in the active project.
Include Selected Files:	Lists all tubes in the selected circuit in the active project.
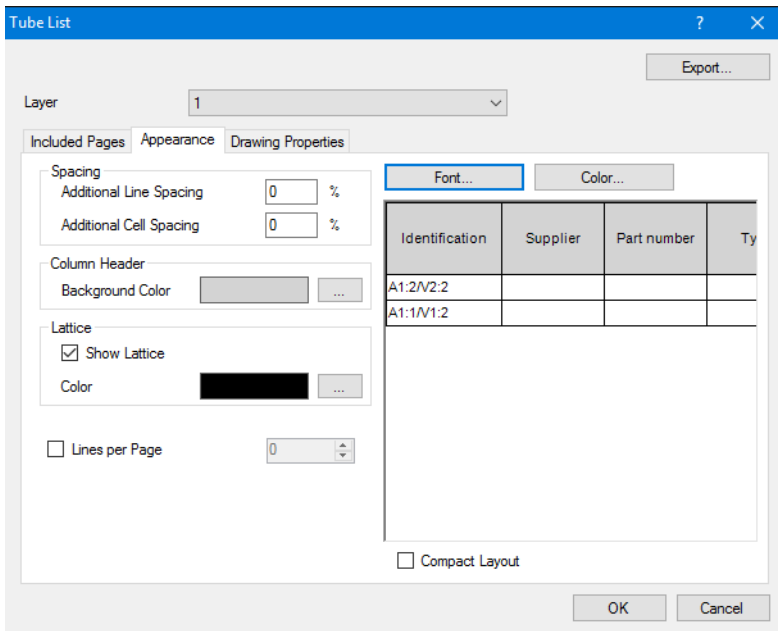
Figure 14/9: Tube List dialog window, *Appearance* tab

Lines per Page

If the list is not fitting on a page completely, additional pages are created automatically, which can be cycled through. Using this option you determine, how many lines per page get listed.

You can customize the appearance of the tube list on the "*Appearance*" tab. You can see the effects of the settings straight away in the preview on the right-hand side.

If the "*Lines per Page*" option is selected, you can specify the number of lines to be displayed per page. The relevant pages will also be printed in a printout of the circuit diagram. Buttons for navigation are displayed underneath the page if the list is split across multiple pages.
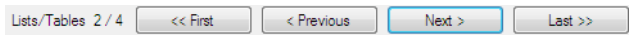
Figure 14/10: Buttons for navigating through lists

Manage projects

Chapter 15

FluidSIM supports the management of projects by compiling different files under one name in a single project file. This has the following benefits: When opening a project all of the associated data is loaded. It is possible to rapidly access files belonging to a project via the project window. Parts lists whose elements are located in different circuit diagram files can be maintained in one project.

15.1 Create new project

⋯⋯▷ Select the New... / Project... menu item from the Project menu and enter a file name for the new project.

Project files possess the prj file suffix. By default they only contain links to files contained in the project. If you wish to pass on a project then you must either pass on all of the associated files along with the project file or activate the "*Save Projects as Single File*" option.

When creating a new project, a project folder is automatically created to store the project file and all other files belonging to the project. This automatically created project folder has the same name as the project file. If you create the project file in an empty folder this will be used for the project (i.e. another new folder will not be created underneath it). The automatic creation of project directories can be activated and deactivated in the options under Save.

In the project window a project is represented hierarchically as a list. The top element is the project node. Below this are the associated circuit nodes and parts list nodes which can be differentiated from each other via the symbol in front of the name.

15.2 Project nodes

Every project possesses one project node as the uppermost ele-
ment. All of the project-specific properties are saved with the pro-
ject node. Right-clicking on a project node opens a context menu.
You can also find the menu items on the Project menu. Here you
can find the functions for adding and removing files, among other
things.

Under the Properties... menu item from the Project menu you
can define properties for the project. Properties that can be speci-
fied for both projects and circuits are described under Circuit and
project properties.

15.2.1 Project archiving

Project files generally consist of links to the files contained therein.
However, where desired FluidSIM can also save the project along
with all of the associated files in one single file. Among other
things, this makes it easier to pass on the project. Activate the *Save
Projects as Single File* option in the *Archiving* tab.
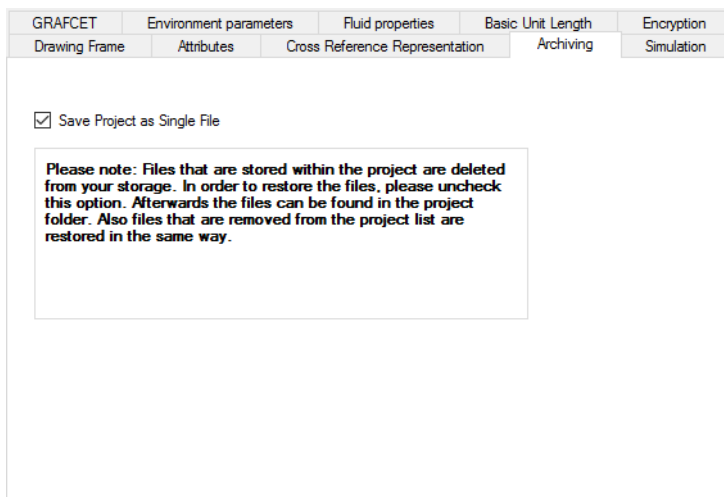
Figure 15/1: *Project* dialog window: *Archiving* tab

Save Projects as Single File   If this option is activated all of the files belonging to the project are saved in a single file.

    Please note the advice displayed under this option.

15.3 Circuit and parts list nodes

A circuit node is created beneath the project node for every circuit file that belongs to the project. This also applies to parts lists since they are saved as circuits. These are just displayed differently in the window. All of the circuit-specific or parts list-specific properties are saved with the circuit node.

Right-clicking a circuit node opens a context menu containing the following menu items:

Open...

> Opens the selected circuit or the selected parts list in a window. Double-clicking on the node in the project tree also opens the window.

Close Windows

> Closes the window of the selected circuit or the selected parts list.

Remove From List

> Removes the selected circuit or the selected parts list from the project.

Rename...

> Changes the description of the selected circuit or the selected parts list.

Properties...

> In this dialog window you can enter data for the circuit or parts list.
>
> Note: Please note that the additional parts list-specific properties can be set using the window view of the parts list.

Figure 15/2: [Page] dialog window: *Drawing Size* tab

Here you can define the circuit dimensions and orientation, both of which are relevant for printing.

Circuit and project properties

Chapter 16

Circuits and projects have a host of common properties. The properties set in the project can be used by circuits in the project. All of the properties that can be specified for both circuits and projects are listed below. The screenshots shown are dialog windows for the circuits.
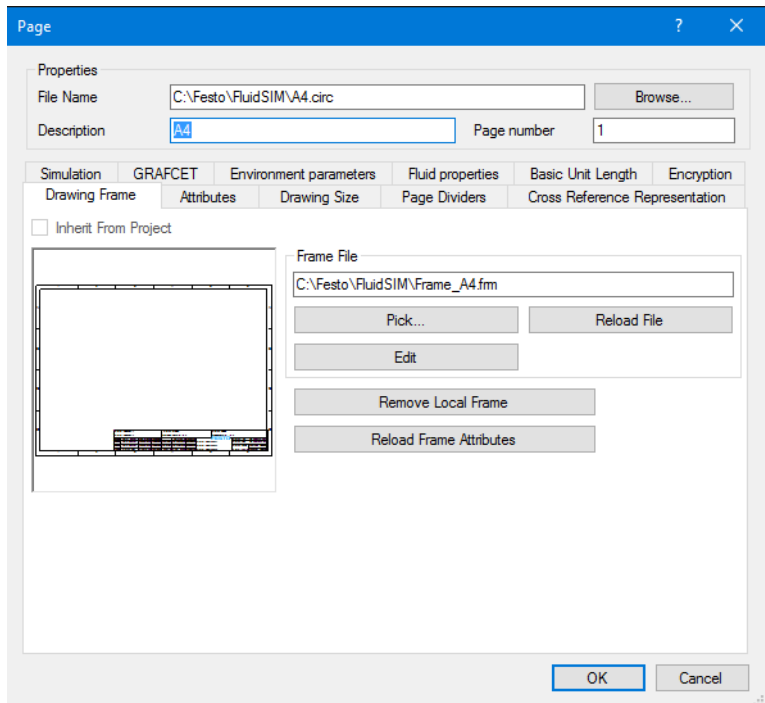
Figure 16/1: Properties dialog window

Properties

The file name field displays the file name of the circuit or project along with the complete path. The file name is carried over to the input field for the "*Description*" and can be edited there. This entry is displayed in the upper margin of the window as well as beside the circuit or project node.

Page number	Here you can specify a page number. The page number can be made up of any character string. The page number can be defined using the "%PageNumber" predefined placeholder. This placeholder can be used in text components and drawing frames among others.
Drawing Frame	Here you can make settings for the drawing frame. This function is described in the section Drawing frame.

16.1 Attributes

Any number of attributes can be created for every circuit or node in a project. The attributes are listed in a table in the "*Attributes*" tab. New attributes can be entered in the empty cells at the end of the table. The use of attributes is described in the section Attributes of the nodes in a project.

The attributes of a project node are automatically copied to all circuit and parts list nodes (inherited) and are thus available in all of the circuit drawings. This concept is particularly useful for the drawing frames if project attributes are to be displayed in the circuit diagram, for example. You can find further information in the section Link text components with attributes.

Circuit attributes copied from a project cannot be edited initially. The corresponding row in the *Attributes* tab of the Page dialog window is grayed out and the "*Inherit From Project*" option in the column is activated.

However it is possible to overwrite a copied attribute in a circuit. The option in the "*Inherit From Project*" column must be deactivated for this. The value of the attribute can then be edited. This function can be used to assign individual page numbers in the drawing frame, for example. If the "*Inherit From Project*" option is reactivated then the attribute value is copied from the project again.

Figure 16/2: *Attributes* tab

Attribute	This column contains the name of the attribute.
Value	This column contains the value of the attribute.
Action	The buttons in this column allow the following actions: if the attribute was created in the parent project node then the " Find Target... " action is available. Clicking this opens the *Project* or *Circuit* dialog window for the project node as the target that contains the corresponding attribute. If the attribute was created in the same node then the " Delete " action that allows you to delete the attribute is available.
Inherit From Project	If the attribute was created in the same node then this option is deactivated and grayed out. This applies to all of the attributes of the project node since it does not have a parent node. For child nodes the value of the attribute from the project node is copied when this option is activated. After deactivating this option it is possible to locally overwrite the attribute value.

Comment	Here you can enter a comment about the attribute.

16.1.1 Predefined placeholders

FluidSIM provides a host of predefined placeholders. These placeholders can be used in text components and drawing frames among others.

The placeholders begin with a percentage sign. The following predefined placeholders are some of those available:

%PageNumber

The page number is specified in the properties dialog window for the circuit diagram.

If analyses are split across several pages, the number of the subpage is added to the page number with a minus sign. If, for example, the entered page number is "42-01" and the page displayed is the third page in an analysis then the placeholder "%PageNumber" is replaced by the character string "42-01-03".

%PageDescription The description for the page is specified in the properties dialog window for the circuit diagram.

%PageFileName Stands for the file name of the page without the file path.

%PageFullFilePath Stands for the file name of the page with the full file path.

%PageFileDateTime Stands for the date and time of the most recent change to the circuit diagram.

%PageFileDate Stands for the date of the most recent change to the circuit diagram.

%PageFileTime Stands for the time of the most recent change to the circuit diagram.

16.2 Page Dividers

Page dividers can only be defined for pages. Editing of page dividers is described under Page dividers.

16.3 Basic Unit Length

The symbols in the FluidSIM symbol libraries are created according to various DIN ISO standards. Instead of specifying absolute units of length, the standards simply use a relative basic unit of length "M". All of the symbols have been created with reference to this basic unit of length "M". The actual size of the symbol is not defined until the symbol is inserted into a circuit.

Information on how to convert the basic unit of length "M" is stored with the circuit diagram. You can change the set values for a circuit diagram by calling up the properties dialog window for the circuit diagram using the Page   Properties... menu. You will find the relevant settings in the *Basic Unit Length* tab.

Figure 16/3: *Basic Unit Length* tab

As soon as the value of "M" is changed, the sizes of the existing symbols are recalculated with respect to the specified basic unit of length. The specification has no effect on elements in the drawing frame.

The *Basic Unit Length* tab is also in the project settings. The settings made in this tab are used as a template for circuit diagrams created from new in the project tree.

16.4 Encryption

Projects and circuit diagrams can be encrypted. The encryption method used is AES-128.

Figure 16/4: *Encryption* tab

Enable Encryption

This option activates and deactivates encryption. When encryption is activated the password to be used can be entered in the *Password* input field.

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16.5 Cross Reference Representation

Figure 16/5: *Cross Reference Representation* tab

This tab is used to define the settings for the cross-reference representation. You can find further information under Cross-reference representation. If the *Inherit From Parent Node* option is active then the settings will be copied from the parent project node.

Example   Illustrates the effects of the settings using an example.

Reset   Resets the settings to the settings defined in FluidSIM.

Special functions for electric circuits

Chapter 17

17.1 Potentials and conduction lines

The creation of horizontal and vertical potential lines is supported by drawing conduction lines. The end points of the conduction line consist of potentials that also serve as interruptions. In the dialog window for drawing conduction lines you can specify whether the potentials should have an identification.

In this example we want to draw three horizontal potential lines where each line comes from a preceding sheet "1" and is continued on a sheet "3".

You open a dialog window where you can make the settings shown using the ‖Insert‖ ‖Conduction Line...‖ menu item or the ⊶ button on the toolbar.
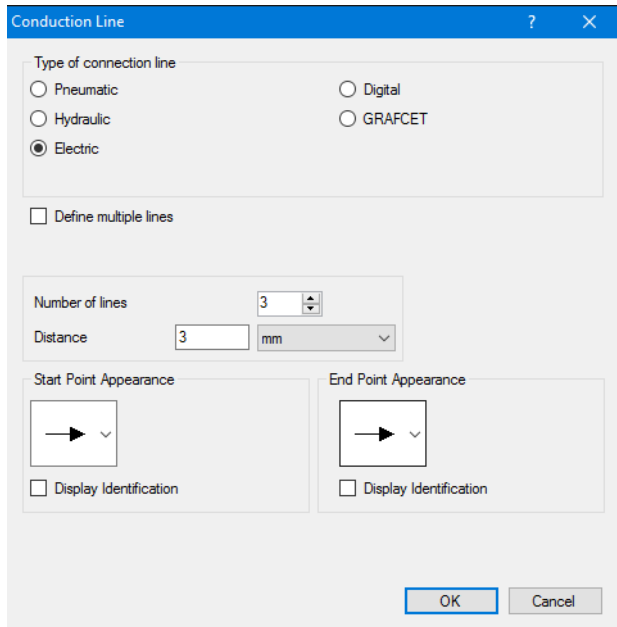
Figure 17/1: Settings for the potential lines to be created

You can then define the end points of the line with two consecutive mouse clicks.
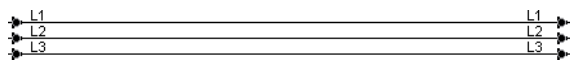
Figure 17/2: Three horizontal potential lines

The identifications of the potentials can be changed. In this example we want to rename the potential from L4 to L6.

⸺⟩ Double-click the left-hand potential L1. Then enter L4 for the identification in the dialog window.

Then following prompt then opens.
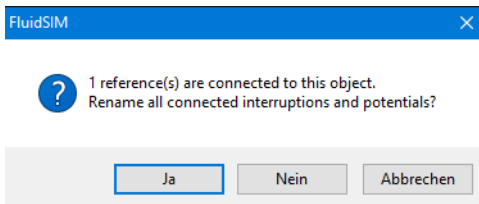
Figure 17/3:

FluidSIM supports the automatic renaming of the potentials linked with the source potential. If you answer "Yes", the potential L1 on the right-hand side will also be renamed L4.

---> Rename the potentials L2 and L3 to L5 and L6 in the same way.

---> Then enter the corresponding markers for the predecessors or successors in the properties dialog windows for the potentials. If the corresponding cross-references have the same markers in the respective predecessor and successor pages, the potential lines might look as follows.
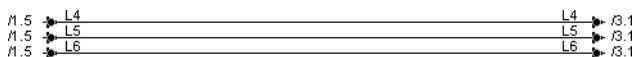
Figure 17/4: Three horizontal potential lines with cross-references

17.2 Cables and wiring

Cables and wiring are represented in the circuit diagram by a special cable symbol. All of the lines defined by the cable symbol are assigned to a cable or to wiring. You can define for the symbol whether it is a cable or wiring.

Wiring only summarizes the defined lines (wires) graphically in the circuit diagram and is assigned the identification "W" by default. Wiring is not listed in analyses such as cable maps and cable lists. Unlike a cable, wiring cannot be assigned to a product. With wiring, product information can only be saved in the lines.

If the cable symbol represents a cable then a cable object must be assigned to the symbol. Product properties can be saved in the cable object and are analyzed in cable maps and cable lists, etc. Several cable symbols can reference the same cable object. This is the case if, for example, a cable has to be spread over several pages.
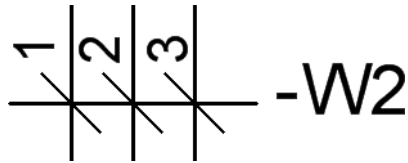
Figure 17/5: Cable symbol

┈┈> Select the ⎡Cable⎤ menu item from the ⎡Insert⎤ menu or click the ⊞ button to define a cable or wiring.

This activates a mode that allows you to insert a cable symbol by making two consecutive clicks. All of the lines that are defined by the cable symbol are initially assigned to wiring.

If you want to use a cable instead of wiring you can assign a cable object to the symbol using the properties dialog window for the cable symbol.
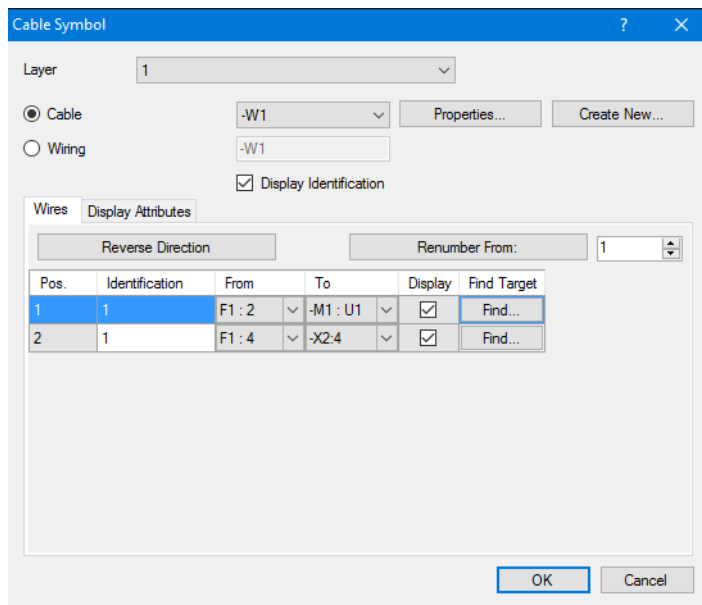
Figure 17/6: *Cable Symbol* dialog window, *Wires* tab

Layer

Defines the drawing layer for the cable symbol.

Cable – Wiring

Defines whether the cable symbol represents a cable or wiring comprising single wires. Wiring is not listed in cable maps, etc. If *Wiring* is selected then an identification can be specified that can be displayed with *Display Identification*.

If *Cable* is selected then an existing cable object can be assigned to the cable symbol using a drop-down list. A new cable object can be created using the Create New... button. Clicking Properties... opens the properties dialog window for the selected cable object.

Wires

In order to analyze cable maps the component connections that join a wire must be determined. The connectors are automatically entered in the list box if they can be uniquely assigned. If a unique assignment is not possible, the relevant connector must be selected manually via the list box. The identification for the individual

wires can also be entered. These are saved in the individual lines (wires). The wire identifications are displayed at the cable symbol using the *Display* button.

Reverse Direction

The entries in the *From* and *To* column are automatically defined as the direction of the wires when creating the cable symbol. Clicking the Reverse Direction button reverses the directions of all of the wires.

Renumber From:

Clicking this button renumbers all of the wires defined by the cable symbol, starting with the number entered in the list box.
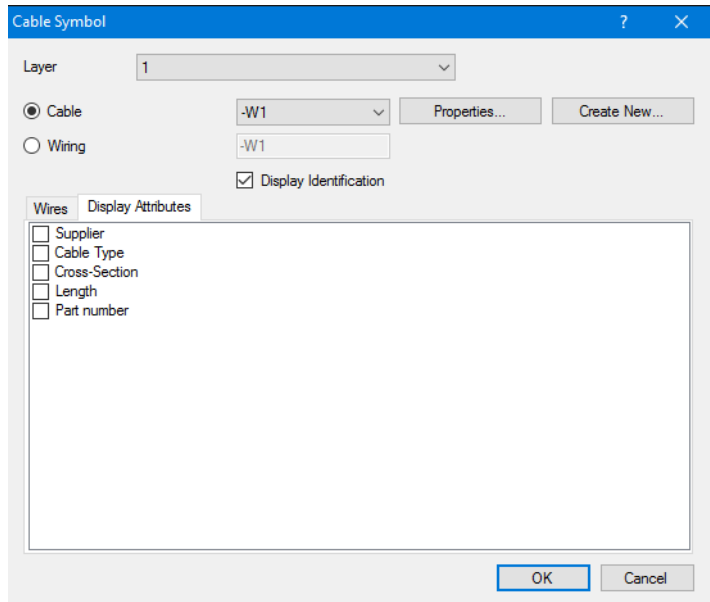
Figure 17/7: *Cable Symbol* dialog window, *Display Attributes* tab

In the "*Display Attributes*" tab you can select the attributes of the associated cable object that are to be displayed at the cable symbol.

⋯⟶ Click the | Create New... | button to create a new cable symbol.

The following dialog window opens.
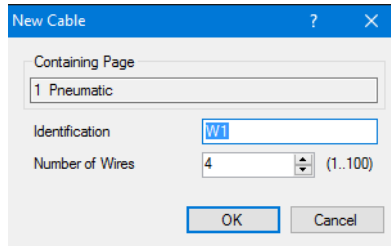
Figure 17/8: *New Cable* dialog window

Containing Page

Indicates the page where the cable object will be saved. This is important if various cable symbols on different pages reference the same cable object. The cable object is only saved with one page.

Identification

Enter the identification for the cable here.

Number of Wires

Enter the number of lines (wires) in the cable here. The number can be higher than the underlying lines if, for example, a concrete cable has unconnected wires. If the associated cable symbols overscore more lines than are defined in the cable object, a warning is output when the page is checked and the corresponding entries are highlighted in color in the cable lists.

After you specify the identification for the cable and confirm the dialog, the cable object is generated and the cable symbol is assigned to it.

⋯⟶ Click the " | Properties... | " button to edit the properties of the cable object.
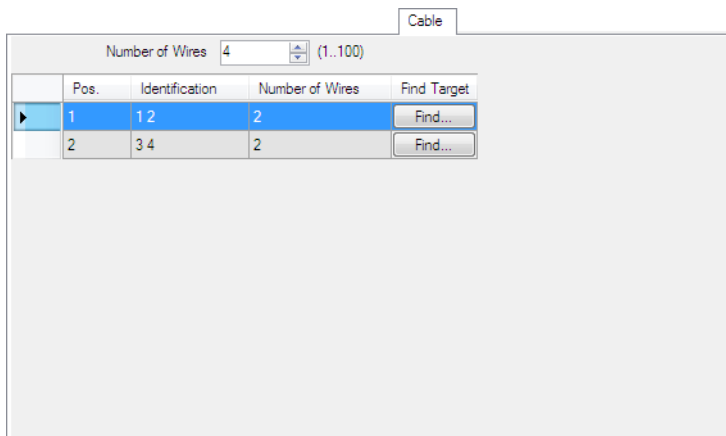
Figure 17/9: *Properties* dialog window: *Cable* tab

Number of Wires

Defines the number of lines (wires) in the cable. The number can be higher than the lines overscored by the associated cable symbols if, for example, a concrete cable has unconnected wires. If the associated cable symbols overscore more lines than are defined in the cable object, a warning is output when the page is checked and the corresponding entries are highlighted in color in the cable lists.

The associated cable symbols are listed in rows in the table. You can jump to the associated cable symbol using the " Find... " button.

The *User Defined Properties* tab in the properties dialog window for the cable symbol lists the cable-specific product properties such as *Cable Type* and *Length*. These properties and the entries in the *Cable* tab are analyzed in the cable map, etc.

17.2.1 Manage cables

All cables within a circuit can be listed and renamed using the Manage Cables... menu item from the Page menu. You open the properties dialog window for the relevant cable object using the Properties... button.

You can also call up the cables of all circuits belonging to the project using the Manage Cables... menu item from the Project menu.
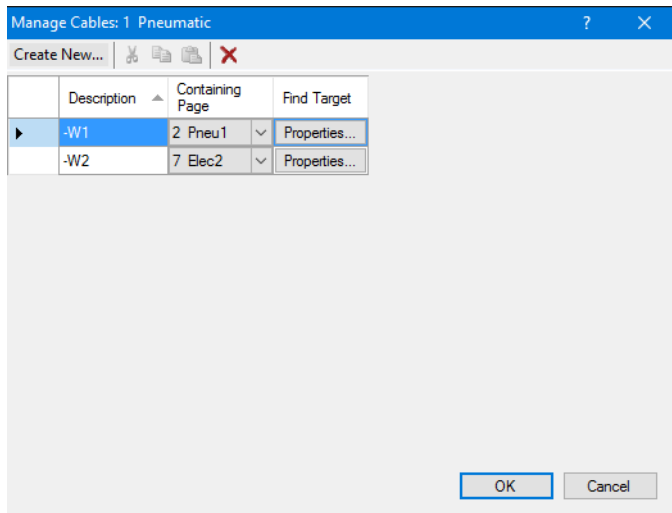
Figure 17/10: Manage Cables... dialog window

Containing Page

Shows which circuit the cable is assigned to. You can edit this assignment within a project.

You can add a new cable object to the project using the Create New... button. Each cable object must be assigned to a page.

Clicking the ⃒ Create New... ⃒ button first opens the following dialog
window where you can define the assignment.
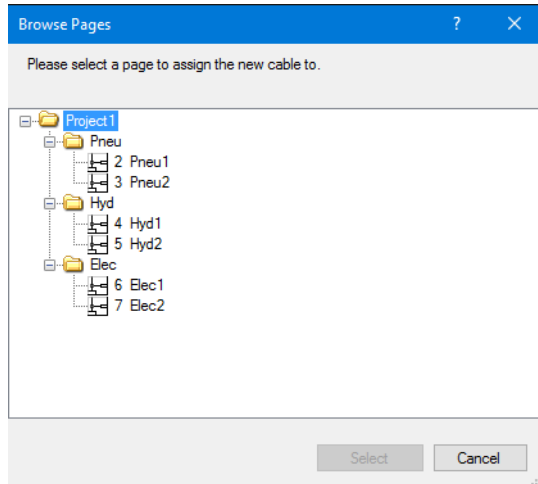
Figure 17/11: *Browse Pages* dialog window

After you click the ⃒ Select ⃒ button a dialog window opens where
you can define the name and number of wires for the new cable
object. The dialog window is described under Cables and wiring.

17.2.2 Insert cable map

You can insert an associated cable map for a cable into the circuit
diagram. You do this by inserting a cable map into a circuit diagram
and then assigning a cable to this map.

⤍ To insert a cable map into the circuit diagram select the Cable
Map menu item from the Insert menu. Alternatively you can

click the ▨ button. Select [Cable Map] in the selection dialog window that opens.

The mouse pointer changes to a crosshair. Click the position in the circuit diagram where you want to insert the cable map. A dialog window then opens where you can assign the relevant cable and customize the appearance.
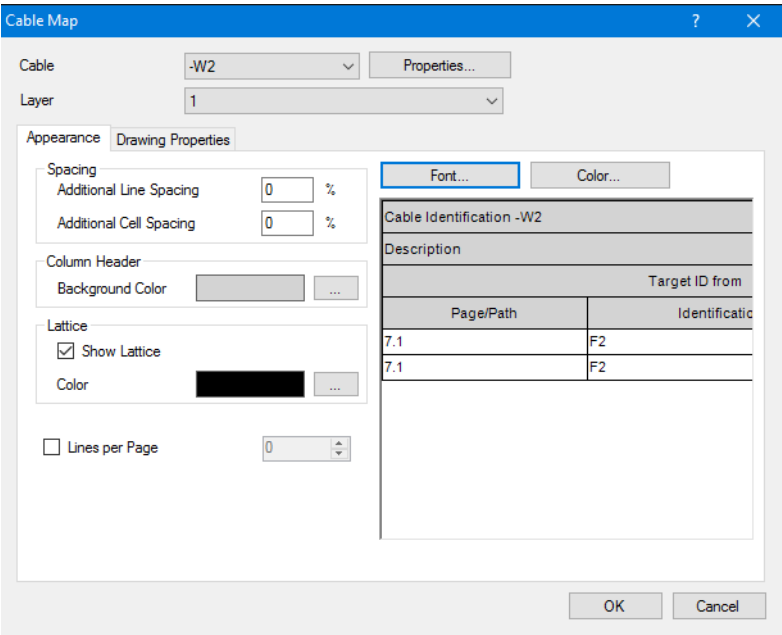
Figure 17/12: [Cable Map] dialog window

Cable   Defines the relevant cable.

Properties...   Opens the properties dialog window for the associated cable symbol.

You can customize the appearance of the cable map in the "*Appearance*" tab. You can see the effects of the settings straight away in the preview on the right-hand side.

If the "*Lines per Page*" option is selected you can specify the number of lines to be displayed per page. The relevant pages will also be output when the circuit diagram is printed. Buttons for navigation are displayed underneath the page if the list is split across multiple pages.

| Lists/Tables 2 / 4 | << First | < Previous | Next > | Last >> |

Figure 17/13: Buttons for navigating through lists

17.2.3 Insert cable list

You can insert a cable list into a circuit diagram.

⤳ To insert a cable list into the circuit diagram select the Cable List menu item from the Insert menu. Alternatively you can click the ▦ button. Select Cable List in the selection dialog window that opens.

The mouse pointer changes to a crosshair. Click the position in the circuit diagram where you want to insert the cable list. A dialog window then opens where you can select the associated cable and customize the appearance.
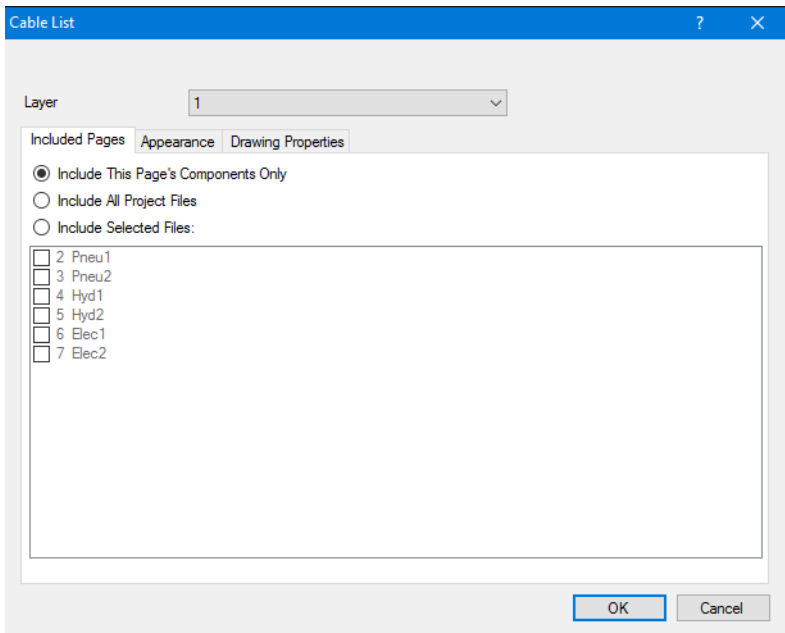
Figure 17/14: Cable List dialog window, *Included Pages* tab

Include This Page's Components Only	Lists only the cables in the associated circuit.
Include All Project Files	Lists all cables in the active project.
Include Selected Files:	Lists all cables in the selected circuit in the active project.
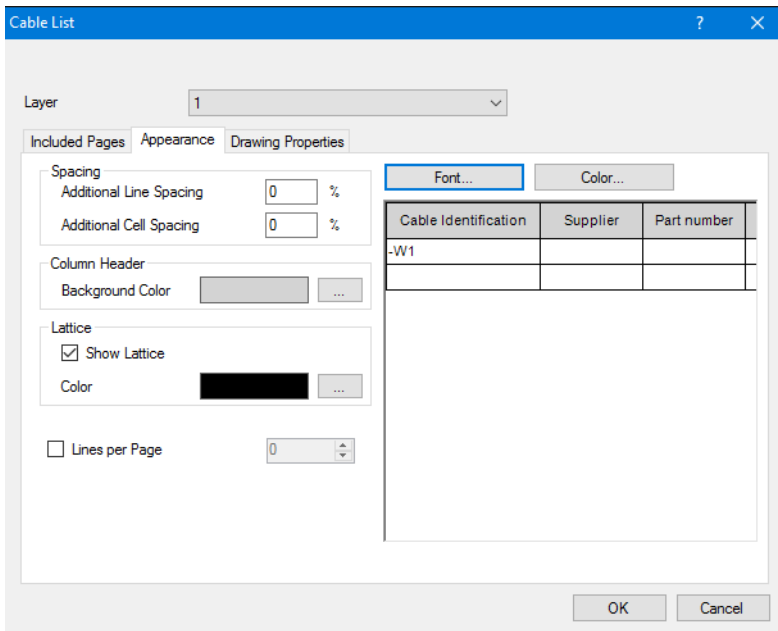
Figure 17/15: Cable List dialog window, *Appearance* tab

You can customize the appearance of the cable map in the "*Appearance*" tab. You can see the effects of the settings straight away in the preview on the right-hand side.

If the cable symbols of a cable object overscore more lines than are defined in the cable object, a warning is output when the page is checked and the corresponding entries are highlighted in color in the cable list.

If the "*Lines per Page*" option is selected you can specify the number of lines to be displayed per page. The relevant pages will also be output when the circuit diagram is printed. Buttons for navigation are displayed underneath the page if the list is split across multiple pages.

Figure 17/16: Buttons for navigating through lists

17.2.4 Insert wiring list

You can insert a wiring list into a circuit diagram.

⟶ To insert a wiring list into the circuit diagram select the Wir-ing List menu item from the Insert menu. Alternatively you can click the ▨ button. Select Wiring List in the selection di-alog window that opens.

The mouse pointer changes to a crosshair. Click the position in the circuit diagram where you want to insert the wiring list. A dialog window then opens where you can select the associated wiring and customize the appearance.
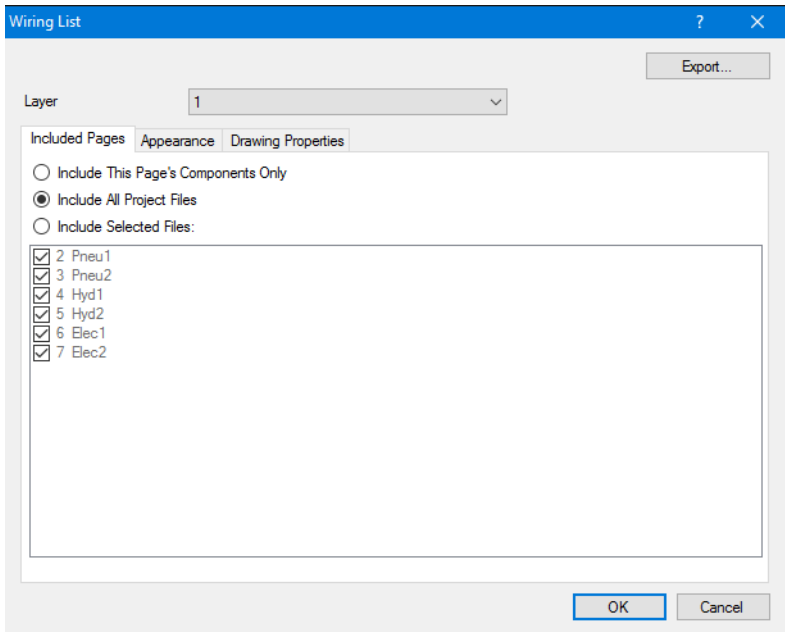
Figure 17/17: Wiring List dialog window, *Included Pages* tab

Include This Page's Components Only	Lists only the wirings in the associated circuit.
Include All Project Files	Lists all wirings in the active project.
Include Selected Files:	Lists all wirings in the selected circuit in the active project.
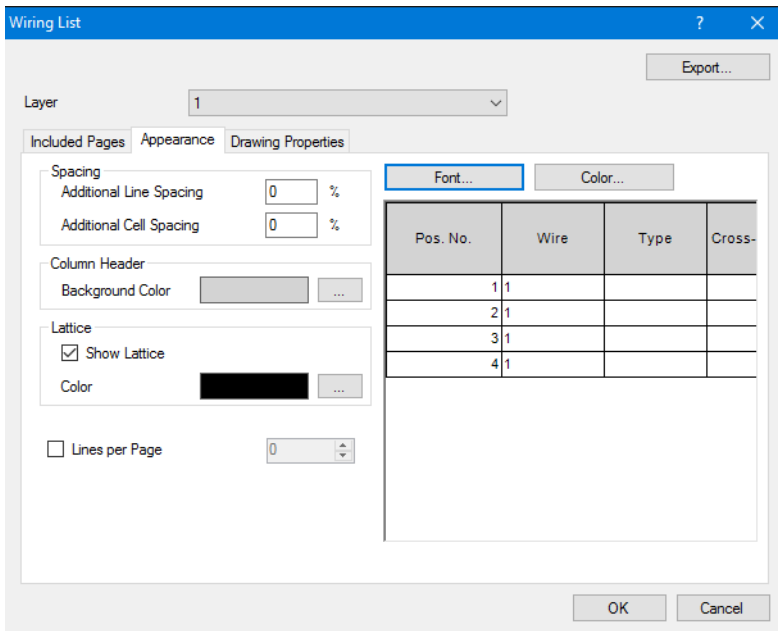
Figure 17/18: Wiring List dialog window, *Appearance* tab

You can customize the appearance of the wiring list in the "*Appear-ance*" tab. You can see the effects of the settings straight away in the preview on the right-hand side.

If the "*Lines per Page*" option is selected you can specify the number of lines to be displayed per page. The relevant pages will also be output when the circuit diagram is printed. Buttons for navigation are displayed underneath the page if the list is split across multiple pages.
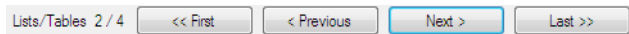
Figure 17/19: Buttons for navigating through lists

17.3 Terminals and terminal strips

17.3.1 Set terminals

You can set individual terminals or multiple terminals in one step.

⌁⟶ Select the Terminal menu item from the Insert menu or click the ⌁ button to define an individual electric terminal.

This activates a mode that allows you to insert a terminal by clicking a free point on the electric line.
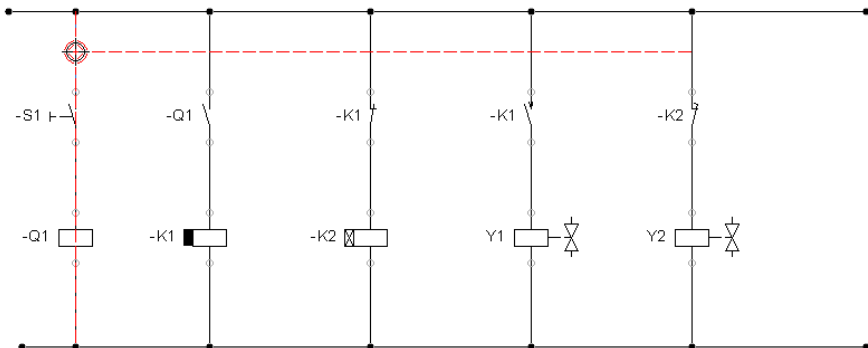
Figure 17/20:

As soon as you have set a new terminal in this way the dialog window containing the settings for this terminal appears. You can use this dialog window to assign the terminal to a terminal strip. This assignment can also be made or changed later.
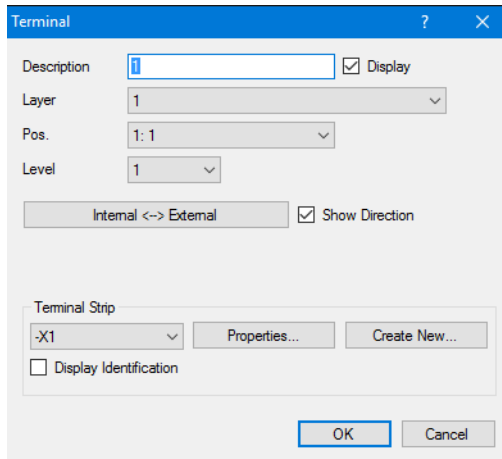
Figure 17/21: *Terminal* dialog window

Description   Contains the description of the terminal or the terminal designa-
                       tion.

Display   If this box is checked then the description entered will be displayed
                       beside the terminal.

Layer   Defines the drawing layer for the terminal.

Pos.   Defines the position of the terminal within the associated terminal
                       strip. An entry is only possible once the terminal has been assigned
                       to a terminal strip.

Internal # External   Changes the direction of the terminal. The direction is indicated in
                       the circuit by an arrow that shows which connector is inside the
                       control cabinet and which is outside. The tip of the arrow points
                       into the control cabinet.

Show Direction   If this box is checked then the direction arrow is displayed at the
                       terminal.

Terminal Strip   Defines the terminal strip containing the terminal in question. The
                       list contains the terminal strips already created. You call up the

properties dialog window for the selected terminal strip using
Properties... . You can also create a new terminal strip using
Create New... .

Display Identification If this box is checked then the identification for the associated terminal strip is displayed beside the terminal.

17.3.2 Set multiple terminals

As well as the option of setting individual terminals, FluidSIM also offers a mode that allows you to set multiple terminals one after the other. You can keep inserting terminals by simply clicking on the electric lines until you leave the mode again.

→ To insert multiple terminals select the Multiple Terminals... menu item from the Insert menu or click the button.
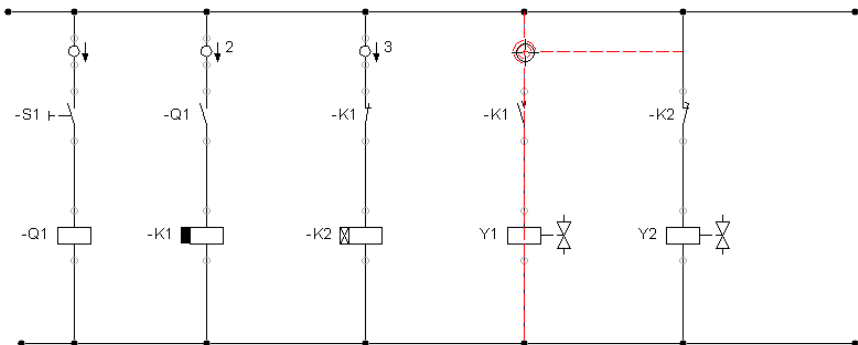
Figure 17/22:

The operation begins with a dialog window where you can make some settings for the new terminals. Above all you need to first select an existing terminal strip or create a new one. If a suitable

terminal strip does not already exist then a prompt to create a new one will automatically appear.
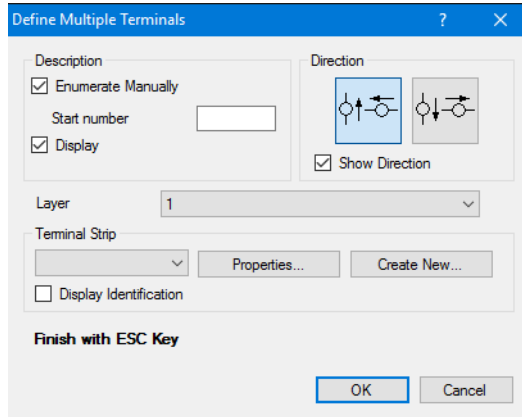
Figure 17/23: *Define Multiple Terminals* dialog window

Description
Defines how the new terminals are to be numbered. The *Enumerate Manually* option allows you to specify a start number from which the numbering continues. Otherwise a free terminal from the selected terminal strip is automatically used. The start number "2" was specified in the example shown.

Display
If this box is checked then the description entered will be displayed beside the terminal.

Direction
Defines the direction of the new terminals. The direction is indicated in the circuit by an arrow that shows which connector is inside the control cabinet and which is outside. The tip of the arrow points into the control cabinet. The direction can also be changed later using the properties dialog window for the individual terminals.

Layer
Defines the drawing layer for the terminals.

Terminal Strip
Defines the terminal strip containing the terminals in question. The list contains the terminal strips already created. You call up the properties dialog window for the selected terminal strip using

| Properties... |. You can also create a new terminal strip using | Create New... |.

Display Identification | If this box is checked then the identification for the associated terminal strip is displayed beside the new terminals.

17.3.3 Create terminal strips

FluidSIM does not treat terminal strips as visible objects within the circuit pages which explains why they cannot be interactively selected using the mouse in order to highlight them, delete them or change their properties. Terminal strips can either be managed via the associated terminals or using the | Manage Terminal Strips... | menu item under | Page | or | Project |.

A terminal strip is always part of a specific circuit. To define a new terminal strip you must therefore define a circuit file in addition to the description and number of terminals.
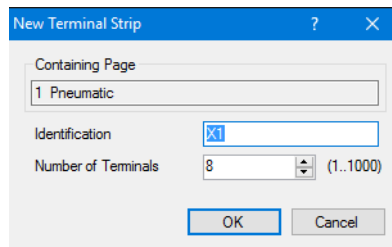
Figure 17/24: *New Terminal Strip* dialog window

All properties can also be changed later at any time. You open the properties dialog window for a terminal strip via any terminal in that terminal strip using the | Properties... | button.

Figure 17/25: *Terminal Strip* dialog window

External Target

If the target of a terminal *inside* the control cabinet is unique due to the wiring, FluidSIM automatically enters the identification for the connected component. Otherwise the list contains the identifications of all objects that can be reached from the terminal. The target search can be controlled by selecting a junction symbol as a T distributor.

Internal Target

The targets of the terminals *outside* the control cabinet are listed here. As with the internal targets, unique links are automatically entered.

Find...   Jumps to the associated terminal in the circuit diagram.

17.3.4 Manage terminal strips

All terminal strips within a circuit can be listed and renamed using the Manage Terminal Strips... menu item from the Page menu. You open the properties dialog window for the relevant terminal strip using the Properties... button.

You can also call up the cables of all terminal strips belonging to the project using the Manage Terminal Strips... menu item from the Project menu.
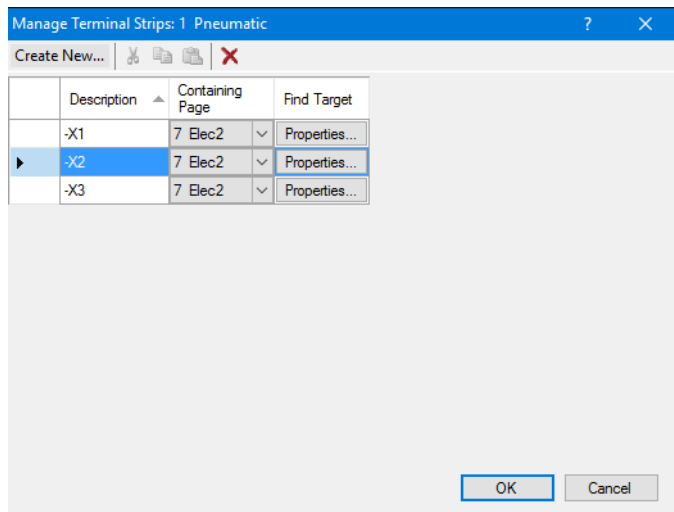
Figure 17/26: Manage Terminal Strips... dialog window

Containing Page   Shows which circuit the terminal strip is assigned to. You can edit this assignment within a project.

You can add a new terminal strip to the project using the ⎢Create⎥ ⎢New...⎥ button. Each terminal strip must be assigned to a page. Clicking the ⎢Create New...⎥ button first opens the following dialog window where you can define the assignment.
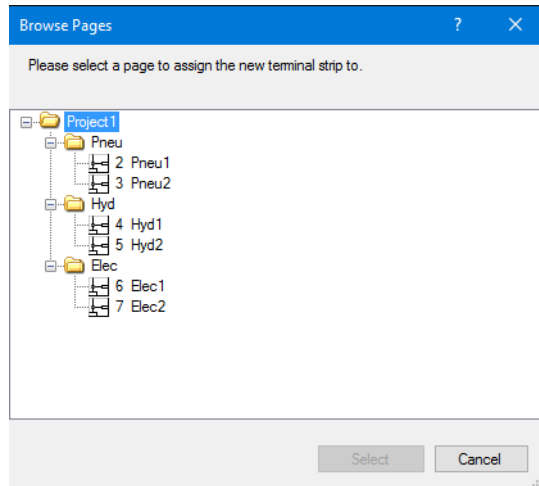
Figure 17/27: *Browse Pages* dialog window

After you click the ⎢Select⎥ button a dialog window opens where you can define the properties of the new terminal strip. The dialog window is described under Create terminal strips.

17.4 Terminal diagram

You can insert an associated terminal diagram for a terminal strip into the circuit diagram. You do this by inserting a terminal diagram into a circuit diagram and then assigning a terminal strip to this diagram.

⸻⸽ Select the [Terminal diagram] menu item from the [Insert] menu or click the ▦ button to insert a terminal diagram into the circuit diagram. Alternatively you can click the ▦ button. Select [Terminal diagram] in the selection dialog window that opens.

The mouse pointer changes to a crosshair. Click the position in the circuit diagram where you want to insert the terminal diagram. A dialog window then opens where you can assign the relevant terminal strip and customize the appearance.
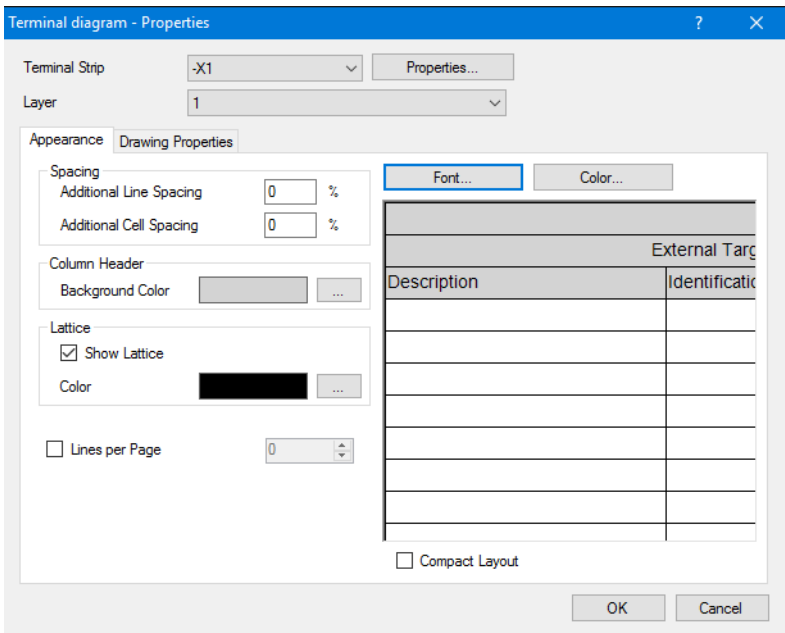
Figure 17/28: *Terminal diagram - Properties* dialog window

Terminal Strip	Defines the associated terminal strip.
Properties...	Opens the properties dialog window for the associated terminal strip.

You can customize the appearance of the terminal diagram in the "*Print Options*" tab. You can see the effects of the settings straight away in the preview on the right-hand side.

If the "*Lines per Page*" option is selected you can specify the number of lines to be displayed per page. The relevant pages will also be output when the circuit diagram is printed. Buttons for navigation are displayed underneath the page if the list is split across multiple pages.

The entries in the "*Description*", "*Identification*" and "*Connector*" columns are taken from the object properties of the associated targets.

17.4.1 Set links

You can set so-called *links* in a terminal strip. These links are drawn in the circuit diagram as regular electric lines and marked as links. The representation of the T distributors can be customized using their properties dialog window.

The following example shows a circuit diagram with a terminal strip X1 with 10 terminals and the associated terminal diagram. A link plug is to be placed at level "1" between terminals "7" and "8" and at level "2" between terminals "8" and "9", and a wire link is to be placed between terminals "9" and "10".

Terminal Strip -X1			
Terminal	Links		
	Link Plug	Wire Link	Identification
1			-S1
2			-Q1
3			-K1
4			-K1
5			-K2
6			-Q1
7			-K1
8			-K2
9			-Y1
10			-Y2

Figure 17/29:

┄┄⟶ Double-click the electric line between terminals "7" and "8".
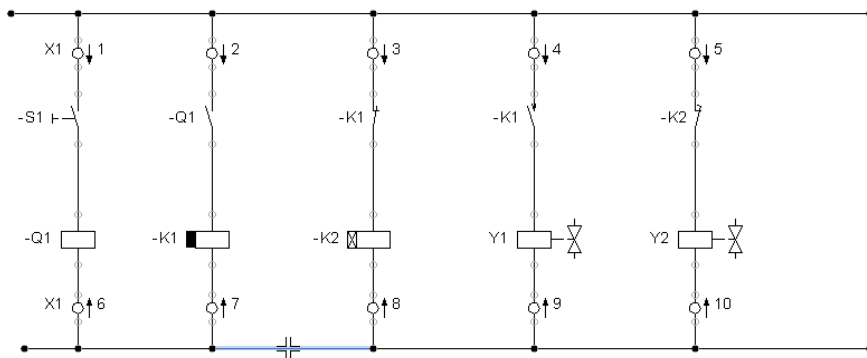
Figure 17/30:

The properties dialog window for the electric line opens. The options for setting the links are in the top right:
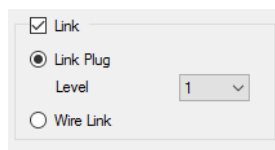
Figure 17/31: Detail of the *Line (electric)* dialog window

Link   Defines that this line is to be treated as a link.

Link Plug   Defines that the link is a link plug.

Level   Specifies the level if a link plug was selected.

Wire Link   Defines that the link is a wire link.

⤑   Set "*Link*", "*Link Plug*" and "*Level 3*".

FluidSIM tracks the line across one distributor point at most. This means that the specified link will find the contacts "7" and "8". This link will be represented in the terminal diagram as follows.

Terminal Strip -X1			
Terminal	Links		Identification
	Link Plug	Wire Link	
1			-S1
2			-Q1
3			-K1
4			-K1
5			-K2
6			-Q1
7			-K1
8			-K2
9			-Y1
10			-Y2

Figure 17/32:

·····> Proceed in the same way to set a link plug between "8" and "9" at level "2" and a wire link between "9" and "10".

The terminal diagram then has the following appearance.

Terminal Strip -X1			
Terminal	Links		Identification
	Link Plug	Wire Link	
1			-S1
2			-Q1
3			-K1
4			-K1
5			-K2
6			-Q1
7			-K1
8			-K2
9			-Y1
10			-Y2

Figure 17/33:

17.5 Contact images

The contact images can be displayed within a circuit diagram beneath relay coils and similar symbols. The contact images list all the contacts of the associated relay coil and show which current paths these contacts are in. The division of the page or circuit diagram can be defined using the page dividers.

⤑   To do this, select the Display Contact Images menu item from the View menu.

The contact images of the current circuit diagram are shown or hidden.

Contact images can be highlighted, moved and aligned like other symbols.
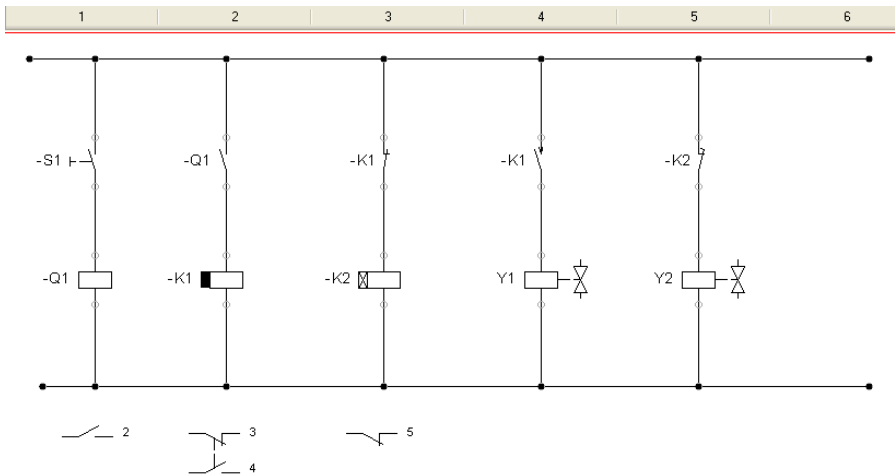
Figure 17/34:

You can have all of the contacts in a contact image displayed in a list and customize the appearance by double-clicking the contact image or highlighting the contact image and selecting the Properties... menu item from the Edit menu.
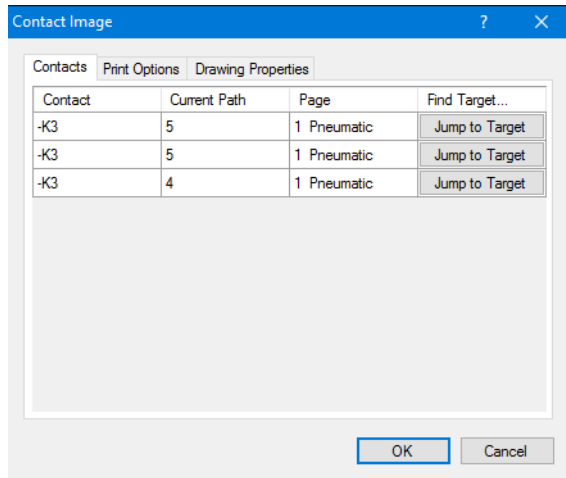
Figure 17/35: *Contact Image* dialog window

You can customize the representation of the contact image in the "*Print Options*" tab.

The "*Contacts*" tab lists all of the associated contacts. You can jump to the corresponding contact in the circuit diagram using the Jump to Target button.

Circuit input and output

Chapter 18

18.1 Print circuit diagram and parts list

FluidSIM circuits and parts lists can be printed by opening the *Print* dialog window via the Print... menu item on the File menu.

In FluidSIM a parts list is the representation of a circuit as a table. If you wish to print an individual parts list then the corresponding circuit must be shown in the parts list display.
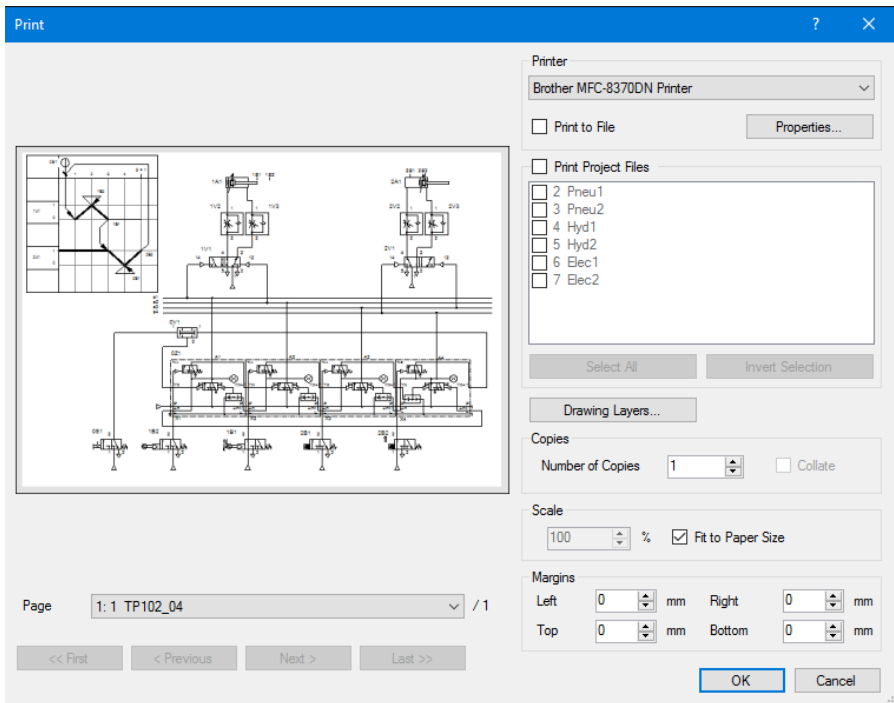
Figure 18/1: *Print* dialog window:

Printer   Select the desired output device from the list of the available print-
                            ers.

Properties...   This button enables you to open the dialog window for setting the
                            printer options.

Print to File   Activate this option if you wish to write the print data to a file.

Print Project Files   When you work in a project you can select which circuits and parts
                            lists are to be printed.

Copies

Select the number of copies. If the printout consists of multiple pages you can cause FluidSIM to print a correspondingly sorted sequence.

Scale

You can increase or decrease the output size by entering a scaling factor. If the dimensions of the area to be printed are larger than the printable area on the paper then the printout is spread across multiple pages (tiled). You can see the page divisions in the print preview.

Note: Please note that it may not always be possible to precisely comply with the page margins. Therefore you should plan a certain amount of leeway for the page margin.

Page

Here you can specify additional margins in order to manually customize the print area.

Margins

You can select which page the print preview displays.

18.2 Import DXF file

Files saved in the DXF format can be imported and retain most of their element attributes. If several special points were taken into account when creating the drawing using a CAD program then FluidSIM can easily expand the symbol library.

18.3 Export circuit

The FluidSIM circuits can be saved as a file with a variety of different formats. The BMP, JPG, GIF, WMF, PNG, DXF, TIF and PDF formats are available. Once you have selected the Export... menu item from the File menu a dialog window opens where you can define the different settings for the export. The settings depend on the format selected.
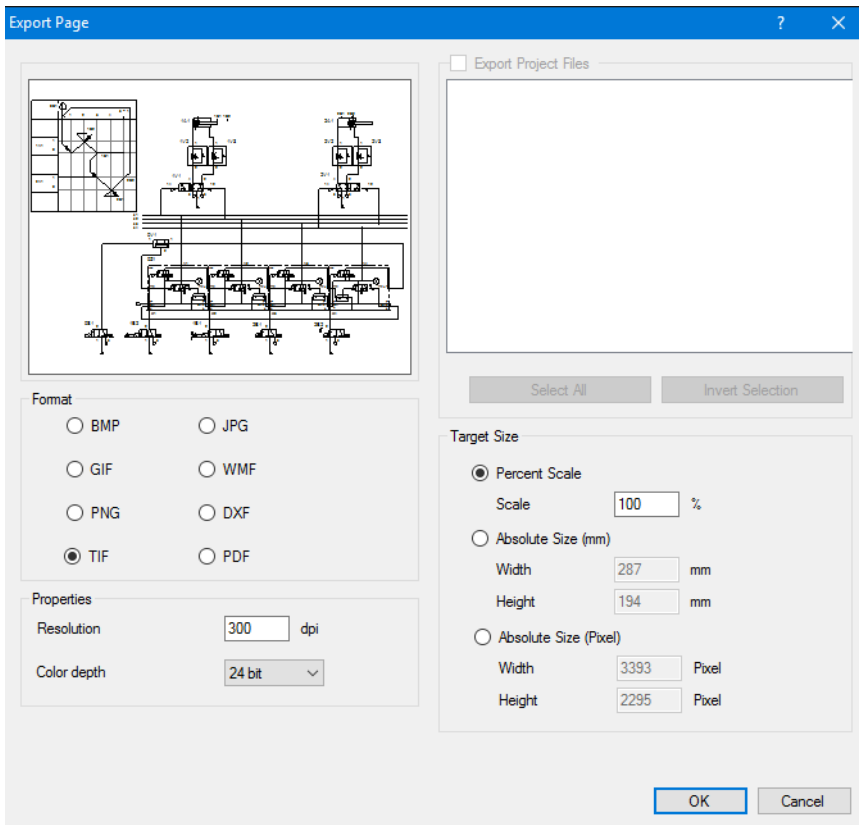
Figure 18/2: *Export Page* dialog window

You are then prompted to select a file name or enter a new one.

Select a suitable resolution for the image file.

Please note that a high resolution generates extremely large files which mean the export may take longer. However you can cancel the image export at any time.

Options

Chapter 19

You can access the various program settings in the *Options* dialog window via the Options... menu item on the Tools menu.

19.1 General
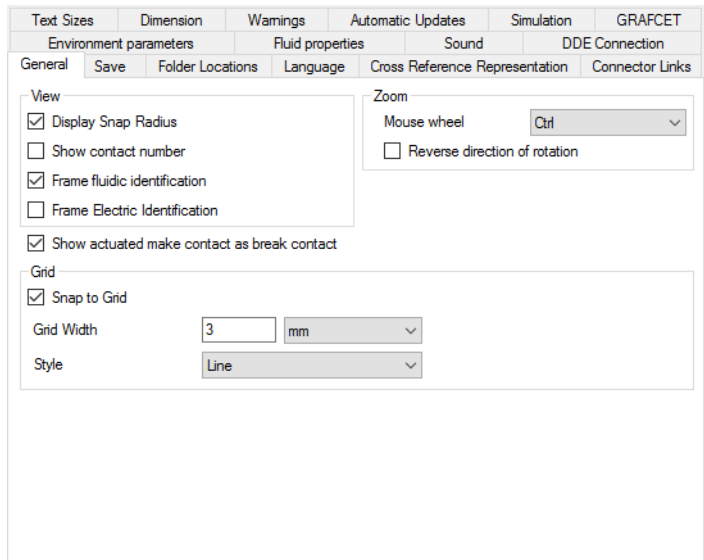
Figure 19/1: *Options* dialog window: *General* tab

Display Snap Radius

In order to simplify connection of connectors FluidSIM draws a small circle around the connectors on the circuit symbols. Deactivate the *Display Snap Radius* option in order to disable the display of the snap-in circles.

Show contact number

Activate the option *Show contact number*, to show, additional to the designation of the corresponding coil, the individual contact

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number. Changing this option doesn't affect already existing contacts but defines the default behavior for newly inserted contacts.

Frame fluidic identification	Activate the *Frame fluidic identification* option if you want fluidic identifications to be framed automatically. This simplifies the depiction of circuits in accordance with standards.
Frame Electric Identification	Activate the *Frame Electric Identification* option if you want electrical identifications to be framed automatically. This simplifies the depiction of circuits in accordance with standards.
Zoom	Here you can set how you can zoom in or out of the page view with the mouse.
Show actuated make contact as break contact	When this option is activated, make switches that are actuated in their initial position are displayed as break switches. Conversely, break switches that are actuated in their initial position are displayed as make switches.
Grid	Here you can set the grid width and the style. To display the grid, select the Show Grid menu item on the View menu.
	As well as absolute values such as "mm" you can also specify the relative basic unit length "M".

19.2 Save
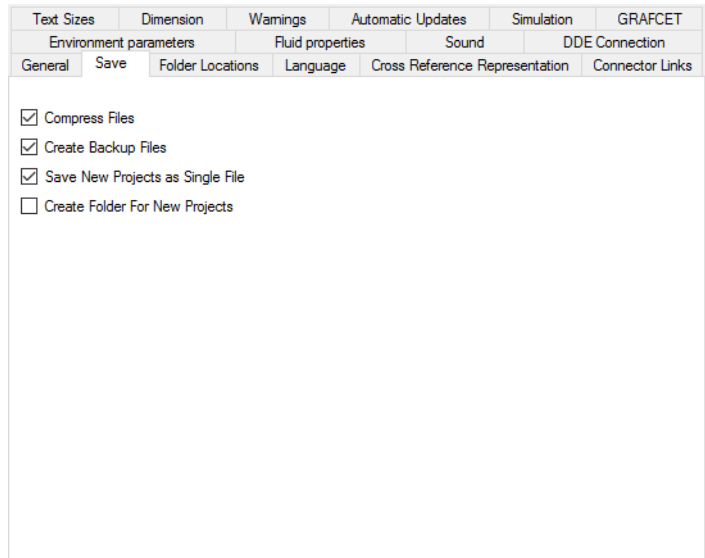
Figure 19/2: *Options* dialog window: *Save* tab

Compress Files	FluidSIM normally compresses the saved files in order to save space on the disk. If you deactivate the option the files are saved as XML files without compression. You can find further information in the Circuit files section.
Create Backup Files	The "*Create Backup Files*" option causes the previous versions of saved files are created with the `bak` file suffix. This enables you to restore previous versions.
Save New Projects as Single File	Project files generally consist of links to the files contained therein. However, where desired FluidSIM can also save the project along with all of the associated circuit files in one single file. This serves to simplify passing on or archiving the project, among other things. You can set whether a project saves links or all of the associated

files using the *Project* dialog window – Properties of the project. This option defines the default setting for new projects.

Create Folder For New Projects

A folder with the project name where all project files are stored is automatically generated when a new project is created if this option is active.

19.3 Folder Locations
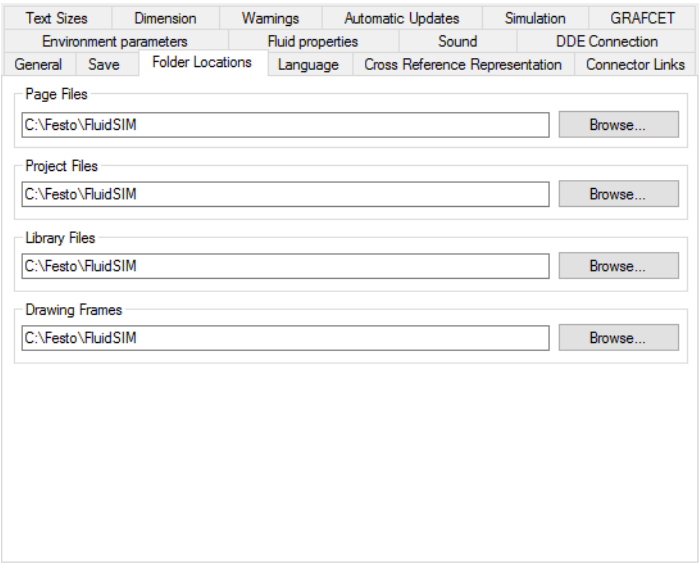
Figure 19/3: *Options* dialog window: *Folder Locations* tab

Page Files

This is the default path for opening and saving circuits.

Project Files

This is the default path for opening and saving projects.

Library Files

This is the default path for opening and saving libraries.

| Drawing Frames | This is the default path for opening and saving drawing frames. |

19.4 Language
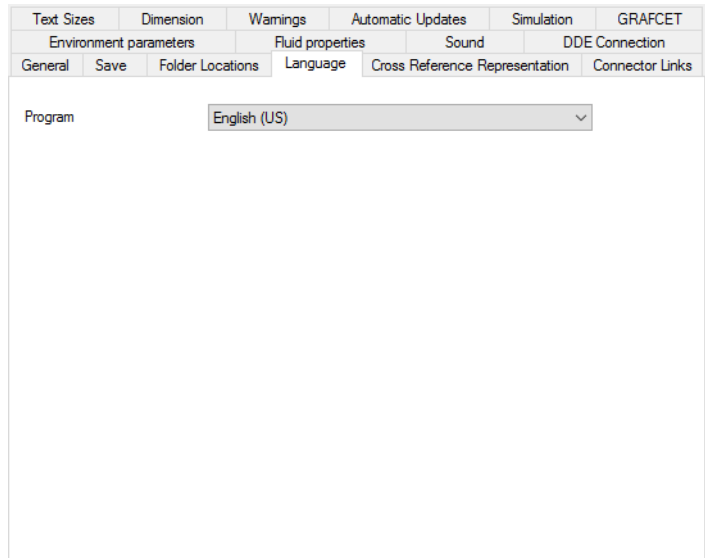
Figure 19/4: *Options* dialog window: *Language* tab

| Program | Defines the languages for the program interface including dialog windows and messages. |

19.5 Dimension

This tab is used to define the default settings for the dimensions. You can find further information under Dimension.
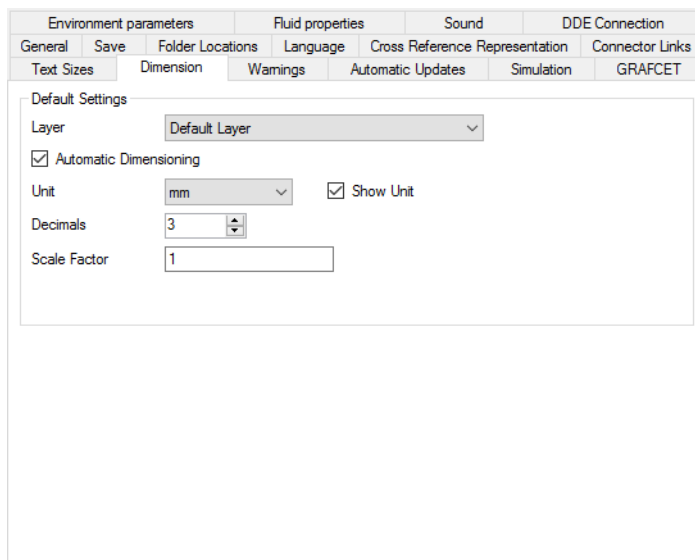
Figure 19/5: *Options* dialog window: *Dimension* tab

All of the settings are only applied to newly generated dimensions. They have no effect on existing dimensions in the circuit.

Layer | Defines the drawing layer where the newly generated dimensions are placed.

Automatic Dimensioning | Activates and deactivates automatic dimensioning. If this option is activated then the displayed dimension value is automatically adapted if the dimension is scaled.

Unit | Defines the unit to be used for the dimension.

Show Unit | Defines whether the unit should be displayed.

Decimals | Defines the number of decimal places.

Scale Factor |

Determines the factor by which the real length is multiplied for the displayed value. This is necessary if you are creating a drawing with a scale other than 1:1.

19.6 Cross Reference Representation

Figure 19/6: *Options* dialog window: *Cross Reference Representation* tab

This tab is used to define the default settings for the cross-reference representation. You can find further information under Cross-reference representation.

The settings are only applied to newly generated projects or circuits. They have no effect on existing objects.

Example	Illustrates the effects of the settings using an example.
Reset	Resets the settings to the settings defined in FluidSIM.

19.7 Connector Links
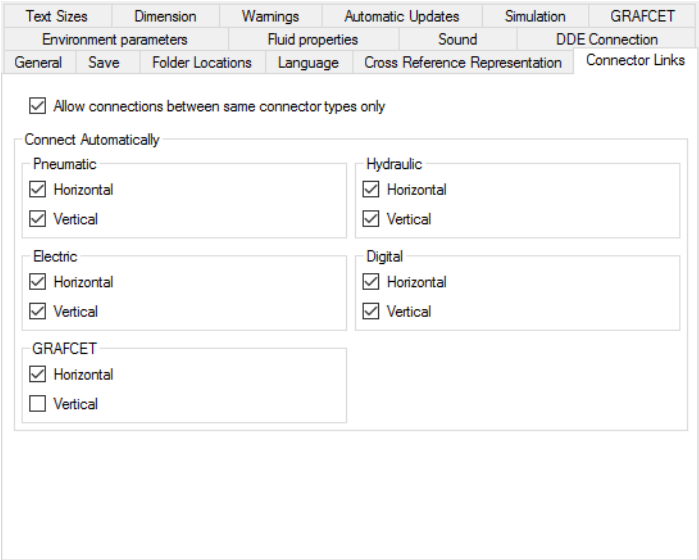
Figure 19/7: *Options* dialog window: *Connector Links* tab

Allow connections between same connector types only	Only connectors of the same type can be connected if this option is active. For example a line from an electric connector to a pneumatic connector cannot be created in this case.
	FluidSIM supports the automatic connection of connectors. The following settings define which connections should be automatically created.

Connect Automatically	FluidSIM supports the automatic connection of connectors. You can define the automatic connection for each connector type individually.
Horizontal	Connectors that are on one horizontal line will be automatically connected when a symbol is inserted or moved.
Vertical	Connectors that are on one vertical line will be automatically connected when a symbol is inserted or moved.

19.8 Warnings
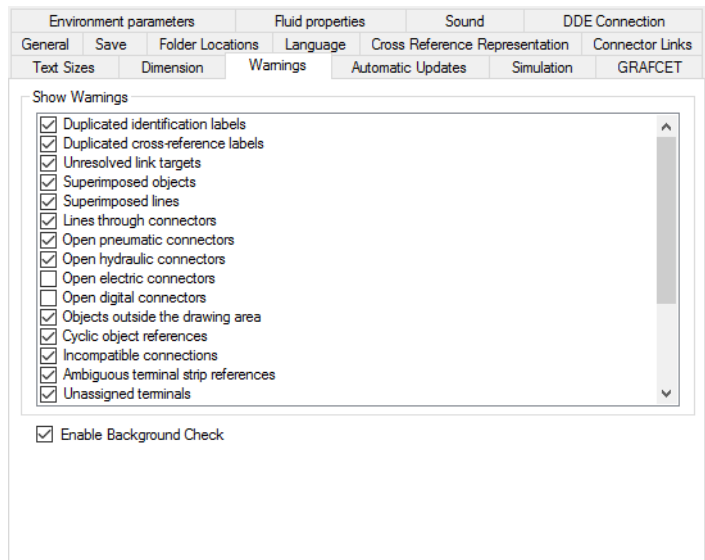
Figure 19/8: *Options* dialog window: *Warnings* tab

Show Warnings	Different types of warnings that FluidSIM should or should not deliver can be activated and deactivated here. These warnings

include "*Duplicated identification labels*" and "*Superimposed objects*".

Enable Background Check　　All of the circuits will be checked during editing if this option is active. Only the criteria that would lead to the warnings specified under "*Show Warnings*" are checked. Objects that caused an error are highlighted in red in the circuit. If this option is not active then the check must be initiated manually using the $\boxed{\text{Page}}$ – $\boxed{\text{Check Drawing}}$ menu.

19.9　Automatic Updates
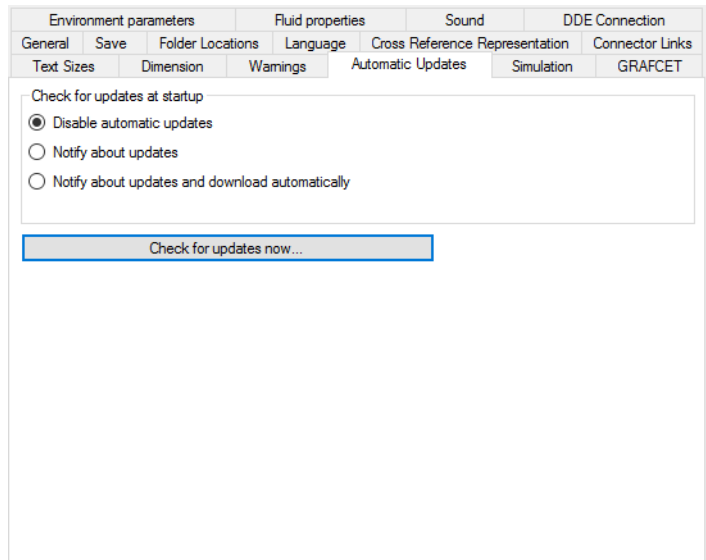
Figure 19/9: *Options* dialog window: *Automatic Updates* tab

Check for updates at startup　　FluidSIM can search on the Internet for a new version when the program starts. You can activate or deactivate the automatic search here.

Check for updates now...   As soon as there is an Internet connection you can use this button to initiate the search for a new FluidSIM version.

19.10 Simulation
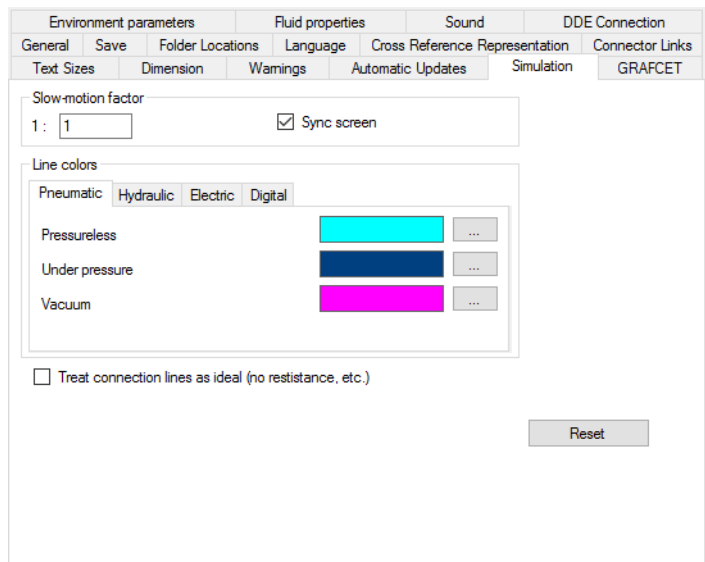
Figure 19/10: *Options* dialog window: *Simulation* tab

Slow-motion factor   You can use this factor to set the ratio of time in which the simulated processes should take place. A value of "1:1" means simulation in real time; "1:10" would mean that the simulation takes place in slow motion, in this case ten times slower than in reality. A ratio of "1:0.1", for example, would mean the simulation is accelerated ten times. Specifications for real time or accelerated processes can only be fulfilled if the computer has sufficient processing power.

Line colors   During the simulation, the pneumatic, hydraulic, electrical, and digital lines will be colored according to their state. You can cus-

tomize the colors for each state. Electrical lines additionally offer the possibility to choose if the line color is determined by current or potential.

Treat connection lines as ideal (no restistance, etc.) By default, pneumatic and hydraulic lines are seen as ideal connections, meaning during simulation pressure loss is not considered. Optional physical models can be chosen in the property dialog of the corresponding lines. For the schematic design these models, being very complex to simulate, are not necessary. Using this global option, the simulation is instructed to ignore the values assigned to the lines.

> **!** In digital technology, it is useful if unused inputs on AND, NAND, and NOT components are automatically set to Hi. Otherwise, for example, an AND gate with three inputs would not function as expected if only two inputs were wired. So that the circuit does not become cluttered with unnecessary permanently Hi level signals, FluidSIM sets unused inputs on the relevant components to Hi automatically. To prevent misunderstandings regarding unused digital inputs, FluidSIM can display a corresponding warning at the start of every simulation.

> **!** Note that these values are only used if no others are defined in the page or project properties.

19.11 GRAFCET
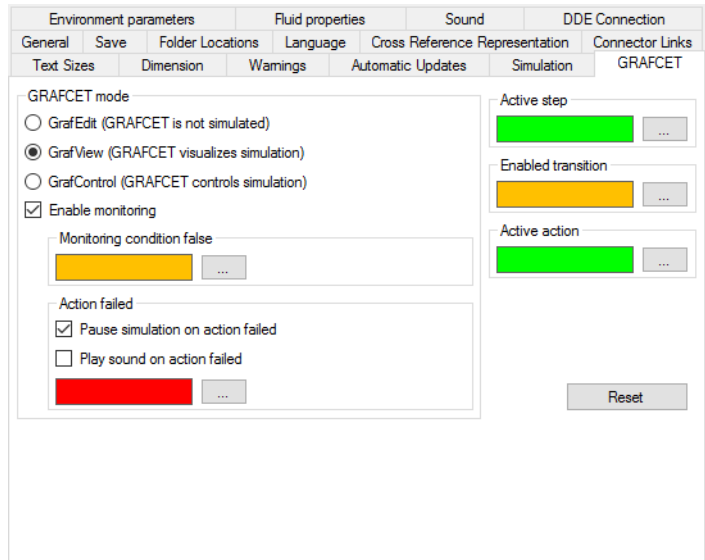
Figure 19/11: *Options* dialog window: *GRAFCET* tab

GRAFCET mode	Here you can set the mode that FluidSIM will apply when handling GRAFCETs during the simulation.
GrafEdit (GRAFCET is not simulated)	In this mode, GRAFCETs are treated as drawings only. They are not incorporated into the simulation. See also Drawing only (GrafEdit).
GrafView (GRAFCET visualizes simulation)	This mode uses GRAFCETs for visual presentation of the simulation. The defined actions, however, have no effect on the simulation. In particular, they do not in any way control the fluidic or electrical components. See also Observation (GrafView).
GrafControl (GRAFCET controls simulation)	In this mode, the GRAFCET has access to all the circuit variables that can be set from outside. This allows it to switch valves over or to adjust throttle valves See also Control (GrafControl).

Enable monitoring

When this option is switched on, the GRAFCET monitors the proper functioning of a fluidic or electrical circuit. For this purpose, you can formulate conditions in the actions which will be checked during the simulation. For more details, see Monitoring with GRAFCET actions.

! Note that these settings are only used if no others are defined in the page or project properties.

19.12 DDE Connection

Figure 19/12: *Options* dialog window: *DDE Connection* tab

Here you can set the default values for the DDE interface.

Server

This is the server name, by which other via DDE linked applications can contact FluidSIM.

| Enable DDE connection | Enables the DDE connectivity. |

! Note that the server name is a global setting of the specific system environment and is not saved with the circuit data. If you want to use the DDE interface in other environments, ensure that the DDE options are adapted accordingly. In particular, ensure that the DDE connection is activated, because it is switched off by default for security reasons.

19.13 Environment parameters

| Ambient temperature | The ambient temperature influences different physical models, e.g the temperature-dependent NTC-resistor or the circuit breaker. |

| Atmospheric pressure | In pneumatics all models use absolute pressures. Indicated pressures are shown as relative pressures compared to the selected atmospheric pressure. |

Figure 19/13: *Options* dialog window: *Environment parameters* tab

Here you can set the default values for the environment parameters.

Note that these values are only used if no others are defined in the page or project properties.

19.14 Fluid properties

Figure 19/14: *Options* dialog window: *Fluid properties* tab

Fluid type

Fluid properties influence different physical models. Density and viscosity in particular influence the calculation of resistance e.g. for valves. This list contains typical oils and other fluids. If you select a predefined fluid, the listed values will be set accordingly.

Note that these values are only used if no others are defined in the page or project properties.

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19.15 Sound

When you click the "*Sound*" tab in the Options... menu, a dialog box appears with parameters for the sound settings:
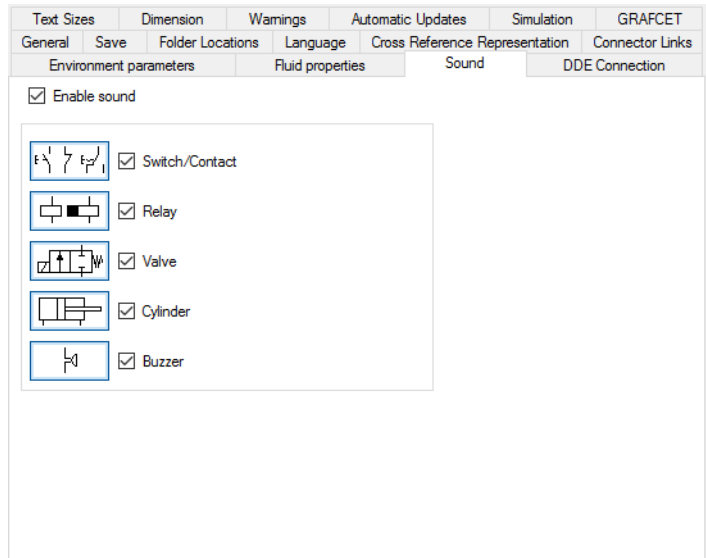
Figure 19/15: *Options* dialog window: *Sound* tab

Enable sound

You can activate/deactivate an audible signal for the components *Switch/Contact*, *Relay*, *Valve*, *Cylinder*, and *Buzzer*.

19.16 Text Sizes
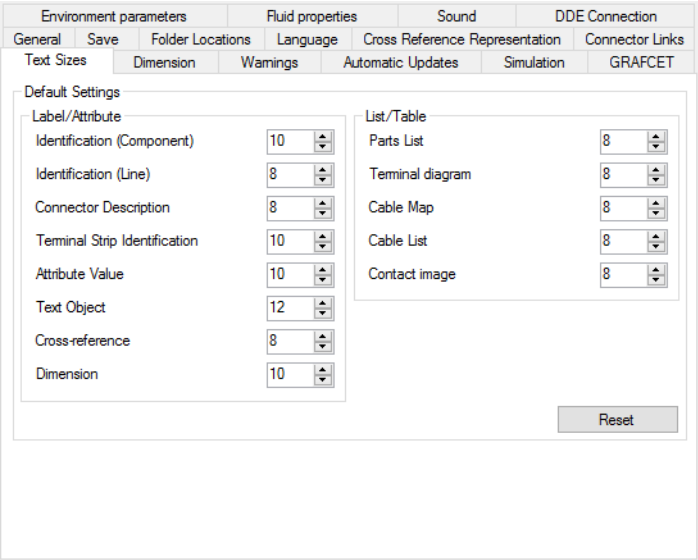
Figure 19/16: *Options* dialog window: *Text Sizes* tab

This tab defines the font sizes to be used for objects newly inserted into the circuit diagram.

Label/Attribute — This group lists the font sizes used for identifications and cross-references, etc.

List/Table — This group lists the font sizes used for analyses and tables.

Menu overview

Chapter 20

20.1 File

New

New / File...

Opens a new window for creating a new circuit drawing.

New / Project...

Opens the dialog window for creating a new project.

Open

Open / File...

Opens a new window for selecting an existing circuit drawing.

Open / Project...

Opens the dialog window for selecting an existing project.

Add

Adds files, etc. to the active project.

Add / New Page

Creates a new circuit file and adds it to the active project.

Add / New Parts List...

Creates a new parts list and adds it to the active project.

Add / Existing Files...

Opens the dialog window for selecting existing files to be added to the active project.

Close

Closes the active window or project, etc.

Close / File...

Closes the active window.

Close / Project...

Closes the active project.

Save File

Saves the circuit diagram in the active window to disk.

Save File As...

Saves the circuit diagram in the active window to disk under a new name.

Save Project

Saves the active project.

Save Project As...

Saves the active project under a new name on the data storage medium. Files that are within the project folder are duplicated while references to external files are left. With external file references you must therefore consider that changes to these files affect all projects containing them.

Save as Component Library...

Saves the active project as a library. As a result a new library symbol is generated for every circuit. The new library bears the name of the project with the `lib` file suffix.

DXF Import...

Opens the dialog window for selecting a saved DXF file. The selected file is subsequently converted into a FluidSIM circuit diagram. The original file remains unchanged.

Export...

Exports the circuit diagram in the active window to the data storage medium as a BMP, JPG, GIF, WMF, PNG, DXF or TIF file.

Page Setup...

Sets up the printer properties for a page to be printed.

Print Preview

Opens a print preview as a page view.

Print...

Opens the FluidSIM *Print* dialog window to set the print options for the active circuit.

Recent Files

A file can be selected for opening from a list of the recently opened files.

Recent Projects

The most recently opened projects can be selected for opening from a list.

Exit

Ends FluidSIM.

20.2 Edit

Undo

Undoes the last editing action for the active circuit.

Redo

Takes back the last undo-action for the active circuit.

Cut

Deletes the selected objects and adds them to the clipboard.

Copy

Copies the selected objects to the clipboard

Paste

Pastes the objects from the clipboard into the active circuit.

Delete

Deletes the selected objects from the active circuit.

Select All

Selects all of the objects from the active circuit.

Group

Groups the selected objects.

Create Macro Object

Creates a macro object out of the selected objects.

Create Cross-reference

Creates a cross-reference.

Ungroup/Break Off

Ungroups the selected groups or macro objects.

Enable Scale

Activates or deactivates the "enable scaling" mode which enables the scaling of symbols with the help of the mouse pointer.

Enable Rotate

Activates or deactivates the "enable rotate" mode which enables the rotation of symbols with the help of the mouse pointer.

Edit Poly Line

Activates or deactivates the "Edit Polyline" mode that allows you to edit a polyline.

Align

Aligns the selected objects with each other.

Rotate

Rotates the selected objects by 90, 180 or 270 degrees anti-clockwise. Grouped objects are rotated around the center point of the group rectangle.

Mirror

Mirrors the selected objects horizontally or vertically. Grouped objects are mirrored along the axis of the group rectangle.

Properties...

Opens the *Properties* dialog window for the selected circuit symbols in order to enter the component properties.

The *Connector* dialog window is opened for the selected component connector enabling you to enter the connector properties.

When a line segment is highlighted a dialog window opens enabling you to enter the line properties.

If multiple objects are selected then a dialog window with a limited selection of properties appears. It only contains those properties which affect all of the selected objects.

20.3 Insert

Find Symbol Description...

Opens the search dialog for selecting a symbol via its appearance or its description.

Conduction Line...

Opens a dialog window that defines the settings for one or more conduction lines that are to be inserted in the circuit diagram after the dialog window is confirmed.

Interruption/Potential...

Adds an interruption or an electric potential to the circuit diagram.

Parts List

Inserts a parts list into the circuit diagram.

Terminal

Inserts a terminal into the circuit diagram.

Multiple Terminals...

Inserts multiple terminals into the circuit diagram.

Terminal diagram

Inserts a terminal diagram into the circuit diagram.

Cable

Inserts a cable into the circuit diagram.

Cable Map

Inserts a cable map into the circuit diagram.

Cable List

Inserts a cable list into the circuit diagram.

Wiring List

Inserts a wiring list into the circuit diagram.

Tube List

Inserts a tube list into the circuit diagram.

20.4 Draw

This menu contains functions for freely drawing graphical elements such as lines, rectangles, circles, etc. as well as for inserting texts and images.

Line

Draws a line by defining two defined end points.

Poly Line

Draws a polyline by defining the vertices with successive mouse clicks. The drawing operation can be cancelled by pressing the Esc key or clicking the right mouse button. The last vertex must be set with a double-click.

Rectangle

Draws a rectangle by defining two diagonally opposite corner points.

Circle

Draws a circle by defining a middle point and a radius.

Ellipse

Draws an ellipse by defining a middle point and two radii on parallel axes.

Text

Inserts a text at the mouse position.

Picture

Inserts an image at the mouse position.

Dimension

Inserts a dimension symbol.

20.5 Page

Check Drawing

Checks the active circuit drawing for drawing errors.

Drawing Size...

Opens a dialog window enabling you to set the paper size.

Manage Terminal Strips...

Opens a dialog window enabling you to manage the terminal strips in the circuit.

Manage Cables...

Opens a dialog window enabling you to manage the cable objects in the circuit.

Properties...

Opens a dialog window enabling you to set the circuit properties.

20.6 Execute

Stop

Switches the currently active circuit into Edit Mode.

Start

Starts the simulation (animation) in the currently active circuit.

Pause

Pauses the simulation in the currently active circuit without exiting Simulation Mode.

If Pause is clicked when in *Edit Mode*, the currently active circuit switches to Simulation Mode without starting the simulation. This allows you to set component states before starting the simulation.

Reset

Resets a circuit to its initial state when a simulation is running or paused. The simulation is then restarted immediately.

Single Step

Stops the simulation after a small step. In other words, the simulation is started for a short period of time before being switched back into pause mode (▐▐). You can switch into single step mode directly from an actively running simulation.

Simulate until State Change

Starts the simulation and runs it until a state change happens; the simulation is then paused (⏸). A state change happens when a cylinder piston moves against a stop, a valve switches over, or a relay or a switch is actuated. You can switch into state change mode directly from an actively running simulation.

Next topic

Switches to the next topic in a presentation.

20.7 Didactics

Component description

Opens the help page for the selected component. It contains the DIN symbol for the component, a short description of the component function, the terminal designations, and a list of any adjustable parameters, with value ranges for those parameters.

Tutorial 'Simulating with FluidSIM'

Opens the tutorial "Simulating with FluidSIM".

Component Library

Opens the reference containing information about the components in the component library.

Didactics Material

Opens an overview of the didactics material. If you copied the film files onto your hard disk during installation, the list of training film chapters will also appear here.

Circuits for exercises (TP)...

Opens a dialog box with exercise circuits for the Festo technology packages.

Presentation...

Opens a dialog box that you can use to retrieve and create presentations. Presentations allow you to combine separate training topics into a cohesive teaching unit.

Extended Presentation...

Opens a dialog box that you can use to retrieve existing presentations in Microsoft PowerPoint format. The presentation files of the extended presentations are located in the **ppx** subfolder of your FluidSIM installation. You can create your own PowerPoint presentations and add them by saving them in "ppt" or "pps" format to the **ppx** folder.

20.8 Diagnosis

Show Diagnosis tool strip

Shows/hides the diagnosis toolbar. The toolbar contains information about any failure configuration that may have been selected, a button for carrying out repairs, defective components, and buttons with virtual measuring instruments.

Insert virtual measuring instrument: Voltage U

Inserts a virtual measuring instrument into the circuit diagram to measure a voltage.

Insert virtual measuring instrument: Current I

Inserts a virtual measuring instrument into the circuit diagram to measure a current.

Insert virtual measuring instrument: Pressure p

Inserts a virtual measuring instrument into the circuit diagram to measure a pressure. The measuring tips for it can be connected to either a pneumatic component or a hydraulic component.

Insert virtual measuring instrument: Flow q

Inserts a virtual measuring instrument into the circuit diagram to measure a flow rate. The measuring tip for it can be connected to either a pneumatic component or a hydraulic component.

Insert universal virtual measuring instrument

Inserts a universal virtual measuring instrument into the circuit diagram. You can then use the Properties dialog window of the measuring instrument to select the variable you want to measure.

Activate repair mode

Activates the repair mode. This function is only available if a failure configuration has been selected in the circuit diagram and the Simulation Mode is active. A component that was previously given a failure can be repaired by clicking it. The repair mode is deactivated again after each attempted repair.

Manage failure configurations...

Opens a dialog window where the failure configuration of the circuit diagram can be managed. Each failure configuration includes a list of components for which specific failures have been selected.

20.9 Project

Add Current Window

Adds the active window to the file list of the open project.

Remove Current Window

Removes the active window from the file list of the open project.

Manage Terminal Strips...

Opens a dialog window enabling you to manage the terminal strips in the project.

Manage Cables...

Opens a dialog window enabling you to manage the cable objects in the project.

Manage Cross References...

Opens a dialog window enabling you to manage the cross-references in the project.

Properties...

Opens the dialog window for entering the project properties.

20.10 View

Circuit Diagram

Switches from the parts list view to the circuit diagram view.

Parts List

Switches to the parts list view.

Library

Shows or hides the libraries window.

Project

Shows or hides the window for managing the project files.

Standard Size

Displays the circuit diagram in its original size.

Previous View

Displays the previous view of the circuit diagram. Repeatedly activating this function switches back and forth between the views previously used.

Fit to Window

Set the zoom level to fit the entire circuit diagram into the window.

View Detail

Defines the new view by drawing a rectangle while holding down the left mouse button.

Zoom In

Zooms the view of the circuit diagram in by one step. Three steps correspond approximately to doubling the zoom factor.

Zoom Out

Zooms the view of the circuit diagram out by one step. Three steps correspond approximately to halving the zoom factor.

Hide didactics explanations

Shows/hides the explanatory text from teaching materials. The explanatory text can be found in pages that can be viewed via the

menu option Didactics *Pneumatic* Didactics Material or Didactics *Hydraulic* Didactics Material .

Full screen (press ESC to exit)

Some teaching materials include films. These films can be shown in full-screen mode. You can exit the full-screen mode using the ESC key.

Show Page Borders

Shows or hides the page borders in the form of a red rectangle. This rectangle displays the borders of the paper format defined on the Drawing Size... menu. Using the print preview you can decide whether and how the drawing is distributed among multiple sheets when printing.

Show Grid

Shows a background grid in the active circuit window. The grid settings can be made in the *General* tab under the Options... menu item from the Tools menu.

Show Rulers

Shows or hides the rulers in the active circuit window.

Show Page Dividers

Shows or hides the page dividers in columns and rows. Cross-references can refer to the column and row containing a symbol. The position and number of the columns and rows can be interactively defined via the page dividers shown.

Quantity Values...

Opens a dialog box for display of quantity values. Here you can define how each quantity value listed ("velocity", "pressure", "current", ...) is to be displayed (" None ", " Individual ", " All ").

Show Flow Direction

If this option is active, small arrows are placed on lines as a visual indication of the flow direction.

Show Flow Animation

If this option is active, lines are animated like conveyor belts as a visual representation of the flow.

GRAFCET...

Opens a dialog box for display of GRAFCET descriptions. Here you can set whether to display the descriptions or the formulas of GRAFCET elements. Note that this option may overwrite the specific settings of individual elements.

Display Current Path Numbering

When this option is active, the current path designations are shown in the electrical circuits. The division of the page or circuit diagram can be defined using the page dividers.

Show Connector Descriptions

Shows or hides the connector descriptions. The *Display* option can be selected in the properties dialog window for the connectors. This option is only evaluated if " Individual " was selected.

Show Connector Descriptions / All

Shows all connector descriptions regardless of the settings at the connectors.

Show Connector Descriptions / Individual

Shows only the connector descriptions for those connectors with the *Display* option activated.

Show Connector Descriptions / None

Hides all connector descriptions regardless of the settings at the connectors.

Show Terminal Directions

Shows or hides the direction arrows at the terminals. The tip of the arrow points into the control cabinet here.

Show Reference Arrow

Shows/hides the reference arrows on measuring instruments to indicate the direction of current.

Show Reference Arrow / All

Shows all arrows regardless of the settings at the terminals.

Show Reference Arrow / Individual

Shows only the arrows for those terminals with the *Show Direction* option activated.

Show Reference Arrow / None

Hides all arrows regardless of the settings at the terminals.

Display Contact Images

Shows or hides the contact images.

Drawing Layers...

Opens a *Drawing Layers* dialog window enabling you to set the properties of the drawing layers.

20.11 Library

Setup units...

Defines, which unit system should be used by default.

Create New Library...

Creates a new library.

Add Existing Library...

Opens the dialog window enabling you to select a saved library file with the **lib** file suffix. The library saved in the file is added to the library window.

Add Existing Symbol Folder...

Opens the dialog window for selecting an existing folder. The entire contents of the selected folder, including all of the circuit symbols and sub-folders contained therein are displayed as a library.

Close Current Library

Removes the active library from the list in the library window. The library file is not deleted by this action and can be opened again using the Library menu and the Add Existing Library... menu item.

Rename Active Library...

Opens a dialog window for entering the name of the library. This function is only available to libraries which the user has created. For write-protected libraries the folder name is shown in the tab.

Sort Current Library Alphabetically

Sorts the contents of the active library alphabetically. This function is only available to libraries which the user has created. Write-protected libraries are automatically sorted and cannot be resorted by the user.

20.12 Tools

Options...

Opens the dialog window with program settings, file paths and language options.

Expert Mode

Switches Expert Mode on and off. Expert Mode provides advanced options for editing and simulation.

Restore Defaults...

Resets the program settings to the default values. This enables you to undo unintentional settings made.

Note: Use this function if you feel that FluidSIM is behaving unexpectedly or files and windows have suddenly disappeared.

20.13 Window

New Window

Opens a window with an additional view of the active window.

Navigation Pane

Opens an overview window with a scaled-down view of the entire circuit diagram. The currently visible area of the active window appears as a white area. The non-visible area of the drawing is shaded grey. By drawing a rectangle in the overview window with the mouse pointer you can define the section of the circuit diagram displayed in the active window. Simply left-clicking on the overview window moves the visible area while retaining the zoom level.

Cascade

Arranges the windows so that they overlap.

Tile Horizontally

Arranges the windows into horizontal tiles.

Tile Vertically

Arranges the windows next to each other.

Close All

Closes all open windows.

20.14 Help

Contents

Displays the contents of the FluidSIM help pages.

Index

Displays the index of the FluidSIM help pages.

Search

Displays the search dialog for the FluidSIM help pages.

Register as user...

Opens a dialog box via which you can register if you would like assistance and information about FluidSIM.

Check for updates...

As soon as there is an Internet connection you can use this menu item to initiate the search for a new FluidSIM version.

About...

Displays the FluidSIM program information.

Functional diagram

Chapter 21

You can find the function diagram in the standard FluidSIM library. You can apply the functions from the Edit menu to the function diagram. Double-click the function diagram or open the *Functional diagram* using the Properties... menu item on the Edit menu.

The buttons in the upper toolbar of the editor are for editing a function diagram. The following six buttons determine the editing mode:

Edit Mode

Draw diagram curves

Insert signal elements

Insert text boxes

Draw signal lines and insert signal connections

Insert additional signal lines

The selected mode is highlighted in white or displayed as a pressed button. shows that signal lines can be drawn in the diagram area by clicking, for example.

If you hover the mouse pointer over a button for a short period of time then a short description is displayed.
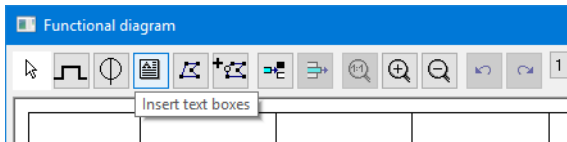
Figure 21/1:

21.1 Edit Mode

This mode serves to adjust the objects in the function diagram. Elements in the diagram can be moved. Changing the size of text boxes is only possible in this mode.

Movement and dragging operations can be cancelled using the Esc key.

If the mouse pointer is moved outside the window area while the left mouse button is held down the view automatically scrolls.

Double-clicking on a diagram element (diagram row, text box, signaling element, etc.) opens a dialog window in which you can make the desired adjustments.

21.1.1 Set diagram properties

Clicking on the Eigenschaften... button opens a dialog window in which you can set the diagram properties.
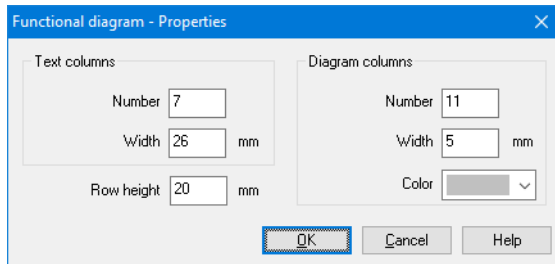
Figure 21/2:

Text columns – Number	If the number of text columns is changed than all of the table text boxes are distributed horizontally and evenly.
Text columns – Width	If the width of the text columns is changed than all of the table text boxes are distributed horizontally and evenly.
Diagram columns – Number	The diagram columns are located on the right-hand side of the function diagram. The diagram curves can be drawn in this area. The number of diagram columns can also be changed by dragging the mouse pointer to the right-hand edge of the diagram.
Diagram columns – Width	Defines the width of the diagram columns.
Color	The color which the grid lines are drawn in the diagram area.
Row height	Defines the row height of all of the rows.

21.1.2 Table textboxes

The table textboxes are located on the left-hand side of the function diagram.

Identification	Description	Function	State

Figure 21/3:

Double-clicking on a table textbox opens the corresponding dialog window.
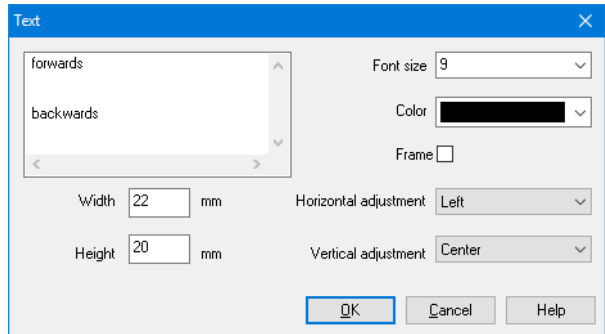
Figure 21/4:

Font size   The font size of the text to be shown.

Color   A selection from sixteen standard colors for the text to be displayed.

Frame   If this field is selected then a frame is drawn around the textbox.

Width   The width of the selected table column can be changed by dragging the mouse pointer.

Height   The height of the selected table column can be changed by dragging the mouse pointer.

Horizontal adjustment   The following alignment options are available: "*Left*" "*Center*" and "*Right*".

Vertical adjustment	The following alignment options are available: "*Top*", "*Center*" and "*Bottom*"
Alignment within a table cell	If a text within a textbox should resemble a table then set a tab stop between the text parts. The text is displayed in the textbox in accordance with the number of tab stops and the specified horizontal and vertical alignment. To enter tab stops hold down the $\boxed{\text{Ctrl}}$ key.

Examples:

1.
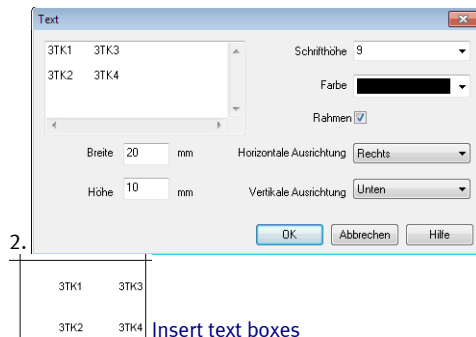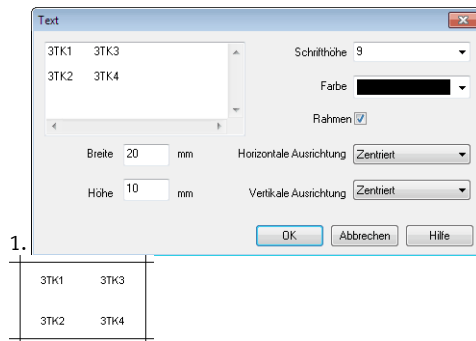
2. Insert text boxes

21.1.3 Adjust the presentation of the diagrams

The area in which curves can be drawn is located on the right-hand side of a diagram row.
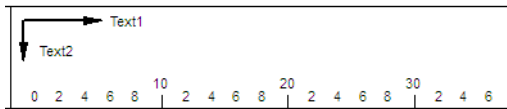
Figure 21/5:

Double-clocking on this area opens a corresponding window in which you can define the appearance of the drawing area. Please ensure that no diagram element, such as a signaling element, for example, is underneath the mouse pointer.
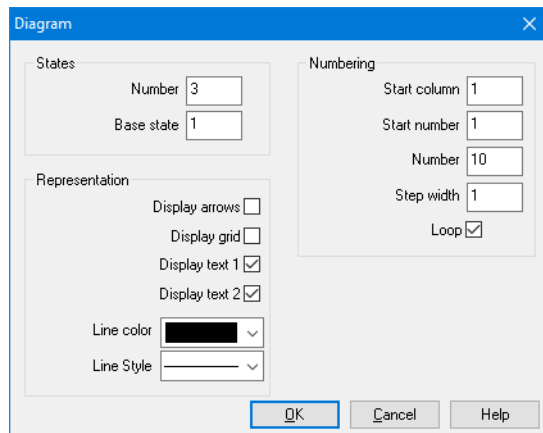
Figure 21/6:

States – Number

The entry defines the number of states and thus the number of horizontal lines in the diagram row.

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States – Base state	Horizontal lines are drawn through the base state with a thin pencil.
Numbering – Start column	The start column defines which column the numbering should begin with.
Numbering – Start number	The start number defines which number the numbering should begin with.
Numbering – Number	The number specified how many steps need to be numbered.
Numbering – Step width	Defines the step width between two numbers.
Numbering – Loop	If this field is selected then an equals sign and the start number are always displayed after the last number.
Representation – Display arrows	If this field is selected then two arrows are displayed.
Representation – Display grid	If this field is selected then the background grid is displayed.
Representation – Display text 1	If this field is selected then a textbox is shown which can serve as a label. This textbox belongs to the selected row and cannot be moved to another row.
Representation – Display text 2	If this field is selected then an additional textbox is shown which can serve as a label. This textbox belongs to the selected row and cannot be moved to another row.
Representation – Line color	Sets the color of the diagram lines.

21.2 Draw diagram curve

In this mode diagram curves can be drawn. Supporting points can only be inserted on the grid. A supporting point is drawn at every left-click.
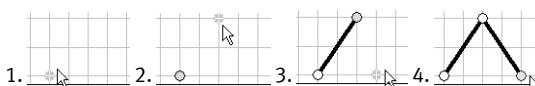
If you hold down the left mouse button then supporting points can be moved as in the selection mode.

Selected supporting points are shown in grey. Use the Del key to delete a selected symbol.

21.3 Insert signal elements

In this mode signaling elements can be inserted by left-clicking.

1.   2.
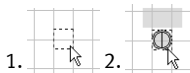
If you hold down the left mouse button then signaling elements can be moved as in the selection mode.

Selected signaling elements are shown in grey. Use the Del key to delete a selected signaling element.

Double-clicking on a signaling element in the selection mode opens a dialog window in which you can modify how the signaling element is shown.
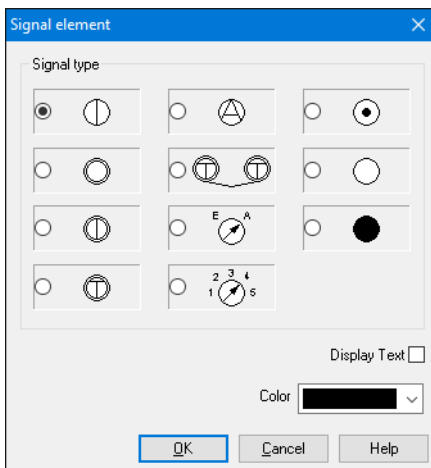
Figure 21/7:

Display Text   If this field is selected then a text is shown which can serve as a label for the signaling element.

Color   The signaling element is displayed in this color.

21.4 Insert text boxes

 In this mode textboxes can be inserted by left-clicking.
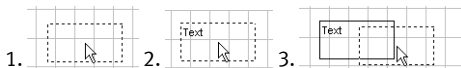
Selected textboxes are shown in grey. Use the Del key to delete a selected textbox.

In "*Edit Mode*" the size and position of a textbox can be changed using the mouse pointer.

Adjust size:

1.   2.   3.

Move textbox:

1.   2.   3.
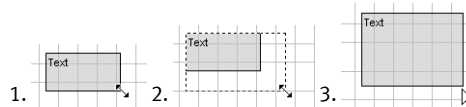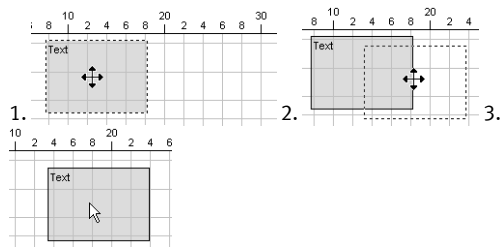
Double-clicking on a textbox in the selection mode opens a dialog window in which you can modify how the textbox is shown.
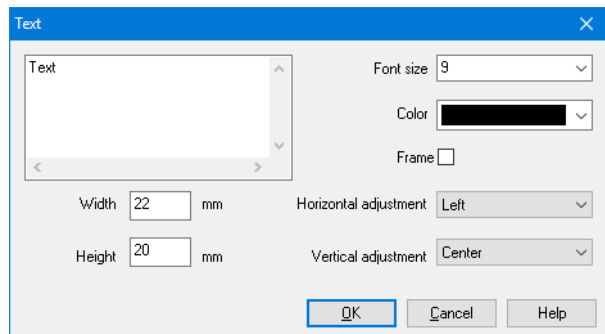
Figure 21/8:

| Font size | The font size of the text to be shown. |
| Color | A selection from sixteen standard colors for the text to be displayed. |

Frame	If this field is selected then a frame is drawn around the textbox.
Width	The width of the textbox.
Height	The height of the textbox.
Horizontal adjustment	The following alignment options are available: "*Left*", "*Center*" and "*Right*".
Vertical adjustment	The following alignment options are available: "*Top*", "*Center*" and "*Bottom*"

Table textboxes

21.5 Draw signal lines and insert signal connections

⊡ In this mode signal lines can be drawn freely or automatically laid from signaling elements.

21.5.1 Free-draw signal lines

An additional supporting point is set with every left-click. The process ends when you click the current line while holding down the Ctrl key, press the Esc key or switch the editing mode. Use the Del key to delete a selected signal line. If only a supporting point is selected then only this is removed from the line.

In "*Edit Mode*" the supporting points belonging to the signal lines can be moved. If the Shift is held down while setting or moving supporting points then the supporting point is vertically or horizontally aligned.

In the selection mode double-clicking can change the way the line is displayed.
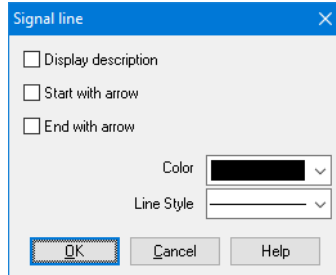
Figure 21/9:

|	
Display description	A framed label on the line and a label next to the framed label are shown. The framed label can be moved freely along the line. The additional label can be moved freely.
Start with arrow	An arrow is displayed at the beginning of the line. The arrow can be moved freely along the line.
End with arrow	An arrow is displayed at the end of the line. The arrow can be moved freely along the line.
Color	Line color

If you click a finished signal line to activate the "Freely move signal lines" mode then a signal logic is inserted. This logic point (snap point) can then be freely moved along the line 1.
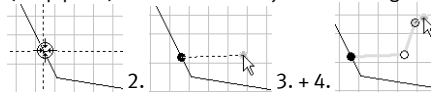
In the selection mode you can change how the signal logic is displayed by double-clicking on it.
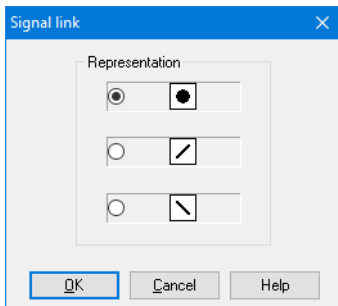
Figure 21/10:

21.5.2 Drawing signal lines from signals

In the "Freely draw signal lines" ⬚ signal lines can be drawn from signals. Left-click a signal and hold down the mouse button. Drag the mouse pointer to a position which you have selected as the end point of a signal line. The signal line will be drawn once you release the mouse button.
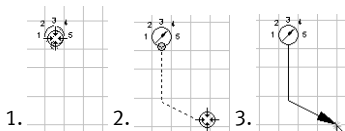
## 21.5.3 Draw signal lines from diagram support points

In the "Freely draw signal lines" mode ⬚ signal lines can be drawn from curve support points. Left-click a supporting point and hold down the mouse button. Drag the mouse pointer to a second supporting point. The signal line will be drawn once you have the

mouse pointer over the second supporting point and release the
mouse button.
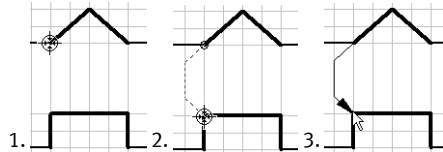
21.6 Insert additional signal lines

In the "*Insert additional signal lines*" mode ⊞ additional support-
ing points can be inserted into existing signal lines.
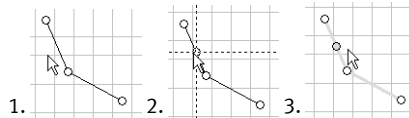
21.7 Insert row

Clicking on the "*Insert row*" button ⊞ inserts a new diagram row
above the current selection. If no cell is market then a new row is
attached to the end of the diagram.

21.8 Delete row

Clicking on the "*Delete row*" button ⊞ deletes a selected diagram
row. If nothing is selected then the function is not available.

21.9 Additional editing functions

21.9.1 Zoom

Using the ⊕ button the view is reset to the standard zoom level.

Using the ⊕ button increases the zoom level.

Using the ⊖ button decreases the zoom level.

21.9.2 Undo editing steps

Using the ↶ button you can undo the last 50 editing steps.

Using the ↷ button you can redo the previously undone editing steps.

The Component Library

Chapter 22

In FluidSIM each component in the component library is assigned a physical model. Using these models, FluidSIM first creates a global behavior model of the circuit which is then processed during simulation.

This chapter provides for a short description of the components in FluidSIM 's component library. If the component has adjustable parameters, their value ranges are given. A number in brackets after the value range indicates the default setting for the parameter.

22.1 Hydraulic

22.1.1 Supply elements
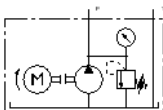
Pump unit

The pump unit supplies a constant volumetric flow. The operating pressure is limited by the internal pressure relief valve. The pump unit has two tank connections.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (6)
Revolution: 0 ... 5000 1/min (1450)
Displacement: 0.1 ... 5000 cm3 (1.6)
Internal leakage: 0 ... 10 l/(min.bar) (0.002)

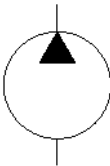**Pump unit (simplified representation)**

Simplified representation of the detailed pump unit. The component does not have tank connections in the circuit diagram.

Adjustable parameters
Delivery rate: 0 ... 500 l/min (2)
Maximum pressure: 0 ... 40 MPa (6)
Internal leakage: 0 ... 10 l/(min.bar) (0)

Fixed displacement pump

The fixed displacement pump delivers a constant volumetric flow rate dependent upon the revolutions and the displacement volume.
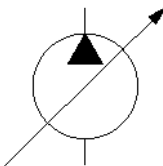
Adjustable parameters
Revolution: 0 ... 5000 1/min (1320)
Displacement: 0.1 ... 10000 cm3 (1.6)
Maximum pressure: 0.1 ... 40 MPa (6)
Internal leakage: 0 ... 10 l/(min.bar) (0)

Variable displacement pump

The revolutions of the variable displacement pump can be changed under operating conditions. The pump delivers a variable volumetric flow rate dependent upon the variable revolutions and the displacement volume.
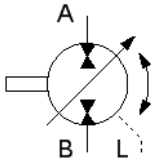
Adjustable parameters
Revolution: 0 ... 5000 1/min (1320)
Displacement: 0.1 ... 10000 cm3 (1.6)
Flow rate ratio: 0 ... 100 % (100)
Maximum pressure: 0.01 ... 40 MPa (6)
Internal leakage: 0 ... 10 l/(min.bar) (0)

Reversible pump-motor unit with two directions of flow and variable displacement volume, external drain and two directions

The pump/motor-unit can be used as a pump as well as a motor. The mode of operation has to be selected for simulation. In operation mode "Pump" the number of revolutions selected by the user is imparted. In operation mode "Motor" the number of revolutions results from the flow rate among other things.

The number of revolutions can be set for both rotation directions. The displacement volume can also be changed during simulation.

The leakage flow has to be diverted using connector L.

Adjustable parameters
Operating mode: Pump,Motor (Pump)
Revolution: -5000 ... 5000 1/min (1450)
Flow rate ratio: 0 ... 100 % (100)
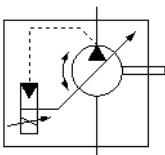**Maximum pressure:** 1 ... 400 bar (160)
Displacement: 0.001 ... 5 l (0.008)
Leakage: 0 ... 10 l/(min.bar) (0.01)
External torque: -1000 ... 1000 N.m (0)
Friction: 0.001 ... 100 N.m.s/rad (0.0108)
Moment of inertia: 0.0001 ... 10 kg.m2 (0.0001)

**Proportional adjustable pump**

The revolutions of the variable displacement pump can be changed proportionally from zero to maximum through a voltage signal between 0 V and 10 V and the assistance of a proportional-amplifier. The pump delivers a variable volumetric flow rate dependent upon the variable revolutions and the displacement volume.

Adjustable parameters
Mode of control: Displacement control,Speed control (Displacement control)
Displacement: 0.1 ... 5000 cm3 (1.6)

Revolution (min): 0 ... 5000 1/min (0)
Revolution (max): 0 ... 5000 1/min (1320)
Flow rate ratio (min): 0 ... 1 (0)
Flow rate ratio (max): 0 ... 1 (1)
Maximum pressure: 0.01 ... 40 MPa (6)
Internal leakage: 0 ... 10 l/(min.bar) (0)
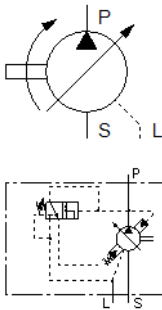
### Variable vane pump, pilot operated

The pump sucks fluid via connection S and displaces it while pressure at connection P is below the zero stroke pressure "p0", set on the pressure controller. Starting at a pressure of "p0 – p_reg" the control piston gets deflected and the flow is reduced. The leakage flow at maximum pressure "p_max" is regulated by "q_L".

The average control time for on-stroke control and off-stroke control is defined by "t_ctr".

The maximum theoretical flow is defined by the product of "V" and "rpm". The actual maximum flow can be limited by setting "q_max". To take effect, "q_max" has to be less than the maximum theoretical flow.

Adjustable parameters
Nominal pressure: 0.1 ... 400 bar (30)
Pressure regulation range: 0.1 ... 100 bar (5)
Max. flow rate: 1 ... 400 l/min (21)
Revolution: 0 ... 5000 1/min (1450)
Displacement: 0.1 ... 400 cm3 (14)
Maximum pressure: 1 ... 400 bar (160)
Internal leakage @ p_max: 0.001 ... 100 l/min (2.7)
Control time (Ø): 1 ... 1000 ms (100)
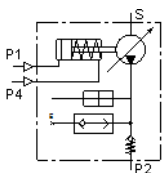
Piston pump, pneumatically operated

This piston pump delivers a hydraulic medium from tank connection S to connection P2. It is actuated by a pneumatic cylinder via

connections P1 and P2. The actuating piston is equipped with a reset spring. The hydraulic part is secured with a rupture disc against high pressures.

The pneumatic / hydraulic transmission can be defined by "r". The transmission ratio is calculated by 1 : r. The flow can be adjusted by a stroke limitation during simulation. It is defined by "x_max_rel" in percent relative to the maximum stroke.

Please note, that using this component in FluidSIM requires a license for hydraulics as well as for pneumatics.
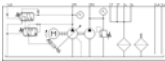
Adjustable parameters
Displacement: 0.01 ... 10000 cm3 (0.5)
Ratio 1:: 0.1 ... 1000 (28)
Burst pressure: 0.1 ... 1000 bar (160)
Total stroke (%): 0.1 ... 100 % (100)
Total stroke: 1 ... 1000 mm (50)

Hydraulic power pack with LS variable and constant displacement pump combination

The hydraulic power pack is suitable for all basic experiments in mobile hydraulics. Both pumps are powered by a single electric motor.

The controllable axial piston pump has a load-sensing pump controller. The constant displacement pump is protected by a pressure relief valve.

The motor-pump unit is located on top of the tank. There's a return filter in the return line to the tank. The tank vent is also filtered. The oil level can be read at the sight glass with temperature indicator.

The motor is switched on and off with an on/off switch. The motor is protected against overloading, and is secured against restart after power failure.

Adjustable parameters

Revolution: 0 ... 5000 1/min (950)
Displacement (Variable displacement pump): 0 ... 10000 cm3 (5.3684)
Leakage: 0.0001 ... 10 l/(min.bar) (0.0075)
Spring preload: 0.1 ... 10 MPa (1.05)
Maximum pressure: 0.1 ... 40 MPa (6)
Pressure regulation range: 0.01 ... 10 MPa (0.1)
Time constant: 0.001 ... 10 s (0.02)
Displacement (Fixed displacement pump): 0 ... 10000 cm3 (4.7368)
Leakage: 0.0001 ... 10 l/(min.bar) (0.01375)
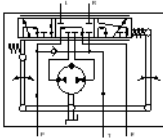**Opening pressure (Fixed displacement pump):** 0 ... 40 MPa (5)

Hydraulic power pack with LS variable and constant displacement pump combination
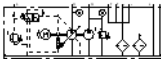
The hydraulic power pack is suitable for all basic tests of mobile hydraulics. The two pumps are both driven by one electric motor. The vane pump with adjustable delivery rate has a load sensing pump controller. The fixed displacement pump is secured by a pressure relief valve. The pump/motor unit sits on the tank. The return into the tank passes through a return flow filter. The ventilation of the tank is also filtered. The oil level can be seen on the sight glass with temperature display. The motor is switched on and off from a control console and is safeguarded against overloading.

Adjustable parameters
Revolution: 0 ... 5000 1/min (910)
Displacement (Variable displacement pump): 0 ... 10000 cm3 (5.6044)
Opening pressure (Variable displacement pump): 0 ... 40 MPa (5)
Spring preload: 0.1 ... 10 MPa (1.17)
Leakage: 0.0001 ... 10 l/(min.bar) (0.028333)
Displacement (Fixed displacement pump): 0 ... 10000 cm3 (4.5055)
Opening pressure (Fixed displacement pump): 0 ... 40 MPa (5)
Leakage: 0.0001 ... 10 l/(min.bar) (0.003333)

Steering unit (Orbitrol)

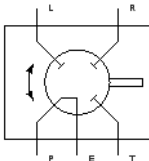The steering unit is used to steer vehicles that are equipped with hydrostatic steering.

The steering unit consists of a proportional rotary valve, a pump control valve and a dosing pump. The rotary valve is opened proportional to torque (steering force) and direction of rotation. The control edges of the proportional valve are arranged radially at several levels on the rotary piston and the inside of the rotary valve housing. A spring package assures a spring centered, closed mid-position.

Adjustable parameters
External torque: -10 ... 10 N.m (0)
Displacement: 0 ... 10000 cm3 (32)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Steering unit (Orbitrol)

The steering unit is used to steer vehicles that are equipped with hydrostatic steering.
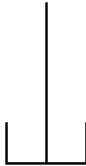
The steering unit consists of a proportional rotary valve, a pump control valve and a dosing pump. The rotary valve is opened proportional to torque (steering force) and direction of rotation. The control edges of the proportional valve are arranged radially at several levels on the rotary piston and the inside of the rotary valve housing. A spring package assures a spring centered, closed mid-position.

Adjustable parameters
External torque: -10 ... 10 N.m (0)
Displacement: 0 ... 10000 cm3 (32)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Tank

The tank is integrated into the pump unit and has a pressure of 0 MPa. It can be inserted into the circuit diagram as an independent component.

Hose with quick-action coupling

The hose is available in 3 lengths: 600 mm, 1500 mm, and 3000 mm. The pressure loss in a hose is taken into account by specifying a hydraulic resistance. In FluidSIM no pressure loss is simulated with simple connections between two components.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)
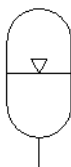
Reservoir

The reservoir enables the performance of a hydraulic system to be optimized. For example, it can be utilized as an energy reservoir and for the absorbance of pressure surges or flow fluctuations. Reservoirs are capable of absorbing a defined volume of fluid under pressure and releasing it again with minimal losses. The construction consists essentially of a pressure resistant container, generally a gas charge of nitrogen and a separator e.g. a piston, a membrane or a bubble elastomer. Hydraulic fluid only starts to flow into the reservoir when the fluid pressure is greater than the gas-preload pressure.

Adjustable parameters
Volume: 0.01 ... 100 l (0.32)
Pre-load pressure: 0 ... 40 MPa (1)
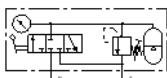**Polytropic exponent:** 0.5 ... 3 (1.4)

Reservoir

The reservoir enables the performance of a hydraulic system to be optimized. For example, it can be utilized as an energy reservoir and for the absorbance of pressure surges or flow fluctuations. Reservoirs are capable of absorbing a defined volume of fluid under pressure and releasing it again with minimal losses. The construction consists essentially of a pressure resistant container, generally a gas charge of nitrogen and a separator e.g. a piston, a membrane or a bubble elastomer. Hydraulic fluid only starts to flow into the reservoir when the fluid pressure is greater than the gas-preload pressure.

Adjustable parameters
Volume: 0.01 ... 100 l (0.32)
Pre-load pressure: 0 ... 40 MPa (1)
Polytropic exponent: 0.5 ... 3 (1.4)

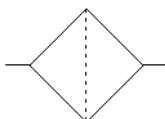### Diaphragm accumulator with shutoff block

Stores the pressure and is equipped with a pressure relief valve to prevent overpressure.

Adjustable parameters
Pre-load pressure: 0 ... 40 MPa (1)
Volume: 0.01 ... 100 l (0.32)
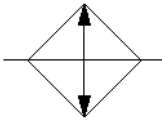**Opening pressure:** 0 ... 35 MPa (8)

Filter

The filter limits the contamination of the fluid respecting a certain tolerance value in order to reduce the risk of damage at the components.

Adjustable parameters

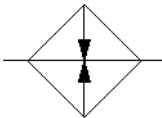**Hydraulic resistance:** 1e-6 ... 1000 bar.min2/l2 (0.001)

Cooler

An unacceptable fall in the hydraulic fluid's viscosity can be avoided through the use of a cooler.

Adjustable parameters
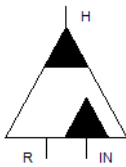**Hydraulic resistance:** 1e-6 ... 1000 bar.min2/l2 (0.001)

Heater

The hydraulic fluid's optimal viscosity can be reached quickly through the use of a heater.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.001)

Pressure intensifier

The pressure intensifier converts a low input pressure to a higher output pressure according to the intensification ratio "r".

An oscillating pump piston, which will be automatically reversed in the end positions by a hydraulically-operated valve, is installed in the intensifier. The ratio of the piston areas corresponds to the intensification ratio "r". For unhindered flow in the low-pressure range, the pump piston will be bypassed by means of a bypass-line. A pilot-controlled check valve shuts off the high pressure.
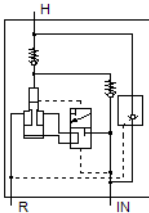
An internal leakage between connections IN and R can be defined by "G_leak".

The exact component parameters are not available in general. The characteristics *Transmission ratio*, *Maximum pressure* (IN), *Max. flow rate* (IN) and *Max. flow rate* (H) can be taken from the data sheets. The component parameters are estimated based on the data sheets.

"q_max_hi" (*Max. flow rate* (H)) relates to a flow at connection H with a counter pressure of 60% of the maximum operating pressure.

Adjustable parameters
Transmission ratio: 1.1 ... 20 (2)
Leakage IN-R: 0 ... 100 l/(min.bar) (0.05)
Maximum pressure (IN): 1 ... 500 bar (125)
Max. flow rate (IN): 0.1 ... 100 l/min (14)
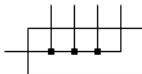**Max. flow rate (H):** 0.1 ... 100 l/min (1.3)

T distributor

The distributor can be used anywhere to create a branch.

Adjustable parameters
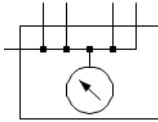**Hydraulic resistance:** 1e-6 ... 1000 bar.min2/l2 (0.04)

4-way distributor plate

All quick connection couplings are connected via holes in the distributor block.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.04)

4-way distributor plate, with pressure gauge

All quick connection couplings are connected via holes in the distributor block. The coupling nipple on the side can be swapped with the blanking plug on the opposite side. The pressure in the distributor can be read off on the pressure gauge.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.04)

Connection (hydraulic)

A hydraulic connection is a place where a hydraulic line can be attached to. To simplify the line drawing process, a connection appears as a small circle in Edit Mode. Hydraulic connections can be shut by means of a blind plug. An open hydraulic connection may result in leaking oil; FluidSIM thus pops up a warning message, if some hydraulic connection was left open. Note that at each hydraulic connection values for the flow and pressure can be displayed.
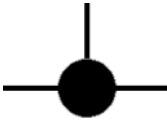
Line (hydraulic)

A hydraulic line is used to connect two hydraulic connectors. These may be either a simple hydraulic connection or a T-junction.A hydraulic line is normally treated as an ideal connection, with no pressure drop being included in the simulation. A frictional loss can be entered via the "*Physical model*" options. If you select "*Simple resistance*", only the "*Hydraulic resistance*" parameter will be included in the simulation. If you select "*Pipe model (Hagen-Poiseuille/Blasius)*", a complex empirical calculation is carried out using a model based on Hagen-Poiseuille for laminar flows and a model based on Blasius for turbulent flows, utilizing the Reynolds number and the wall surface roughness.

Error models

Component clogged: The component is clogged. The restricted flow can be adjusted.

Hydraulic T-connection

A T-junction joins up to four hydraulic lines, thus having a single pressure potential. Note that T-junctions are introduced automatically by FluidSIM when dropping the line drawing cursor onto another line in Edit Mode.

22.1.2 *Directional valves, Configurable*
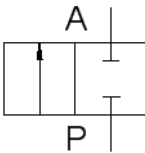
2/n Way Valve

The configurable 2/n way valve is a way valve with two connections, where both its body elements and its operation modes are user-definable.

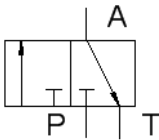Additionally, the hydraulic connections can be closed with blind plug.

Adjustable parameters
Desired position: 0 … 4 (0)
Hydraulic resistance: 1e-6 … 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 … 10 s (0.02)
Reset time: 1e-4 … 10 s (0.03)
Minimum voltage: 0.1 … 300 V (20)
Electrically left at U_min: 0.01 … 100 N (70)
Electrically right at U_min: 0.01 … 100 N (70)
Mechanically left: 0.01 … 100 N (100)
Mechanically right: 0.01 … 100 N (100)
Physical spring force: 0.01 … 100 N (30)
Minimum force: 0.01 … 100 N (20)
Min. pilot control force: 0.01 … 100 N (15)

Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

3/n Way Valve

The configurable 3/n way valve is a way valve with three connections, where both its body elements and its operation modes are user-definable.

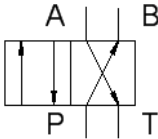Additionally, the hydraulic connections can be closed with blind plugs.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

4/n Way Valve

The configurable 4/n way valve is a way valve with three connections, where both its body elements and its operation modes are user-definable.

Additionally, the hydraulic connections can be closed with blind plugs.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
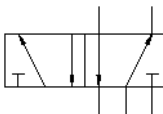**Left:** 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

5/n Way Valve

The configurable 5/n way valve is a way valve with three connections, where both its body elements and its operation modes are user-definable.

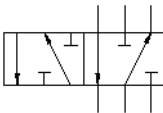Additionally, the hydraulic connections can be closed with blind plugs.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

6/n-way directional valve

The configurable 6/n way valve is a way valve with three connections, where both its body elements and its operation modes are user-definable.

Additionally, the hydraulic connections can be closed with blind plugs.
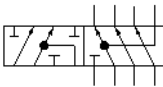
Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)

Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

8/n-way directional valve

The configurable 8/n way valve is a way valve with three connections, where both its body elements and its operation modes are user-definable.

Additionally, the hydraulic connections can be closed with blind plugs.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
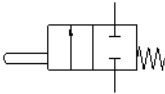
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

22.1.3 *Directional valves, Mechanically operated*

2/2-way stem-actuated valve

If the cylinder piston actuates the stem, flow is enabled from P to A.

This valve is derived from a configurable 2/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
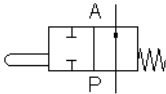**Left:** 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)

Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

2/2-way stem-actuated valve

If the cylinder piston actuates the stem, the flow from P to A is shut off.

This valve is derived from a configurable 2/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
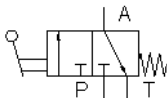**Min. pilot control force:** 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

3/2-way hand-lever valve

In normal position the connection P is closed and A to T opened. When manually actuated T is shut off and P to A opened. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.
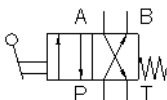
Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.

4/2-way hand-lever valve (i)

In normal position the connection P is open to B and A to T. When manually actuated the valve is set to parallel position. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.
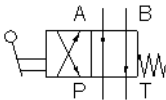
Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/2-way hand-lever valve (ii)

In normal position the connection P is open to A and B to T. When manually actuated the valve is set to crossover position. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
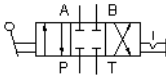**Electrically right at U_min:** 0.01 ... 100 N (70)

Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way hand-lever valve with shutoff position (i)

In normal position all connections are closed. When manually actuated the valve is set to parallel or crossover position. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
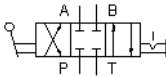**Pilot control left:** 0.01 ... 100 cm2 (1)

Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way hand-lever valve with shutoff position (ii)

In normal position all connections are closed. When manually actuated the valve is set to crossover or parallel position. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves",
under the Library menu.

Adjustable parameters
Desired position: 0 ... 4   (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
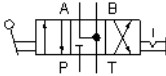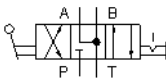**Pilot control left:** 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way hand-lever valve with floating position (i)

In normal position the connections A and B are open to T. When manually actuated the valve is set to parallel or crossover position. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way hand-lever valve with floating position (ii)

In normal position the connections A and B are open to T. When manually actuated the valve is set to crossover or parallel position. This valve is derived from a configurable 4/n way valve. You find

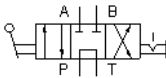this valve in the component library "Frequently used Way Valves",
under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all con-
nectors are internally connected.

4/3-way hand-lever valve with bypass position (i)

In normal position the connections A and B are closed and P to T
opened. When manually actuated the valve is set to parallel or
crossover position. This valve is derived from a configurable 4/n
way valve. You find this valve in the component library "Frequently
used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
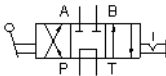**Reset time:** 1e-4 ... 10 s (0.03)

Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way hand-lever valve with bypass position (ii)

In normal position the connections A and B are closed and P to T opened. When manually actuated the valve is set to crossover or parallel position. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4   (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
**Min. pilot control force:** 0.01 ... 100 N (15)

Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

22.1.4 *Directional valves, Solenoid operated*

4/2-way solenoid valve (i)
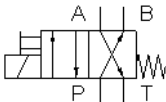
In normal position the connection P is open to B and A to T. When actuated by the control solenoid, the valve is set to parallel position. If no current is flowing through the control solenoid, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)

Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
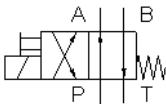**Pilot control left:** 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/2-way solenoid valve (ii)

In normal position the connection P is open to A and B to T. When actuated by the control solenoid, the valve is set to crossover position. If no current is flowing through the control solenoid, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
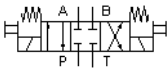**Pilot control left:** 0.01 ... 100 cm2 (1)
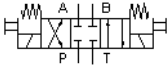**Pilot control right:** 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way solenoid valve with shutoff position (i)

In normal position all connections are closed. When actuated by the control solenoids, the valve is set to parallel or crossover position. If no current is flowing through the control solenoids, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way solenoid valve with shutoff position (ii)

In normal position all connections are closed. When actuated by the control solenoids, the valve is set to crossover or parallel position. If no current is flowing through the control solenoids, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way solenoid valve with floating position (i)

In normal position the connections A and B are open to T. When actuated by the control solenoids, the valve is set to parallel or crossover position. If no current is flowing through the control

solenoids, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way solenoid valve with floating position (ii)

In normal position the connections A and B are open to T. When actuated by the control solenoids, the valve is set to crossover or parallel position. If no current is flowing through the control solenoids, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters

Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way solenoid valve with bypass position (i)

In normal position the connections A and B are closed and P to T opened. When actuated by the control solenoids, the valve is set to parallel or crossover position. If no current is flowing through the control solenoids, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)

Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
**Min. pilot control force:** 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all connectors are internally connected.

4/3-way solenoid valve with bypass position (ii)

In normal position the connections A and B are closed and P to T opened. When actuated by the control solenoids, the valve is set to crossover or parallel position. If no current is flowing through the control solenoids, the valve can be manually actuated. This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4   (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.164)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (30)
Minimum force: 0.01 ... 100 N (20)
Min. pilot control force: 0.01 ... 100 N (15)

Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1)
Pilot control right: 0.01 ... 100 cm2 (1)

Error models
Piston blocked: The valve can not change its switching position.
All ports connected in position 2: In switching position 2 all con-
nectors are internally connected.

22.1.5 Flow control valves/Shutoff valves

Shutoff valve
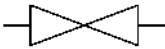
The shutoff valve can be manually opened or closed. The hydraulic
resistance relates to the completely opened valve.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Error models
Hand lever 90° rotated: The hand lever was rotated 90° during
assembly. The valve is in the open position when the hand lever is
perpendicular.
Component always open: The component is always open.
Component always closed: The component is always closed.
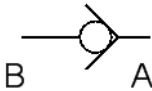
Check valve

If the inlet pressure at A is higher than the outlet pressure at B, then the check valve allows the flow to pass, otherwise it blocks the flow.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.09)
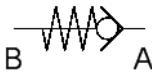
Check valve

If the inlet pressure at A is higher than the outlet pressure at B and the nominal pressure, then the check valve allows the flow to pass, otherwise it blocks the flow.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.6)
Pressure regulation range: 0.01 ... 10 MPa (0.864)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.09)
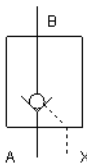
Check valve with pilot control

If the input pressure is higher than the output pressure, the check valve opens. Otherwise it is shut. In addition, the check valve can be opened via a control line, allowing flow in both directions.

Adjustable parameters
Area ratio: 0.1 ... 10 (3.3)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.093)
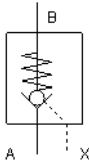
Check valve with pilot control

If the input pressure is higher than the output and nominal pressure, the check valve opens. Otherwise it is shut. In addition, the check valve can be opened via a control line, allowing flow in both directions.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.2)
Pressure regulation range: 0.01 ... 10 MPa (0.864)
Area ratio: 0.1 ... 10 (3.3)
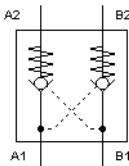**Hydraulic resistance:** 1e-6 ... 1000 bar.min2/l2 (0.093)
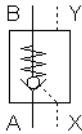
Vented pilot to open check valve

The valve is a pilot to open check valve, which may be opened to permit flow in the reverse direction. It allows free flow from port A to B, if the differential pressure exceeds the opening pressure and blocks flow in the opposite direction. Pressure at the pilot port X will open the valve from port B to port A. Pilot pressure needed to open the valve is directly proportional to the load pressure at port B. The valve is insensitive to pressure at port A, because the spring chamber is connected with the vent port Y.

The area ratio relates to the working area ratio X : B.

If the ports X and Y are not under pressure, the valve starts to open, when $pA - pB > p0$.

The pressure regulation range dp is the pressure increment above the opening pressure, at which the valve is fully open.

The valve is fully open, when $pA - pB > p0 + dp$.

The hydraulic resistance relates to the fully open valve.

Adjustable parameters

Opening pressure: 0 ... 400 bar (5)
Pressure regulation range: 0 ... 100 bar (5)
Area ratio X : B: 0.1 ... 10 (3)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.01)
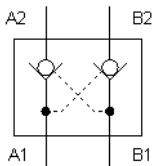
Double non-return valve, delockable

The valve is made up of two delockable non-return valves.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.093)
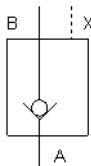**Area ratio:** 0.1 ... 10 (3.3)

Double non-return valve, delockable

The valve is made up of two delockable non-return valves.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.093)
Area ratio: 0.1 ... 10 (3.3)

Pilot to close check valve

If the inlet pressure at A is higher than the outlet pressure at B, then the check valve allows the flow to pass, otherwise it blocks the flow. Additionally, the check valve can be closed using the pilot line X.

Adjustable parameters
Area ratio: 0.1 ... 10 (3.3)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.093)

Pilot to close spring loaded check valve

If the inlet pressure at A is higher than the outlet pressure at B and the nominal pressure, then the check valve allows the flow to pass, otherwise it blocks the flow. Additionally, the check valve can be closed using the pilot line X.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.2)
Pressure regulation range: 0.01 ... 10 MPa (0.864)
Area ratio: 0.1 ... 10   (3.3)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.093)

Shuttle valve
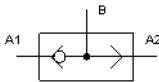
If one of the two input pressures is larger than zero, the shuttle valve opens (OR function) and the higher input pressure becomes the output pressure.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.09)

Two pressure valve
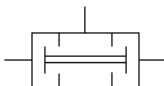
If both input pressures are larger than zero, the two-pressure valve opens (AND function) and the higher input pressure becomes the output pressure.

Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.09)

22.1.6 Pressure control valves
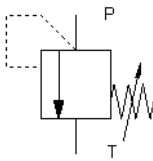
Pressure relief valve

In normal position the valve is closed. If the opening pressure is reached at P, T opens. When the pressure drops below the preset level, the valve closes again. The flow direction is indicated by the arrow. The hydraulic resistance relates to the completely opened valve.
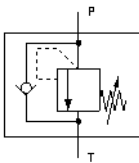
Adjustable parameters
Opening pressure: 0 ... 40 MPa (3)
Pressure regulation range: 0.01 ... 10 MPa (3.8)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.17)

Error models
Linear scaling: Instead of the nominal value u the lineal scaling y = slope_err*u+ offset_err is used.

Pressure relief valve

The valve restricts the pressure at port P to the set value compared with the pressure at T.

If the differential pressure (dp=pP-pT) times the cross-sectional area of the sealing cone exceeds the spring force, the sealing cone lifts out of the seat and allows oil through to port T. The valve closes again once the pressure in port P drops again. The cushioning piston acts like a shock absorber to increase stability during the control response. The spring pretension can be adjusted at the hand wheel. Oil flows through the non-return valve if the pressure at port T is greater than at P.

Adjustable parameters

Opening pressure: 0 ... 40 MPa (3)
Pressure regulation range: 0.01 ... 10 MPa (3.5)
**Hydraulic resistance (Pressure relief valve):** 1e-6 ... 1000 bar.min2/l2 (0.08)
Hydraulic resistance (Non-return valve): 1e-6 ... 1000 bar.min2/l2 (0.06)

Error models
Check valve always closed: The check valve is always closed.
Check valve always open: The check valve is always open.
Linear scaling: Instead of the nominal value u the lineal scaling y = slope_err*u+ offset_err is used.
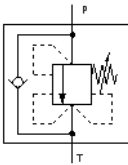
Pressure regulator, balanced

The valve restricts the pressure at port P to the set value compared with the pressure at T.

If the hydraulic force at the sealing cone exceeds the spring force, the sealing cone lifts out of the seat and allows oil to flow to port T. The valve closes again once the pressure in port P drops again. The cushioning piston acts like a shock absorber to increase stability. The spring pretension can be adjusted at the hand wheel. Oil flows through the non-return valve when the pressure at port T is greater than at P. Since the spring chamber is separated from the oil by the stem, the pressure in T has no effect on the limiting pressure.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (3)
Pressure regulation range: 0.01 ... 10 MPa (3.5)
Hydraulic resistance (Pressure relief valve): 1e-6 ... 1000 bar.min2/l2 (0.09)
Hydraulic resistance (Non-return valve): 1e-6 ... 1000 bar.min2/l2 (0.7)
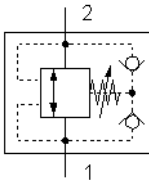
Bi-directional pressure relief valve

In initial position the valve is closed. When the differential pressure between ports 1 and 2 exceeds the opening pressure, the valve starts to open, regardless of flow direction.

The pressure regulation range dp specifies the additional differential pressure above the opening pressure, at which the valve is completely opened ($p1 - p2 > p0 + dp$ or $p2 - p1 > p0 + dp$).
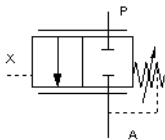
The hydraulic resistance relates to the completely opened valve.

A leakage flow from port 1 to 2 can be specified.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (10)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.16)
Leakage: 0 ... 100 l/(min.bar) (0)
Pressure regulation range: 0.01 ... 10 MPa (2.3)
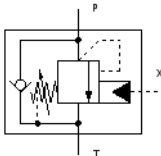
Counterbalance valve

The valve limits pressure at port P vis-à-vis pressure applied to T to the selected value.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (3.0)
Pressure regulation range: 0.01 ... 10 MPa (1)
Hydraulic resistance (Pressure control valve): 1e-6 ... 1000 bar.min2/l2 (0.1)
Area ratio: 0.1 ... 10 (3)
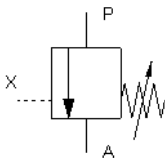**Hydraulic resistance (Non-return valve):** 1e-6 ... 1000 bar.min2/l2 (0.1)

Pressure sequence valve

The valve connects port P and port T if the pressure at port X is greater than the total of the spring force and pressure in port T.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (3)
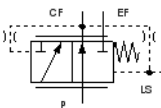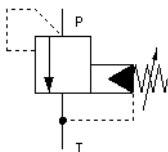**Pressure regulation range:** 0.01 ... 10 MPa (0.7)

Pressure sequence valve

If the opening pressure is reached at the control line connection, the valve opens from P to T. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (3)
Pressure regulation range: 0.01 ... 10 MPa (0.7)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Priority valve Load Sensing, dynamic

The priority valve assures that priority is given to outlet CF as opposed to outlet EF.

Adjustable parameters
Spring preload: 0 ... 40 MPa (0.8)
Pressure regulation range: 0.01 ... 10 MPa (0.24)
Hydraulic resistance (P-CF): 1e-6 ... 1000 bar.min2/l2 (0.9)
Hydraulic resistance (P-EF): 1e-6 ... 1000 bar.min2/l2 (0.9)
Hydraulic resistance (CF): 1e-6 ... 1000 bar.min2/l2 (10)
Hydraulic resistance (LS-EF): 1e-6 ... 1000 bar.min2/l2 (1450)
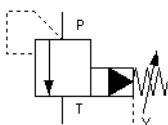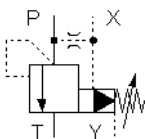
Pressure relief valve, piloted

In normal position the valve is closed. If the opening pressure is reached at P, T opens. When the pressure drops below the preset level, the valve closes again. In simple terms, the pilot pressure is generated by the input pressure. The flow direction is indicated by the arrow. The pilot operated pressure relief valve consists of a pilot stage and a main stage. When open, there is less volumetric flow at the pilot stage that leads internally to connection T. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (3.5)
Pressure regulation range: 0.01 ... 10 MPa (3.5)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.08)

Pressure relief valve, piloted

The valve is closed in the idle position. The hydraulic fluid drains off at T, when the pressure difference at the connections P and T exceeds the nominal pressure. If the pressure falls below the preset value, the valve closes again. The flow direction is marked with an arrow. The pilot operated pressure relief valve consists of a pilot stage and a main stage. When open, there is less volumetric flow at the pilot stage that leads to connection Y. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (3.5)
Pressure regulation range: 0.01 ... 10 MPa (3.5)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.08)

Pressure relief valve, piloted

With the help of a pilot actuated pressure relief valve, pressure can be limited for larger volumetric flow rates than would be possible with a directly actuated valve. Fundamentally, the valve consists of 3 components: a directly actuated pressure-relief valve as pilot stage, a pressure balance as primary stage and a throttle nozzle for limiting control oil.

Oil flows from port P through the throttle nozzle to port X. The pilot valve limits pressure at X to the desired value. At the same time, this pressure acts upon the pressure balance. The pressure balance limits pressure from port P to port T in accordance with the spring, and pressure applied to X. Pressure within the valve's working ranges drops via the throttle nozzle only by an amount equal to differential pressure resulting from the spring (opening pressure $p0\_M$) and the primary stage.

The pilot stage can be bypassed using port X. In this way a pressure shut-off and a pressure switching can be realized.

The pressure regulation range dp_P is the pressure increment above the opening pressure $p0\_P$ of the pilot stage, at which the pilot stage is fully open.

The pilot stage starts to open, when $pX > p0\_P$. It is fully open, when $pX > p0\_P + dp\_P$.

The pressure regulation range dp_M is the pressure increment above the opening pressure of the main stage, at which the main stage is fully open.

The main stage starts to open, when $pP > pX + p0\_M$. It is fully open, when $pP > pX + p0\_M + dp\_M$.

The hydraulic resistances relate to the fully open stages. A leakage for each stage can be specified.

Adjustable parameters
Opening pressure (Pilot stage): 0 ... 40 MPa (1)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (1)
Pressure regulation range: 0.01 ... 10 MPa (0.1)
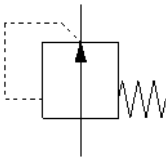**Leakage:** 0 ... 100 l/(min.bar) (0)
Opening pressure: 0 ... 40 MPa (0.55)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.3)

Pressure regulation range: 0.01 ... 10 MPa (0.7)
Leakage: 0 ... 100 l/(min.bar) (0)
Diameter: 0.001 ... 100 mm (0.5)
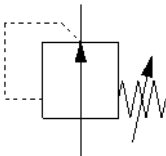
Pressure reducing valve

The pressure regulator valve regulates the pressure at connection A to the preset operating pressure and equalizes the pressure fluctuations. The valve closes when the pressure at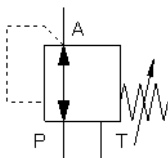 connection A exceeds the operating pressure. The setting of the real components is component dependent and cannot be changed. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (1)
Pressure regulation range: 0.01 ... 10 MPa (0.2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Variable pressure reducing valve

The pressure regulator valve regulates the pressure at connection A to the preset operating pressure and equalizes the pressure fluctuations. The valve closes when the pressure at connection A exceeds the operating pressure.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (1)
Pressure regulation range: 0.01 ... 10 MPa (0.2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)
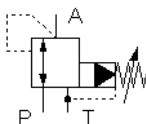
3-way pressure regulator

The pressure reducing valve maintains a constant output pressure despite fluctuating input pressure. The hydraulic fluid is drained off at T when the pressure at connection A exceeds the operating pressure. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (3)
Pressure regulation range: 0.01 ... 10 MPa (1.9)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

3-way pressure reducing valve, piloted

The valve maintains a constant output pressure despite fluctuating input pressure. If the pressure continues to rise, the hydraulic fluid is drained off at T. The valve is then working as a pressure relief valve.

The valve is initially fully open from port P to A until the outlet pressure at port A exceeds the opening pressure of the pilot stage. Port A and the pilot stage are connected by a throttle nozzle, whose diameter can be specified.

When opening pressure of the pilot stage is reached, a pilot flow occurs, causing a pressure imbalance (due to the throttle nozzle) across the main spool, which then moves throttling the inlet flow from port P to A. If the pressure continues to rise, the connection between port P and A is closed and the connection between A and T starts to open.

The pressure regulation range dp_P is the pressure increment above the opening pressure $p0\_P$ of the pilot stage, at which the pilot stage is fully open.

The pilot stage starts to open, if $pA > p0\_P$. It is fully open, when $pA > p0\_P + dp\_P$.

The pressure regulation range p_reg_M is the pressure increment above the closing pressure of the main stage, at which the main stage is fully closed.

The transition pressure range p_tr_M is the pressure increment above the pressure of the fully closed reducing valve needed to reach the pressure at which the pressure relief valve starts to open.

If pM is the inlet pressure of the pilot stage (behind the throttle nozzle), the main stage starts to close, when pA › pM + p0_M. It is fully closed, when pA › pM + p0_M + p_reg_M. As long as the pilot stage is closed, it is pA = pM.

The main stage starts to open, when pA › pM + p0_M + p_reg_M + p_tr_M. It is fully open, when pA › pM + p0_M + 2*p_reg_M + p_tr_M.

The hydraulic resistances relate to the fully open stages. A leakage for each stage can be specified.

Adjustable parameters
Opening pressure (Pilot stage): 0 ... 40 MPa (1)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)
Pressure regulation range: 0.01 ... 10 MPa (0.1)
Leakage: 0 ... 100 l/(min.bar) (0)
Nominal pressure: 0 ... 40 MPa (0.1)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.15)
Leakage: 0 ... 100 l/(min.bar) (0)
Pressure regulation range: 0.01 ... 40 MPa (0.5)
Transition pressure range: -5 ... 5 MPa (0)
Diameter: 0.001 ... 100 mm (0.5)

Pressure compensator, upstream (pre)

The pressure compensator maintains the differential pressure between port A und port X.
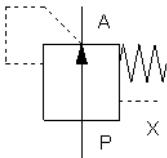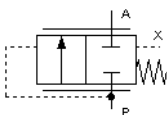
If, for example, a throttle point is located between A and X, pressure is held constant over the throttle point. This corresponds to the function of a 2-way flow control valve.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.4)
Pressure regulation range: 0.01 ... 10 MPa (0.15)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.06)
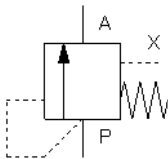
Pressure compensator, upstream (pre)

The pressure compensator maintains the differential pressure between port A und port X.

If, for example, a throttle point is located between A and X, pressure is held constant over the throttle point. This corresponds to the function of a 2-way flow control valve.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.4)
Pressure regulation range: 0.01 ... 10 MPa (0.15)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.06)

**Pressure compensator, downstream (post)**

The valve is used as a downstream pressure compensator for flow control in combination with a pump controlled by means of load sensing (variable volume LS pump).

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.02)
Pressure regulation range: 0.01 ... 10 MPa (0.018)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.058)

Pressure compensator, downstream (post)

The valve is used as a downstream pressure compensator for flow control in combination with a pump controlled by means of load sensing (variable volume LS pump).

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.02)
Pressure regulation range: 0.01 ... 10 MPa (0.018)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.058)
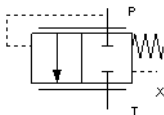
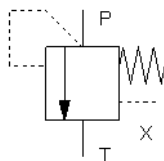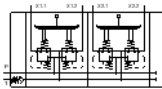## Load-Sensing Pressure compensator for open centre load sensing

P -> T, pX = 0 MPa: Pressure at P pushes the piston against the spring. As of adjusted pressure, the valve opens: P -> T. P -> T, pX > 0 MPa: Pressure at X is added to spring force. The valve opens as soon as opening pressure plus spring pressure is greater than pX.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.4)
Pressure regulation range: 0.01 ... 10 MPa (0.15)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.058)

Load-Sensing Pressure compensator for open centre load sensing

P -> T, pX = 0 MPa: Pressure at P pushes the piston against the spring. As of adjusted pressure, the valve opens: P -> T. P -> T, pX > 0 MPa: Pressure at X is added to spring force. The valve opens as soon as opening pressure is greater than pX.

Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.4)
Pressure regulation range: 0.01 ... 10 MPa (0.15)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.058)

### Pilot valves (Joystick), 2x2-channel

2-channel hydraulic pilot control is used. Each channel consists of two pressure regulators. Depending on direction, the hand lever actuates one of the two pressure regulators via a rocker. Pressure is then regulated at the respective pilot port proportional to deflection.

Adjustable parameters
Maximum pressure: 0 ... 40 MPa (1.5)
Displacement (Left group): -100 ... 100 % (0)
Displacement (Right group): -100 ... 100 % (0)
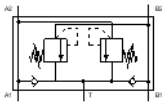
Shock and anti-cavitation valve

The valve limits pressure from port A or B vis-à-vis pressure applied to T to the selected value.

Adjustable parameters
Opening pressure (Left group): 0 ... 40 MPa (3)
Pressure regulation range (Left group): 0.01 ... 10 MPa (3.8)
Hydraulic resistance (Left group): 1e-6 ... 1000 bar.min2/l2 (0.08)
Opening pressure (Right group): 0 ... 40 MPa (3)
Pressure regulation range (Right group): 0.01 ... 10 MPa (3.8)
Hydraulic resistance (Right group): 1e-6 ... 1000 bar.min2/l2 (0.08)
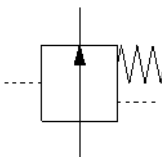
Closing pressure compensator

The pressure compensator represents a pressure dependent hydraulic resistance. The pressure compensator closes when the pressure difference X-Y exceeds the nominal pressure. A pressure regulating valve is implemented by the combination of connections A and X. The pressure balance is also a component of 2-way flow control valves. The nominal pressure setting of the real compo-
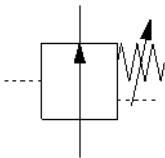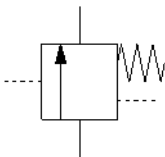
nents is component dependent and cannot be changed. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (1)
Pressure regulation range: 0.01 ... 10 MPa (0.2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)
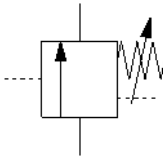
Variable closing pressure compensator

The pressure compensator represents a pressure dependent hydraulic resistance. The pressure compensator closes when the pressure difference X-Y exceeds the nominal pressure. A pressure regulating valve is implemented by the combination of the connections A and X. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (1)
Pressure regulation range: 0.01 ... 10 MPa (0.2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Opening pressure compensator

The pressure compensator represents a pressure dependent hydraulic resistance. The pressure compensator opens when the pressure difference X-Y exceeds the nominal pressure. A pressure relief valve is implemented by the combination of connections P and X. The pressure balance is also a component of 3-way flow control valves. The nominal pressure setting of the real components is component dependent and cannot be changed. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (1)
Pressure regulation range: 0.01 ... 10 MPa (0.2)

Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Variable opening pressure compensator

The pressure compensator represents a pressure dependent hydraulic resistance. The pressure compensator opens when the pressure difference X-Y exceeds the nominal pressure. A pressure relief valve is implemented by the combination of connections P and X. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Nominal pressure: 0 ... 40 MPa (1)
Pressure regulation range: 0.01 ... 10 MPa (0.2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)
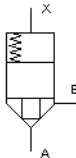
Opening cartridge valve

The 2/2-way cartridge valve is a 2/2-way valve. It is fitted with two working ports and the two switch positions "closed" and "open". Whether or not the cartridge valve is open or closed depends on the effective areas A, B and X, the adjacent pressures pA, pB and pX, as well as the spring force. A+B=X is valid. If pA*A + pB*B › pX*X + F, then the valve opens, otherwise it is closed. The valve therefore operates purely pressure dependent and can, with the appropriate control, assume directional-, flow- and pressure functions. The spring force is specified by means of the nominal pressure. This is the minimum pressure, with pressureless connections at B and X, necessary at connection A to open the valve. Whether the valve has one (A=B) or two (A ◇ B) effective areas can be specified in the properties window. The relevant symbol is automatically depicted. The hydraulic resistance relates to the completely opened valve.
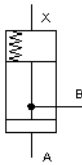
Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.5)
Area A: 0.1 ... 100 cm2 (6)

Area B: 0.1 ... 100 cm2 (3)
Pressure regulation range: 0.01 ... 10 MPa (0.05)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.01)

Closing cartridge valve

The 2/2-way cartridge valve is a 2/2-way valve. It is fitted with two working ports and the two switch positions "closed" and "open". Whether or not the cartridge valve is open or closed depends on the effective areas A and X, the adjacent pressures pA, and pX, as well as the spring force. A=X is valid. If pA*A › pX*X + F, then the valve closes, otherwise it is open. The valve therefore operates purely pressure dependent and can, with the appropriate control, assume directional-, flow- and pressure functions. The spring force is specified by means of the nominal pressure. This is the minimum pressure, with pressureless connections at B and X, necessary at connection A to open the valve. The hydraulic resistance relates to the completely opened valve.
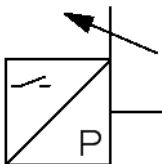
Adjustable parameters
Opening pressure: 0 ... 40 MPa (0.5)
Area: 0.1 ... 100 cm2 (6)
Pressure regulation range: 0.01 ... 10 MPa (0.05)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.01)

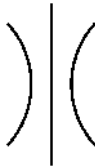## 22.1.7 Pressure switch

Pressure sensor

The pressure switch takes the pressure and actuates the associated electrical pressure switch if the preset switching pressure is exceeded.

Adjustable parameters
Switching pressure: -0.1 … 40 MPa (3)
Hysteresis: 0 … 10 MPa (0)
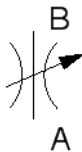
22.1.8 Flow control valves/Shutoff valves

Nozzle

The nozzle represents a hydraulic resistance.

Adjustable parameters
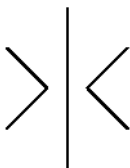**Hydraulic resistance:** 1e-6 … 1000 bar.min2/l2 (0.19)

Flow control valve

The setting of the throttle valve is set by means of a rotary knob. Please note that by the rotary knob no *absolute* resistance value can be set. This means that, in reality, different throttle valves can generate different resistance values despite identical settings.

Adjustable parameters
Opening level: 0 … 100 % (100)
Hydraulic resistance: 1e-6 … 1000 bar.min2/l2 (0.19)

Orifice

The orifice represents a hydraulic resistance.

Adjustable parameters
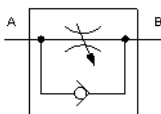**Hydraulic resistance:** 1e-6 ... 1000 bar.min2/l2 (0.19)

Variable orifice

The orifice represents a variable hydraulic resistance.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.19)

Throttle check valve

The setting of the One-way flow control valve is set by means of a rotary knob. A check valve (see check valve) is located parallel to the throttle valve. Please note that by the rotary knob no *absolute* resistance value can be set. This means that, in reality, different throttle valves can generate different resistance values despite identical settings.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Hydraulic resistance (Flow control valve): 1e-6 ... 1000 bar.min2/l2 (0.07)
Hydraulic resistance (Non-return valve): 1e-6 ... 1000 bar.min2/l2 (0.05)

Error models

Check valve always closed: The check valve is always closed.
Check valve always open: The check valve is always open.

2-way flow control valve

If the pressure is sufficient, the preset flow is maintained to a constant level in the direction of the arrow. The hydraulic resistance relates to the completely opened valve.

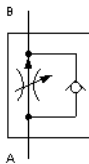*Adjustable parameters*
Nominal flow: 0 ... 500 l/min (1)
Spring preload: 0 ... 10 MPa (0.6)
Pressure regulation range: 0.01 ... 10 MPa (0.05)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.3)

Error models
Pressure compensator without function: The pressure compensator does not work. The component is therefore not able to do a regulation.

2-way flow control valve

If the pressure is sufficient, the preset flow is maintained to a constant level in the direction of the arrow. The hydraulic resistance relates to the completely opened valve.

Adjustable parameters
Nominal flow: 0 ... 500 l/min (1)
Spring preload: 0 ... 10 MPa (0.45)
Pressure regulation range: 0.01 ... 10 MPa (0.05)
Hydraulic resistance (Flow control valve): 1e-6 ... 1000 bar.min2/l2 (0.4)
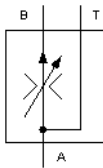**Hydraulic resistance (Non-return valve):** 1e-6 ... 1000 bar.min2/l2 (0.08)

Error models
Pressure compensator without function: The pressure compensator does not work. The component is therefore not able to do a regulation.
Check valve always closed: The check valve is always closed.
Check valve always open: The check valve is always open.

3-way flow control valve

With sufficient pressure, the preset flow rate is kept constant in the direction of the arrow. The surplus hydraulic fluid is drained at connection T using a pressure compensator. The inlet pressure pA is load dependent, i.e. it changes with the outlet pressure pB. Therefore a parallel circuit of several 3-way flow control valves is not possible. In this case, the inlet pressures would be defined by the valve with the lowest inlet pressure. Compared to the 2-way flow control valve, the 3-way flow control valve is admittedly more efficient in its energy consumption. The hydraulic resistance relates to the completely closed pressure compensator.
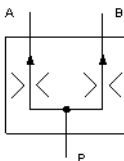
Adjustable parameters
Nominal flow: 0 ... 500 l/min (1)
Spring preload: 0 ... 10 MPa (0.5)
Pressure regulation range: 0.01 ... 10 MPa (0.05)
**Hydraulic resistance:** 1e-6 ... 1000 bar.min2/l2 (0.4)

Flow divider valve

The flow divider valve divides the flow from P into two equal flows at A and B. This is achieved using two measuring orifices and two variable control resistors. The control resistors are unified in a pressure compensator. The hydraulic resistance relates to the resistance of the individual measuring orifices and control resistors.

Adjustable parameters

Hydraulic resistance (Pressure compensator): 1e-6 ... 1000 bar.min2/l2 (0.375)
Hydraulic resistance (Metering orifice): 1e-6 ... 1000 bar.min2/l2 (0.537)
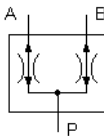
Flow Divider/Combiner

The flow divider/combiner is a spring loaded, sliding spool, pressure compensated valve used to split flow in one direction and combines flow in the opposite direction by a given flow ratio. A leakage flow from A to B can be specified.

The pressure regulation range determines the differential pressure between A and B, when the sliding spool reaches its maximum displacement. The smaller the pressure regulation range is chosen, the higher the accuracy of the valve is for a given flow ratio.
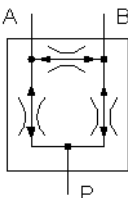
Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.01)
Leakage A–B: 0 ... 100 l/(min.bar) (0)
Ratio qA : qB: 0.1 ... 10 (1)
Pressure regulation range: 0.001 ... 10 MPa (0.025)

Synchronizing flow divider/combiner

The flow divider/combiner is a spring loaded, sliding spool, pressure compensated valve used to split flow in one direction and combines flow in the opposite direction by a given flow ratio. A leakage flow from A to B can be specified.

When one port is blocked, the sliding spool can be maximally extended depending on the acting pressures. In this case, a flow is metered from A to B. With the synchronizing feature, this valve can be used to allow two hydraulic cylinders to fully stroke and synchronize at the end of the stroke.

The pressure regulation range determines the differential pressure between A and B, when the sliding spool reaches its maximum displacement. The smaller the pressure regulation range is chosen, the higher the accuracy of the valve is for a given flow ratio.
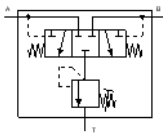
Adjustable parameters
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.01)
Leakage A–B: 0 ... 100 l/(min.bar) (0)
Ratio qA : qB: 0.1 ... 10 (1)
Pressure regulation range: 0.001 ... 10 MPa (0.025)

Flush valve with pressure relief valve

If differential pressure exceeds the required force for the spring, the valve opens from B to the pressure-relief valve.

The pressure-relief valve assures that pressure on the suction side does not drop to below the required minimum pressure for the pump.

Adjustable parameters
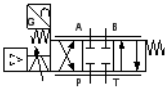**Spring preload:** 0 ... 40 MPa (0.25)
Hydraulic resistance (Directional valve): 1e-6 ... 1000 bar.min2/l2 (0.08)
Opening pressure: 0 ... 40 MPa (0.5)
Hydraulic resistance (Pressure control valve): 1e-6 ... 1000 bar.min2/l2 (0.08)

22.1.9 Proportional valves

4/3-ways control valve

The regulating valve transforms an analog electrical input signal into corresponding opening cross-sections at the outputs. The setpoint signal must be within the range -10 V to +10 V. At 0 V the hydraulic mid-position is adopted and the valve stops the flow (in relation to the null overlap).

The cross section area of the flow opening widens with increasing slide distance. How far the area, and with it the flow at the valve, changes depends on the shape and form of the control notches. A triangular shaped notch results in a progressive flow behavior, a rectangular shaped notch in a linear flow behavior.

The hydraulic resistance relates to a completely opened leading edge and the internal leakage relates to one leading edge as appropriate. The overlap of the leading edges can be specified relative to the maximal slide distance. By the use of an integrated electronic position controller for the slide distance, beneficial static and dynamic characteristics are achieved that are manifested in a minimal hysteresis (less than 0,2 %) and a response time of less than 12 ms at a signal change of 0 - 100.
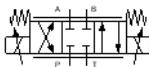
Adjustable parameters
Control notch shape: Rectangular,Triangular (Rectangular)
Relative spool overlap: -50 ... 50 % (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (1.4)
Leakage: 0 ... 10 l/(min.bar) (0.00026)

4/3-way proportional valve

By use of a twin-channel proportional amplifier, the proportional valve transforms an analog electrical input signal into corresponding opening cross-sections at the outputs. The setpoint signal must

be within the range -10 V to +10 V. At 0 V the hydraulic mid-position is adopted and the valve stops the flow (in relation to the null overlap).

The cross section area of the flow opening widens by increasing slide distance. How far the area, and with it the flow at the valve, changes depends on the shape and form of the control notches. A triangular shaped notch results in a progressive flow behavior, a rectangular shaped notch in a linear flow behavior.

The hydraulic resistance relates to a completely opened leading edge and the internal leakage relates to one leading edge as appropriate. The overlap of the leading edges can be specified relative to the maximal slide distance.
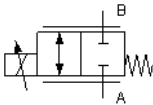
Adjustable parameters
Control notch shape: Rectangular,Triangular (Triangular)
Relative spool overlap: -50 ... 50 % (25)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (3.2)
Leakage: 0 ... 10 l/(min.bar) (0.001)

Proportional throttle valve

In order to alter the flow rate through the valve, the cross section of the throttle valve is electrically manipulated with the assistance of a proportional amplifier. The control voltage must be between 0 V and 10 V. The deflection of the slide is proportional to the applied voltage. At 0 V the valve is completely closed (in relation to the null overlap). The hydraulic resistance relates to the completely opened valve. The overlap of the leading edges can be specified relative to the maximal slide distance.
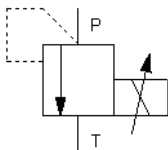
Adjustable parameters
Control notch shape: Rectangular,Triangular (Triangular)
Relative spool overlap: -50 ... 50 % (0)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)
Leakage: 0 ... 10 l/(min.bar) (0)

Proportional pressure relief valve

The proportional pressure relief valve, with the assistance of a proportional amplifier, is a continuous, electrically adjustable pressure relief valve. The control piston has two adjacent areas exposed to pressure. The first area is exposed to the pressure at connection P, the other to connection T. If the magnet is not supplied with electricity, then the piston is fully retracted and the complete passage from connection P to connection T is free. The proportional magnet creates a force proportional to its magnetic current, which moves the control piston according to the balance of the adjacent forces (magnetic force, spring force and pressures).

The control voltage must be in the range 0 V to 10 V. The minimum nominal pressure defines the opening pressure through the spring force at 0 V. The maximum nominal pressure defines the opening pressure at 10 V. The hydraulic resistance relates to the completely opened main stage leading edge.

Adjustable parameters
Min. Opening pressure: 0 ... 40 MPa (0)
Max. Opening pressure: 0 ... 40 MPa (10)
Pressure regulation range: 0.01 ... 10 MPa (2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.1)

Pilot-operated proportional pressure relief valve

The pilot operated pressure relief valve consists of a pilot stage with poppet valve and a main stage with control slide valve. The pressure at connection P acts upon the pilot poppet via a drilling in the control slide valve.

If the force of the proportional magnet is greater than the pressure exercised at connection P, then the pilot stage remains closed. A spring keeps the main stage poppet valve closed and the flow rate is null.

If the force, that the pressure exercises, exceeds the closing force of the pilot poppet, then this opens. A lower flow rate develops from connection P to connection Y. The flow of fluid causes a pressure loss at the throttle valve inside the control slide valve. Thus the pressure at the spring side is lower than the pressure at connection P. Due to the pressure difference, the control slide valve opens so far until the spring force re-establishes an equilibrium of forces and the valve is perfused from P to T.

The control voltage must be between 0 V and 10 V. The minimum nominal pressure defines the opening pressure at the pilot stage via the spring force at 0 V. The maximum nominal pressure defines the opening pressure at 10 V. The hydraulic resistance relates to the completely opened main stage leading edge.
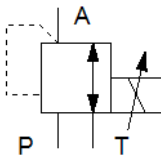
Adjustable parameters
Min. Opening pressure: 0 ... 40 MPa (0)
Max. Opening pressure: 0 ... 40 MPa (10)
Pressure regulation range: 0.01 ... 10 MPa (2)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.05)

3-way proportional pressure reducing valve

The valve maintains a constant output pressure despite fluctuating input pressure. If the pressure continues to rise, the hydraulic fluid is drained off at T. The valve is then working as a pressure relief valve.

The nominal pressure p_set is proportional to the control current. In the de-energized state of the solenoid, port P is closed and port A is connected with T.

The relation between current and nominal pressure p_set is modeled as a linear function. The current I_min_rel, at which the minimal nominal pressure p_min should be reached, must be specified relative to the maximum current.

In control mode the connection between P and A is initially fully open. As soon as the pressure at port A exceeds the nominal pressure, the spool moves and throttles the inlet flow from port P to A.

If the pressure continues to rise, the connection between port P and A is closed and the connection between A and T starts to open.

The pressure regulation range p_reg is the pressure increment above the nominal pressure, at which the connection P-A is fully closed.

The connection P-A starts to close, when pA › p_set.

The connection P-A fully closed, when pA › p_set + p_reg.

The transition pressure range p_tr is the pressure increment above the pressure of the fully closed connection P-A, at which the connection A-T starts to open. The connection A-T is fully open after an additional increase by pressure regulation range p_reg.

The connection A-T starts to open, when pA › p_set + p_reg + p_tr.

The connection A-T fully open, when pA › p_set + p_reg + p_tr + p_reg = p_set + 2*p_reg + p_tr.

The hydraulic resistances relate to the fully open connections P-A and A-T.

Adjustable parameters
Min. Nominal pressure: 0 ... 400 bar (0)
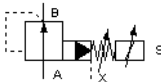**Max. Nominal pressure:** 0 ... 400 bar (110)
Min. Current (% I_max): 0 ... 100 % (10)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.0625)
Pressure regulation range: 0.1 ... 400 bar (20)
Transition pressure range: 0 ... 400 bar (4)

Pilot-operated proportional pressure reducing valve

The pilot operated proportional pressure regulator valve consists of a pilot stage with poppet valve and a main stage with control slide valve. The pressure at connection A acts upon the pilot poppet via a drilling in the control slide valve. The proportional magnet exercises the electrically adjustable counter force with the assistance of a proportional amplifier.

If the pressure at connection A is below the preset value, then the pilot control remains closed. The pressure on both sides of the control slide valve is equal. A spring holds the main stage control slide valve open and the hydraulic fluid flow freely from connection P to connection A.

If the pressure at connection A exceeds the preset value, then the pilot stage opens causing less volumetric flow to flow to connection A. The pressure falls at the throttle valve inside the control slide valve. Thus the pressure at the spring side is lower than the pressure at connection A. Due to the pressure difference, the control slide valve closes so far until the spring force re-establishes an equilibrium of forces. As a result, the flow resistance at the control edge between connections P and A increases and the pressure at connection A sinks.

The control voltage must be between 0 V and 10 V. The minimum nominal pressure defines the opening pressure at the pre stage via the spring force at 0 V. The maximum nominal pressure defines the opening pressure at 10 V. The hydraulic resistance relates to the completely opened main stage leading edge.
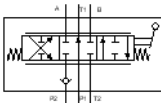
Adjustable parameters
Min. Nominal pressure: 0 ... 40 MPa (0)
Max. Nominal pressure: 0 ... 40 MPa (3)
Pressure regulation range: 0.01 ... 10 MPa (0.1)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.05)

Proportional 6/3-way hand lever valve

The valve is used to control volumetric flow. Flow rate and direction of flow are controlled. The mid-position is spring centered. The piston is pushed out of its mid-position and against the spring with the hand lever.

Adjustable parameters
Displacement: -100 ... 100 % (0)
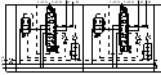**Hydraulic resistance (P1->T1):** 1e-6 ... 1000 bar.min2/l2 (0.045)
Hydraulic resistance (P2->A,B): 1e-6 ... 1000 bar.min2/l2 (0.051)
Hydraulic resistance (T2->A,B): 1e-6 ... 1000 bar.min2/l2 (0.0362)

Leakage: 0 ... 10 l/(min.bar) (5E-06)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.01)

Load-sensing control block

The valve block has two slices, each with a proportional directional control valve for controlling speed and direction. The directional control valve in each slice has an upstream pressure compensator. As a result, the slice functions like a proportional current regulator.

Adjustable parameters
Displacement (Left group): -100 ... 100 % (0)
Displacement (Right group): -100 ... 100 % (0)

22.1.10   Actuators
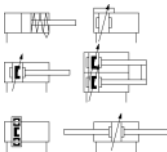
Configurable cylinder

The configurable cylinder can be customized via its properties dialog. Almost any combination of piston type (single-acting, double-acting), the specification of the piston rods (double ended, with magnetic coupling or slide) and the number (none, one, two) is possible. An end position cushioning (without, with, adjustable) can also be defined. FluidSIM automatically adjusts the symbol according to the preset configuration. In addition, a load to be moved (including possible static and sliding friction) and a variable force profile can be defined in the properties dialog. In the component library from FluidSIM there are several pre-configured cylinders that can be inserted in your circuit and directly used. Should no suitable symbol be available, then simply choose the compo-

nent with the most similarity to the required component, open the properties dialog and adjust the configuration accordingly.

Adjustable parameters
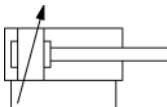**Piston diameter:** 1 ... 1000 mm (16)
Piston rod diameter: 0 ... 1000 mm (10)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Break-away force: 0 ... 10000 N (65)
Coulomb friction force: 0 ... 10000 N (55)
Viscous friction: 0.1 ... 10000 N.s/m (215)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 40 MPa (0.4)
Spring pressure at x=x_max: 0 ... 40 MPa (1)
Damping length: 0 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Double acting cylinder

Double acting cylinder with piston rod on one side. The piston of the cylinder contains a permanent solenoid which can be used to operate a proximity switch.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (16)
Piston rod diameter: 0 ... 1000 mm (10)

Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Break-away force: 0 ... 10000 N (65)
Coulomb friction force: 0 ... 10000 N (55)
Viscous friction: 0.1 ... 10000 N.s/m (215)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 40 MPa (0.4)
Spring pressure at x=x_max: 0 ... 40 MPa (1)
Damping length: 0 ... 100 mm (10)
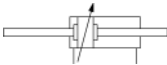**Piston area:** 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Double acting cylinder with shock adsorber at stroke end

The piston of the cylinder is controlled by the connected pressure loads. The shock adsorber can be adjusted by means of two adjustment screws. The piston contains a permanent solenoid which can be used to operate a proximity switch.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (16)
Piston rod diameter: 0 ... 1000 mm (10)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)

Break-away force: 0 ... 10000 N (65)
Coulomb friction force: 0 ... 10000 N (55)
Viscous friction: 0.1 ... 10000 N.s/m (215)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 40 MPa (0.4)
Spring pressure at x=x_max: 0 ... 40 MPa (1)
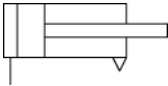**Damping length:** 0 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Double acting cylinder with in and out piston rod and shock adsorber at stroke end

The piston of the cylinder is controlled by the connected pressure loads. The shock adsorber can be adjusted by means of two adjustment screws. The piston of the cylinder contains a permanent solenoid which can be used to operate a proximity switch.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (16)
Piston rod diameter: 0 ... 1000 mm (10)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Break-away force: 0 ... 10000 N (65)
Coulomb friction force: 0 ... 10000 N (55)
Viscous friction: 0.1 ... 10000 N.s/m (215)
Parameter input: Calculate automatically,Enter manually (Calcu-

late automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 40 MPa (0.4)
Spring pressure at x=x_max: 0 ... 40 MPa (1)
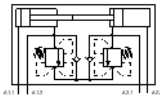**Damping length:** 0 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Single acting cylinder

By connecting a sufficiently high pressure load, the piston of the cylinder is extended to its stop. To move the piston back, an external force must be applied.
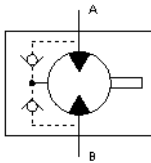
Adjustable parameters
Piston diameter: 1 ... 1000 mm (16)
Piston rod diameter: 0 ... 1000 mm (10)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Break-away force: 0 ... 10000 N (65)
Coulomb friction force: 0 ... 10000 N (55)
**Viscous friction:** 0.1 ... 10000 N.s/m (215)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 40 MPa (0.4)
Spring pressure at x=x_max: 0 ... 40 MPa (1)
Damping length: 0 ... 100 mm (10)

Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Loading unit/cylinder load simulator

Two cylinders are positioned opposite each other. Various cylinder types and loads can be combined using the four piston surfaces.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (16)
Piston rod diameter: 1 ... 1000 mm (10)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 10000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Moving mass: 0.01 ... 1000 kg (0.6)
Opening pressure: 0 ... 40 MPa (12)
Break-away force: 0 ... 10000 N (65)
Coulomb friction force: 0 ... 10000 N (55)
Viscous friction: 0.1 ... 10000 N.s/m (215)

Loading unit/cylinder load simulator

Two cylinders are positioned opposite each other. Various cylinder types and loads can be combined using the four piston surfaces.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (16)
Piston rod diameter: 1 ... 1000 mm (10)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 10000 mm (200)

Mounting angle: 0 ... 360 deg (0)
Moving mass: 0.01 ... 1000 kg (0.6)
Break-away force: 0 ... 10000 N (65)
Coulomb friction force: 0 ... 10000 N (55)
Viscous friction: 0.1 ... 10000 N.s/m (215)

Hydraulic motor

The hydraulic motor transforms hydraulic energy into mechanical energy.

The evolutions can be counted with the help of an opto-electrical sensor.

Adjustable parameters
External torque: -1000 ... 1000 N.m (0)
Displacement: 0.001 ... 5 l (0.008)
Friction: 0.001 ... 100 N.m.s/rad (0.0108)
Moment of inertia: 0.0001 ... 10 kg.m2 (0.0001)
Leakage: 0 ... 10 l/(min.bar) (0.0126)
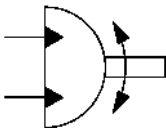
Semi-rotary actuator

The semi-rotary actuator is controlled by alternately switching the pressure. In the end positions the swivel cylinder can activate switches or valves via labels.

Adjustable parameters
Initial Position: 0 ... 360 deg (0)
Rotation angle (max): 1 ... 360 deg (180)
Displacement: 0.01 ... 1000 l (0.1)
Friction: 0.01 ... 100 N.m.s/rad (0.1)
Moment of inertia: 1e-005 ... 1 kg.m2 (0.0001)
External torque: -1000 ... 1000 N.m (0)

22.1.11 Measuring instruments and sensors
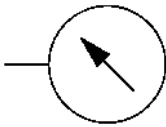
Pressure gauge

The manometer measures the pressure at its connection.
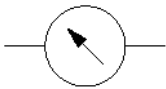
Differential pressure gauge

The differential pressure gauge displays the pressure difference between the adjacent pressures at the left and the right connection.
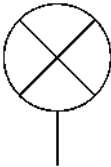
Pressure indicator

An optical signal is activated when the pressure at the connection to the pressure display exceeds the preset switching pressure.

Adjustable parameters
Switching pressure: -0.1 … 40 MPa (3)

Analog pressure sensor

This symbol represents the hydraulic part of the analog pressure sensor. The analog pressure sensor measures the adjacent pressure and transforms it into a proportional electrical voltage signal. In the process, only pressures in the specified pressure ranges are considered. Within this range, the pressure in the voltage range from 0 V to 10 V is represented, i.e. the minimum pressure delivers 0 V and the maximum pressure 10 V.
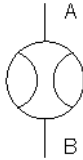
Adjustable parameters

Minimum pressure: -40 ... 40 MPa (0)
Maximum pressure: -40 ... 40 MPa (10)
Voltage at p1: -100 ... 100 V (0)
Voltage at p2: -100 ... 100 V (10)
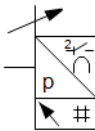
Pressure switch, electronic

The electronic pressure switch has a measuring cell that works according to the strain gauge principle. The measuring cell signal is digitalized and processed in the pressure switch's processor. The processed signal is output as a voltage, current or switching signal at the connector plug. The integrated digital display shows the measured pressure. The pressure is shown in the selected unit (bar, psi, MPa).

The pressure switch has two switching outputs and one analogue output. The control elements of the pressure switch can be used to select and set the characteristics of the outputs in the basic setting menu. Each switching output can be set as either an N/C or N/O contact.

Adjustable parameters
Output function: Make switch,Break switch   (Make switch)
Switching function: Threshold value,Window comparator (Threshold value)
Switching pressure 1: 0 ... 40 MPa (3)
Switching pressure 2: 0 ... 40 MPa (4)
Hysteresis: 0 ... 40 MPa (0)
Output function: Make switch,Break switch   (Make switch)
Switching function: Threshold value,Window comparator (Threshold value)
Switching pressure 1: 0 ... 40 MPa (3)
Switching pressure 2: 0 ... 40 MPa (4)
Hysteresis: 0 ... 40 MPa (0)
Minimum pressure: 0 ... 40 MPa (0)
Maximum pressure: 0 ... 40 MPa (10)
Voltage at p1: -100 ... 100 V (0)
Voltage at p2: -100 ... 100 V (10)
Minimum voltage: 1 ... 300 V (18)

Flow meter

The flow meter measures the flow rate. Either the current flow or the total quantity flowed can be displayed. The component image is automatically adjusted accordingly.

Adjustable parameters
Hydraulic resistance: 1e-6 … 1000 bar.min2/l2 (0.001)
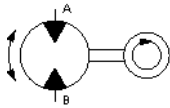
Flow meter

The flow meter consists of a hydraulic motor connected to an RPM gauge.

In addition to the measurement of speed in rpm via direct contact with the motor shaft, revolutions can also be counted with the help of an opto-electrical sensor.

Adjustable parameters
Displacement: 0.1 … 5000 cm3 (8.2)
Friction: 0.001 … 100 N.m.s/rad (0.0108)
Moment of inertia: 0.0001 … 10 kg.m2 (0.0001)
Leakage: 0 … 10 l/(min.bar) (0.0126)
Pulses per revolution: 0 … 20   (3)
Flow Direction: Ignore,Consider   (Ignore)
Flow rate (min): -500 … 500 l/min (0)
Flow rate (max): -500 … 500 l/min (10)
Voltage (q1): -100 … 100 V (0)
Voltage (q2): -100 … 100 V (10)

Analog flow meter

This symbol represents the hydraulic part of the analog flow meter. The analog flow meter measures the volumetric flow and transforms it into a proportional electrical voltage signal. In the process,

only flow rates in the specified pressure ranges are considered. Within this range, the flow rate in the voltage range from 0 V to 10 V is represented, i.e. the minimum volumetric flow delivers 0 V and the maximum volumetric flow 10 V.

Adjustable parameters
Flow Direction: Ignore,Consider (Ignore)
Flow rate (min): -500 ... 500 l/min (0)
Flow rate (max): -500 ... 500 l/min (10)
Voltage (q1): -100 ... 100 V (0)
Voltage (q2): -100 ... 100 V (10)
Hydraulic resistance: 1e-6 ... 1000 bar.min2/l2 (0.001)

22.2 Pneumatic

22.2.1 Supply elements
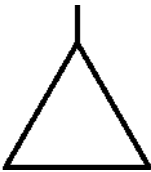
Compressed air supply

The compressed air supply provides the needed compressed air. It contains a pressure control valve that can be adjusted to output the desired operating pressure.

Adjustable parameters
Operating pressure: 0 ... 2 MPa (0.6)
Max. flow rate: 0 ... 5000 l/min (1000)
Volume: 0.001 ... 1000 l (0.1)
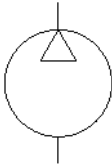
Compressor

The compressor provides the necessary compressed air. The pressure is restricted to the preset operating pressure.

Adjustable parameters
Operating pressure: 0 ... 2 MPa (0.6)
Max. flow rate: 0 ... 5000 l/min (1000)
Volume: 0.001 ... 1000 l (0.1)
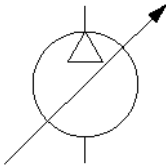
Variable compressor

The adjustable compressor provides the necessary compressed air, whereby the maximum flow rate can be adjusted under actual operating conditions and in the simulation. The pressure is restricted to the preset operating pressure.

Adjustable parameters
Operating pressure: 0 ... 2 MPa (0.6)
Max. flow rate: 0 ... 5000 l/min (1000)
Volume: 0.001 ... 1000 l (0.1)
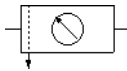
Air service unit, simplified representation

The service unit is made up of a compressed air filter with water separator and a pressure control valve.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Standard nominal flow rate (Pressure regulator): 0.1 ... 5000 l/min (750)
Standard nominal flow rate (Filter): 0.1 ... 5000 l/min (1000)

Error models
Component clogged: The component is clogged. The restricted flow can be adjusted.
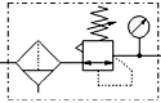
Air service unit

The service unit is made up of a compressed air filter with water separator and a pressure control valve.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Standard nominal flow rate (Pressure regulator): 0.1 ... 5000 l/min (750)
Standard nominal flow rate (Filter): 0.1 ... 5000 l/min (1000)

Error models
Component clogged: The component is clogged. The restricted flow can be adjusted.
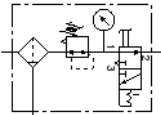
Start-up valve with filter control valve

The filter with water separator cleans the compressed air of dirt, pipe scale, rust and condensate. The pressure regulator adjusts the compressed air supplied to the set operating pressure and compensates for pressure fluctuations. The pressure gauge shows the preset pressure. The on/off valve exhausts the entire control.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Standard nominal flow rate (Pressure regulator): 0.1 ... 5000 l/min (110)
Standard nominal flow rate (Directional valve): 0.1 ... 5000 l/min (500)
Standard nominal flow rate (Filter): 0.1 ... 5000 l/min (1000)

Error models
Component clogged: The component is clogged. The restricted flow can be adjusted.
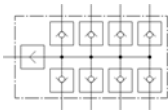
Manifold

The manifold enables a control system to be supplied with compressed air eight individual connections.

Air pressure reservoir

The air pressure reservoir serves as compensation for pressure fluctuations and is utilized (as a reservoir) for abruptly occurring air consumption. Large time delays can be attained when used in conjunction with time delay- and throttle valves.

Adjustable parameters
Volume: 0.001 ... 1000 l (0.4)

Air pressure reservoir

The air pressure reservoir serves as compensation for pressure fluctuations and is utilized (as a reservoir) for abruptly occurring air consumption. Large time delays can be attained when used in conjunction with time delay- und throttle valves.
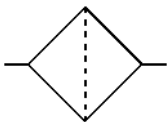
Adjustable parameters
Volume: 0.001 ... 1000 l (0.4)

Air filter

The compressed air filter removes contamination from the compressed air. The size of the filterable particles is dependent upon the filter class.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (1000)

Error models
Component clogged: The component is clogged. The restricted flow can be adjusted.
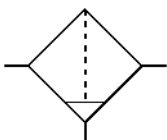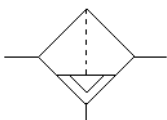
Manual drain filter

The compressed air filter removes contamination from the compressed air. The size of the filterable particles is dependent upon the filter class. Condensation, which can occur through sinking temperatures or the expansion of the compressed air, can be manually drained off.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (1000)

Error models
Component clogged: The component is clogged. The restricted flow can be adjusted.

Automatic drain filter

The compressed air filter removes contamination from the compressed air. The size of the filterable particles is dependent upon

the filter class. Condensation, which can occur through sinking temperatures or the expansion of the compressed air, is automatically drained off.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (1000)

Error models
Component clogged: The component is clogged. The restricted flow can be adjusted.
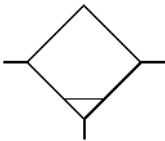
Manual drain

The water separator drains off accrued water.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (1000)
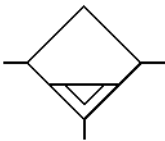
Automatic drain

The water separator drains off accrued water and is automatically emptied.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (1000)
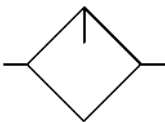
Lubricator

The lubricator enriches the compressed air with oil.

Adjustable parameters

Standard nominal flow rate: 0.1 ... 5000 l/min (1000)
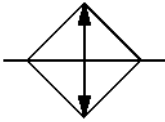
Cooler

The cooler cools the compressed air.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (1000)
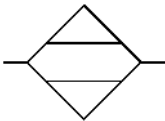
Air Dryer

The adsorption dryer reduces the humidity in the compressed air.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (1000)

Connection (pneumatic)

A pneumatic connection is a place where a pneumatic line can be attached to. To simplify the line drawing process, a connection appears as a small circle in Edit Mode. Pneumatic connections can be shut by means of a blind plug. An open pneumatic connection may result in leaking air; FluidSIM thus pops up a warning message, if some pneumatic connection was left open. Note that at each pneumatic connection values for the flow and pressure can be displayed.

Line (pneumatic)

A pneumatic line is used to connect two pneumatic connectors. These may be either a simple pneumatic connection or a T-junction.

A pneumatic line is normally treated as an ideal connection, with no pressure drop being included in the simulation. A frictional loss can be entered via the "*Physical model*" options. If you select "*Simple resistance*", only the "*Standard nominal flow rate*" parameter will be included in the simulation. If you select "*Empirical model*", an empirical model is applied that utilizes the length and inner diameter.
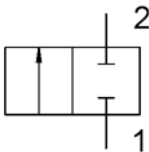
Error models
Component clogged: The component is clogged. The restricted flow can be adjusted.
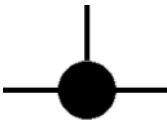
Pneumatic T-connection

A T-junction joins up to four pneumatic lines, thus having a single pressure potential. Note that T-junctions are introduced automatically by FluidSIM when dropping the line drawing cursor onto another line in Edit Mode.

22.2.2 *Directional valves, Configurable*

2/n Way Valve

The configurable 2/n way valve is a way valve with two connections, where both its body elements operation modes are user-definable.

Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.

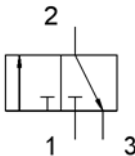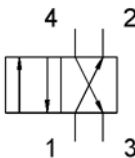*Adjustable parameters*
Desired position: 0 ... 4   (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)

Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.

3/n Way Valve

The configurable 3/n way valve is a way valve with two connections, where both its body elements operation modes are user-definable.

Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)

Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
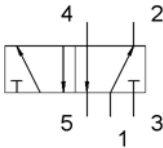**Pilot control left:** 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.

4/n Way Valve

The configurable 4/n way valve is a way valve with two connections, where both its body elements operation modes are user-definable.

Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
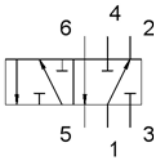
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.

5/n Way Valve

The configurable 5/n way valve is a way valve with two connections, where both its body elements operation modes are user-definable.

Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.

Adjustable parameters
Desired position: 0 ... 4   (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
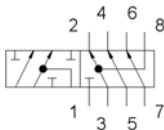**Pilot control right:** 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models

Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one:
5/3-way valve, pneumatically actuated in both directions, mid-position pressurized

6/n-way directional valve

The configurable 6/n way valve is a way valve with two connections, where both its body elements operation modes are user-definable.

Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.

8/n-way directional valve

The configurable 8/n way valve is a way valve with two connections, where both its body elements operation modes are user-definable.

Additionally, the pneumatic connections can be closed with either blind plugs or exhausts.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.

22.2.3 *Directional valves*, *Mechanically operated*

3/2-way roller lever valve, normally closed
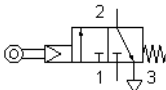
The roller lever valve is operated by pressing on the lever, for example through the use of a switching cam of a cylinder. The flow passes through from 1 to 2. After releasing the lever, the valve returns to its initial position through the use of a return spring. Connection 1 is shut. In the Simulation Mode, the valve can be switched manually by clicking on the component, thus not requiring a cylinder to operate the valve. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the con-

nectors 1 and 3 occurs. The value of the leakage is adjustable.
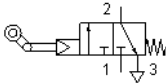
3/2-way roller lever valve, normally open
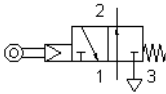
The roller lever valve is operated by pressing on the lever, for example through the use of a switching cam of a cylinder. Connection 1 is shut. After releasing the lever, the valve returns to its initial position through the use of a return spring. The flow may pass through freely from 1 to 2. In the Simulation Mode, the valve can be switched manually by clicking on the component, thus not requiring a cylinder to operate the valve. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.
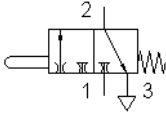
3/2-way idle return roller valve, normally closed

The idle return roller valve is operated when the roller is driven in a specific direction by the switching cam of a cylinder. After releasing the roller, the valve returns to its initial position through the use of a return spring. Connection 1 is shut. When the roller is driven in the opposite direction, the valve is not operated. In the Simulation Mode, the valve can be switched manually by clicking on the component, thus not requiring a cylinder to operate the valve. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4   (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.

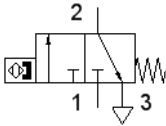© Festo Didactic SE • Art Systems GmbH • FluidSIM

Pressurizing valve

The pressurizing valve with plunger control is operated by the surface of the cylinder cam. When the plunger is operated, compressed air flows freely until the nozzle is closed. A signal up to the level of the boost pressure is assembled at exit connection 2. In the Simulation Mode, the valve can be switched manually by clicking on the component, thus not requiring a cylinder to operate the valve.
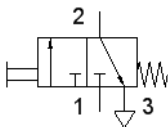
Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.

Pneumatic proximity switch, solenoid operated

A permanent solenoid found on the piston of a cylinder drives this 3/2 pneumatic directional valve and triggers the control signal. The flow passes freely from 1 to 2. In the Simulation Mode, the valve can be switched manually by clicking on the component, thus not requiring a cylinder to operate the valve. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.
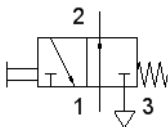
3/2-way valve with pushbutton, normally closed

Pressing the pushbutton operates the valve. The flow passes freely from 1 to 2. Releasing the pushbutton allows the valve to return to its starting position through the use of a return spring. Connection 1 is shut. By holding down the Shift key and simultaneously clicking on the component with the mouse cursor, FluidSIM keeps the valve in permanent operating position. Simply clicking on the component cancels the operated state and returns the valve to its starting position. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.
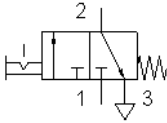
3/2-way valve with pushbutton, normally open

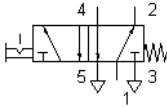Pressing the pushbutton operates the valve. Connection 1 is shut. Releasing the pushbutton allows the valve to returns to its starting position through the use of a return spring. The passes freely from 1 to 2. By holding down the Shift key and simultaneously click-ing on the component with the mouse cursor, FluidSIM keeps the valve in permanent operating position. Simply clicking on the component cancels the operated state and returns the valve to its starting position. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4   (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the con-nectors 1 and 3 occurs. The value of the leakage is adjustable.

3/2-way valve with selection switch or striking button

Pressing the red striking button operates the valve. The flow passes freely from 1 to 2. Releasing the button has no effect; the valve remains in its operating position. Turning the button to the right sets the striking button back to its original position and the valve returns to its starting position through the use of a return spring. Connection 1 is shut. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.
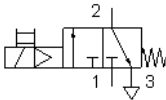
Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.
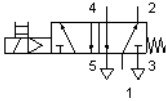
5/2-way valve, with selection switch

Turning the selection switch operates the valve. The flow passes
freely from 1 to 4. Releasing the switch has no effect; the valve
remains in its operating position. Turning the switch back to its
original position allows the flow to pass freely from 1 to 2. This
valve is derived from a configurable 5/n way valve. You find this
valve in the component library "Frequently used Way Valves",
under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one:
5/3-way valve, pneumatically actuated in both directions, mid-
position pressurized

22.2.4 *Directional valves, Solenoid operated*

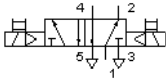**3/2-way solenoid valve, normally closed**

The solenoid valve is controlled by applying a voltage signal at the solenoid coil. The flow passes freely from 1 to 2. By stopping the signal the valve is set back to its starting position through the use of a return spring. Connection 1 is shut. If no signal is applied to the valve, it can be manually operated. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.

3/2-way solenoid valve, normally open

The solenoid valve is controlled by applying a voltage signal at the solenoid coil. Connection 1 is shut. By stopping the signal the valve is set back to its starting position through the use of a return spring. The flow passes freely from 1 to 2. If no signal is applied to the valve, it can be manually operated. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the [Library] menu.
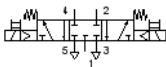
Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.

5/2-way solenoid valve

The solenoid valve is controlled by applying a voltage signal at the solenoid coil. The flow passes freely from 1 to 4. By stopping the signal the valve is set back to its starting position through the use of a return spring. The flow passes freely from 1 to 2. If no signal is applied to the valve, it can be manually operated. This valve is derived from a configurable 5/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.
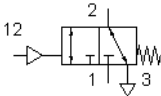
Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one: 5/3-way valve, pneumatically actuated in both directions, mid-position pressurized

5/2-way solenoid impulse valve

The solenoid valve is controlled by applying a voltage signal at the solenoid coil (flow passes from 1 to 4) and remains in this operating position even when the signal is cut off. Only by applying an opposite signal will the valve return to its starting position (flow passes freely from 1 to 2). If no signal is applied to the valve, it can be manually operated. This valve is derived from a configurable 5/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one: 5/3-way valve, pneumatically actuated in both directions, mid-position pressurized

5/3-way solenoid valve, mid-position closed

The solenoid valve is controlled by applying a voltage signal at the solenoid coil (flow passes from 1 to 4 or from 1 to 2). By stopping the signal the valve is set back to its starting position through the use of a return spring. Connections 1, 2, and 4 are shut. If no signal is applied to the valve, it can be manually operated. This valve is derived from a configurable 5/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.
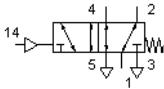
Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one: 5/3-way valve, pneumatically actuated in both directions, mid-position pressurized

22.2.5 *Directional valves, Pneumatically operated*

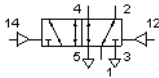**3/2-way valve, pneumatically operated, normally closed**

The pneumatic valve is controlled by applying a pilot pressure at connection 12. The flow passes freely from 1 to 2. By stopping the signal the valve is set back to its starting position through the use of a return spring. Connection 1 is shut. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.

3/2-way valve, pneumatically operated, normally open

The pneumatic valve is controlled by applying a pilot pressure at connection 10. Connection 1 is shut. By stopping the signal the valve is set back to its starting position through the use of a return spring. The flow passes freely from 1 to 2. This valve is derived from a configurable 3/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.
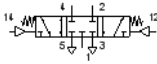
Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Leakage between 1 and 3: An internal leakage between the connectors 1 and 3 occurs. The value of the leakage is adjustable.

5/2-way valve, pneumatically operated

The pneumatic valve is controlled by applying a pilot pressure at connection 14. The flow passes freely from 1 to 4. By stopping the signal the valve is set back to its starting position through the use of a return spring. The flow passes freely from 1 to 2. This valve is derived from a configurable 5/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one: 5/3-way valve, pneumatically actuated in both directions, mid-position pressurized
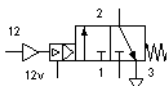
5/2-way impulse valve, pneumatically operated

The pneumatic valve is controlled by applying reciprocal pilot pressures at connection 14 (flow passes from 1 to 4) and connection 12 (flow passes from 1 to 2). The valve's operating position remains until an opposite signal is received by the valve. This valve is derived from a configurable 5/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4   (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one: 5/3-way valve, pneumatically actuated in both directions, mid-position pressurized

5/3-way pneumatic valve, mid-position closed

The pneumatic valve is controlled by applying reciprocal pilot pressures at connection 14 (flow passes from 1 to 4) and connection 12 (flow passes from 1 to 2). By stopping the signals the valve is set back to its starting position through the use of a return spring. Connections 1, 2, and 4 are shut. This valve is derived from a configurable 5/n way valve. You find this valve in the component library "Frequently used Way Valves", under the Library menu.

Adjustable parameters
Desired position: 0 ... 4   (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
Positioning time: 1e-4 ... 10 s (0.02)
Reset time: 1e-4 ... 10 s (0.03)
Minimum voltage: 0.1 ... 300 V (20)
Electrically left at U_min: 0.01 ... 100 N (70)
Electrically right at U_min: 0.01 ... 100 N (70)
Mechanically left: 0.01 ... 100 N (100)
Mechanically right: 0.01 ... 100 N (100)
Physical spring force: 0.01 ... 100 N (20)
Minimum force: 0.01 ... 100 N (15)
Min. pilot control force: 0.01 ... 100 N (15)
Left: 0.01 ... 100 cm2 (1)
Right: 0.01 ... 100 cm2 (1)
Pilot control left: 0.01 ... 100 cm2 (1.3)
Pilot control right: 0.01 ... 100 cm2 (1.3)
air spring left: 0.01 ... 100 cm2 (0.5)
air spring right: 0.01 ... 100 cm2 (0.5)

Error models
Piston blocked: The valve can not change its switching position.
Mid-position pressurized: The valve acts like the following one: 5/3-way valve, pneumatically actuated in both directions, mid-position pressurized

Low pressure amplifier unit, 2 compartments

Each of the two double-level low pressure amplifier units has the function of a 3/2 directional valve that is normally closed. The signal at connection 12 is raised to a higher boost pressure level through the use of a double-level amplifier and is put out by connection 2.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (60)

22.2.6 Flow control valves/Shutoff valves

Shuttle valve
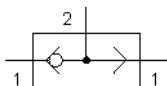
The shuttle valve is switched based on the compressed air entering into either input connection 1 and leaving via an output connection 2. Should both input connections begin receiving compressed air, the connection with the higher pressure takes precedence and is put out (OR function).

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (500)

Quick exhaust valve
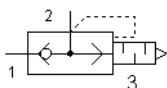
The compressed air passes from connection 1 to connection 2. If the pressure should decrease at connection 1, then the com-

pressed air from connection 2 will escape to the outside via the installed silencer.

Adjustable parameters
Standard nominal flow rate 1...2: 0.1 ... 5000 l/min (300)
Standard nominal flow rate 2...3: 0.1 ... 5000 l/min (550)

Two pressure valve
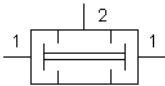
The two pressure valve is switched based on the compressed air entering into both input connections 1 and leaving via an output connection 2. Should both input connections begin receiving compressed air, the connection with the lower pressure takes precedence and is put out (AND function).

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (550)

Check valve
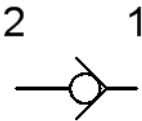
If the inlet pressure at 1 is higher than the outlet pressure at 2, then the check valve allows the flow to pass, otherwise it blocks the flow.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (136)

Spring loaded check valve
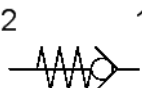
If the inlet pressure at 1 is higher than the outlet pressure at 2 and the nominal pressure, then the check valve allows the flow to pass, otherwise it blocks the flow.
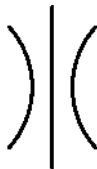
Adjustable parameters
Opening pressure: 0 ... 2 MPa (0.1)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
**Standard nominal flow rate:** 0.1 ... 5000 l/min (136)
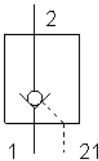
Check valve with pilot control

If the entering pressure at connection 1 is higher that the outgoing pressure at 2, the check valve allows the flow to pass freely. Otherwise, the valve stops the flow. Additionally, the check valve can be opened via the control line 12. This action allows the flow to pass freely in both directions.

Adjustable parameters
Area ratio: 0.1 ... 10 (3.3)
Standard nominal flow rate: 0.1 ... 5000 l/min (108)
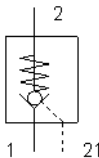
Spring loaded pilot-operated check valve

If the inlet pressure at 1 is higher than the outlet pressure at 2 and the nominal pressure, then the check valve allows the flow to pass, otherwise it blocks the flow. Additionally, the check valve can be released using the pilot line 12, thus enabling the flow in both directions.

Adjustable parameters
Opening pressure: 0 ... 2 MPa (0.1)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Area ratio: 0.1 ... 10 (3.3)
Standard nominal flow rate: 0.1 ... 5000 l/min (108)
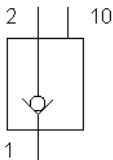
Pilot to close check valve

If the inlet pressure at 1 is higher than the outlet pressure at 2, then the non-return valve allows the flow to pass, otherwise it blocks the flow. Additionally, the non-return valve can be closed using the pilot line 10.

Adjustable parameters
Area ratio: 0.1 ... 10 (3.3)
Standard nominal flow rate: 0.1 ... 5000 l/min (108)
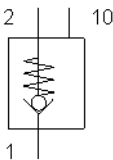
Pilot to close spring loaded check valve

If the inlet pressure at 1 is higher than the outlet pressure at 2 and the nominal pressure, then the non-return valve allows the flow to pass, otherwise it blocks the flow. Additionally, the non-return valve can be closed using the pilot line 10.

Adjustable parameters
Opening pressure: 0 ... 2 MPa (0.1)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Area ratio: 0.1 ... 10 (3.3)
Standard nominal flow rate: 0.1 ... 5000 l/min (108)

Nozzle

The nozzle represents a pneumatic resistance.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (100)
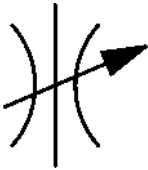
Throttle valve

The setting of the throttle valve is set by means of a rotary knob. Please note that by the rotary knob no *absolute* resistance value can be set. This means that, in reality, different throttle valves can generate different resistance values despite identical settings.

Adjustable parameters
Opening level: 0 ... 100 % (100)
**Standard nominal flow rate:** 0.1 ... 5000 l/min (100)
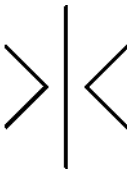
Orifice

The orifice represents a pneumatic resistance.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (100)

Variable orifice

The orifice represents a variable pneumatic resistance.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Standard nominal flow rate: 0.1 ... 5000 l/min (100)
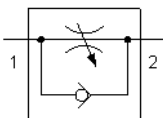
Throttle check valve

The one-way flow control valve is made up of a throttle valve and a check valve. The check valve stops the flow from passing in a certain direction. The flow then passes though the throttle valve. The

cross-section of the throttle is adjustable via a regular screw. In the opposite direction the flow can pass through the check valve.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Standard nominal flow rate (Flow control valve): 0.1 ... 5000 l/min (85)
Standard nominal flow rate (Non-return valve): 0.1 ... 5000 l/min (110)

Error models
Check valve always closed: The check valve is always closed.
Check valve always open: The check valve is always open.
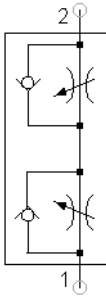
Throttle check valve, x2

These components combine two one-way flow control valves in one unit.

Adjustable parameters
Opening level (Flow control valve 1): 0 ... 100 % (100)
Standard nominal flow rate: 0.1 ... 5000 l/min (85)
Standard nominal flow rate: 0.1 ... 5000 l/min (110)
Opening level (Flow control valve 2): 0 ... 100 % (100)
Standard nominal flow rate: 0.1 ... 5000 l/min (85)
Standard nominal flow rate: 0.1 ... 5000 l/min (110)

Pneumatic counter
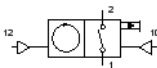
The counter registers pneumatic signals starting at a predetermined number and counting backwards. If zero is reached, then the counter releases an output signal. This output signal continues until the counter is reset either by hand or from at signal at connection 10.

Adjustable parameters

Counter: 0 ... 9999 (3)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)

Pneumatic timer, normally closed
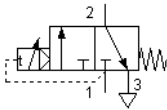
The time delay valve is actuated by a pneumatic signal at port 1 after a preset time delay has elapsed. It is returned to the normal position via return spring when the signal is removed. The time delay is infinitely adjustable by means of a regulating screw. The time delay is reset automatically within 200 ms.

Adjustable parameters
Delay time: 0.1 ... 100 s (3)
Standard nominal flow rate: 0.1 ... 5000 l/min (50)

Pneumatic timer, normally open
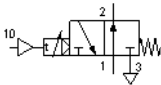
After the pilot signal is applied at port 10, a preset time elapses before the pneumatic timer is actuated. It returns to its initial position via a return spring once the signal is removed. The time delay is infinitely adjustable by means of a regulating screw. The time delay is reset automatically within 200 ms.

Adjustable parameters
Delay time: 0.1 ... 100 s (3)
Standard nominal flow rate: 0.1 ... 5000 l/min (50)

Ring sensor

The ring sensor is a non-contact pneumatic signal output module. It is supplied with low pressure at connection 1. If, due to an object, the entering air flow is disturbed, a low pressure signal will be put out by connection 2. To simulate an object in the air flow, as pre-

sented above, simply click on the component during FluidSIM
Simulation Mode.

22.2.7 Pressure control valves
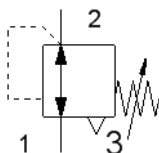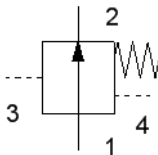
Pressure reducing valve

The pressure regulator valve regulates the compressed air supply
to the preset nominal pressure and equalizes pressure fluctuations.
The valve closes when the pressure at connection 2 exceeds the
nominal pressure. The setting for the real components is compo-
nent dependent and cannot be changed.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)

Variable pressure reducing valve

The pressure regulator valve regulates the compressed air supply
to the preset nominal pressure and equalizes pressure fluctuations.
The valve closes when the pressure at connection 2 exceeds the
nominal pressure.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)

Pressure control valve with manometer

The pressure control valve regulates the supplied pressure based on the adjustable operating pressure and the variations in the pressure. The manometer displays the pressure at connection 2.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)

Pressure reducing valve

The pressure regulator valve regulates the compressed air supply to the preset nominal pressure and equalizes pressure fluctuations. The compressed air is discharged via connection 3 when the pressure at connection 2 exceeds the nominal pressure. The setting for the real components is component dependent and cannot be changed.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)

Variable pressure reducing valve

The pressure regulator valve regulates the compressed air supply to the preset nominal pressure and equalizes pressure fluctuations. The compressed air is discharged via connection 3 when the pressure at connection 2 exceeds the nominal pressure.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)

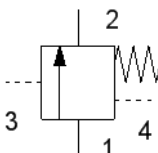**Standard nominal flow rate:** 0.1 ... 5000 l/min (300)

Closing pressure compensator

The pressure compensator represents a pressure dependent pneumatic resistance. The pressure compensator closes when the pressure d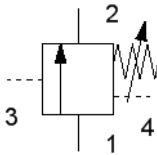ifference p3-p4 exceeds the nominal pressure. A pressure regulating valve is implemented by the combination of connections 2 and 3. The nominal pressure setting of the real components is component dependent and cannot be changed.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)
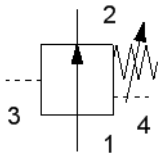
Variable closing pressure compensator

The pressure compensator represents a pressure dependent pneumatic resistance. The pressure compensator closes when the pressure difference p3-p4 exceeds the nominal pressure. A pressure regulating valve is implemented by the combination of connections 2 and 3.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)

Opening pressure compensator

The pressure compensator represents a pressure dependent pneumatic resistance. The pressure compensator opens when the pressure difference p3-p4 exceeds the nominal pressure. A se-

quence valve is implemented by the combination of connections 1 and 3. The nominal pressure setting of the real components is component dependent and cannot be changed.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)

Variable opening pressure compensator

The pressure compensator represents a pressure dependent pneumatic resistance. The pressure compensator opens when the pressure difference p3-p4 exceeds the nominal pressure. A sequence valve is implemented by the combination of connections 1 and 3.

Adjustable parameters
Nominal pressure: 0 ... 2 MPa (0.4)
Pressure regulation range: 0.01 ... 1 MPa (0.05)
Standard nominal flow rate: 0.1 ... 5000 l/min (300)

22.2.8 Pressure Operated Switches
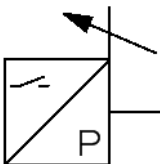
Pressure sensor

The pressure sensor measures the pressure and operates the pressure switch when the adjustable switching pressure has been exceeded.

Adjustable parameters

Type: Pressure switch,Vacuum switch   (Pressure switch)
Switching pressure: -0.1 ... 2 MPa (0.3)
Hysteresis: 0 ... 1 MPa (0)
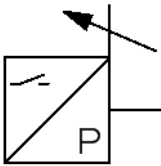
Vacuum switch

The vacuum switch operates the linked pressure switch, when the pressure falls below the adjustable switching pressure. If the symbol is used as a pressure switch the respective switch is operated when the pressure exceeds the switching pressure.

Adjustable parameters
Type: Pressure switch,Vacuum switch   (Vacuum switch)
Switching pressure: -0.1 ... 2 MPa (-0.04)
Hysteresis: 0 ... 1 MPa (0)
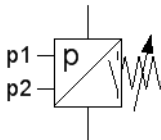
Pneumatic to electric converter

The differential pressure switch can be employed as a pressure switch (connection P1), a vacuum switch (connection P2) or as a differential pressure switch (P1-P2). The respective pneumatic to electric converter is operated when the difference in pressure between P1-P2 exceeds the adjustable switching pressure.

Adjustable parameters
Switching pressure: -2 ... 2 MPa (0.3)
Hysteresis: 0 ... 1 MPa (0)

22.2.9 Vacuum technology

Vacuum generator 05 H
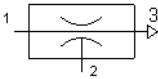
The vacuum suction nozzle creates its vacuum based on the ejector principle. In this case, compressed air flows from connection 1 to 3, creating a vacuum at connection 1v. A sucker can be connected to the vacuum connection 1v. Stopping the input of compressed air at connection 1 stops any suction also.
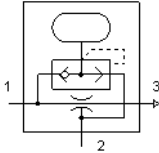
Adjustable parameters
Maximum vacuum: -0.999 ... 0 bar (-0.85)
Operating pressure for max. vacuum: 0.1 ... 20 bar (5)
Air consumption at 600 kPa: 1 ... 1000 l/min (11.6)
Max. suction rate: 0.1 ... 1000 l/min (6)

Vacuum generator 05 L
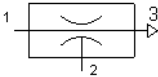
The vacuum suction nozzle creates its vacuum based on the ejector principle. In this case, compressed air flows from connection 1 to 3, creating a vacuum at connection 1v. A sucker can be connected to the vacuum connection 1v. Stopping the input of compressed air at connection 1 stops any suction also.

Adjustable parameters
Maximum vacuum: -0.999 ... 0 bar (-0.6)
Operating pressure for max. vacuum: 0.1 ... 20 bar (6)
Air consumption at 600 kPa: 1 ... 1000 l/min (12)
Max. suction rate: 0.1 ... 1000 l/min (15)

Single-level ejector with push-out unit (Vacuum generator)

The vacuum generator functions like the vacuum suction nozzle, except that an integrated reservoir is filled with air during the suction process. When the input line is switched off, the compressed air stored in the reservoir discharges in a pulse via the port (quick exhaust), securely repelling the suctioned workpiece from the vacuum cup. The volume can be enlarged by means of an additional port. This additional volume allows the energy of the vent pulse to be varied as required.

Adjustable parameters
Maximum vacuum: -0.999 ... 0 bar (-0.85)
Operating pressure for max. vacuum: 0.1 ... 20 bar (4.25)
Air consumption at 600 kPa: 1 ... 1000 l/min (11.6)
Max. suction rate: 0.1 ... 1000 l/min (6)
Volume: 0.001 ... 10 l (0.05)
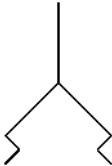
Vacuum suction cup

The suction cup can be used together with the vacuum suction nozzle to grip objects by suction. Lowering the cup onto an object is simulated in FluidSIM in Simulation Mode by clicking on the component. An additional click lifts the suction cup.

Adjustable parameters
Diameter: 1 ... 1000 mm (20)
Load to be lifted: 0.001 ... 1000 kg (0.1)
Safety factor: 0.1 ... 100 (1)
Leakage: 0 ... 1000 l/min (0)
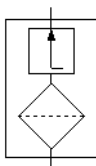
Vacuum efficiency valve

If multiple suction cups are supplied with vacuum by one vacuum suction nozzle, the vacuum will collapse if one or more cups do not

form a suction grip on the workpiece or workpieces. To prevent
this, so-called vacuum security valves are used. Vacuum security
valves are installed between the vacuum suction nozzle and the
suction cup. If, during vacuum generation, a suction cup is uncov-
ered, or only partly covered, the vacuum security valve automatical-
ly stops the influx of air. If the suction cup is open to the environ-
ment, the float is pressed up against the housing by the vacuum. In
this position, air can only flow through a small hole at the front of
the float, greatly reducing the air flow. If a workpiece comes in
contact with the suction cup, the air flow is reduced and the spring
forces the float downward. The air flow flows around the float, with
the larger opening allowing generation of a complete vacuum in the
suction cup.

Adjustable parameters
Min. spring pressure: 0 ... 1 bar (0.1)
Max. Spring pressure: 0.01 ... 1 bar (0.2)
Min. Flow rate at p1-p2 = 50 kPa: 0.001 ... 1000 l/min (1.9)
Max. Flow rate at p1-p2 = 50 kPa: 0.1 ... 1000 l/min (4)

Adjustable vacuum actuator valve
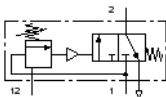
The vacuum actuator valve is employed through the conversion of a
vacuum signal. As soon as the vacuum reaches the adjustable
value at connection 1v, the attached valve body is switched.

Adjustable parameters
Switching pressure: -0.1 ... 0 MPa (-0.025)
Standard nominal flow rate: 0.1 ... 5000 l/min (100)

22.2.10   Valve groups

Pressure sequence valve
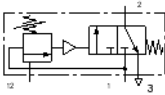
The sequence valve is operated when the control pressure at connection 12 has been reached. The flow passes freely from 1 to 2. Removing the signal allows the valve to return to its starting position through the use of a return spring. Connection 1 is shut. The pressure of the control signal is infinitely adjustable via a pressure setting screw.

Adjustable parameters
Switching pressure: 0 ... 20 bar (3)
Standard nominal flow rate: 0.1 ... 5000 l/min (100)

Time delay valve, normally closed
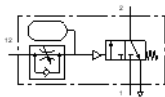
The time delay valve is made up of a pneumatically operated 3/2-way valve, a one-way flow control valve, and small air accumulator. When the necessary pressure is reached at the control connection 12 of the unit, the 3/2-way valve switches and the flow passes freely from 1 to 2.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Standard nominal flow rate (Flow control valve): 0.1 ... 5000 l/min (10)
Volume: 0.001 ... 100 l (0.01)
Standard nominal flow rate (Directional valve): 0.1 ... 5000 l/min (50)
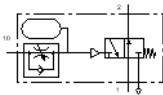
Time delay valve, normally open

The time delay valve is made up of a pneumatically operated 3/2-way valve, a one-way flow control valve, and small air accumulator. When the necessary pressure is reached at the control connection 10 of the unit, the 3/2-way valve switches and stops the flow from passing between 1 and 2.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Standard nominal flow rate (Flow control valve): 0.1 ... 5000 l/min (10)
Volume: 0.001 ... 100 l (0.01)
Standard nominal flow rate (Directional valve): 0.1 ... 5000 l/min (50)
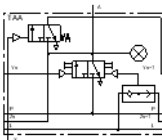
Stepper module, type TAA

The stepper module is made up of a memory unit (3/2-way impulse valve), an AND and an OR component, a viewable announcement, and an auxiliary manual operation.

Adjustable parameters
Initial Position: Left,Right (Left)
Desired position: 0 ... 2 (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)
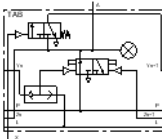
Stepper module, type TAB

The stepper module is made up of a memory unit (3/2-way impulse valve), an AND and an OR component, a viewable announcement, and an auxiliary manual operation.

Adjustable parameters

Initial Position: Left,Right   (Right)
Desired position: 0 ... 2   (0)
Standard nominal flow rate: 0.1 ... 5000 l/min (60)

Quickstepper

The Quickstepper is a ready to be fitted, mechanical/pneumatic control device with 12 in- and outputs. The outputs are successively synchronized with the input signals.

Two-hand control block
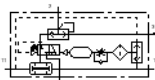
The control block for two-hand start ZSB is a pneumatic AND element. If the inputs 11 and 12 are pressurized within max. 0.5 s one after the other, the ZSB will switch through: an output signal is present at port 2. Control takes place via two external 3/2-way pushbutton valves. As long as both pushbutton valves are activated, outlet port 2 is pressurized. If one or both pushbuttons are released, outlet port 2 is unpressurized. The system exhausts from 2 to 3.

Adjustable parameters
Opening level: 0 ... 100 % (100)
Standard nominal flow rate: 0.1 ... 5000 l/min (50)

22.2.11 Proportional valves

Proportional 5/3-way directional valve
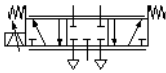
The proportional valve transforms an analog electrical input signal into corresponding opening cross-sections at the outputs. At half nominal voltage i.e. 5 V, the pneumatic mid-position is taken. Here all leading edges are closed, so that no air flows through the valve. Beneficial static and dynamic characteristics with minimal hysteresis (less than 0,3 %), short actuating time (typically 5 ms), and a higher upper frequency limit (approx. 100 Hz), are achieved through an integrated electronic position control for the slide distance. Thus the valve, as control element and especially in combination with a higher ranked position controller, is suitable for the positioning of a pneumatic cylinder.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (773)

Proportional pressure regulator
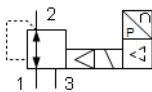
The regulating valve is intended for regulating pressure proportionally to a specified setpoint value given by a voltage. A built-in pressure sensor records the pressure at the working port and compares this value with the setpoint value. If the actual value differs from the setpoint value, the regulating valve is actuated until the outlet pressure reaches the setpoint value.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (850)
Voltage (Min.): 0.1 ... 100 V (0)
Voltage (Max.): 0.1 ... 100 V (10)
Nominal pressure (U_min): 0 ... 20 bar (0)
Nominal pressure (U_max): 0 ... 20 bar (6)
Pressure regulation range: 0.01 ... 10 bar (0.15)

22.2.12   Actuators
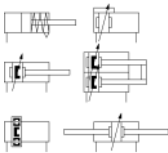
Configurable cylinder

The configurable cylinder can be customized via its properties dialog. Almost any combination of piston type (single-acting, double-acting), the specification of the piston rods (double ended, with magnetic coupling or slide) and the number (none, one, two) is possible. An end position cushioning (without, with, adjustable) can also be defined. FluidSIM automatically adjusts the symbol according to the preset configuration. In addition, a load to be moved (including possible static and sliding friction) and a variable force profile can be defined in the properties dialog. In the component library of FluidSIM there are several pre-configured cylinders that can be inserted in your circuit and directly used. Should no suitable symbol be available, then simply choose the component with the most similarity to the required component, open the properties dialog and adjust the configuration accordingly.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually   (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually   (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 10 MPa (0.05)

Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
**Ring area:** 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Single acting cylinder

The piston rod of a single acting cylinder is operated by the input of compressed air at the front end position. When the compressed air is shut off, the piston returns to its starting position via a return spring. The piston of the cylinder contains a permanent solenoid which can be used to operate a proximity switch.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)

Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)
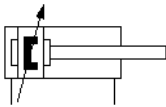
Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Single acting cylinder, return spring in piston chamber
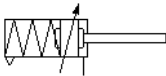
The piston of the single acting cylinder is extended to its back position by the input of compressed air. When the compressed air is switched off, a return spring moves the piston back to its front position.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)

Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)
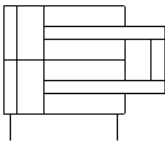
Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Double acting cylinder

The piston rod of a double acting cylinder is operated by the reciprocal input of compressed air at the front and back of the cylinder. The end position damping is adjustable via two regular screws. The piston of the cylinder contains a permanent solenoid which can be used to operate a proximity switch.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)

Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)
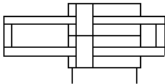
Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Cylinder, Double-acting, with in and out Piston Rod
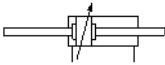
The in and out piston rod of the double acting cylinder is controlled by alternating the compressed air input. The cushioning can be adapted with two adjustment screws.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)

Spring pressure at x=0: 0 … 10 MPa (0.05)
Spring pressure at x=x_max: 0 … 10 MPa (0.1)
Damping length: 1 … 100 mm (10)
Piston area: 0 … 10000 cm2 (2.0106)
Ring area: 0 … 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Cylinder, double-acting, with two piston rods and single trestle

This twin cylinder has two in and out piston rods that move in parallel and that are coupled by a trestle. The construction guarantees minimum torsion when positioning and moving tools or assemblies. Moreover, coming along with the same construction height, the double piston rod conveys the double force as compared to standard cylinders.

Adjustable parameters
Piston diameter: 1 … 1000 mm (20)
Piston rod diameter: 0 … 1000 mm (8)
Piston Position: 0 … 5000 mm (0)
Maximum stroke: 1 … 5000 mm (200)
Mounting angle: 0 … 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 … 20 bar (6)
Reference velocity: 0.1 … 2 m/s (1)
Friction at dp_ref: 1 … 5000 N (120)
Break-away force at dp_ref: 1 … 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)

Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Cylinder, double-acting, with two in and out piston rods and double trestle

This twin cylinder has two in and out piston rods that move in parallel and that are coupled by a double trestle. The construction guarantees minimum torsion when positioning and moving tools or assemblies. Moreover, coming along with the same construction height, the double piston rod conveys the double force as compared to standard cylinders.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)

Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
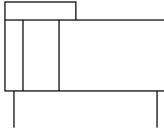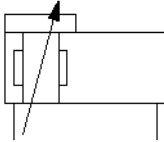**Ring area:** 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Multiple position cylinder, double-acting

By connecting two cylinders of same piston diameter but different maximum stroke three piston stop positions can be realized. From the first stop position the third stop can be reached either directly or via the intermediate stop. Note that the maximum stroke of the second piston must be larger than the preceding one. When moving back, an intermediate stop requires a particular control. The shorter maximum stroke is half of the other maximum stroke.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 1 ... 1000 mm (8)
Total stroke: 1 ... 2000 mm (200)
Piston Position: 0 ... 2000 mm (0)
Intermediate position: 0 ... 1000 mm (0)
External force: -10000 ... 10000 N (0)
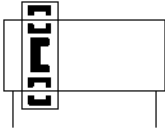
Linear drive with solenoid coupling

The sliding of the piston in the double rod cylinder is controlled by a reciprocal input of compressed air.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
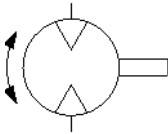**Ring area:** 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Linear drive, pneumatic, with shape-fitting adaptor

The sledge of the double acting cylinder without a piston rod is controlled by alternating the compressed air input. This type of linear drive conveys forces by means of a shape-fitting piston-sledge construction. The slitted cylinder prohibits the torsion of the slider.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Linear drive, pneumatic, with shape-fitting adaptor

The sledge of the double acting cylinder without a piston rod is controlled by alternating the compressed air input. This type of linear drive conveys forces by means of a shape-fitting piston-sledge construction. The slitted cylinder prohibits the torsion of the slider.

Adjustable parameters
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Piston Position: 0 ... 5000 mm (0)
Maximum stroke: 1 ... 5000 mm (200)
Mounting angle: 0 ... 360 deg (0)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Reference pressure: 0.1 ... 20 bar (6)
Reference velocity: 0.1 ... 2 m/s (1)
Friction at dp_ref: 1 ... 5000 N (120)
Break-away force at dp_ref: 1 ... 5000 N (12)
Parameter input: Calculate automatically,Enter manually (Calculate automatically)
Moving mass: 0.01 ... 1000 kg (0.3)
Leakage: 0 ... 10 l/(min.bar) (0)
Spring pressure at x=0: 0 ... 10 MPa (0.05)
Spring pressure at x=x_max: 0 ... 10 MPa (0.1)
Damping length: 1 ... 100 mm (10)
Piston area: 0 ... 10000 cm2 (2.0106)
Ring area: 0 ... 10000 cm2 (1.2252)

Error models
Internal leakage: An internal leakage occurs. The value can be adjusted.
Leakage A: A leakage at the left connector A occurs. The value of the leakage is adjustable.
Leakage B: A leackage at the right connector B occurs. The value of the leackage is adjustable.
High friction: A high friction occurs at the piston. The value of the friction can be adjusted.

Air motor

The air motor transforms pneumatic energy into mechanical energy.

Adjustable parameters
External torque: -1000 ... 1000 N.m (0)
Displacement: 0.001 ... 5 l (0.1)
Friction: 0.001 ... 100 N.m.s/rad (3)
Moment of inertia: 0.0001 ... 10 kg.m2 (0.0001)
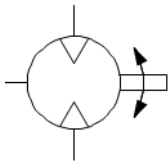
Compressed air motor with mid-exhaust

The motor converts pneumatic energy into mechanical, rotary energy. In can be operated in both the clockwise and counterclockwise directions. With the help of a centrifugal mass, the stopping of a load and the resulting consequences can be observed.

In addition to the measurement of speed in rpm via direct contact with the motor shaft, revolutions can also be counted with the help of an opto-electrical sensor.

Adjustable parameters
Pressure: 0.1 ... 2 MPa (0.3)
Revolution: 1 ... 10000 1/min (975)
Torque: 0.01 ... 100 N.m (0.62)
n_0 : n_N: 1.001 ... 10 (2)
External torque: -100 ... 100 N.m (0)
External torque: Torque (braking),Torque (driving)   (Torque (braking))
Moment of inertia: 1e-6 ... 10 kg.m2 (0.002)
Pulses per revolution: 0 ... 20 (1)
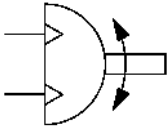
Semi-rotary actuator

The semi-rotary actuator is controlled by a reciprocal input of compressed air.

In the end positions the semi-rotary actuator can activate switches or valves via labels.

Adjustable parameters
Initial Position: 0 ... 360 deg (0)
Rotation angle (max): 1 ... 360 deg (180)
Displacement: 0.01 ... 1000 l (0.1)
Friction: 0.01 ... 100 N.m.s/rad (0.1)
Moment of inertia: 1e-005 ... 1 kg.m2 (0.0001)
External torque: -1000 ... 1000 N.m (0)

Semi-rotary actuator

The semi-rotary actuator is controlled by a reciprocal input of compressed air.

In the end positions the semi-rotary actuator can activate switches or valves via labels.

An external load is determined by a mass. The distance "e" from the center of gravity of the mass to the rotation axis can be specified. An additional moment of inertia is calculated with J = m * e * e from the distance and the mass. If the rotation axis is horizontal to the earth surface, also an additional torque is taken into account, which results from the force of gravity, the rotation angle and the distance "e". The position of the mass refers to the angle of rotation 0.

Adjustable parameters
Initial Position: 0 ... 360 deg (0)
Rotation angle (max): 1 ... 360 deg (180)
Torque (6 bar): 0.01 ... 1000 N.m (2)
Moment of inertia: 1e-005 ... 1 kg.m2 (0.0001)

Friction: 0.01 ... 100 N.m.s/rad (0.1)
External torque: -1000 ... 1000 N.m (0)
Axis of rotation: Horizontal,Vertical   (Horizontal)
Position: Left,Right,Top,Bottom   (Left)
Moving mass: 0 ... 10000 kg (0)
Distance to axis of rotation: 1 ... 10000 mm (10)

Fluidic muscle

Fluidic muscle is a tensile actuator which mimics the natural movement of a muscle. It consists of contractible tubing and appropriate connectors.

The contractible tubing is formed by a pressure-tight length of rubber hose, sheathed in high-strength fibres. The fibres create a rhomboidal pattern with a three-dimensional grid structure.

The tubing stretches in circumferential direction when an internal pressure is applied, generating a tensile force and a contraction movement in the longitudinal direction of the muscle. The usable tensile force is at its maximum at the start of the contraction and then decreases to zero in a virtually linear manner as a function of the stroke.

The fluidic muscle can only apply tensile forces. The size of the stroke which can be achieved through contraction is about 25% of the total muscle length. External tensile forces permit maximum pretensioning of 5%.

For the fluidic muscle, not only the force, but the stroke directly depends on the current working pressure. Positioning in the stroke direction is very easy. Instead of a displacement encoder which has to be integrated parallel to the drive, a pressure sensor can be installed at a favourable position. By allocating pressure and stroke, almost any number of positions can be realised.

Adjustable parameters
Type: DMSP-10,DMSP-20,DMSP-40,MAS-10,MAS-20,MAS-40 (DMSP-10)
Length: 40 ... 9000 mm (250)

External force: -1000000 ... 1000000 N (0)
Moving mass: 0 ... 10000 kg (0)
Static friction coefficient: 0 ... 2   (0)
Sliding friction coefficient: 0 ... 2   (0)
Mounting angle: 0 ... 360 deg (0)
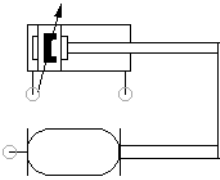
Fluidic muscle with one double acting cylinder

Fluidic muscle can be guided by coupling it mechanically with a double-acting cylinder. It is also possible to apply a load to the muscle via the cylinder.

Adjustable parameters
Type: DMSP-10,DMSP-20,DMSP-40,MAS-10,MAS-20,MAS-40 (DMSP-10)
Length: 40 ... 9000 mm (250)
Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Maximum stroke: 1 ... 5000 mm (200)
Piston Position: 0 ... 5000 mm (0)
Damping length: 1 ... 100 mm (10)
External force: -1000000 ... 1000000 N (0)
Moving mass: 0 ... 10000 kg (0)
Static friction coefficient: 0 ... 2   (0)
Sliding friction coefficient: 0 ... 2   (0)
Mounting angle: 0 ... 360 deg (0)
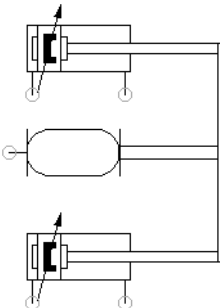
Fluidic muscle with two double acting cylinders

Fluidic muscle can be guided by coupling it mechanically with two double-acting cylinders. It is also possible to apply a load to the muscle via the cylinders.

Adjustable parameters
Type: DMSP-10,DMSP-20,DMSP-40,MAS-10,MAS-20,MAS-40 (DMSP-10)
Length: 40 ... 9000 mm (250)

Piston diameter: 1 ... 1000 mm (20)
Piston rod diameter: 0 ... 1000 mm (8)
Maximum stroke: 1 ... 5000 mm (200)
Piston Position: 0 ... 5000 mm (0)
Damping length: 1 ... 100 mm (10)
External force: -1000000 ... 1000000 N (0)
Moving mass: 0 ... 10000 kg (0)
Static friction coefficient: 0 ... 2 (0)
Sliding friction coefficient: 0 ... 2 (0)
Mounting angle: 0 ... 360 deg (0)

22.2.13 Measuring instruments and sensors
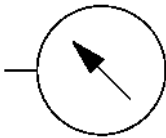
Pressure gauge

The manometer displays the pressure at its connection.

Error models
Linear scaling: Instead of the nominal value u the lineal scaling y = slope_err*u+ offset_err is used.

Differential pressure gauge

The differential pressure gauge displays the pressure difference between the adjacent pressures at the left and the right connection.
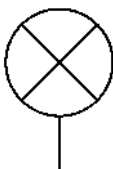
Pressure indicator

An optical signal is activated when the pressure at the connection to the pressure indicator exceeds the preset switching pressure.

Adjustable parameters
Switching pressure: -0.1 ... 2 MPa (0.3)

Analog pressure sensor

This symbol represents the pneumatic part of the analog pressure sensor. The analog pressure sensor measures the adjacent pressure and transforms it into a proportional electrical voltage signal. In the process, only pressures in the specified pressure ranges are considered. Within this range, the pressure in the voltage range from 0 V to 10 V is represented, i.e. the minimum pressure delivers 0 V and the maximum pressure 10 V.

Adjustable parameters
Minimum pressure: -2 ... 2 MPa (0)
Maximum pressure: -2 ... 2 MPa (1)
Voltage at p1: -100 ... 100 V (0)
Voltage at p2: -100 ... 100 V (10)

Analog pressure sensor

This symbol represents the pneumatic part of the analog pressure sensor.

Adjustable parameters
Minimum pressure: -2 ... 2 MPa (0)
Maximum pressure: -2 ... 2 MPa (1)
Voltage at p1: -100 ... 100 V (0)
Voltage at p2: -100 ... 100 V (10)
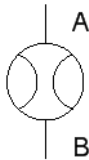
Flow meter

The flow meter measures the flow rate. Either the current flow or the total quantity flowed can be displayed. The component image is automatically adjusted accordingly.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (2000)
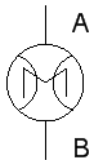
Flow meter

The flow meter measures the flow rate. Either the current flow or the total quantity flowed can be displayed. The component image is automatically adjusted accordingly.

Adjustable parameters
Standard nominal flow rate: 0.1 ... 5000 l/min (2000)

Analog flow meter

This symbol represents the pneumatic part of the analog flow meter. The analog flow meter measures the volumetric flow and transforms it into a proportional electrical voltage signal. In the process, only flow rates in the specified pressure ranges are considered. Within this range, the flow rate in the voltage range from 0 V to 10 V is represented, i.e. the minimum volumetric flow delivers 0 V and the maximum volumetric flow 10 V.

Adjustable parameters
Flow Direction: Ignore,Consider (Ignore)
Flow rate (min): -500 ... 500 l/min (0)
Flow rate (max): -500 ... 500 l/min (1000)
Voltage (q1): -100 ... 100 V (0)
Voltage (q2): -100 ... 100 V (10)

Standard nominal flow rate: 0.1 ... 5000 l/min (2000)
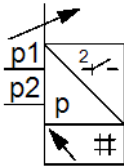
Pressure sensor with switching outputs and display

The pressure sensor is a piezo-resistive relative pressure transducer with integrated amplifier and built-in temperature compensation. The pressure to be measured is transferred to a piezo-resistive element via a silicone layer. The signal change generated in the element is output as a switching signal at the connector plug via an integrated amplifier.

The pressure sensor has two compressed air connections, each of which is assigned an independent sensor element. The measured input values (In A/In B) are output via two configurable switching outputs (Out A/Out B). The measured pressure is shown numerically and graphically on the display.

Adjustable parameters
Output function: Make switch,Break switch (Make switch)
Switching function: Threshold value,Window comparator (Threshold value)
Switching pressure 1: -0.1 ... 2 MPa (0.3)
Switching pressure 2: -0.1 ... 2 MPa (1)
Hysteresis: 0 ... 2 MPa (0)
Output function: Make switch,Break switch (Make switch)
Switching function: Threshold value,Window comparator (Threshold value)
Switching pressure 1: -0.1 ... 2 MPa (0.3)
Switching pressure 2: -0.1 ... 2 MPa (1)
Hysteresis: 0 ... 2 MPa (0)
Minimum voltage: 1 ... 300 V (13)
Idle current (24 V): 1 ... 10000 mA (32)
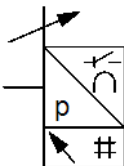
Pressure sensor with display

The pressure sensor is a piezoresistive relative pressure transducer with integrated amplifier and built-in temperature compensation.

The pressure to be measured is transferred onto a silicone coated piezoresistive element. The signal change generated therein is output as a voltage or switching signal at the connector plug via an integrated amplifier.

Adjustable parameters
Output function: Make switch,Break switch (Make switch)
Switching function: Threshold value,Window comparator (Threshold value)
Switching pressure 1: -0.1 ... 2 MPa (0.3)
Switching pressure 2: -0.1 ... 2 MPa (1)
Hysteresis: 0 ... 2 MPa (0)
Minimum pressure: -0.1 ... 2 MPa (0)
Maximum pressure: -0.1 ... 2 MPa (1)
Voltage at p1: -100 ... 100 V (0)
Voltage at p2: -100 ... 100 V (10)
Minimum voltage: 1 ... 300 V (13)
Idle current (24 V): 1 ... 10000 mA (32)
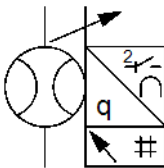
Flow sensor

The flow sensor is used to measure and monitor flow rate and air consumption values. Measurement is carried out by means of a thermal procedure, whereby the amount of heat drawn from a heated surface of the sensor by the medium flowing past it is calculated. The flow rate or the accumulated air consumption is based on the amount of heat drawn.

Connection to higher-order systems is established via two switching outputs (Out A/B) and an analogue output (Out C). Switching points can be defined for both binary outputs. Switching points are possible for both switching outputs for measuring the flow rate; a consumption switching pulse for output A (Out A) is possible for measuring the accumulated air consumption. The flow rate value is output via the analogue output. The flow rate or air consumption is shown on the display.

Adjustable parameters
Output function: Make switch,Break switch (Make switch)
Switching function: Threshold value,Window comparator

(Threshold value)
Volume measurement: ... (false)
Switching point 1 (Flow rate): -5000 ... 5000 l/min (10)
Switching point 2 (Flow rate): -5000 ... 5000 l/min (20)
Hysteresis (Flow rate): 0 ... 5000 l/min (0)
Switching point 1 (Volume): 0 ... 100000 l (100)
Switching point 2 (Volume): 0 ... 100000 l (200)
Hysteresis (Volume): 0 ... 10000 l (0)
Output function: Make switch,Break switch (Make switch)
Switching function: Threshold value,Window comparator
(Threshold value)
Volume measurement: ... (false)
Switching point 1 (Flow rate): -5000 ... 5000 l/min (10)
Switching point 2 (Flow rate): -5000 ... 5000 l/min (20)
Hysteresis (Flow rate): 0 ... 5000 l/min (0)
Switching point 1 (Volume): 0 ... 100000 l (100)
Switching point 2 (Volume): 0 ... 100000 l (200)
Hysteresis (Volume): 0 ... 10000 l (0)
Min. Flow rate: -5000 ... 5000 l/min (0)
Max. Flow rate: -5000 ... 5000 l/min (100)
Voltage at q1: -100 ... 100 V (0)
Voltage at q2: -100 ... 100 V (10)
Minimum voltage: 1 ... 300 V (12)
Idle current (24 V): 1 ... 10000 mA (32)

22.3 Electrical Controls (IEC)

22.3.1 Power supply

Electrical connection 0V

0 V ○—

0V connection of the power supply.

Adjustable parameters
Voltage: -400 ... 400 V (0)

Electrical connection 24V+

24 V ○—

24V connection of the power supply.

Adjustable parameters
Voltage: -400 ... 400 V (24)

Function generator

The function generator is a voltage source that can create constant, rectangle, sine and triangle signals. The voltage range is restricted to -10 V to +10 V. The frequency, the amplitude and the Y-offset of the signal can be set within this range. A voltage profile can be additionally specified. Data points can be set interactively with a mouse-click in the relevant graphic field. These can then be combined to a closed polygon. Alternatively, existing data points can be marked and both numeric values for the time and the corresponding voltage can be entered in the input fields. If the option "*Loop*" is selected, then the voltage profile is started again.

Adjustable parameters
Signal type: Rectangle,Sine,Triangle,Constant,Profile   (Sine)
Frequency: 0.01 ... 100000 Hz (1)
Amplitude: 0 ... 400 V (5)
y offset: -400 ... 400 V (0)
Min. Voltage: -400 ... 400 V (-400)
Max. Voltage: -400 ... 400 V (400)

Function generator

The function generator is a voltage source that can create constant, rectangle, sine and triangle signals. The voltage range is restricted to -10 V to +10 V. The frequency, the amplitude and the Y-offset of the signal can be set within this range. A voltage profile can be additionally specified. Data points can be set interactively with a mouse-click in the relevant graphic field. These can then be combined to a closed polygon. Alternatively, existing data points can be marked and both numeric values for the time and the corresponding voltage can be entered in the input fields. If the option "*Loop*" is selected, then the voltage profile is started again.

Adjustable parameters
Signal type: Rectangle,Sine,Triangle,Constant,Profile (Sine)
Frequency: 0.01 ... 100000 Hz (1)
Amplitude: 0 ... 400 V (5)
y offset: -400 ... 400 V (0)
Min. Voltage: -400 ... 400 V (-400)
Max. Voltage: -400 ... 400 V (400)

Setpoint value card

Voltage profiles in the range -10 V to +10 V can be created using the setpoint value card. Up to 8 setpoints W1 to W8 can be specified in the voltage range -10 V to +10 V. The setpoint card requires a power supply of 24 V.

The increase from the current setpoint to the next setpoint is defined using 4 ramps R1 to R4 with values between 0 s/V and 10 s/V, i.e. a low ramp value signifies a large increase, whereas a high ramp value results in a small increase. The active ramp is defined as follows: R1 by a positive increase of 0 V, R2 by a negative increase up to 0 V, R3 by a negative increase of 0 V and R4 by a positive increase up to 0 V.

Three operating modes can be selected: "*Wait for switching time*", "*Advance setpoints*" and "*External control*".

In operating mode "*Wait for switching time*" the setpoints are sequentially advanced when the preset change over time has expired.

If "*Advance setpoints*" is selected then, upon attaining the active setpoint, the next setpoint is started without delay.

In operating mode "*External control*" the selection of the active setpoint is effected by gating the inputs I1, I2 and I3 with at least 15 V. The corresponding setpoint is selected by means of the specified bit table. During the process, the internal switching time is inactive.

W1:	I1=0	I2=0	I3=0
W2:	I1=1	I2=0	I3=0
W3:	I1=0	I2=1	I3=0
W4:	I1=1	I2=1	I3=0
W5:	I1=0	I2=0	I3=1
W6:	I1=1	I2=0	I3=1
W7:	I1=0	I2=1	I3=1
W8:	I1=1	I2=1	I3=1

Connection (electrical)

An electric connection is a place where an electric line can be attached to. To simplify the line drawing process, a connection appears as a small circle in Edit Mode. Note that at each electric connection values for the voltage and current can be displayed.

Line (electrical)

An electrical line links two electrical connections. Note that an electrical connection may be a simple electrical connection or a T-junction. An electrical line causes no voltage drop, i. e., it has no electrical resistance.

Adjustable parameters
Physical model: Ideal connection,Simple resistance,Electrical conductor   (Ideal connection)
Length: 0.01 ... 1000 m (0.5)
Inner diameter: 0.1 ... 100 mm (2.5)
Specific resistance: 0.001 ... 1 Ohm.mm2/m (0.0178)
Resistance: 1e-4 ... 1e6 Ohm (0.0018131)

Error models
Current interrupted: The line is interrupted and current cannot flow.
Faulty resistance value: The resistor specified in the failure configuration is used, in order to simulate an excessive resistance for example.
Short circuit to ground: The conductor is connected directly to ground (0V potential) and can trigger a short circuit.
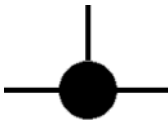
Electrical T-connection

A T-junction joins up to four electrical lines, thus having a single voltage potential. Note that T-junctions are introduced automatically by FluidSIM when dropping the line drawing cursor onto another line in Edit Mode.

22.3.2 Actuators
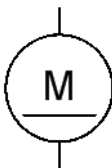
DC Motor

The DC motor transforms electrical energy into mechanical energy. DC motors produce the continual rotation through repeated changes in the direction of current. The characteristics of the 24 V DC motor relate to the motor used by the Festo Didactic conveyor belts.

Adjustable parameters
External torque: 0 ... 20 N.m (0)
Idle revolution: 10 ... 20000 1/min (75)

Solenoid
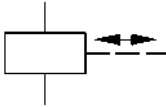
The solenoid converts electrical energy into mechanical energy. An iron core is pulled when a current flows through a coil. The iron core is returned to its neutral position by a spring after electrical current to the coil has been switched off. The solenoid can be used as a gate or a stopper.

Adjustable parameters
Resistance: 1 ... 10000 Ohm (20)

Injector
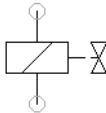
Injectors are used to spray fuel into the intake area or directly into the cylinders of combustion engines. The amount of fuel injected can be adjusted by varying the valve opening time.

The model used in FluidSIM represents only the valve solenoid that opens and closes the valve.

Adjustable parameters
Rated voltage: 0.1 ... 400 V (12)
Rated current: 0.001 ... 100 A (0.125)
Time constant (Coil): 0.01 ... 1000 ms (2.5)

Proportional adjustment unit
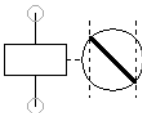
The proportional adjusting mechanism in FluidSIM is used for visual representation of a proportional valve as an actuator.

The model used in FluidSIM represents only the proportional sole-
noid of the electrical section. The position of the proportional
solenoid is proportional to the current, and is represented visually.
The maximum displacement is attained at the nominal current.

Adjustable parameters
Rated voltage: 0.1 ... 400 V (12)
Rated current: 0.001 ... 100 A (0.125)
Time constant (Coil): 0.01 ... 1000 ms (2.5)

22.3.3 Measuring instruments and sensors
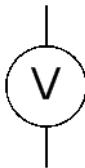
Volt meter

With a voltmeter, the voltage between two positions in a circuit can
be measured.

Adjustable parameters
Measure mode: Instantaneous value,Effective (RMS) voltage
without DC component,Effective (RMS) voltage   (Instantaneous
value)
Time interval: 0.001 ... 100 s (0.1)
Resistance: 1E-3 ... 10 MOhm (1)
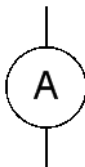
Ampere meter

With an ammeter, the amperage (current strength) of the current
between two positions in a circuit can be measured.

Adjustable parameters

Measure mode: Instantaneous value,Effective (RMS) current without DC component,Effective (RMS) current   (Instantaneous value)
Time interval: 0.001 ... 100 s (0.1)
Resistance: 1e-6 ... 10 Ohm (1e-3)

Indicator light

If current flows, the indicator light is displayed in the user-defined color.

Adjustable parameters
Resistance: 0.01 ... 1E4 Ohm (193.5)
Minimum voltage: 0.1 ... 300 V (5)

Lamp

When current flows through the lamp, an optical signal is activated. In FluidSIM, the lamp is colored with the set color.

There are two different physical models to choose from.

In the case of a simple resistor, the lamp is modeled as an ohmic load with a constant resistance. The resistance is given by the nominal voltage and the nominal power.

If the "temperature-dependent resistor" is chosen, the resistance increases as the temperature increases, as in a real light bulb. The relationship between cold resistance and hot resistance is observed here. The hot resistance is given by the nominal voltage and the nominal power.

Adjustable parameters
Physical model: Simple resistance,Temperature dependent resistance   (Simple resistance)
Rated voltage: 0.1 ... 400 V (12)
Rated power: 0.1 ... 10000 W (5)

Ratio R_cold:R_warm: 0.001 … 1000   (0.1)

Error models
Filament blown: No current flows because the lamp has blown.
Short circuit: The lamp causes a short circuit.
Faulty voltage value: The nominal voltage specified in the failure configuration is used. This may lead to an unexpected flow of current.
Faulty power value: The nominal power specified in the failure configuration is used. This may lead to an unexpected flow of current.
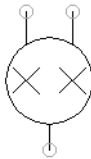
Two-filament lamp

A two-filament lamp is used in vehicles in devices such as combined brake light/taillights.

Adjustable parameters
Physical model: Simple resistance,Temperature dependent resistance   (Temperature dependent resistance)
Rated voltage: 0.1 … 400 V (12)
Rated power: 0.1 … 10000 W (21)
Ratio R_cold:R_warm: 0.001 … 1000   (0.1)
Rated power: 0.1 … 10000 W (5)
Ratio R_cold:R_warm: 0.001 … 1000   (0.1)

Error models
Filament blown: No current flows because the left or right lamp has blown.
Short circuit: The left or right lamp causes a short circuit.
Faulty power value: The nominal power specified in the failure configuration is used for the left or right lamp. This may lead to an unexpected flow of current.

Buzzer

If current flows, a flashing ring around the buzzer is shown. Moreover, if "Buzzer" is activated in the menu under Options... *Sound*, the buzzer is activated if a sound hardware is installed.

Adjustable parameters
Resistance: 0.01 ... 1E4 Ohm (100)
Minimum voltage: 0.1 ... 300 V (5)
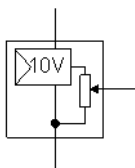
Displacement encoder

The displacement encoder is a slide potentiometer with longitudinal contact and no connecting-rods. It delivers a voltage signal that is proportional to the pickup position. The pickup position is determined by the piston stroke. The voltage range, which will depict the minimal and maximal piston position, can be defined within the range -10 V to +10 V by the user. The displacement encoder requires a power supply of at least 13 V.

Adjustable parameters
Voltage (Cylinder retracted): -10 ... 10 V (0)
Voltage (Cylinder extracted): -10 ... 10 V (10)
Minimum voltage: 0.1 ... 300 V (13)
Resistance: 1 ... 10000 Ohm (100)
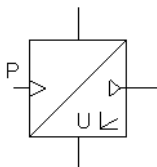
Pneumatic analog pressure sensor (electrical part)

This symbol represents the electrical part of the Analog-pressure sensor.
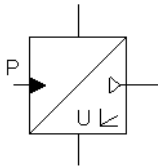
Hydraulic analog pressure sensor (electrical part)

This symbol represents the electrical part of the Analog-pressure sensor.
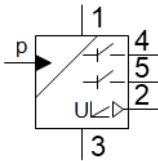
Pressure switch, electronic (electrical part)

This symbol represents the electrical part of the hydraulic pressure switch.
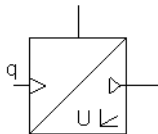
Pneumatic analog flow meter (electrical part)

This symbol represents the electrical part of the Analog-flow meter.
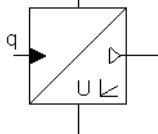
Hydraulic analog flow meter (electrical part)

This symbol represents the electrical part of the Analog-flow meter.
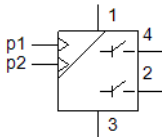
Pressure sensor with switching outputs and display (electrical part)

This symbol represents the electrical part of the pneumatic pressure sensor.
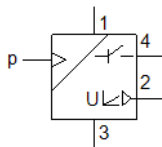
Pressure sensor with display (electrical part)

This symbol represents the electrical part of the pneumatic pressure sensor.
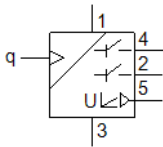
Flow sensor (electrical part)

This symbol represents the electrical part of the pneumatic flow sensor.
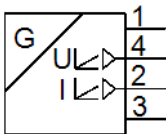
Position transmitter

The position transmitter is used for continuous detection of the piston position of magnetically sensed drives. The piston position is sensed without contact (magnetic). The measurement result is output in the sensing range of 50 mm as a current and voltage signal via two analogue outputs. A displacement-proportional output signal is supplied within the sensing range.

Adjustable parameters
Voltage (Cylinder retracted): -100 ... 100 V (2)
Voltage (Cylinder extracted): -100 ... 100 V (10)
Current (Cylinder retracted): -10000 ... 10000 mA (4)
Current (Cylinder extracted): -10000 ... 10000 mA (20)
Minimum voltage: 1 ... 300 V (15)
Idle current (24 V): 1 ... 10000 mA (32)
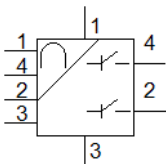
Signal converter

The signal converter converts analogue voltage output signals from a sensor into switching points. It closes or opens one of the two circuits (Out A, Out B) when the adjustable switching points are reached. Possible switching functions are threshold value, hysteresis or window comparator. The switching characteristic (N/C, N/O) can also be selected.

Adjustable parameters
Output function: Make switch,Break switch   (Make switch)
Switching function: Threshold value,Window comparator (Threshold value)
Switching point 1: -100 ... 100 V (1)

Switching point 2: -100 ... 100 V (8)
Hysteresis: 0 ... 100 V (0)
Output function: Make switch,Break switch   (Make switch)
Switching function: Threshold value,Window comparator
(Threshold value)
Switching point 1: -100 ... 100 V (1)
Switching point 2: -100 ... 100 V (8)
Hysteresis: 0 ... 100 V (0)
Switching time: 1e-5 ... 10 s (0.001)
Minimum voltage: 1 ... 300 V (15)
Idle current (24 V): 1 ... 10000 mA (32)
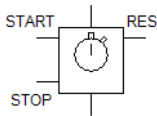
Stopwatch

The stopwatch can perform timing manually as well as in response to electrical signals. The stopwatch needs a supply voltage.

Timing is started by a signal at the "Start" input. A signal at the "Stop" input stops or pauses timing. A signal at the "Reset" input stops the measurement and resets the measured time.

An "R" appears in the top right corner during simulation. Clicking in this area stops the measurement and resets the measured time. Clicking outside this area starts or pauses timing.

Adjustable parameters
Minimum voltage: 0.1 ... 30 V (15)

22.3.4 General switches

Break switch

General break switch that is tailored depending on the type of component that actuates it. For example, if the break switch is linked via a label to a switch-off delay relay, the break switch changes to a switch-off delay break switch in the circuit diagram.

Make switch

General make switch that is tailored according to the component that actuates it. For example, if the make switch is linked via a label to a switch-on delayed relay, the make switch changes to a switch-on delayed make switch in the circuit diagram.

Changeover switch

General changeover switch that is tailored according to the component that actuates it. For example, if the changeover switch is linked via a label to a switch-on delayed relay, the changeover switch changes to a changeover switch in the circuit diagram.
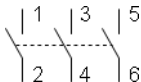
Make contact, 3x

The general triple make contact can be actuated by various components.

22.3.5 Delay Switches

Break switch (switch-on delayed)

Switch with delayed opening after pickup. Switch-on delayed break switches are created by using a general break switch and setting a label.

Make switch (switch-on delayed)

Switch with delayed closing after pickup. Switch-on delayed make switches are created by using a general make switch and setting a label.

Changeover switch (switch-on delayed)

Changeover switch with delayed changeover after pickup. Switch-on delayed changeover switches are created by using a general changeover switch and setting a label.

Break switch (switch-off delayed)

Switch with delayed closing after dropout. Switch-off delayed break switches are created by using a general break switch and setting a label.

Make switch (switch-off delayed)

Switch with delayed opening after dropout. Switch-off delayed make switches are created by using a general make switch and setting a label.

6   8

Changeover switch (switch-off delayed)

Changeover switch with delayed changeover after dropout. Switch-off delayed changeover switches are created by using a general changeover switch and setting a label.

5

22.3.6 Limit Switches

1

Limit switch (break)

Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch. Limit switches are created by using a general break switch and setting a label.

2

1

Switch with roll (break)

Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch. Switches with roll are created by using a general break switch, setting a label and selecting the switch type in the component's properties dialog.

2

Reed contact (break)

Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch. Reed contacts are created by using a general break switch, setting a label and selecting the switch type in the component's properties dialog.

Limit switch (make)

Switch that is closed by a cam attached to the cylinder rod. The switch opens immediately when the cam has passed the switch. Limit switches are created by using a general make switch and setting a label.

Switch with roll (make)

Switch that is closed by a cam attached to the cylinder rod. The switch opens immediately when the cam has passed the switch. Switches with roll are created by using a general make switch, setting a label and selecting the switch type in the component's properties dialog.

Reed contact (make)

Switch that is closed by a cam attached to the cylinder rod. The switch opens immediately when the cam has passed the switch. Reed contacts are created by using a general make switch, setting a label and selecting the switch type in the component's properties dialog.

2   4   Limit switch (changeover)

Switch that is changed over by a cam attached to the cylinder rod. The switch changes back immediately when the cam has passed the switch. Limit switches are created by using a general changeover switch and setting a label.

2   4   Switch with roll (changeover)

Switch that is changed over by a cam attached to the cylinder rod. The switch changes back immediately when the cam has passed the switch. Switches with roll are created by using a general changeover switch, setting a label and selecting the switch type in the component's properties dialog.

2   4   Reed contact (changeover)

Switch that is changed over by a cam attached to the cylinder rod. The switch changes back immediately when the cam has passed the switch. Reed contacts are created by using a general changeover switch, setting a label and selecting the switch type in the component's properties dialog.

22.3.7 *Switches, Manually operated*

Pushbutton (break)

Switch that opens when actuated and closes immediately when released. In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and

pushing the Shift key. This permanent actuation is released by a simple click on the component.

Error models
Short circuit: The lamp causes a short circuit.
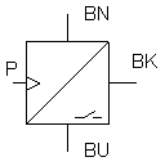**Current interrupted:** The line is interrupted and current cannot flow.

Pushbutton (make)

Switch that closes when actuated and opens immediately when released. In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift - key. This permanent actuation is released by a simple click on the component.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.

Pushbutton (changeover)

Switch that changes over when actuated and changes back imme-diately when released. In FluidSIM switches can be actuated per-manently (locked) when continuing to hold down the mouse button and pushing the Shift - key. This permanent actuation is released by a simple click on the component.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.

Detent switch (break)

Switch that opens and locks when actuated.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.

Detent switch (make)

Switch that closes and locks when actuated.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.
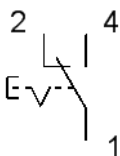
Detent switch (changeover)

Switch that changes over and locks when actuated.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.
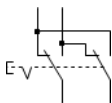
Crossover switch

The crossover switch consists of two coupled changeover switches. The crossover switch can be used to implement changeover circuits with several switching points.

22.3.8 Pressure Operated Switches

Pneumatic to electric converter (electrical part)

The converter produces an electrical signal, if the preset differential pressure of the differential pressure switch is exceeded.

Pressure switch (break)

Switch that opens when the preset switching pressure of the pneumatic or hydraulic pressure switch is exceeded. Pressure switches are created by using a general break switch and setting a label.

Pressure switch (make)

The switch closes when the preset switching pressure of the pneumatic or hydraulic pressure switch is exceeded. Pressure switches are created by using a general make switch and setting a label.

Pressure switch (changeover)

The switch changes over when the preset switching pressure of the pneumatic or hydraulic pressure switch is exceeded. Pressure switches are created by using a general changeover switch and setting a label.

Pneumatic pressure sensor (electrical part)

The switch relays an electrical signal when the preset switching pressure at the pneumatic pressure switch is exceeded.
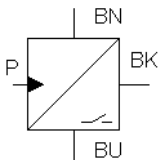
Hydraulic pressure sensor (electrical part)

The switch relays an electrical signal when the preset switching pressure at the hydraulic pressure switch is exceeded.

22.3.9 Proximity Switches
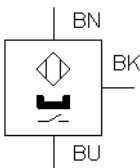
Magnetic proximity switch

Switch that closes when a solenoid is brought nearby. In the Simulation Mode the proximity switch can also be actuated by clicking on it.
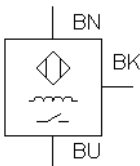
Inductive proximity switch

Switch that closes when the induced electro-magnetic field is changed. In the Simulation Mode the proximity switch can also be actuated by clicking on it.
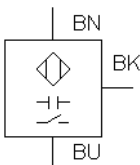
Capacitive proximity switch

Switch that closes when its electrostatic field is changed. In the Simulation Mode the proximity switch can also be actuated by clicking on it.
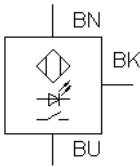
Optical proximity switch

Switch that closes when the light barrier is interrupted. In the Simulation Mode the proximity switch can also be actuated by clicking on it.

22.3.10   Relays
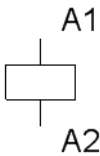
Relay

The relay picks up immediately when current is supplied and drops out immediately when current is removed.

Adjustable parameters
On-delay: 0.01 ... 10000 ms (10)
Off-delay: 0.01 ... 10000 ms (8)
Resistance: 1 ... 10000 Ohm (550)
Minimum voltage: 0.1 ... 300 V (20)
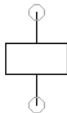
Relay

The relay picks up when a certain percentage of the nominal voltage is applied and drops out again when the voltage falls below a certain percentage of the nominal voltage. The buildup and dissipation of the magnetic field is not modeled. However, a pickup delay and a dropout delay may be specified.

Adjustable parameters

Rated voltage: 0.1 ... 400 V (24)
On-delay: 0.01 ... 10000 ms (10)
Off-delay: 0.01 ... 10000 ms (8)
Rated power: 0.1 ... 10000 W (1.5)
Pick-up voltage: 0 ... 100 % (70)
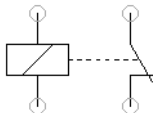**Drop-out voltage:** 0 ... 100 % (30)

Error models
Relay coil broken: The relay cannot pick up because current cannot flow through the broken relay coil.
Relay coil shortcut: The installation of the coil is faulty, creating a short circuit. The coil resistance specified in the failure configuration is used.
Relay picked up permanently: The contacts are being actuated permanently due to a mechanical defect.
Relay does not pick up: The contacts cannot be actuated due to a mechanical defect.
Relay does not drop out: Once the relay has picked up, it no longer drops out.

Relay with switch-on delay

The relay picks up after a preset time when current is supplied and drops out immediately when current is removed.

Adjustable parameters
Delay time: 0 ... 999 s (5)
Resistance: 1 ... 10000 Ohm (550)
Minimum voltage: 0.1 ... 300 V (20)

Relay with switch-off delay

The relay picks up immediately when current is supplied and drops out after a preset time when current is removed.

Adjustable parameters

Delay time: 0 ... 999 s (5)
Resistance: 1 ... 10000 Ohm (550)
Minimum voltage: 0.1 ... 300 V (20)

Relay counter

The relay picks up after a predefined number of current pulses has/have been counted between the connections A1 and A2. If a potential is supplied between the connections R1 and R2, the counter is reset to its predefined value.

In the Simulation Mode the relay counter can also be reset by clicking on it.

The relay works as a simple counter when the default number is set to 0. In this case the relay never picks up.

Adjustable parameters
Counter: 0 ... 9999 (5)
Resistance: 1 ... 10000 Ohm (550)
Minimum voltage: 0.1 ... 300 V (20)

Starting current limiter

The starting current limiter consists essentially of a relay, whose coil is situated between the connections IN and 0V, and whose switch contact is situated between the connections 24V and OUT. An electronic longitudinal controller restricts, with a switched relay contact, the current flow to the preset value for the specified duration. The starting current limiter is usually deployed in combination with the electric motor.

Adjustable parameters
Duration: 1 ... 10000 ms (0.05)
Current limit: 0.01 ... 100 A (2)
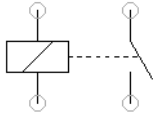
Relay with make contact

The relay consists of a coil and a make contact. The response time varies depending on the time constant of the coil.

The time constant indicates when 63% of the nominal current is reached if the nominal voltage is applied abruptly.

Adjustable parameters
Rated voltage: 0.1 ... 400 V (12)
Rated power: 0.1 ... 10000 W (1.5)
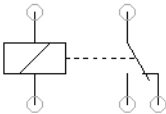**Time constant (Coil):** 0.01 ... 1000 ms (2.5)

Error models
Relay coil broken: The relay cannot pick up because current cannot flow through the broken relay coil.
Relay coil shortcut: The installation of the coil is faulty, creating a short circuit. The coil resistance specified in the failure configuration is used.
**Relay picked up permanently:** The contacts are being actuated permanently due to a mechanical defect.
Relay does not pick up: The contacts cannot be actuated due to a mechanical defect.
Relay does not drop out: Once the relay has picked up, it no longer drops out.

Relay with break contact

The relay consists of a coil and a break contact. The response time varies depending on the time constant of the coil.

The time constant indicates when 63% of the nominal current is reached if the nominal voltage is applied abruptly.

Adjustable parameters
Rated voltage: 0.1 ... 400 V (12)
Rated power: 0.1 ... 10000 W (1.5)

Time constant (Coil): 0.01 ... 1000 ms (2.5)

Error models
Relay coil broken: The relay cannot pick up because current cannot flow through the broken relay coil.
Relay coil shortcut: The installation of the coil is faulty, creating a short circuit. The coil resistance specified in the failure configuration is used.
Relay picked up permanently: The contacts are being actuated permanently due to a mechanical defect.
Relay does not pick up: The contacts cannot be actuated due to a mechanical defect.
Relay does not drop out: Once the relay has picked up, it no longer drops out.

Relay with changeover contact

The relay consists of a coil and a changeover contact. The response time varies depending on the time constant of the coil.

The time constant indicates when 63% of the nominal current is reached if the nominal voltage is applied abruptly.

Adjustable parameters
Rated voltage: 0.1 ... 400 V (12)
Rated power: 0.1 ... 10000 W (1.5)
Time constant (Coil): 0.01 ... 1000 ms (2.5)

Error models
Relay coil broken: The relay cannot pick up because current cannot flow through the broken relay coil.
Relay coil shortcut: The installation of the coil is faulty, creating a short circuit. The coil resistance specified in the failure configuration is used.
Relay picked up permanently: The contacts are being actuated permanently due to a mechanical defect.
Relay does not pick up: The contacts cannot be actuated due to a mechanical defect.

Relay does not drop out: Once the relay has picked up, it no longer drops out.

Relay coil (AC)
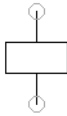
The relay coil is energized when actuated with alternating current. The relay coil can also be actuated with direct current. In this case though, it must be noted that a higher actuating current flows through the coil due to the lack of reactance.

The relay coil is modeled as a series connection of an ideal resistor and an ideal coil. The resistance and inductance are automatically calculated from the component parameters.

Adjustable parameters
Effective (RMS) voltage: 0.1 ... 600 V (230)
Apparent power: 0.1 ... 10000 W (15)
Power factor cos φ: 0.001 ... 1 (0.35)
Frequency: 30 ... 100 Hz (50)

Flasher relay
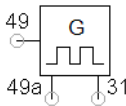
The hazard flasher relay is used for the cyclical switching off and on of a vehicle's turn signal lights and hazard flasher system.

Terminal 31 is connected to ground. Once terminal 49 is supplied with voltage, the internal electronics ensure that the voltage applied to terminal 49 is switched through cyclically to terminal 49a.

The hazard flasher relay is in fact a specialized pulse-width modulated switch. The switch-on time and the switch-off time are identical for the hazard flasher relay. The frequency specifies how often the switch is switched on and off per second.

Adjustable parameters
Frequency: 0.1 ... 100 Hz (1.5)
Rated voltage: 0.1 ... 400 V (12)

Rated power: 0.01 ... 100 W (1)

Error models
Component without function: The hazard flasher relay does not switch through to terminal 49a.
Faulty frequency: The hazard flasher relay switches with the frequency specified in the failure configuration.
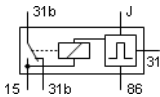
Windshield wiper interval relay

The windshield wiper interval relay can be used to switch the wiper system of a vehicle on and off in a clocked manner.

If a voltage is applied to terminal J, the clocked activation of the relay is started. If a voltage is applied to terminal 86, the relay is energized permanently.

Terminal 15 is connected to 12 V and terminal 31 to ground.

Adjustable parameters
Frequency: 0.01 ... 10 Hz (0.2)
Rated voltage: 0.1 ... 400 V (12)
Rated power: 0.1 ... 10000 W (1)

22.3.11 Controller

Comparator
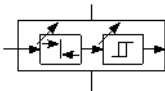
The comparator is a discontinuous (switching) two-step action controller with differential gap (hysteresis). When activated, it

delivers a predefined voltage signal. The switch-on value for the activation is defined by nominal value + 1/2 hysteresis and the switch-off value by nominal value - 1/2 hysteresis. The comparator requires a power supply of 24 V.

Adjustable parameters
Set value voltage: -300 ... 300 V (5)
Hysteresis: 0 ... 100 V (0)
Minimum voltage: 0.1 ... 300 V (13)
Resistance: 1 ... 10000 Ohm (100)

PID controller
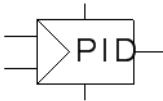
The PID-Controller is a continuous controller consisting of three control elements: Proportional, Integral and Derivative. The adjustable parameters refer to the PID-Controller in the Technology Package TP111 pneumatic control TP511 hydraulic control from Festo Didactic.

The output voltage restriction can be set within the range (i) -10 V to + 10 V or (ii) 0 V to +10 V. In the range (i), a manipulated variable offset from -7 V to + 7 V can be specified, and in the range (ii) a manipulated variable offset from 1.5 V to 8.5 V can be specified. The PID-controller requires a power supply of 24 V.

Adjustable parameters
Range selection: -10 .. 10 V,0 .. 10 V   (-10 .. 10 V)
Proportional gain: 0 ... 1000   (1)
Integral gain: 0 ... 1000 1/s (0)
Derivation gain: 0 ... 1000 ms (0)
Control quantity offset: -7 ... 7 V (0)
Minimum voltage: 0.1 ... 300 V (21.6)

Loop controller
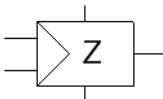
The status controller is especially suitable for controlling pneumatic positioning circuits. A pneumatic positioning circuit counts to the

controlled systems that can only be unsatisfactorily controlled with a standard controller. Three parameters can be attributed to the present status controller: position, speed and acceleration of the piston. The controller is therefore referred to as a "triple loop" controller. Speed and acceleration are not measured with sensors out of cost reasons. They are calculated by the controller from the differences in position. The adjustable parameters refer to the status controller in the Technology Package TP111 Closed-loop pneumatics TP511 Closed-loop hydraulics from Festo Didactic.

The output voltage restriction can be set within the range (i) -10 V to + 10 V or (ii) 0 V to +10 V. In the range (i), a manipulated variable offset from -7 to + 7 V can be specified, and in the range (ii) a manipulated variable offset from 1.5 V to 8.5 V can be specified. The status controller requires a power supply of 24 V.

Adjustable parameters
Range selection: -10 .. 10 V,0 .. 10 V   (-10 .. 10 V)
Deviation gain: 0 ... 10   (1)
Velocity damping: 0 ... 100 ms (0)
Acceleration damping: 0 ... 10 ms2 (0)
Total gain: 0 ... 1000   (1)
Control quantity offset: -7 ... 7 V (0)
Minimum voltage: 0.1 ... 300 V (21.6)

22.3.12 EasyPort/OPC/DDE

FluidSIM Output Port
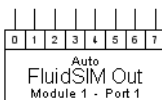
Communication with the EasyPort-Hardware and other applications is implemented with the FluidSIM-Output.
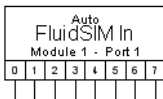
FluidSIM Input Port

Communication with the EasyPort-Hardware and other applications is implemented with the FluidSIM-Input.
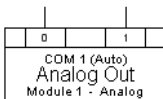
FluidSIM Output Port (analog)

Communication with the EasyPort-Hardware and other applications is implemented with the analog FluidSIM-Output.
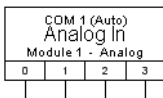
FluidSIM Input Port (analog)

Communication with the EasyPort-Hardware and other applications is implemented with the analog FluidSIM-Input.
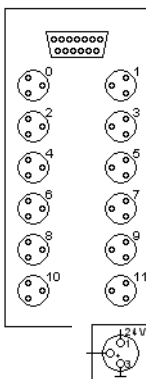
Multi-pin plug distributor

Communication with EasyPort hardware, as well as with other applications, is carried out with the multi-pin plug distributor. The contacts on the right-hand side (1, 3, 5, 7, 9 and 11) represent the digital outputs, and the contacts on the left-hand side (0, 2, 4, 6, 8 and 10) the digital inputs. If the "*Priority for connected hardware*" switch is activated, only the input signals from the external sensors are taken into consideration, if an EasyPort has been connected.

Universal I/O

The universal input/output-unit is connected with the multi-pin plug distributor by a label. The component is an input if the label refers to an input channel of the multi-pin plug distributor. The component is an output if the label refers to an output channel of the multi-pin plug distributor.

If used as an input the universal I/O-component is a voltage source. If the correspondent input channel of the multi-pin plug distributor on high level, the universal I/O-Component delivers 24 V, otherwise 0V.

If used as an output channel, the universal I/O-component sets the correspondent output channel of the multi-pin plug distributor on high level, if there is a higher voltage than 20 V.

22.4 Electrical Controls (NEMA)

22.4.1 Power supply

Electrical connection 0V

0V connection of the power supply.

Adjustable parameters
Voltage: -400 ... 400 V (0)

Electrical connection 24V+

24V connection of the power supply.

Adjustable parameters
Voltage: -400 ... 400 V (24)

22.4.2 Measuring instruments and sensors
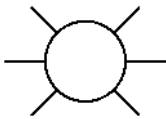
Indicator light

If current flows, the indicator light is displayed in the user-defined color.

Adjustable parameters
Resistance: 0.01 ... 1E4 Ohm (193.5)
Minimum voltage: 0.1 ... 300 V (5)

22.4.3 General switches

Break switch

General break switch that is tailored depending on the type of component that actuates it. For example, if the break switch is linked via a label to a switch-off delay relay, the break switch changes to a switch-off delay break switch in the circuit diagram.

Make switch

General make switch that is tailored according to the component that actuates it. For example, if the make switch is linked via a label to a switch-on delayed relay, the make switch changes to a switch-on delayed make switch in the circuit diagram.

Changeover switch

General changeover switch that is tailored according to the component that actuates it. For example, if the changeover switch is linked via a label to a switch-on delayed relay, the changeover switch changes to a switch-on delayed changeover switch in the circuit diagram.

22.4.4 Delay Switches

Break switch (switch-on delayed)

Switch with delayed opening after pickup. Switch-on delayed break switches are created by using a general break switch and setting a label.

Make switch (switch-on delayed)

Switch with delayed closing after pickup. Switch-on delayed make switches are created by using a general make switch and setting a label.

Changeover switch (switch-on delayed)

Changeover switch with delayed changeover after pickup. Switch-on delayed changeover switches are created by using a general changeover switch and setting a label.

Break switch (switch-off delayed)

5   6

Switch with delayed closing after dropout. Switch-off delayed break switches are created by using a general break switch and setting a label.

Make switch (switch-off delayed)

7   8

Switch with delayed opening after dropout. Switch-off delayed make switches are created by using a general make switch and setting a label.

Changeover switch (switch-off delayed)

8   5

6

Changeover switch with delayed changeover after dropout. Switch-off delayed changeover switches are created by using a general changeover switch and setting a label.

22.4.5 Limit Switches
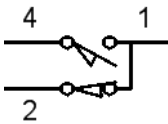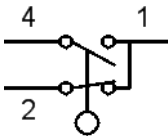
Limit switch (break)

1   2

Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch. Limit switches are created by using a general break switch and setting a label.

Switch with roll (break)
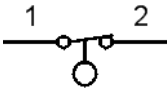
Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch. Limit switches are created by using a general break switch and setting a label.

Reed contact (break)

Switch that is opened by a cam attached to the cylinder rod. The switch closes immediately when the cam has passed the switch. Limit switches are created by using a general break switch and setting a label.

Limit switch (make)

Switch that is closed by a cam attached to the cylinder rod. The switch opens immediately when the cam has passed the switch. Limit switches are created by using a general make switch and setting a label.

Switch with roll (make)
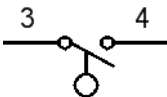
Switch that is closed by a cam attached to the cylinder rod. The switch opens immediately when the cam has passed the switch. Limit switches are created by using a general make switch and setting a label.

Reed contact (make)

Switch that is closed by a cam attached to the cylinder rod. The switch opens immediately when the cam has passed the switch.

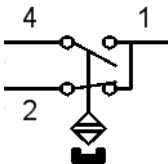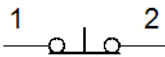Limit switches are created by using a general make switch and setting a label.

Limit switch (changeover)

Switch that is changed over by a cam attached to the cylinder rod. The switch changes back immediately when the cam has passed the switch. Limit switches are created by using a general changeover switch and setting a label.

Switch with roll (changeover)

Switch that is changed over by a cam attached to the cylinder rod. The switch changes back immediately when the cam has passed the switch. Switches with roll are created by using a general changeover switch, setting a label and selecting the switch type in the component's properties dialog.

Reed contact (changeover)

Switch that is changed over by a cam attached to the cylinder rod. The switch changes back immediately when the cam has passed the switch. Reed contacts are created by using a general changeover switch, setting a label and selecting the switch type in the component's properties dialog.

22.4.6 *Switches, Manually operated*
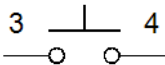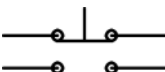
Pushbutton (break)

Switch that opens when actuated and closes immediately when released. In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift key. This permanent actuation is released by a simple click on the component.

Error models
Short circuit: The lamp causes a short circuit.
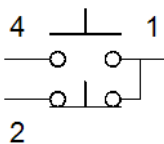**Current interrupted:** The line is interrupted and current cannot flow.

Pushbutton (make)

Switch that closes when actuated and opens immediately when released. In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift key. This permanent actuation is released by a simple click on the component.

Error models
Short circuit: The lamp causes a short circuit.
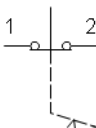**Current interrupted:** The line is interrupted and current cannot flow.

Pushbutton (changeover)

Switch that changes over when actuated and changes back immediately when released. In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift key. This permanent actuation is released by a simple click on the component.

Error models
Short circuit: The lamp causes a short circuit.
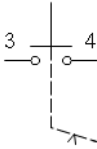**Current interrupted:** The line is interrupted and current cannot flow.

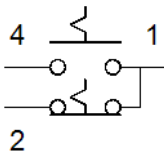**Pushbutton (changeover)**

Switch that changes over when actuated and changes back immediately when released. In FluidSIM switches can be actuated permanently (locked) when continuing to hold down the mouse button and pushing the Shift key. This permanent actuation is released by a simple click on the component.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.

Detent switch (break)

Switch that opens and locks when actuated.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.

Pushbutton (make)

Switch that closes and locks when actuated.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.
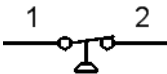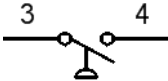
Detent switch (changeover)

Switch that changes over and locks when actuated.

Error models
Short circuit: The lamp causes a short circuit.
Current interrupted: The line is interrupted and current cannot flow.
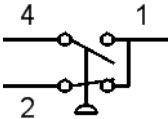
22.4.7 Pressure sensor

Pressure switch (break)

Switch that opens when the preset switching pressure of the pneumatic or hydraulic pressure switch is exceeded. Pressure switches are created by using a general break switch and setting a label.

Pressure switch (make)

The switch closes when the preset switching pressure of the pneumatic or hydraulic pressure switch is exceeded. Pressure switches are created by using a general make switch and setting a label.
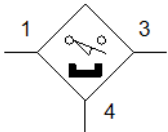
Pressure switch (changeover)

The switch changes over when the preset switching pressure of the pneumatic or hydraulic pressure switch is exceeded. Pressure switches are created by using a general changeover switch and setting a label.

22.4.8 Proximity Switches

Magnetic proximity switch

Switch that closes when a solenoid is brought nearby. In the Simulation Mode the proximity switch can also be actuated by clicking on it.
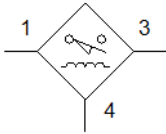
Adjustable parameters
Switching output: PNP,NPN (PNP)
Output function: Make switch,Break switch (Make switch)
Switching time: 1e-5 ... 10 s (0.001)
Minimum voltage: 1 ... 300 V (10)
Idle current (24 V): 1 ... 10000 mA (32)

Inductive proximity switch

Switch that closes when the induced electro-magnetic field is changed. In the Simulation Mode the proximity switch can also be actuated by clicking on it.
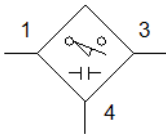
Adjustable parameters
Switching output: PNP,NPN (PNP)
Output function: Make switch,Break switch (Make switch)
Switching time: 1e-5 ... 10 s (0.001)
Minimum voltage: 1 ... 300 V (10)
Idle current (24 V): 1 ... 10000 mA (32)

Capacitive proximity switch

Switch that closes when its electrostatic field is changed. In the Simulation Mode the proximity switch can also be actuated by clicking on it.
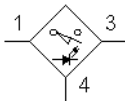
Adjustable parameters
Switching output: PNP,NPN (PNP)
Output function: Make switch,Break switch (Make switch)
Switching time: 1e-5 ... 10 s (0.001)
Minimum voltage: 1 ... 300 V (10)
Idle current (24 V): 1 ... 10000 mA (32)

Optical proximity switch

Switch that closes when the light barrier is interrupted. In the Simulation Mode the proximity switch can also be actuated by clicking on it.

Adjustable parameters
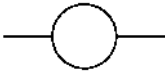**Switching output:** PNP,NPN (PNP)
Output function: Make switch,Break switch (Make switch)

Switching time: 1e-5 ... 10 s (0.001)
Minimum voltage: 1 ... 300 V (10)
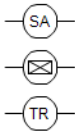**Idle current (24 V):** 1 ... 10000 mA (32)

22.4.9 Relays

Relay

The relay picks up immediately when current is supplied and drops out immediately when current is removed.

Adjustable parameters
On-delay: 0.01 ... 10000 ms (10)
Off-delay: 0.01 ... 10000 ms (8)
Resistance: 1 ... 10000 Ohm (550)
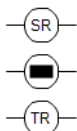**Minimum voltage:** 0.1 ... 300 V (20)

Relay with switch-on delay

The relay picks up after a preset time when current is supplied and drops out immediately when current is removed.

Adjustable parameters
Delay time: 0 ... 999 s (5)
Resistance: 1 ... 10000 Ohm (550)
Minimum voltage: 0.1 ... 300 V (20)
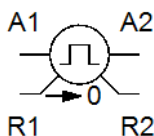
Relay with switch-off delay

The relay picks up immediately when current is supplied and drops out after a preset time when current is removed.

Adjustable parameters
Delay time: 0 … 999 s (5)
Resistance: 1 … 10000 Ohm (550)
Minimum voltage: 0.1 … 300 V (20)

Relay counter

The relay picks up after a predefined number of current pulses has/have been counted between the connections A1 and A2. If a potential is supplied between the connections R1 and R2, the counter is reset to its predefined value.

In the Simulation Mode the relay counter can also be reset by clicking on it.

The relay works as a simple counter when the default number is set to 0. In this case the relay never picks up.
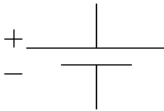
Adjustable parameters
Counter: 0 … 9999 (5)
Resistance: 1 … 10000 Ohm (550)
Minimum voltage: 0.1 … 300 V (20)

22.5 Electrical engineering/Electronics

22.5.1 Power supply

Constant voltage source

A constant voltage source is an ideal voltage source, which can maintain a fixed voltage that does not depend on the output current or load resistance.

Adjustable parameters
Voltage: 0 ... 400 V (12)

Error models
Faulty voltage value: The nominal voltage specified in the failure configuration is used. This may lead to an unexpected flow of current.
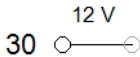
Potential

5 V

A potential is an ideal voltage source with a reference point of "ground".

Adjustable parameters
Voltage: -400 ... 400 V (5)

Potential/Terminal

12 V

30 ○——○

In FluidSIM the terminal/potential symbol is assigned to the power supply. The symbol is therefore connected by default to a potential, e.g. 12 V.

The voltages calculated in FluidSIM are calculated as potentials relative to 0 V (ground) and can be displayed on the connectors of the electrical symbols.

In automobile applications, terminal 15 is only connected to a potential via the ignition switch. For this reason the Properties dialog window for the symbol allows the user to specify that the symbol should not be given a potential. In this case, the symbol functions like the end of a line. If the ignition switch is not represented in the circuit diagram, terminal 15 can be connected to a potential directly.

If the symbol is connected to a potential directly, the voltage level is displayed on the symbol. Furthermore, the symbol can be clicked during the simulation to disconnect it from the potential, as with a switch.

Adjustable parameters
Terminal: ... (30)
Connected to potential: ... (true)
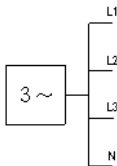**Voltage:** 0 ... 400 V (12)
Switched on: ... (true)

Error models
Faulty voltage value: The nominal voltage specified in the failure configuration is used. This may lead to an unexpected flow of current.

Ground

The ground symbol defines the 0 V reference potential for all signal and operating voltages.

L1
L2
L3
N

Three-phase alternator

A three-phase alternator supplies a combined set of three sinusoidal alternating electric voltages. The voltages are phase shifted to one another.

There are three inductors inside the alternator, spatially off-set by 120°. The magnetic field of an evenly rotating permanent magnet induces three alternating voltages, phase shifted to one another by 120°.

Adjustable parameters
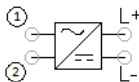**Frequency:** 0.01 ... 1000 Hz (50)
String voltage: 0 ... 400 V (7)
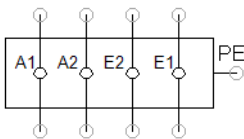
Connector panel

Simple connector panel

DC power supply

Transformer for transforming alternating voltage into direct voltage.

Terminals 1 and 2 are used for connection to the alternating voltage source. The desired direct voltage is made available at terminals L+ and L-.

Adjustable parameters

Effective (RMS) voltage (min): 10 ... 400 V (90)
AC Frequency (min): 10 ... 100 Hz (30)
Voltage (DC): 0 ... 400 V (12)
Efficiency: 0.1 ... 1 (0.9)

L1 —⊙   **Phase conductor**

Phase conductor which makes a sinusoidal alternating voltage available with adjustable amplitude, frequency and phase displacement. A phase displacement of 0° is preset as a default value for L1.

Adjustable parameters
Effective (RMS) voltage: 0 ... 400 V (230)
Frequency: 1 ... 100 Hz (50)
Phase shift: 0 ... 360 deg (0)

L2 —⊙   **Phase conductor**

Phase conductor which makes a sinusoidal alternating voltage available with adjustable amplitude, frequency and phase displacement. A phase displacement of 120° is preset as a default value for L2.

Adjustable parameters
Effective (RMS) voltage: 0 ... 400 V (230)
Frequency: 1 ... 100 Hz (50)
Phase shift: 0 ... 360 deg (120)

L3 —⊙   **Phase conductor**

Phase conductor which makes a sinusoidal alternating voltage available with adjustable amplitude, frequency and phase dis-

placement. A phase displacement of 240° is preset as a default value for L3.

Adjustable parameters
Effective (RMS) voltage: 0 ... 400 V (230)
Frequency: 1 ... 100 Hz (50)
Phase shift: 0 ... 360 deg (240)

N ⊸ **Neutral conductor**

Neutral conductor.

PE ⊸ **Protective earth conductor**

Protective earth conductor.

Plug and socket

The connection between plug and socket can be disconnected both in edit mode and during simulation.

During simulation, a click on the symbol changes the connection state.

Adjustable parameters
**Plugged in:** ... (true)

Error models
Current interrupted: The line is interrupted and current cannot flow.
Faulty resistance value: The resistor specified in the failure configuration is used, in order to simulate an excessive resistance for example.
Short circuit to ground: The conductor is connected directly to

ground (0V potential) and can trigger a short circuit.

DC power supply
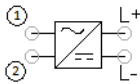
Transformer for transforming alternating voltage into direct voltage.

Terminals 1 and 2 are used for connection to the alternating voltage source. The desired direct voltage is made available at terminals L+ and L-.

Adjustable parameters
Effective (RMS) voltage (min): 10 ... 400 V (90)
AC Frequency (min): 10 ... 100 Hz (30)
Voltage (DC): 0 ... 400 V (12)
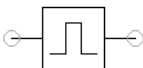**Efficiency:** 0.1 ... 1 (0.9)

Transformer DC/DC

The transformer transforms a DC input voltage into an DC output voltage. A simplified mathematical model is used for this in FluidSIM.

Adjustable parameters
Voltage: 0.1 ... 400 V (5)

Generator (Pulse Width Modulation)

The generator supplies a pulse-width modulated output signal in the form of a square voltage. The amplitude of the output voltage can be adjusted.

The switch-on time is the time in which the high voltage is supplied. The frequency is the inverse of the cycle period.

The duty cycle is the ratio of the switch-on time to the cycle period, expressed as a percentage. A duty cycle of 100% therefore means that the voltage is supplied at the set amplitude continuously.

The generator must be supplied with direct voltage.
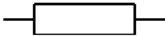
Adjustable parameters
Frequency: 0.01 ... 10000 Hz (1)
Pulse duty ratio: 0 ... 100 % (50)
Amplitude: 0 ... 400 V (5)

22.5.2 Passive components

Resistor

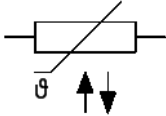A resistor represents an ideal ohmic resistor.

Adjustable parameters
Resistance: 1e-3 ... 1E8 Ohm (100)

Error models
Faulty resistance value: The resistor specified in the failure configuration is used, in order to simulate an excessive resistance for example.
Current interrupted: The line is interrupted and current cannot flow.

Resistor, temperature-dependent (NTC)

In a temperature-dependent resistor of type NTC (Negative Temperature Coefficient), the resistance value falls as the temperature rises.

Temperature-depended resistors can be heated by external or internal heating. In case of external heating, the component is heated by ambient temperature and by the current running through the component.

The local ambient temperature "T_e" can be changed during simulation and is displayed as a colored scale with a pointer. The arising component temperature "T" is not shown symbolically. But it can be shown in a diagram or the circuit.

A Steinhart-Hart-equation with four coefficients is used as mathematical model. The coefficients are automatically calculated by FluidSIM by providing four reference resistance values "R1" - "R4".

Adjustable parameters
Ambient temperature: -40 ... 140 °C (22)
Reference Resistance 1 (-40 °C): 1 ... 1E7 Ohm (147560)
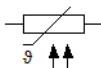**Reference Resistance 2 (0 °C):** 1 ... 1E7 Ohm (15040)
Reference Resistance 3 (20 °C): 1 ... 1E7 Ohm (5855)
Reference Resistance 4 (120 °C): 1 ... 1E7 Ohm (187.9)
Thermal time constant: 0.001 ... 1000 s (15)
Dissipation factor: 1e-5 ... 1 W/K (0.0156)

Resistor, temperature-dependent (PTC)

In a temperature-dependent resistor of type PTC (Positive Temperature Coefficient), the resistance value rises as the temperature rises.

Temperature-depended resistors can be heated by external or internal heating. In case of external heating, the component is

heated by ambient temperature and by the current running through the component.

The local ambient temperature "T_e" can be changed during simulation and is displayed as a colored scale with a pointer. The arising component temperature "T" is not shown symbolically. But it can be shown in a diagram or the circuit.

Especially PTC resistors build from metal behave like NTC resistors up to a certain temperature. This is taken into account by FluidSIM and can be specified by providing three reference points.

1. Reference resistance "R_0" at low temperature "T_0". 2. Temperature "T_C" at minimal resistance "R_C". 3. Reference resistance "R_1" at high temperature ""T_1".

This means the resistance falls to "T_C" and rises afterwards.

Adjustable parameters
Ambient temperature: -40 ... 140 °C (22)
Thermal time constant: 0.001 ... 1000 s (5)
Dissipation factor: 1e-5 ... 1 W/K (7.5e-4)
Reference temperature: -80 ... 300 °C (-40)
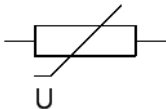**Reference Resistance:** 1 ... 1E7 Ohm (105)
Reference temperature: -80 ... 300 °C (20)
Reference Resistance: 1 ... 1E7 Ohm (63)
Reference temperature: -80 ... 300 °C (80)
Reference Resistance: 1 ... 1E7 Ohm (22000)

Resistor, voltage-dependent (VDR)

A varistor is a voltage-dependent resistor. Resistance decreases abruptly once a particular voltage threshold is exceeded.
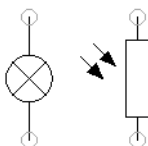
Resistor, light-dependent (LDR)

A light-dependent resistor consists of an amorphous semiconductor film. As the incidence of light is increased, electrical resistance is decreased, due to the internal photoelectric effect.

Adjustable parameters
Light intensity: 0 ... 100 % (0)
Min. Resistance: 1 ... 1E6 Ohm (183)
Max. Resistance: 1 ... 1E6 Ohm (34324)

Lght-dependent resistor (LDR) with lamp

The symbol is a combination of a light-dependent resistor (LDR) and a lamp.

The resistor can be masked continuously during the simulation. The minimum resistance is reached when the lamp is supplied with its nominal voltage and the resistor is not masked.

Adjustable parameters
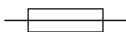**Rated voltage:** 0.1 ... 400 V (12)
Rated power: 0.1 ... 10000 W (2.4)
Ratio R_cold:R_warm: 0.001 ... 1000 (0.1)
Covering: 0 ... 1 (0)
Min. Resistance: 1 ... 1E6 Ohm (176.5)
Max. Resistance: 1 ... 1E6 Ohm (2333.3)

Fuse

A fuse is an overcurrent protection device that interrupts the circuit when the current exceeds a given value for a given period of time. The fuse will not trip while the current remains below the nominal current I_N.

A tripped fuse can be reset during the simulation by clicking it with the mouse. However, it will trip again if the current was not reduced.

In FluidSIM, fuses are modeled by a general fuse, the tripping characteristics of which can be specified as a trip curve. The trip curve is a curve describing the relationship between the current intensity and the trip time. The curve is defined by two points. The two points can be defined by the user by selecting "*User Defined*".

The first point is the time when the fuse trips if ten times the nominal current is applied constantly. The factor c1h is specified in FluidSIM for the second point. At a constant current intensity of c1h * I_N the fuse trips after exactly one hour. This factor can be found in the manufacturer's specifications.

If the user selects FF (*Very Fast Acting*), F (*Fast Acting*), M (*Medium Acting*), T (*Slow Acting*) or TT (*Very Slow Acting*), an average value will be selected automatically for the first time point.

Adjustable parameters
Tripping characteristic: User Defined,FF (Very Fast Acting),F (Fast Acting),M (Medium Acting),T (Slow Acting),TT (Very Slow Acting) (M (Medium Acting))
Rated current: 0.01 ... 10000 A (5)
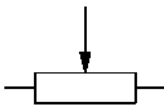**Tripping time (10*I_N):** 0.0001 ... 10 s (0.02)
Factor Rated current (Tripping time 1h): 1.21 ... 9.9 (1.5)
Resistance: 0.0001 ... 100 Ohm (0.01)

Error models
Fuse blown: The tripped fuse interrupts the current flow.

Potentiometer

A potentiometer is an electrical resistance component with mechanically adjustable (by means of rotation or sliding) resistance values. It provides three connectors and is mainly used as a continuously adjustable voltage divider.

Adjustable parameters
Potentiometer position: 0 ... 100 % (0)
Resistance: 1E-4 ... 100000 kOhm (1)
Protective resistance: 1E-6 ... 1000 Ohm (1e-6)

Error models
Faulty resistance value: The resistor specified in the failure configuration is used, in order to simulate an excessive resistance for example.
Faulty position value: The component is simulated with a faulty position value.

Double potentiometer

The double potentiometer is a combination of two potentiometers whose potentiometer positions are mechanically interlinked.
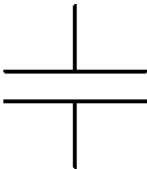
Adjustable parameters
Potentiometer position: 0 ... 100 % (0)
Resistance: 1E-4 ... 100000 kOhm (1)
Protective resistance: 1E-6 ... 1000 Ohm (1e-6)
Resistance: 1E-4 ... 100000 kOhm (1)
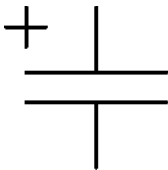**Protective resistance:** 1E-6 ... 1000 Ohm (1e-6)

Capacitor

A capacitor is a passive electrical component which is able to store electric charge (and therefore electric energy.)

The capacitor in its basic configuration consists of two electrically conductive surfaces, the electrodes. The electrodes are separated through an insulating material, the so-called dielectric. The separation of the two electrodes is so narrow, that the electrical forces are able to act through the insulating material.

If a constant voltage is applied to the connectors of an uncharged capacitor, a current flows for a short period of time and one of the electrodes is positively charged, the other one negatively. This electric charge is retained when the capacitor is disconnected from the voltage source. If charge resp. electric flow is extracted from the capacitor, its voltage drops again.

Adjustable parameters
Capacity: 1E-4 ... 1E7 uF (1)

Capacitor, polarized

A capacitor is a passive electrical component which is able to store electric charge (and therefore electric energy.)

The capacitor in its basic configuration consists of two electrically conductive surfaces, the electrodes. The electrodes are separated through an insulating material, the so-called dielectric. The separation of the two electrodes is so narrow, that the electrical forces are able to act through the insulating material.

If a constant voltage is applied to the connectors of an uncharged capacitor, a current flows for a short period of time and one of the electrodes is positively charged, the other one negatively. This electric charge is retained when the capacitor is disconnected from the voltage source. If charge resp. electric flow is extracted from the capacitor, its voltage drops again.

In contrast to the non-polarized capacitor, the polarized capacitor is only suitable for DC and for AC voltage that does not reverse the capacitor's polarity. The advantage of the polarized capacitor is the much higher capacity for the same form factor compared to non-polarized capacitors.

Adjustable parameters
**Capacity:** 1E-4 ... 1E7 uF (1)

Coil

An inductor is a passive electrical component which is able to create induction voltage.

An inductor, also called an inductance, in its basic configuration consists of wire coils. The inductor provides two terminals.

If an inductor is connected to a DC voltage, then an exponentially increasing current will flow.

Adjustable parameters
Inductance: 1E-3 ... 1E4 mH (100)
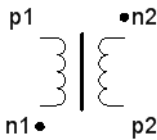
Transformer

The transformer consists of two transformer coils. If an alternating voltage is applied to one transformer coil, an alternating voltage is induced in the second coil. In the no-load case, the value of the new voltage when compared to the originally supplied voltage, follows the ratio of the number of windings of the corresponding coils to each other.

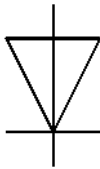*Adjustable parameters*
Inductance 1: 1E-3 ... 1E4 mH (595)
Windings 1: 1E-3 ... 5E4   (600)
Windings 2: 1E-3 ... 5E4   (200)
Coupling coefficient: 0 ... 1   (0.9)

22.5.3 Semiconductors

1N4007, Diode

A diode allows an electric current to pass in only one direction, while in the opposite direction it acts as an insulator. Therefore, diodes have a forward direction and a reverse direction.

Since version 5.6c the maximum power P_max can be specified. If this value is exceeded during simulation, the diode burns out. For reasons of compatibility with older circuit diagrams, the default value is unrealistically high.
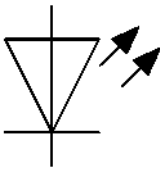
Adjustable parameters
Maximum power : 0.1 … 100000 W (1000)
Reference voltage: 0.1 … 100 V (0.7)
Reference current: 1 … 10000 mA (12.6)
Resistance in series: 0.001 … 1000 Ohm (0.0341512)
Saturation current: 1e-15 … 100 A (7.02767e-9)

LED, red

A light-emitting diode (LED) is a semiconductor component that emits light and has the electrical characteristics of a diode. If an electric current is flowing through the diode in forward direction, it emits light with a wavelength that depends on the semiconductor material and doping.

To make the use of the LED as a simple signal indicator easier, FluidSIM allows setting the color independent of the physical characteristics.

Since version 5.6c the maximum power P_max can be specified. If this value is exceeded during simulation, the diode burns out. For reasons of compatibility with older circuit diagrams, the default value is unrealistically high.
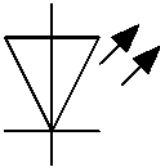
Adjustable parameters
Maximum power : 0.1 ... 100000 W (1000)
Reference voltage: 0.1 ... 100 V (2)
Reference current: 1 ... 10000 mA (25)
Resistance in series: 0.001 ... 1000 Ohm (9)
Saturation current: 1e-15 ... 100 A (1e-12)

LED, green

A light-emitting diode (LED) is a semiconductor component that emits light and has the electrical characteristics of a diode. If an electric current is flowing through the diode in forward direction, it emits light with a wavelength that depends on the semiconductor material and doping.

To make the use of the LED as a simple signal indicator easier, FluidSIM allows setting the color independent of the physical characteristics.

Since version 5.6c the maximum power P_max can be specified. If this value is exceeded during simulation, the diode burns out. For reasons of compatibility with older circuit diagrams, the default value is unrealistically high.

*Adjustable parameters*
Maximum power : 0.1 ... 100000 W (1000)
Reference voltage: 0.1 ... 100 V (2.2)
Reference current: 1 ... 10000 mA (30)
Resistance in series: 0.001 ... 1000 Ohm (9)
**Saturation current:** 1e-15 ... 100 A (1e-12)
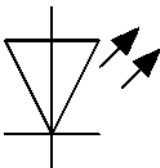
LED, blue

A light-emitting diode (LED) is a semiconductor component that emits light and has the electrical characteristics of a diode. If an electric current is flowing through the diode in forward direction, it

emits light with a wavelength that depends on the semiconductor material and doping.

To make the use of the LED as a simple signal indicator easier, FluidSIM allows setting the color independent of the physical characteristics.

Since version 5.6c the maximum power P_max can be specified. If this value is exceeded during simulation, the diode burns out. For reasons of compatibility with older circuit diagrams, the default value is unrealistically high.

Adjustable parameters
Maximum power : 0.1 ... 100000 W (1000)
Reference voltage: 0.1 ... 100 V (4)
Reference current: 1 ... 10000 mA (35)
Resistance in series: 0.001 ... 1000 Ohm (12.5)
Saturation current: 1e-15 ... 100 A (1e-12)

LED, red or green
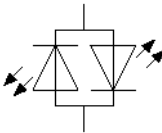
A light-emitting diode (LED) is a semiconductor component that emits light and has the electrical characteristics of a diode. If an electric current is flowing through the diode in forward direction, it emits light with a wavelength that depends on the semiconductor material and doping.

In this component, a green and a red LED with opposite polarity are connected in parallel. Depending on the current direction either the green or red LED lights up. Connected to alternating current with a frequency higher than about 30 Hz, the human eye cannot recognize the blinking and it seems as if both LEDs are lit simultaneously.

Since version 5.6c the maximum power P_max can be specified. If this value is exceeded during simulation, the diode burns out. For reasons of compatibility with older circuit diagrams, the default value is unrealistically high.

Adjustable parameters

Maximum power : 0.1 ... 100000 W (1000)
Resistance in series: 0.001 ... 1000 Ohm (9)
Reference voltage (Red LED): 0.1 ... 100 V (2)
Reference current (Red LED): 1 ... 10000 mA (25)
Saturation current (Red LED): 1e-15 ... 100 A (1e-12)
Reference voltage (Green LED): 0.1 ... 100 V (2.2)
Reference current (Green LED): 1 ... 10000 mA (30)
**Saturation current (Green LED):** 1e-15 ... 100 A (1e-12)
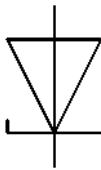
Z-diode

Because of their characteristics, zener diodes are used in numerous circuitries for stabilizing and limiting electrical voltages. In forward direction, they behave like normal diodes. In reverse direction, resistance drops off considerably after the voltage exceeds a certain value, the so-called breakdown voltage. The voltage does not increase by much after that, even if the electric current is increased.

Adjustable parameters
Reference voltage: 0.1 ... 100 V (0.7)
Reference current: 1 ... 10000 mA (9)
Saturation current: 1e-10 ... 100 A (1e-10)
Z-voltage: 0.1 ... 100 V (10)
Current at Z-voltage: 1 ... 10000 mA (15)
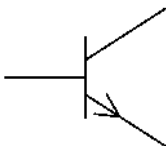
BC140, NPN transistor

An NPN transistor is a bipolar junction transistor (BJT). It is operated with an electric current and is used for switching and amplifying signals without using mechanically moving parts.

There are two types of BJTs: NPN and PNP. The letters indicate the order and doping type of the layers. Essentially, a BJT constitutes two p-n junctions connected together in series (like that of a p-n diode.) The three terminals are called collector (C), base (B) and emitter (E).
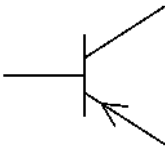
Adjustable parameters
Forward current gain: 0.1 ... 1000 (120)
Reverse current gain: 0.1 ... 1000 (1)
Saturation current: 1e-16 ... 1e-3 A (8.81138e-14)
Forward early voltage: 1 ... 1000 V (64)

BC160, PNP transistor

A PNP transistor is a bipolar junction transistor (BJT). It is operated with an electric current and is used for switching and amplifying signals without using mechanically moving parts.

There are two types of BJTs: NPN and PNP. The letters indicate the order and doping type of the layers. Essentially, a BJT constitutes two p-n junctions connected together in series (like that of a p-n diode.) The three terminals are called collector (C), base (B) and emitter (E).

Adjustable parameters
Forward current gain: 0.1 ... 1000 (230)
Reverse current gain: 0.1 ... 1000 (1)
Saturation current: 1e-16 ... 1e-3 A (8.81138e-14)
Forward early voltage: 1 ... 1000 V (64)
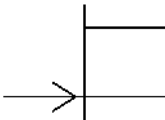
2N3819, N-channel JFET transistor

A junction gate field-effect transistor (JFET) controls the electrical current that flows through the channel between the source and drain terminals, by using a junction between the gate connector and the channel.

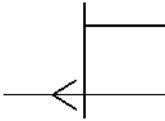Depending on doping type, JFETs are classified in two types: n-channel and p-channel JFETs.

Adjustable parameters
Threshold voltage: -20 ... 0 V (-3)
Transconductance parameter: 1e-6 ... 1e-1 A/V2 (1.304e-3)

Channel-length modulation parameter: 1e-6 ... 1e-1 1/V (2.25e-3)

2N3820, P-channel JFET transistor

A junction gate field-effect transistor (JFET) controls the electrical current that flows through the channel between the source and drain terminals, by using a junction between the gate terminal and the channel.

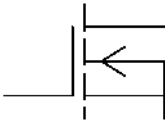Depending on doping type, JFETs are classified in two types: n-channel and p-channel JFETs.

Adjustable parameters
Threshold voltage: 0 ... 20 V (2.5)
Transconductance parameter: 1e-6 ... 1e-1 A/V2 (1.271e-3)
Channel-length modulation parameter: 1e-6 ... 1e-1 1/V (0.04)

BUZ10, N-channel MOSFET transistor

A metal-oxide-semiconductor field-effect transistor (MOSFET) is an active component with at least three terminals (electrodes): G (gate), D (drain) and S (source.) In some designs, an additional B (bulk) terminal is fed to the outside. Usually though, B is connected internally with S.

Like other field-effect transistors, a MOSFET acts as a voltage-controlled resistor, meaning that the voltage between gate and source can be used to change the resistance (and thus the electrical current) between drain and source by several orders of magnitude.

Depending on doping type, MOSFETs are classified in two types: n-channel and p-channel MOSFETs.
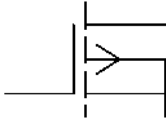
BS250, P-channel MOSFET transistor

A metal-oxide-semiconductor field-effect transistor (MOSFET) is an active component with at least three terminals (electrodes): G (gate), D (drain) and S (source.) In some designs, an additional B (bulk) terminal is fed to the outside. Usually though, B is connected internally with S.

Like other field-effect transistors, a MOSFET acts as a voltage-controlled resistor, meaning that the voltage between gate and source can be used to change the resistance (and thus the electrical current) between drain and source by several orders of magnitude.

Depending on doping type, MOSFETs are classified in two types: n-channel and p-channel MOSFETs.
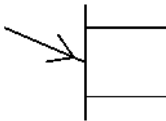
Unijunction transistor

Similar to a normal bipolar transistor, a unijunction transistor (UJT) provides three terminals. Unlike a bipolar transistor however, but similar to a diode, there is only one p-n junction. In practice, it acts like a controlled diode that, despite the constant polarity of the applied voltage, can be made conductive or non-conductive. Because of the two B terminals, the UJT is also called "double-base diode."

If a small, positive control voltage against B1 is applied to the emitter, nothing happens at first. If the control voltage is raised further and a certain potential is reached, the UEB1 voltage will collapse abruptly, and at the same time the emitter current will jump to a certain value. In a sense, the UJT "has been fired." This behavior is very similar to a thyristor. A UJT is cleared when the emitter current falls below a certain threshold.
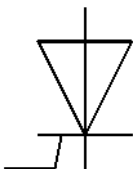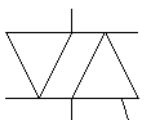
Thyristor

A thyristor is a semiconductor component built from four or more semiconductor films of varying levels of doping. Thyristors are switchable components, meaning they are non-conductive in their initial state and can be switched on through a small gate current. After a thyristor has been switched on, it remains conductive even if there is no gate current. A thyristor can be switched off by falling below a minimum current, the so-called holding current.
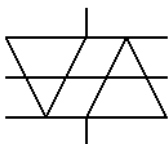
Diac

A DIAC (diode for alternating current) is an electronic component with only two terminals. DIACs are also referred to as "symmetrical trigger diodes." The junction between the terminals only becomes conductive after a breakover voltage has been reached.

The DIAC's bidirectional layout allows for the switching of alternating voltages. As soon as the voltage on the terminals (A1 and A2) rises above a certain threshold voltage, it will switch through and the p-n junction becomes conductive. Resistance will rise rapidly again after the current that is flowing through the DIAC falls below a certain value (the holding current.) This procedure is referred to as "resetting the DIAC."

Triac

In principle, A TRIAC (triode for alternating current) represents an inverse-parallel connection of two thyristors. This allows for switching of alternating current, while a single thyristor can switch in only one direction and thus acts - in its on-state - like a diode.

A TRIAC has a control terminal G (gate) and two main terminals MT1 and MT2, where MT2 is usually directly connected to the casing. In order to be able to use a single control terminal for both thyristors, TRIACs contain two firing, or helper, thyristor junctions, so that it

can be flipped into the low-impedance state by using a positive and negative control pulse.

Photodiode
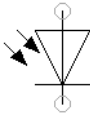
A photodiode is an electronic component that can be influenced by light. It can function either as a photoelectric cell (solar cell) or as a light-dependent resistor if it is reverse-biased in the circuit. The light applied generates a voltage in the photodiode.
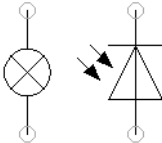
Adjustable parameters
Illuminance: 0 ... 100000 lx (0)
Dark current: 1e-6 ... 1000 uA (1e-3)
Short circuit current (100 lx): 0.001 ... 1000 uA (2)

Photodiode with lamp

The symbol is a combination of a photodiode and a lamp.

The photodiode can be masked continuously during the simulation. The maximum voltage is reached when the lamp is supplied with its nominal voltage and the photodiode is not masked.

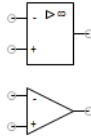*Adjustable parameters*
Rated voltage: 0.1 ... 400 V (12)
Rated power: 0.1 ... 10000 W (2.4)
Ratio R_cold:R_warm: 0.001 ... 1000 (0.1)
Covering: 0 ... 1 (0)
Dark current: 1e-6 ... 1000 uA (1e-3)
Short circuit current (100 lx): 0.001 ... 1000 uA (10)

Operational amplifier

The operational amplifier amplifies the differential input voltage U_in with

U_in = U_n – U_p

by the open-loop voltage gain V0, which inverts the output voltage U_out.

Given an ideal linear model, the output voltage can therefore be calculated with the following equation:

U_out = -Vo * U_in

Additionally, the supply voltage restricts the output voltage.

The positive supply voltage US_p and the negative supply voltage US_n can be assigned in the property dialog when using the simplified symbol.

When the non-linear model is used (which is FluidSIMs default setting), the previously stated equation is only satisfied by approximation. The output voltage approaches the limiting voltage without abrupt change in the slope.

The inputs are provided with a high resistance while the output is provided with a low resistance.

The operational amplifier is not modelled as an integrated circuit in detail. The temporal relation between input and output signal is modelled as a PT1-System with time constant T.

Adjustable parameters
Physical model: Linear model, Non-linear model (Non-linear model)
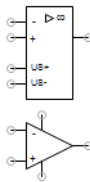**Open loop gain:** 1 ... 1e7 (10000)
Input resistance: 1 ... 1e9 Ohm (1e6)
Output resistance: 1 ... 1000 Ohm (10)
Max. Voltage: -400 ... 400 V (12)

Min. Voltage: -400 ... 400 V (-12)
Time constant: 0.001 ... 1 ms (0.1)

Operational amplifier with power supply pins

The operational amplifier amplifies the differential input voltage U_in with

$$U\_in = U\_n - U\_p$$

by the open-loop voltage gain V0, which inverts the output voltage U_out.

Given an ideal linear model, the output voltage can therefore be calculated with the following equation:

$$U\_out = -Vo * U\_in$$

Additionally, the supply voltage restricts the output voltage.

The connectors of the supply voltage need to be interconnected, in order for the operational amplifier to work.

When the non-linear model is used (which is FluidSIMs default setting), the previously stated equation is only satisfied by approximation. The output voltage approaches the limiting voltage without abrupt change in the slope.

The inputs are provided with a high resistance while the output is provided with a low resistance.

The operational amplifier is not modelled as an integrated circuit in detail. The temporal relation between input and output signal is modelled as a PT1-System with time constant T.

Adjustable parameters
Physical model: Linear model,Non-linear model   (Non-linear model)
Open loop gain: 1 ... 1e7 (10000)

Input resistance: 1 ... 1e9 Ohm (1e6)
Output resistance: 1 ... 1000 Ohm (10)
Time constant: 0.001 ... 1 ms (0.1)

22.5.4 Measuring instruments and sensors
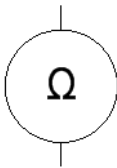
Ohmmeter

An ohmmeter is an electrical test instrument which is used to measure the electrical resistance of components.

Adjustable parameters
Voltage: 0.1 ... 9 V (9)
Series resistor: 1 ... 1000 kOhm (47)

Oscilloscope

An oscilloscope is an electronic test instrument that allows visual observation of one or more electrical voltages and their change over time on a display device. The oscilloscope displays a history graph, usually as a two-dimensional graph, where the horizontal x-axis represents time and the vertical y-axis the voltages that are to be displayed. The resulting image is called an oscillogram.

Adjustable parameters
Channel 2: ... ()
Channel 3: ... ()
Channel 4: ... ()
Resistance: 1E-3 ... 10 MOhm (10)
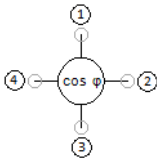
Power factor meter

Effective power factor is measured in AC circuits with the power factor meter. The measuring instrument is equipped with a current path (terminals 1 and 3) and a voltage path (terminals 4 and 2). Connect the measuring instrument's current path like an ammeter and the voltage path like a voltmeter.
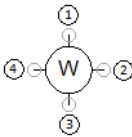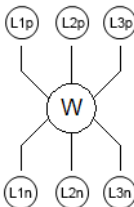
Wattmeter

The wattmeter is used to measure effective power in electric circuits. It's equipped with a current path (terminals 1 and 3) and a voltage path (terminals 4 and 2). The wattmeter multiplies measured values for voltage and current with each other and displays the result. Connect the measuring instrument's current path like an ammeter and the voltage path like a voltmeter.

Apparent power, reactive power and power factor can be measured with this wattmeter in addition to effective power.

Adjustable parameters
Time interval: 0.001 ... 100 s (0.1)
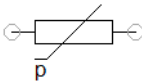
Wattmeter (3 phases)

The wattmeter with three phases is used to measure effective power in electric circuits with three-phase alternating current. The connections L1p and L1n are connected in series of the first phase, the connections L2p and L2n are connected in series of the second phase and connections L3p and L3n are connected in series of the third phase.

Apparent power, reactive power and power factor can be measured with this wattmeter in addition to effective power.

Pressure sensor

The pressure sensor is modeled as a simple force-dependent resistor. During the simulation, the mouse can be used to set a force acting on the sensor. The greater the force, the greater the resistance.

In an automobile, the pressure sensor can determine the pressure of a fluid that requires measurement. The pressure is the product of the effective surface area and the force acting on the sensor.

Adjustable parameters
External force: 0 ... 10000 N (0)
Area: 0.01 ... 1000 cm2 (0.25)
External force (Min.): 0 ... 10000 N (0)
External force (Max.): 1e-3 ... 10000 N (1)
Resistance (F_min): 1 ... 1e5 kOhm (900)
Resistance (F_max): 1 ... 1e5 kOhm (11.1)

Hot-film air-mass meter

The hot-film mass air flow sensor is modeled as a simple temperature-dependent resistor. In FluidSIM, an air flow can be specified during the simulation as a qualitative value between 0 and 1. The air flow cools the hot-film mass air flow sensor. The cooler it is, the greater is its resistance.
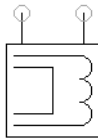
Adjustable parameters
Airflow: 0 ... 1 (0)
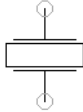
Knock sensor

The knock sensor is a piezoelectric voltage source. The smallest of impacts produce a voltage.

In FluidSIM, an impact can be triggered during the simulation by clicking with the mouse. The voltage curve that results can be measured, using an oscilloscope for example.

Reluctance speed sensor

The inductive sensor is a magneto whose alternating voltage can be interpreted directly by a controller in an automobile.

The inductive sensor can be used in an automobile as an r.p.m. sensor. For a controller, the cycle period is the dimension for the rotational speed. The more teeth the sensor's trigger wheel has and the faster it turns, the shorter the cycle period is.

In FluidSIM, a trigger wheel with 8 teeth is used and is displayed during the simulation. The rotational speed can be modified during the simulation.

Adjustable parameters
Revolution: -8000 ... 8000 1/min (0)
Wheel position: 0 ... 360 deg (0)
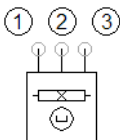
Hall sensor

In a Hall sensor, an electric voltage called Hall voltage is generated. The required electric and magnetic processes take place in the smallest of spaces on the Hall IC, which requires an external power supply (positive terminal: connector 1, negative terminal: connector 2).

The Hall sensor can record a rotational position without contact. In FluidSIM, a trigger wheel with 8 teeth is used and is displayed during the simulation. The rotational position and the rotational speed can be modified during the simulation.

The Hall sensor is modeled as a simple electronic switch. If there is a tooth in front of the sensor, connector 1 is switched through to connector 3.

Adjustable parameters
Revolution: -8000 ... 8000 1/min (0)
Wheel position: 0 ... 360 deg (0)
Rated voltage: 0.1 ... 400 V (12)
Rated power: 0.1 ... 1000 W (0.1)

22.5.5 Switches

Circuit breaker

Circuit breakers protect connected circuits from overloading. They're equipped with a thermal trigger and an electromagnetic trigger. The thermal trigger is usually a bimetallic switch which is tripped after a specified period of time when current flowing through the circuit breaker is greater than nominal current. In the event of a short-circuit or excessive overcurrent, the electromagnetic trigger is tripped and the circuit break opens very quickly. The circuit breaker is equipped with trip-free release, which means that it opens even if it's held closed manually.   The switch's characteristic can be selected under the circuit breaker's attributes. If characteristic B is selected, the electromagnetic trigger is tripped at an amperage of 3 times nominal current, or at 5 times nominal current if characteristic C is selected. For thermal triggering, a selected tripping point can be specified for a given overcurrent value.

The symbol for the circuit breaker shows the switch in its open state. The circuit breaker is closed automatically when simulation in FluidSIM is started, so that it doesn't have to be closed manually for each simulation.
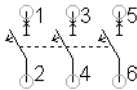
Adjustable parameters
Rated current: 0.1 … 100 A (4)
Tripping characteristic: B,C (B)
Tripping temperature: 50 … 150 °C (80)
Multiple of nominal current: 1.5 … 10 (2)
Tripping time: 0.1 … 100 s (30)

Circuit breaker three phase

Circuit breakers protect connected circuits from overloading. They're equipped with a thermal trigger and an electromagnetic trigger. The thermal trigger is usually a bimetallic switch which is tripped after a specified period of time when current flowing through the circuit breaker is greater than nominal current. In the event of a short-circuit or excessive overcurrent, the electromagnetic trigger is tripped and the circuit break opens very quickly. The circuit breaker is equipped with trip-free release, which means that it opens even if it's held closed manually.

In the case of this 3-phase circuit breaker, each phase is monitored separately. If overloading occurs in any single phase, all three phases are interrupted. The switch's characteristic can be selected under the circuit breaker's attributes. If characteristic B is selected, the electromagnetic trigger is tripped at an amperage of 3 times nominal current, or at 5 times nominal current if characteristic C is selected. For thermal triggering, a selected tripping point can be specified for a given overcurrent value.

The symbol for the circuit breaker shows the switch in its open state. The circuit breaker is closed automatically when simulation in FluidSIM is started, so that it doesn't have to be closed manually for each simulation.
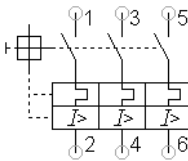
Adjustable parameters

Rated current: 0.1 ... 100 A (10)
Tripping characteristic: B,C (B)
Tripping temperature: 50 ... 150 °C (80)
Multiple of nominal current: 1.5 ... 10 (2)
**Tripping time:** 0.1 ... 100 s (30)

Motor circuit breaker

Motor circuit breaker are used to protect connected motors against overloading. They're equipped with a thermal trigger for minimal overcurrent and an electromagnetic trigger for short-circuits. This motor circuit breaker has a 10 A tripping class. The thermal trigger starts to trip as of an amperage of 1.2 times nominal current and the electromagnetic trigger is tripped as of 7.2 times nominal current. If overloading occurs in any single phase, all three phases are interrupted when the circuit breaker is tripped. The circuit breaker has to be closed manually after tripping.

The symbol for the motor circuit breaker shows the switch in its open state. The circuit breaker is closed automatically when simulation in FluidSIM is started, so that it doesn't have to be closed manually for each simulation.

Adjustable parameters
Rated current: 0.1 ... 100 A (0.5)
Tripping temperature: 50 ... 150 °C (80)
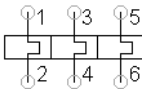
Motor protection relay

Motor protection relays are used to protect connected motors against overloading. If overloading occurs in any of the three connected phases, a connected switch can be actuated by means of the motor protection relay. In the event of overloading, power supply to the motor is usually interrupted via the its control circuit.

Adjustable parameters

Rated current: 0.1 ... 100 A (0.5)
Tripping temperature: 50 ... 150 °C (80)
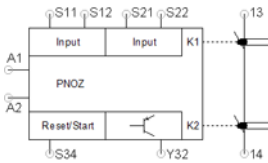
Safety relay PNOZ

Safety switching devices are essential constituents of safety technology. This safety relay with positively driven contacts is used for the implementation of safety functions such as emergency stop or the monitoring of safety doors.

This type of safety relay is based on the safety switching device for the emergency stop function and the safety door in Festo Didactic's equipment set TP 250, "Safety in pneumatic systems". The PNOZ S4 safety relay from Pilz is used in the equipment set. Correct wiring of the safety switching device is described in the operating instructions included with the PNOZ S4.

Adjustable parameters
Operating mode: Automatic/Manual start,Monitored reset with falling edge,Monitored reset with rising edge   (Automatic/Manual start)
Min. Voltage: 0.1 ... 100 V (21.6)

22.5.6 *Switches, Automotive*
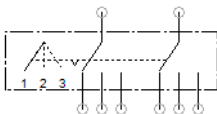
Configurable switch

The configurable switch can be used to configure a switch combination of up to three switches. Each switch is assigned to just one input. The switching positions of the individual switches are me-

chanically interlinked. Up to 6 switching positions can be configured.

The graphical representation can be modified via Options.

Ignition-starter switch
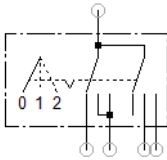
The ignition switch is usually installed behind the ignition lock in a vehicle, and takes the form of a rotary switch.

The ignition switch has three switching positions: 0, 1, and 2. In FluidSIM the switching between the positions 0 and 1 is realized as in a detenting switch. The switching between 1 and 2 works like a momentary-contact pushbutton. When the mouse button is pressed and held, the position changes from 1 to 2. Once the mouse button is released again, the ignition switch goes back to position 1.

Adjustable parameters
Position: 0,1,2   (0)
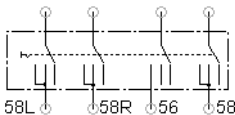
Light switch

The light switch is a combination of 4 switches whose switching positions are mechanically interlinked. The light switch can be used to switch the various lighting functions of a vehicle on and off.

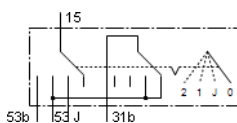The light switch has three switching positions: 0, 1, and 2. In FluidSIM the switching between the positions is realized as in a detenting switch.

Adjustable parameters
Position: 0,1,2   (0)
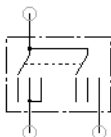
Fog light switch

The fog light switch is a combination of 2 switches whose switching positions are mechanically interlinked. The switch can be used to switch the front and rear fog lights of a vehicle on and off.

The fog light switch has three switching positions: 0, 1, and 2. In FluidSIM the switching between the positions is realized as in a detenting switch.

Adjustable parameters
Position: 0,1,2   (0)
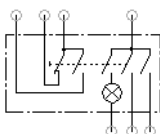
Hazard flasher switch

The hazard warning light switch has two switching positions, 0 and 1. It can be used to switch a vehicle's hazard flasher system on and off. Switching position 1 can be signaled by the integrated lamp when voltage is applied.

In FluidSIM the switching between the positions is realized as in a detenting switch.

Adjustable parameters
Position: 0,1   (0)
Rated voltage (Lamp): 0.1 ... 400 V (12)
Rated power (Lamp): 0.1 ... 1000 W (0.1)

Wiper switch

The wiper switch is a combination of 2 switches whose switching positions are mechanically coupled to each other. The switch can be used to control the wiper interval relay and a two-stage wiper motor.

With appropriate wiring, the wiper system is switched off in position 0 and in position J in interval mode. Positions 1 and 2 allow a wiper motor to run slowly and quickly . In FluidSIM the switching between the positions is realized as in a detenting switch.

Adjustable parameters
Position: 0,J,1,2 (0)

Thermal switch
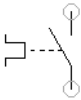
The thermostatic switch switches over when the ambient temperature exceeds the preset trip temperature.
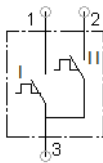
In FluidSIM, the ambient temperature on the symbol can be modified during the simulation.

Adjustable parameters
Ambient temperature: -40 ... 140 °C (22)
Tripping temperature: -40 ... 140 °C (40)
Hysteresis: 0 ... 20 °C (0)

Thermal switch, 2 stages

The two-stage thermostatic switch is a combination of two thermostatic switches connected in parallel. Each individual thermostatic switch switches over when the ambient temperature exceeds the trip temperature preset for it.

In FluidSIM, the ambient temperature on the symbol can be modified during the simulation.

Adjustable parameters
Ambient temperature: -40 ... 140 °C (22)
Tripping temperature: -40 ... 140 °C (60)
Hysteresis: 0 ... 20 °C (0)
Tripping temperature: -40 ... 140 °C (100)

Hysteresis: 0 ... 20 °C (0)

Pressure switch, automotive specific

The switch closes when the preset pressure is exceeded. The current pressure can only be set by clicking with the mouse during simulation. It is not possible to access a real pressure within a pneumatic or hydraulic circuit.

Adjustable parameters
Input pressure: -1 ... 1000 bar (0)
Output function: Make switch,Break switch   (Make switch)
Switching function: Threshold value,Window comparator (Threshold value)
Switching pressure 1: -1 ... 1000 bar (30)
Switching pressure 2: -1 ... 1000 bar (40)
Hysteresis: 0 ... 1000 bar (0)

Error models
Component does not switch: The component is always switched off.
Component always switches: The component is always switched on.
Faulty switching value: The component switches at a faulty value.
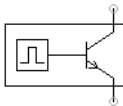
Control unit (Pulse Width Modulation)

The controller supplies a pulse-width modulated output signal. It works like a switch that switches on and off periodically.

The switch-on time is the time in which the switch is switched on. The frequency is the inverse of the cycle period.

The duty cycle is the ratio of the switch-on time to the cycle period, expressed as a percentage. A duty cycle of 100% therefore means that the switch is switched on permanently.

Adjustable parameters
Frequency: 0.01 ... 100000 Hz (10)
Pulse duty ratio: 0 ... 100 % (50)

22.5.7 Machines

Capacitor motor

The capacitor motor is a machine for converting electrical energy into mechanical energy (rotary motion). Capacitor motors are single-phase AC motors with squirrel-cage rotor. The rotary field in the stator is generated with the help of an additional capacitor, from which the name "capacitor motor" originates. In order to improve starting torque, a starter capacitor is used in addition to the operating capacitor. The capacitance of the starter and operating capacitors can be adjusted, and direction of rotation can be selected. The *Revolution* (*Switch*) parameter indicates as of which speed switching from the starter capacitor to the operating capacitor takes place.

Terminal 1 and 2 are used to connect the alternating current required to operate the motor. Terminal 3 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

The capacitor motor's characteristic data (for example winding resistances, inductances, number of pole pairs etc.) are automatically ascertained in the background after entering the performance data. Details can be found in the following separate section: Simulation of rotating machines.

Adjustable parameters

Power: 0.001 ... 100 kW (0.25)
Revolution: 1 ... 30000 1/min (1400)
Voltage: 1 ... 10000 V (230)
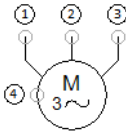**Frequency:** 30 ... 100 Hz (50)
Current: 0.01 ... 100 A (1.86)
Capacity (Starting capacitor): 0.1 ... 100 uF (25)
Capacity (Running capacitor): 0.1 ... 100 uF (10)
Direction of rotation: Right,Left (Right)
External torque: 0 ... 100 N.m (0)
Revolution (Switch): 1 ... 100000 1/min (1000)

Capacitor motor

The capacitor motor is a machine for converting electrical energy into mechanical energy (rotary motion). Capacitor motors are single-phase AC motors with squirrel-cage rotor. The rotary field in the stator is generated with the help of an additional capacitor, from which the name "capacitor motor" originates. In order to improve starting torque, a starter capacitor is used in addition to the operating capacitor. The capacitance of the starter and operating capacitors can be adjusted, and direction of rotation can be selected. The *Revolution* (*Switch*) parameter indicates as of which speed switching from the starter capacitor to the operating capacitor takes place.

The exploded view of the motor makes it possible to manually wire the stator coils and the capacitors to operating voltage.

Terminals 1 and 2 make reference to the operating capacitor. Terminals 3 and 4 make reference to the starter capacitor including a centrifugal switch, which opens when a specified speed is exceeded (parameter: *Revolution* (*Switch*)). Terminal 5 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

The capacitor motor's characteristic data (for example winding resistances, inductances, number of pole pairs etc.) are automatically ascertained in the background after entering the performance

data. Details can be found in the following separate section: Simulation of rotating machines.

Adjustable parameters
Power: 0.001 ... 100 kW (0.25)
Revolution: 1 ... 30000 1/min (1400)
Voltage: 1 ... 10000 V (230)
Frequency: 30 ... 100 Hz (50)
Current: 0.01 ... 100 A (1.86)
Capacity (Starting capacitor): 0.1 ... 100 uF (25)
Capacity (Running capacitor): 0.1 ... 100 uF (10)
External torque: 0 ... 100 N.m (0)
Revolution (Switch): 1 ... 100000 1/min (1000)

Three-phase current squirrel-cage asynchronous motor

The 3-phase asynchronous motor is a machine for converting electrical energy into mechanical energy (rotary motion). It's a widely used type of induction motor which is simple, rugged and maintenance-free. It uses a short-circuited rotor and rotor current is generated by means of induction. Asynchronous motors are used in particular as high-performance servo-drives. The stator includes three windings, each of which is arranged at an angle 120° to the next. A slotted, laminated rotor core is used. A cage made of die-cast aluminum is inserted into the slots. The cage thus comprises a system of short-circuited electrical conductors.

The three phases of the 3-phase current are connected to terminal 1 through 3. Terminal 4 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

The inner wiring selected in the parameters determines how entered machine performance data is interpreted in order to ascertain the machine's characteristics data such as winding resistances, inductances, number of pole pairs etc. These characteristic machine data are ascertained automatically in the background after the performance data have been entered. Details can be found in the following separate section: Simulation of rotating machines. In

addition to the performance data, tightening torque and pull-out torque can also be entered to the parameters as a ratio to nominal torque. This makes it possible to specify the characteristic load curve of an actual machine somewhat more accurately.

Adjustable parameters
Internal wiring: Star connection,Delta connection   (Delta connection)
Power: 0.001 ... 1000 kW (0.25)
Revolution: 1 ... 10000 1/min (1350)
Power factor cos φ: 0.1 ... 0.99   (0.78)
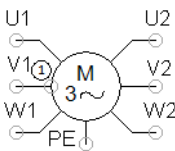**Line-to-line voltage:** 1 ... 10000 V (400)
Phase current: 0.1 ... 100 A (0.77)
Frequency: 30 ... 100 Hz (50)
T_0 : T_N: 0.1 ... 10   (1.35)
T_B : T_N: 0.1 ... 10   (1.58)
External torque: 0 ... 100 N.m (0)

Three-phase current squirrel-cage asynchronous motor

The 3-phase asynchronous motor is a machine for converting electrical energy into mechanical energy (rotary motion). It's a widely used type of induction motor which is simple, rugged and maintenance-free. It uses a short-circuited rotor and rotor current is generated by means of induction. Asynchronous motors are used in particular as high-performance servo-drives. The stator includes three windings, each of which is arranged at an angle 120° to the next. A slotted, laminated rotor core is used. A cage made of die-cast aluminum is inserted into the slots. The cage thus comprises a system of short-circuited electrical conductors.

The three phases of the 3-phase current are connected to terminal 1 through 3. Terminal 4 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.) The other electrical terminals are used for connection to the electrical section of the motor test bench.

The inner wiring selected in the parameters determines how entered machine performance data is interpreted in order to ascertain the machine's characteristics data such as winding resistances, inductances, number of pole pairs etc. These characteristic machine data are ascertained automatically in the background after the performance data have been entered. Details can be found in the following separate section: Simulation of rotating machines. In addition to the performance data, tightening torque and pull-out torque can also be entered to the parameters as a ratio to nominal torque. This makes it possible to specify the characteristic load curve of an actual machine somewhat more accurately.

Adjustable parameters
Internal wiring: Star connection,Delta connection (Delta connection)
Power: 0.001 ... 1000 kW (0.25)
Revolution: 1 ... 10000 1/min (1350)
Power factor cos φ: 0.1 ... 0.99 (0.78)
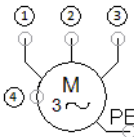**Line-to-line voltage:** 1 ... 10000 V (400)
Phase current: 0.1 ... 100 A (0.77)
Frequency: 30 ... 100 Hz (50)
T_0 : T_N: 0.1 ... 10 (1.35)
T_B : T_N: 0.1 ... 10 (1.58)
External torque: 0 ... 100 N.m (0)

Three-phase current squirrel-cage asynchronous motor

The 3-phase asynchronous motor is a machine for converting electrical energy into mechanical energy (rotary motion). It's a widely used type of induction motor which is simple, rugged and maintenance-free. It uses a short-circuited rotor and rotor current is generated by means of induction. Asynchronous motors are used in particular as high-performance servo-drives. The stator includes three windings, each of which is arranged at an angle 120° to the next. A slotted, laminated rotor core is used. A cage made of die-cast aluminum is inserted into the slots. The cage thus comprises a system of short-circuited electrical conductors.

In this representation of the 3-phase motor, the terminals for the stator windings (U1-U2, V1-V2, W1-W2) are led to the outside. In

this way, the desired wiring of the windings with star or delta connection can be completed from the outside. Terminal 1 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

The inner wiring selected in the parameters determines how entered machine performance data is interpreted in order to ascertain the machine's characteristics data such as winding resistances, inductances, number of pole pairs etc. These characteristic machine data are ascertained automatically in the background after the performance data have been entered. Details can be found in the following separate section: Simulation of rotating machines. In addition to the performance data, tightening torque and pull-out torque can also be entered to the parameters as a ratio to nominal torque. This makes it possible to specify the characteristic load curve of an actual machine somewhat more accurately.

Adjustable parameters
: Star connection,Delta connection   (Delta connection)
Power: 0.001 ... 1000 kW (0.25)
Revolution: 1 ... 10000 1/min (1350)
Power factor cos φ: 0.1 ... 0.99   (0.78)
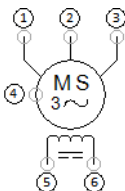**Line-to-line voltage:** 1 ... 10000 V (400)
Phase current: 0.1 ... 100 A (0.77)
Frequency: 30 ... 100 Hz (50)
T_0 : T_N: 0.1 ... 10   (1.35)
T_B : T_N: 0.1 ... 10   (1.58)
External torque: 0 ... 100 N.m (0)

Three-phase current squirrel-cage asynchronous motor

The 3-phase asynchronous motor is a machine for converting electrical energy into mechanical energy (rotary motion). It's a widely used type of induction motor which is simple, rugged and maintenance-free. It uses a short-circuited rotor and rotor current is generated by means of induction. Asynchronous motors are used in particular as high-performance servo-drives. The stator includes three windings, each of which is arranged at an angle 120° to the

next. A slotted, laminated rotor core is used. A cage made of die-cast aluminum is inserted into the slots. The cage thus comprises a system of short-circuited electrical conductors.

The three phases of the 3-phase current are connected to terminal 1 through 3. Terminal 4 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

The inner wiring selected in the parameters determines how entered machine performance data is interpreted in order to ascertain the machine's characteristics data such as winding resistances, inductances, number of pole pairs etc. These characteristic machine data are ascertained automatically in the background after the performance data have been entered. Details can be found in the following separate section: Simulation of rotating machines. In addition to the performance data, tightening torque and pull-out torque can also be entered to the parameters as a ratio to nominal torque. This makes it possible to specify the characteristic load curve of an actual machine somewhat more accurately.

Adjustable parameters
Internal wiring: Star connection,Delta connection (Delta connection)
Power: 0.001 ... 1000 kW (0.25)
Revolution: 1 ... 10000 1/min (1350)
Power factor cos φ: 0.1 ... 0.99 (0.78)
Line-to-line voltage: 1 ... 10000 V (400)
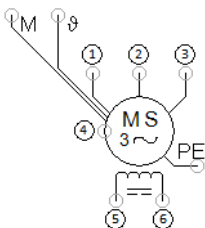**Phase current:** 0.1 ... 100 A (0.77)
Frequency: 30 ... 100 Hz (50)
T_0 : T_N: 0.1 ... 10 (1.35)
T_B : T_N: 0.1 ... 10 (1.58)
External torque: 0 ... 100 N.m (0)

Synchronous motor

The synchronous motor is a machine for converting electrical energy into mechanical energy (rotary motion). It's a 3-phase motor in which the rotor always runs synchronous to the stator's rotary field.

This version of the synchronous motor is equipped with an additional squirrel cage, so that it can be started up in accordance with the asynchronous motor principle.

Terminals 1 through 3 are used to connect 3-phase current for the generation of a rotary field in the motor's stator. Terminals 5 and 6 are used to connect direct current to the excitation windings. Terminal 4 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

If the synchronous motor is idled without a load, a so-called V curve can be recorded which reflects the relationship between excitation current and effective stator current. Nominal excitation current indicates the point of minimum stator current, at which power factor is also equal to 1.

Nominal excitation current can be specified as a ratio to maximum excitation current with the parameter *Ratio Current* : *Max. Current*. The absolute value of nominal excitation current is determined by multiplying maximum excitation current by the specified ratio (e.g. maximum excitation current 0.95 A * 0.5 = nominal excitation current 0.475 A).

The synchronous motor's characteristic data (for example winding resistances, inductances, number of pole pairs etc.) are automatically ascertained in the background after entering the performance data. Details can be found in the following separate section: Simulation of rotating machines.

Adjustable parameters
Power: 0.001 ... 1000 kW (0.3)
Revolution: 1 ... 10000 1/min (1500)
Power factor cos φ: 0.1 ... 1   (0.97)
Line-to-line voltage: 1 ... 10000 V (400)
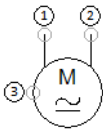**Phase current:** 0.1 ... 100 A (0.66)
Frequency: 30 ... 100 Hz (50)
Voltage (Max.): 1 ... 10000 V (150)
Current (Max.): 0.1 ... 100 A (0.95)
I_f : I_f_max: 0.01 ... 1   (0.5)
External torque: 0 ... 100 N.m (0)

Synchronous motor

The synchronous motor is a machine for converting electrical energy into mechanical energy (rotary motion). It's a 3-phase motor in which the rotor always runs synchronous to the stator's rotary field. This version of the synchronous motor is equipped with an additional squirrel cage, so that it can be started up in accordance with the asynchronous motor principle.

Terminals 1 through 3 are used to connect 3-phase current for the generation of a rotary field in the motor's stator. Terminals 5 and 6 are used to connect direct current to the excitation windings. Terminal 4 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.) The other electrical terminals are used for connection to the electrical section of the motor test bench.

If the synchronous motor is idled without a load, a so-called V curve can be recorded which reflects the relationship between excitation current and effective stator current. Nominal excitation current indicates the point of minimum stator current, at which power factor is also equal to 1.

Nominal excitation current can be specified as a ratio to maximum excitation current with the parameter *Ratio Current : Max. Current*. The absolute value of nominal excitation current is determined by multiplying maximum excitation current by the specified ratio (e.g. maximum excitation current 0.95 A * 0.5 = nominal excitation current 0.475 A).

The synchronous motor's characteristic data (for example winding resistances, inductances, number of pole pairs etc.) are automatically ascertained in the background after entering the performance data. Details can be found in the following separate section: Simulation of rotating machines.

Adjustable parameters
Power: 0.001 … 1000 kW (0.3)
Revolution: 1 … 10000 1/min (1500)
Power factor cos φ: 0.1 … 1   (0.97)

Line-to-line voltage: 1 ... 10000 V (400)
Phase current: 0.1 ... 100 A (0.66)
Frequency: 30 ... 100 Hz (50)
Voltage (Max.): 1 ... 10000 V (150)
Current (Max.): 0.1 ... 100 A (0.95)
I_f : I_f_max: 0.01 ... 1 (0.5)
External torque: 0 ... 100 N.m (0)

Universal motor

The universal motor is a machine for converting electrical energy into mechanical energy (rotary motion). Its layout corresponds to that of a DC series motor (stator and rotor windings are connected in series). It can be operated with either direct current or alternating current. As opposed to DC motors, stator and rotor cores are made of laminated sheet in order to keep eddy-current losses to a minimum in the case of alternating voltage.

Terminals 1 and 2 are used to connect operating voltage (AC/DC) to the motor. Terminal 3 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

The *Current* (RMS) parameter is used to specify nominal current for operation with direct voltage as well as alternating voltage. Idling speed of the motor during operation with direct current can be indicated as a ratio to nominal rotary speed with the parameter *Idle revolution* : *Rated speed*. The absolute value of idling speed is determined by multiplying nominal speed by the specified ratio (e.g. nominal rotary speed 2000 rpm * 1.1 = idling speed 2200 rpm).   The additional simulation value, *Revolution* (ø), is used to read out average motor speed, so that design-related vibration due to rotational speed is compensated for in the display in the case of operation with alternating current.

Adjustable parameters
Characteristic data: Alternating current, Direct current   (Alternating current)
Power: 0.001 ... 1000 kW (0.2)

Revolution: 1 ... 30000 1/min (3000)
Voltage: 1 ... 10000 V (230)
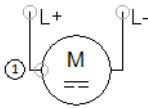**Current (RMS):** 0.01 ... 100 A (3)
Frequency: 30 ... 100 Hz (50)
U_N_AC : U_N_DC: 1 ... 10 (1.643)
n_0 : n_N: 1.001 ... 100 (1.5)
Direction of rotation: Right,Left (Right)
External torque: 0 ... 100 N.m (0)
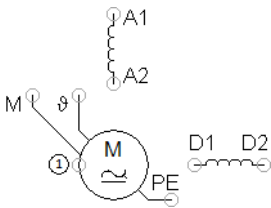
Universal motor

The universal motor is a machine for converting electrical energy into mechanical energy (rotary motion). Its layout corresponds to that of a DC series motor (stator and rotor windings are connected in series). It can be operated with either direct current or alternating current. As opposed to DC motors, stator and rotor cores are made of laminated sheet in order to keep eddy-current losses to a minimum in the case of alternating voltage.

In this representation of the universal motor, the terminals for the armature windings (A1-A2) and the excitation winding (D1-D2) are led to the outside. In this way, the desired wiring of the windings can be completed from the outside. The other electrical terminals are used for connection to the electrical section of the motor test bench.

Terminal 1 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

The *Current* (RMS) parameter is used to specify nominal current for operation with direct voltage as well as alternating voltage. Idling speed of the motor during operation with direct current can be indicated as a ratio to nominal rotary speed with the parameter *Idle revolution* : *Rated speed*. The absolute value of idling speed is determined by multiplying nominal speed by the specified ratio (e.g. nominal rotary speed 2000 rpm * 1.1 = idling speed 2200 rpm). The additional simulation value, *Revolution* (ø), is used to read out average motor speed, so that design-related vibration due

to rotational speed is compensated for in the display in the case of operation with alternating current.

Adjustable parameters
Characteristic data: Alternating current,Direct current (Alternating current)
Power: 0.001 ... 1000 kW (0.2)
Revolution: 1 ... 30000 1/min (3000)
Voltage: 1 ... 10000 V (230)
Current (RMS): 0.01 ... 100 A (3)
Frequency: 30 ... 100 Hz (50)
U_N_AC : U_N_DC: 1 ... 10 (1.643)
n_0 : n_N: 1.001 ... 100 (1.5)
External torque: 0 ... 100 N.m (0)

DC permanet-magnet motor

The DC permanent-magnet motor is a machine for converting electrical energy into mechanical energy (rotary motion). Its stator consists of a permanent magnet, and only the armature consists of a coil through which current flows.

The L+ and L- terminals are used to connect the armature winding. If L+ is connected to positive potential and L- is connected to ground, the motor turns in the direction specified in the parameters. Terminal 1 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

Idling speed of the motor can be indicated as a ratio to nominal rotary speed with the parameter *Idle revolution* : *Rated speed*. The absolute value of idling speed is determined by multiplying nominal speed by the specified ratio (e.g. nominal rotary speed 2000 rpm * 1.1 = idling speed 2200 rpm).

Winding resistance is calculated automatically based on the entered parameters.

Adjustable parameters

Power: 0.001 ... 1000 kW (0.3)
Revolution: 1 ... 30000 1/min (2000)
Voltage: 1 ... 10000 V (220)
Current: 0.01 ... 100 A (1.8)
Inductance: 0 ... 10 H (0.01)
n_0 : n_N: 1.001 ... 100   (1.1)
Direction of rotation: Right,Left   (Right)
External torque: 0 ... 100 N.m (0)
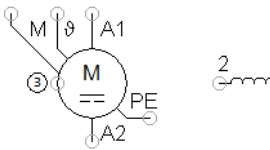
DC separately excited motor

The separately excited DC motor is a machine for converting electrical energy into mechanical energy (rotary motion). Its armature and excitation windings are supplied with power from different voltage sources.

Terminals A1-A2 are used to connect the armature winding and terminals 1-2 are used to connect the excitation winding. Terminal 3 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.) The other electrical terminals are used for connection to the electrical section of the motor test bench.

Armature and excitation winding connections can be selected in the motor's parameters under *Characteristic data*. The selection of these connections influences automatic calculation of winding resistances. The desired performance values are only attained if the motor is externally wired as specified in the parameters.

Idling speed of the motor can be indicated as a ratio to nominal rotary speed with the parameter *Idle revolution* : *Rated speed*. The absolute value of idling speed is determined by multiplying nominal speed by the specified ratio (e.g. nominal rotary speed 2000 rpm * 1.1 = idling speed 2200 rpm).

Adjustable parameters
Characteristic data: Shunt-wound machine,Series-wound machine (Shunt-wound machine)
Power: 0.001 ... 1000 kW (0.3)

Revolution: 1 ... 30000 1/min (2000)
Voltage: 1 ... 10000 V (220)
Current: 0.1 ... 100 A (1.8)
Inductance (Armature): 1e-6 ... 10 H (0.01)
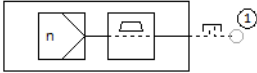**Voltage:** 1 ... 10000 V (220)
Current: 0.01 ... 100 A (0.3)
Inductance (Exciter): 1e-6 ... 10 H (0.01)
n_0 : n_N: 1.001 ... 100 (1.1)
External torque: 0 ... 100 N.m (0)
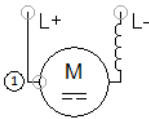
DC series motor

The DC series motor is a machine for converting electrical energy into mechanical energy (rotary motion). Its armature and excitation windings are connected in series.

Terminals L+ and L- are used to connected supply power. If L+ is connected to positive potential and L- is connected to ground, the motor turns in the direction specified in the parameters. Terminal 1 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

Idling speed of the motor can be indicated as a ratio to nominal rotary speed with the parameter *Idle revolution* : *Rated speed*. The absolute value of idling speed is determined by multiplying nominal speed by the specified ratio (e.g. nominal rotary speed 2000 rpm * 1.1 = idling speed 2200 rpm).

Winding resistances are calculated automatically based on the entered parameters.

Adjustable parameters
Power: 0.001 ... 1000 kW (0.3)
Revolution: 1 ... 30000 1/min (2000)
Voltage: 1 ... 10000 V (220)
Current: 0.01 ... 100 A (1.9)
n_0 : n_N: 1.001 ... 100 (1.7)
Direction of rotation: Right,Left (Right)

External torque: 0 ... 100 N.m (0)
Inductance (Armature): 1e-6 ... 10 H (0.001)
Inductance (Exciter): 1e-6 ... 10 H (0.001)
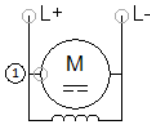
DC shunt motor

The DC shunt motor is a machine for converting electrical energy into mechanical energy (rotary motion). Its armature and excitation windings are connected in parallel.

Terminals L+ and L- are used to connected supply power. If L+ is connected to positive potential and L- is connected to ground, the motor turns in the direction specified in the parameters. Terminal 1 is a rotary terminal mechanism. A motor test bench or a further motor can be connected here, for example. (The direction of rotation is usually reversed via the connection. This can be selected with the connecting cable.)

Idling speed of the motor can be indicated as a ratio to nominal rotary speed with the parameter *Idle revolution* : *Rated speed*. The absolute value of idling speed is determined by multiplying nominal speed by the specified ratio (e.g. nominal rotary speed 2000 rpm * 1.1 = idling speed 2200 rpm).

Winding resistances are calculated automatically based on the entered parameters.

Adjustable parameters
Power: 0.001 ... 1000 kW (0.3)
Revolution: 1 ... 30000 1/min (2000)
Voltage: 1 ... 10000 V (220)
Current: 0.1 ... 100 A (1.8)
Inductance (Armature): 1e-6 ... 10 H (0.01)
Voltage: 1 ... 10000 V (220)
Current: 0.01 ... 100 A (0.3)
Inductance (Exciter): 1e-6 ... 10 H (0.01)
n_0 : n_N: 1.001 ... 100 (1.1)
Direction of rotation: Right,Left (Right)
External torque: 0 ... 100 N.m (0)

Engine test bench

The motor test bench is used to test a connected motor independent of its normal conditions of use. Examinations can be conducted with reference to a given torque or a given rotational speed.

A rotary terminal mechanism, for example at a motor, can be connected to the motor test bench via terminal 1. A specific, predefined load or a specified rotational speed can then be selected at the motor test bench. The selected load or limited rotational speed acts upon the connected shaft as soon as the switch next to the rotary terminal is activated. Not until then is a mechanical connection established, as a result of which the connected motor is subjected to a load.

The way in which the selected torque acts upon the connected motor can be specified in the parameters of the motor test bench under *Controlled variable*. *Torque* (*braking*) means that the selected torque value acts upon the motor as friction or as reaction torque in opposition to the motor's torque. *Torque* (*driving*) means that the motor test bench functions itself as a drive and applies the corresponding torque to the connected axis of rotation. If a rotational speed is specified, torque output or input is adjusted such that the desired rotational speed is attained. With regard to the regulation of rotational speed, maximum torque can be specified as a separate parameter.

This component represents the mechanical section of the motor test bench from Festo Didactic's equipment set TP 1410, "Servo brake and drive system".

Adjustable parameters
Controlled variable: Torque (braking),Torque (driving),Revolution (Torque (braking))
Torque: -100 ... 100 N.m (0)
Revolution: -30000 ... 30000 1/min (0)
Torque (max): 0.1 ... 100 N.m (100)
Moment of inertia: 1e-6 ... 10 kg.m2 (0.0001)
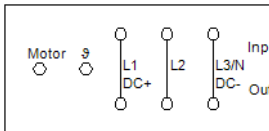
Engine test bench (electrical part)

This element is used to measure certain characteristic data, for example effective power and apparent power, of a motor during simulation.

The Motor and ϑ terminals are used to connect the motor's thermal switch. Connect these two terminals to the motor's M and ϑ terminals. Input terminals L1, L2 and L3 at the top are used to connect supply power. The motor is connected to output terminals L1, L2 and L3 at the bottom. The PE terminal is for the protective conductor.

This component represents the electrical section of the motor test bench from Festo Didactic's equipment set TP 1410, "Servo brake and drive system".

Adjustable parameters
Time interval: 0.001 ... 100 s (0.1)
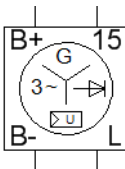
Generator

The alternator is realized as a compact AC generator with a multi-functional controller. The alternator in an automobile supplies the power to charge the battery. It essentially consists of a three-phase generator, a rectifier, and a voltage regulator. The transformation of alternating current to direct current by the rectifier results in a residual ripple in the generated direct voltage.

The generated direct voltage is applied to connectors B+ and B+. If a potential to ground is applied at terminal 15, the potential is briefly switched through to terminal L.

In FluidSIM the alternator is only modeled qualitatively. Specifying a rotational frequency generates direct voltage with a residual ripple, without factoring in the effects of the actual electronic arrangement.

Adjustable parameters
Frequency: 0 ... 20 Hz (0)
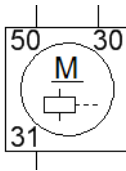
Starter motor with engagement relay

The function of the starter is to start combustion engines. In FluidSIM, the starter motor and the starter solenoid are modeled internally.

Terminal 30 is connected directly to the supply voltage and terminal 31 is connected to ground. When voltage is applied to terminal 50, the starter solenoid relay picks up, the starter motor is connected to the engine, the contact for the primary starter current is closed, and the starter motor starts running.

In FluidSIM, only the rotation of the starter motor is animated.
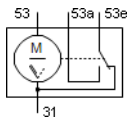
Wiper motor, one-stage

The wipers of a vehicle can be driven by the wiper motor. The wiper motor contains a changeover contact with terminals 531, 53e and 31. In the initial position of the wiper blades, terminals 53e and 31 are connected. While the motor is moving the wiper blades, terminals 53a and 53e are connected. With appropriate wiring, an end stop of the wiper motor can be realized.

Terminal 53 is connected to the winding of the motor.

Terminal 31 is connected to ground.
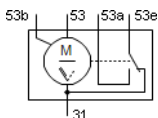
Wiper motor, two-stage

The wipers of a vehicle can be driven by the wiper motor. The wiper motor contains a changeover contact with terminals 531, 53e and 31. In the initial position of the wiper blades, terminals 53e and 31

are connected. While the motor is moving the wiper blades, terminals 53a and 53e are connected. With appropriate wiring, an end stop of the wiper motor can be realized.

Terminal 53 is connected to the first winding (slow speed) and terminal 53b is connected to the second winding (fast speed) of the motor.

Terminal 31 is connected to ground.

22.5.8 Controller

Add3 element

The summator element is a closed-loop control technology component. An output signal/potential is generated at output 4, which corresponds to the sum of the three input signals/potentials at inputs 1 through 3. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V => control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).
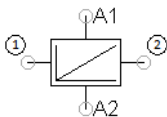
This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).

Adjustable parameters
y offset: -5 ... 5 V (0)
Efficiency: 0 ... 1 (0.9)
Minimum voltage: 0 ... 10 V (1.5)

Derivation element

The D element is a transfer element used in closed-loop control technology with a derivative response characteristic. The output signal/potential at output 2 depends on the rate of change of the input signal/potential at input 1. The D element is modelled as an actual D element in this case, also known as a derivative-action element, with first-order time delay, because an ideal D element is technically infeasible. Derivative-action coefficient Kd and delay time T can be adjusted. In order to keep circuit wiring as straight-forward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V => control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a mini-mum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either termi-nal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).
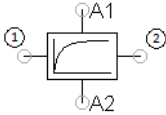
This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).
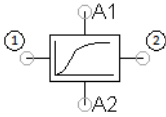
Adjustable parameters
Derivation gain: 1 ... 1000 ms (2)
Time constant (PT1): 0.01 ... 100 ms (0.8)
Efficiency: 0 ... 1 (0.9)
Minimum voltage: 0 ... 10 V (1.5)

Proportional element

The P element is a transfer element used in closed-loop control technology with a proportional response characteristic. The input signal/potential at input 1 is amplified by adjustable proportional-action coefficient Kp and read out as an output signal/potential at output 2. In the event of a proportional-action coefficient of less than 1, we no longer speak of amplification, but rather of attenuation. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V =› control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).

This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).
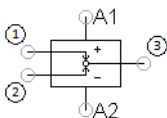
Adjustable parameters
Proportional gain: 0 ... 1000 (1)
Efficiency: 0 ... 1 (0.9)

Minimum voltage: 0 ... 10 V (1.5)

Hysteresis element

The hysteresis element acts as a two-step action controller with symmetrical hysteresis. If the input signal/potential at input 1 is increased to above the selected hysteresis value, output 2 auf is switched to +15 V. If the input signal/potential then drops to below the hysteresis value with a preceding minus sign, the output is switched to -15 V. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V => control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).

This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).

Adjustable parameters
Hysteresis: 0 ... 10 V (0)
Efficiency: 0 ... 1 (0.9)
Minimum voltage: 0 ... 10 V (1.5)

Integrator element

The I element is a transfer element used in closed-loop control technology with an integral response characteristic. The input signal/potential at input 1 is summed up over time and results in the output signal/potential at output 2. The speed at which the input signal is integrated can be adjusted with the integral-action coefficient. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V =› control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).

This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).

Adjustable parameters
Integral gain: 1 ... 1000 1/s (100)
Efficiency: 0 ... 1   (0.9)
Minimum voltage: 0 ... 10 V (1.5)

PT1 element

The PT1 element is a first-order proportional delay element used in closed-loop control technology. The input signal/potential at input 1 is amplified or attenuated by proportional-action coefficient Kp and delayed by delay time T, and is read out as the output signal/potential at output 2. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V => control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).

This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).

Adjustable parameters
Time constant: 0.001 ... 1 s (0.01)
Proportional gain: 0 ... 10 (1)
Efficiency: 0 ... 1 (0.9)
Minimum voltage: 0 ... 10 V (1.5)

PT2 element

The PT2 element is a second-order proportional delay element used in closed-loop control technology. The input signal/potential at input 1 is amplified or attenuated by proportional-action coefficient Kp and delayed by delay times T1 and T2, and is read out as the output signal/potential at output 2. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V => control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).

This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).

Adjustable parameters
Time constant: 1e-5 ... 1 s (0.01)
Proportional gain: 0 ... 10 (1)
**Damping:** 1e-5 ... 1000 (1)
Efficiency: 0 ... 1 (0.9)
Minimum voltage: 0 ... 10 V (1.5)

Difference amplifier

The differential amplifier is a closed-loop control technology component. An output signal/potential is generated at output 3, which corresponds to the difference between the two input signals/potentials at inputs 1 (w) and 2 (x). In the field of closed-loop control technology, the differential amplifier is used to determine deviation. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The output signal's voltage range is determined by the potential applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V => control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).

This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).

Adjustable parameters
Efficiency: 0 ... 1 (0.9)
Minimum voltage: 0 ... 10 V (1.5)
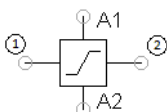
Limiter

The limiter is a closed-loop control technology component. Within a defined voltage range, the input signal/potential at input 1 is

replicated to another defined voltage range of the output signal/potential. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) is not led out as a terminal, but rather wired internally.

The voltage range of the input and output signals are specified after selecting the *Operating mode* option. The output signal is additionally limited by the potentials applied to terminals A1 and A2 relative to ground (0 V). If a positive potential is connected to A1 and a negative potential to A2, the available output signal is no greater than the smaller numeric value of the two (example: A1 = +15 V, A2 = -10 V => control range = ±10 V). This can be further limited by means of a parameter, in order to take losses from the control electronics within the component into account.

The component does not generate an output signal unless a minimum potential is connected to both the A1 and the A2 terminals. The value can be adjusted in the advanced settings. If either terminal A1 or A2 is not connected to any potential, the potential of the connected terminal is passed through to the output (4).

This element is based on the element with the same designation from Festo Didactic's equipment set for "Basic principles of control technology" (TP 1013).

Adjustable parameters
Operating mode: In [-10 V..10 V] –> Out [0 V..10 V], In [-10 V..10 V] –› Out [-10 V..10 V], Enter manually (In [-10 V..10 V] –> Out [0 V..10 V])
Efficiency: 0 ... 1 (0.9)
Min. Voltage (in): -400 ... 400 V (-10)
Max. Voltage (in): -400 ... 400 V (10)
Min. Voltage (out): -400 ... 400 V (-10)
Max. Voltage (out): -400 ... 400 V (10)
Minimum voltage: 0 ... 10 V (1.5)

22.5.9 Controller (block diagram)

Add3 element
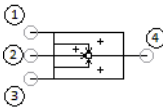
The summator element is a closed-loop control technology component. An output signal/potential is generated at output 4, which corresponds to the sum of the three input signals/potentials at inputs 1 through 3. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Adjustable parameters
y offset: -5 ... 5 V (0)

Derivation element

The D element is a transfer element used in closed-loop control technology with a derivative response characteristic. The output signal/potential at output 2 depends on the rate of change of the input signal/potential at input 1. The D element is modelled as an actual D element in this case, also known as a derivative-action element, with first-order time delay, because an ideal D element is technically infeasible. Derivative-action coefficient Kd and delay time T can be adjusted. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Adjustable parameters
Derivation gain: 1 ... 1000 ms (2)
Time constant (PT1): 0.01 ... 100 ms (0.8)

Proportional element
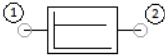
The P element is a transfer element used in closed-loop control technology with a proportional response characteristic. The input signal/potential at input 1 is amplified by adjustable proportional-action coefficient Kp and read out as an output signal/potential at output 2. In the event of a proportional-action coefficient of less than 1, we no longer speak of amplification, but rather of attenuation. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Adjustable parameters
Proportional gain: 0 ... 1000 (1)

Hysteresis element
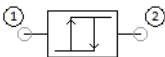
The hysteresis element acts as a two-step action controller with symmetrical hysteresis. If the input signal/potential at input 1 is increased to above the selected hysteresis value, output 2 auf is switched to +15 V. If the input signal/potential then drops to below the hysteresis value with a preceding minus sign, the output is switched to -15 V. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Adjustable parameters
Hysteresis: 0 ... 10 V (0)
Minimum output voltage: -400 ... 400 V (-1)
Maximum output voltage: -400 ... 400 V (1)

Integrator element
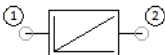
The I element is a transfer element used in closed-loop control technology with an integral response characteristic. The input

signal/potential at input 1 is summed up over time and results in the output signal/potential at output 2. The speed at which the input signal is integrated can be adjusted with the integral-action coefficient. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Adjustable parameters
Integral gain: 1 ... 1000 1/s (100)

PT1 element
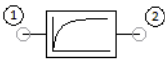
The PT1 element is a first-order proportional delay element used in closed-loop control technology. The input signal/potential at input 1 is amplified or attenuated by proportional-action coefficient Kp and delayed by delay time T, and is read out as the output signal/potential at output 2. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Adjustable parameters
Time constant: 0.001 ... 1 s (0.01)
Proportional gain: 0 ... 10 (1)

PT2 element

The PT2 element is a second-order proportional delay element used in closed-loop control technology. The input signal/potential at input 1 is amplified or attenuated by proportional-action coefficient Kp and delayed by delay times T1 and T2, and is read out as the output signal/potential at output 2. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Adjustable parameters
Time constant: 1e-5 ... 1 s (0.01)
Proportional gain: 0 ... 10 (1)

Damping: 1e-5 ... 1000 (1)

Difference amplifier
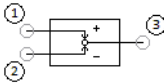
The differential amplifier is a closed-loop control technology component. An output signal/potential is generated at output 3, which corresponds to the difference between the two input signals/potentials at inputs 1 (w) and 2 (x). In the field of closed-loop control technology, the differential amplifier is used to determine deviation. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

Limiter
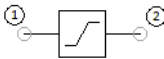
The limiter is a closed-loop control technology component. Within a defined voltage range, the input signal/potential at input 1 is replicated to another defined voltage range of the output signal/potential. In order to keep circuit wiring as straightforward as possible, required earthing (0 V) and supply voltage are not led out as terminals, but rather wired internally.

The voltage range of the input and output signals are specified after selecting the *Operating mode* option.

Adjustable parameters
Operating mode: In [-10 V..10 V] → Out [0 V..10 V], In [-10 V..10 V] –> Out [-10 V..10 V],Enter manually   (In [-10 V..10 V] → Out [0 V..10 V])
Min. Voltage (in): -400 ... 400 V (-10)
Max. Voltage (in): -400 ... 400 V (10)
Min. Voltage (out): -400 ... 400 V (-10)
Max. Voltage (out): -400 ... 400 V (10)

22.6 Digital components with electrical signals

The digital components in this library simulate real components. The input and output signals are not purely logical signals, but are in fact voltage levels. The connections are therefore electrical connections, which can be connected to all other electrical components, such as switches, resistors and capacitors.

The symbols' presettings correspond to those of the components used in the training package TP 1012 from Festo Didactic. Transistor-transistor logic modules (TTL modules) of type 74HCxx are used in this component set. These standard TTL-ICs are designed for operation with a supply voltage of 5 V. The supply voltage connections are not shown explicitly in FluidSIM. There must be adequate supply voltage present to generate the required output voltages.

In digital technology, a distinction is made between just two voltage levels: high voltage and low voltage. The presettings in FluidSIM correspond to those of the standard TTL-ICs. Input voltages below 0.8 V are regarded as low, while input voltages above 2.0 V are regarded as high. The low output voltage level is 0 V and the high output voltage level is 5 V. These settings can be changed for each symbol.

In order to designate the voltage levels in abstract terms, the two logical states are usually called simply high and low, true and false, or the abbreviations 1 and 0 are used.

In order to guarantee efficient simulation, the digital components in FluidSIM are not modeled as a circuit consisting of transistors, but as a simplified model that nonetheless takes the essential characteristics of the components into account. Output voltages rise and fall via a voltage ramp up to the required voltage level within around 20 nanoseconds. Output connections are connected to the output voltage with an adjustable internal resistor, i.e. ohmic loads at the output result in a voltage drop. The voltage level at inputs that are not connected is always 0 V.

22.6.1 Basic symbols

AND
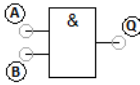
The output Q is only set to 1 if there is a 1 at all inputs (A, B). The standard symbol has two inputs. Extended symbols can have more than two inputs.

Truth table

A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

The IC 74HC08 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
**Resistance:** 0.1 ... 1000 Ohm (60)

OR
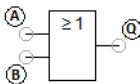
The output Q is only set to 1 if there is a 1 at a minimum of one input (A, B). The standard symbol has two inputs. Extended symbols can have more than two inputs.

Truth table

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

The IC 74HC32 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
**Resistance:** 0.1 ... 1000 Ohm (45)

Inverter (NOT)
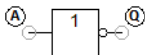
The inverter inverts the value of input A and thus generates a 0 at output Q from a 1 at the input and vice versa.

Truth table

A	Q
0	1
1	0

The IC 74HC14 is used as a component in the training package TP 1012 from Festo Didactic.
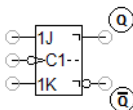
Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (45)

Schmitt trigger
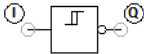
The Schmitt trigger (named after its inventor Otto Schmitt) converts an analogue input signal into a digital output signal. In the case of TTL modules, this means that any analogue input voltage between 0 V and 5 V at input I is transformed into a logic output level of either 0 V or 5 V at output Q.

This conversion takes place with the help of a lower and upper trigger level. If the input signal lies below the lower trigger level, the low level (usually 0 V) is output; above the upper trigger level the high level (e.g. 5 V) is output. The difference between the two threshold voltages is called hysteresis.

The output Q of the current Schmitt trigger is inverted, i.e. the low level is output if the upper trigger level is exceeded and the high level is output if the value falls below the lower trigger level.

If the input voltage changes only in the range between the lower and upper trigger level, the output level does not change.

The IC 74HC14 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
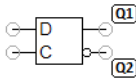**Voltage level (lo):** 0.1 ... 24 V (2.1)
Voltage level (hi): 0.1 ... 24 V (2.4)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (45)

NAND
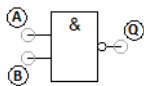
The output Q is only set to 0 if all inputs (A, B) have the value 1. The function of a NAND gate corresponds to that of an AND gate, whereby the output level is inverted by a NOT gate.

Truth table

A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

The IC 74HC00 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
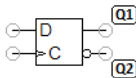**Voltage level (lo):** 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (40)

NOR
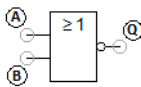
The output Q is only set to 1 if the value 0 is present at all inputs (A, B). The function of a NOR gate corresponds to that of an OR gate, whereby the output level is inverted by a NOT gate.

Truth table

A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0

The IC 74HC02 is used as a component in the training package TP 1012 from Festo Didactic.

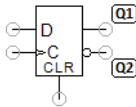*Adjustable parameters*
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)

Resistance: 0.1 … 1000 Ohm (45)

XOR
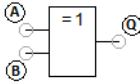
The output Q of the XOR gate is only set to 1 if the input values (A, B) are different. And thus the XOR gate corresponds to the OR function, except that a high output level only occurs when exclusively one input is 1, thus resulting in the name "exclusive or".

Truth table

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0

The IC 74HC86 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 … 24 V (0.8)
Voltage level (hi): 0.1 … 24 V (2)
Voltage level (lo): 0 … 24 V (0)
Voltage level (hi): 0.1 … 24 V (5)
Resistance: 0.1 … 1000 Ohm (45)

22.6.2 Flip-flops
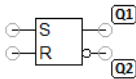
RS flip-flop

The RS flip-flop is an asynchronous flip-flop, which is controlled via the S (set) and R (reset) inputs. The flip-flop has two outputs Q1 and Q2, which are complementary to one another during normal flip-flop operation.

With S=1 and R=0, Q1 is set to 1 and Q2 is set to 0. With S=0 and R=1, Q1 is set to 0 and Q2 is set to 1.

The assignment of S=1 and R=1 is a special case, which should be avoided for the reasons outlined below. An RS flip-flop can be implemented in a number of ways using electronic components. The FluidSIM implementation corresponds to the real design consisting of two NOT and two NAND gates. Consequently, the assignment of S=1 and R=1 produces a stable state Q1=1 and Q2=1. Implementation with two NOR gates produces the stable state Q1=0 and Q2=0 for S=1 and R=1. In both cases, Q1 and Q2 are not complementary to one another.

A problem occurs with the transition from S=1 and R=1 to S=0 and R=0. This transition is, in any case, nondeterministic (virtually random), i.e. even the smallest runtime differences in the gates used decide whether (Q1=0, Q2=1) or (Q1=1, Q2=0) is achieved as the stable state. The same situation occurs when the supply voltage is applied.

The assignment of S=0 and R=0 has no effect on the current output values other than the problematic transition described above.

Adjustable parameters
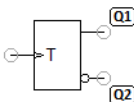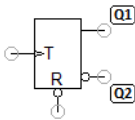**Voltage level (lo):** 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)
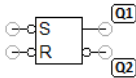
RS flip-flop with inverted inputs

This RS flip-flop is controlled by a 0 at the control inputs. This is indicated in the symbol by the negation circuits for S and R. If there is a NOT gate upstream of the inputs, this flip-flop behaves in exactly the same way as the standard RS flip-flop.

Adjustable parameters
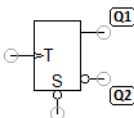**Voltage level (lo):** 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)
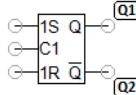
Synchronous RS flip-flop

The clocked RS flip-flop only processes signals at S and R if the clock signal C=1. If C=0, the values of S and R have no effect on the output signals. If C=1, this flip-flop behaves in exactly the same way as the standard RS flip-flop.
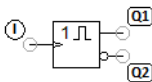
Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)
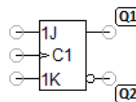
JK flip-flop, edge triggered

The edge-controlled JK flip-flop behaves exactly like an RS flip-flop with one exception. The inputs are labeled J and K to distinguish them from S and R. Just like with an RS flip-flop, a 1 at the input J means set, a 1 at the input K means reset and 0 for J and K means

hold. If J and K are set to 1, however, an edge at C causes the flip-flop to toggle to the other state.

Adjustable parameters
Voltage level (lo): 0.1 … 24 V (0.8)
Voltage level (hi): 0.1 … 24 V (2)
Voltage level (lo): 0 … 24 V (0)
Voltage level (hi): 0.1 … 24 V (5)
Resistance: 0.1 … 1000 Ohm (50)

JK flip-flop, edge triggered, K inverted
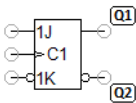
With this JK flip-flop the input K is inverted. If there is a NOT gate upstream of the input K, this flip-flop behaves in exactly the same way as the standard JK flip-flop.

Adjustable parameters
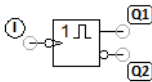**Voltage level (lo):** 0.1 … 24 V (0.8)
Voltage level (hi): 0.1 … 24 V (2)
Voltage level (lo): 0 … 24 V (0)
Voltage level (hi): 0.1 … 24 V (5)
Resistance: 0.1 … 1000 Ohm (50)

JK flip-flop with SET and RESET inputs, edge triggered
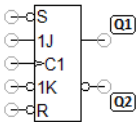
Compared with a standard JK flip-flop, this JK flip-flop also has an inverted input S for set and an inverted input R for reset. The input K is also inverted.

Truth table

not S	not R	C	J	not K	Q1	Q2
0	1	x	x	x	1	0
1	0	x	x	x	0	1
0	0	x	x	x	1	1

1	1	↑	1	0	q2	q1
1	1	↑	0	0	0	1
1	1	↑	1	1	1	0
1	1	↑	0	1	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q before the edge

The IC 74HC109 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (55)

JK MS flip-flop

A JK MS flip-flop (JK master/slave flip-flop) is a clock-skewed JK flip-flop. With the rising edge at the clock input, the flip-flop transfers the input information to a buffer. This new state is not forwarded to the output until the falling edge.

In the circuit diagram "TP1012_05_3a2.circ", implementation of the JK MS flip-flop is shown with two JK flip-flops and an inverter.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
**Resistance:** 0.1 ... 1000 Ohm (50)

D flip-flop

A D flip-flop can be used to store a single bit. In this context it is also referred to as a latch. The "D" stands for "data". The value at input D is saved precisely when input C=1 (clock) at the input. If C=0, the stored value is retained regardless of the input value D.

Truth table

C	D	Q1	Q2
0	x	q1	q2
1	0	0	1
1	1	1	0

Comments:

x = any (0 or 1) q = state of output Q remains unchanged

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

D flip-flop, edge triggered

The edge-triggered D flip-flop corresponds to a D flip-flop, with the addition that the value at the input D is only stored if there is a positive edge from 0 to 1 at clock input C.

Truth table

C	D	Q1	Q2
↑	0	0	1

↑	1	1	0
x	x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q remains unchanged

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

D flip-flop with CLR input

This D flip-flop is an edge-triggered D flip-flop with an additional input CLR (clear), via which the internal state can be set directly to 0.

Truth table

CLR	C	D	Q1	Q2
1	x	x	0	1
0	↑	0	0	1
0	↑	1	1	0
0	x	x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q remains unchanged

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)

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Resistance: 0.1 ... 1000 Ohm (50)
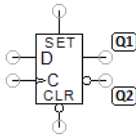
D flip-flop with SET and CLR inputs

This D flip-flop is an edge-triggered D flip-flop with two additional inputs CLR (clear) and SET (set). With the input CLR, the internal state can be set directly to 0. The input CLR is inverted, i.e. CLR=0 sets the internal state directly to 0. With the input SET, the internal state can be set directly to 1.   Truth table

CLR	SET	C	D	Q1	Q2
1	1	x	x	1	0
0	0	x	x	0	1
0	1	x	x	1	1
1	0	↑	0	0	1
1	0	↑	1	1	0
1	0	x	x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q remains unchanged

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

T flip-flop

The T flip-flop (toggle flip-flop) has only one input T. If there is a positive edge at input T from 0 to 1, the outputs change (toggle)

their states. The initial state of the outputs when the supply voltage is applied is random. However, Q1 = not Q2 always applies.

Truth table

T	Q1	Q2
↑	q2	q1
x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q before the edge
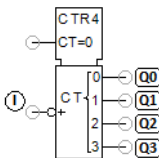
Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

T flip-flop with RESET input
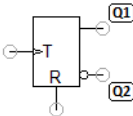
This T flip-flop is a T flip-flop with an additional input R (reset), via which the output Q1 can be set directly to 0.

Truth table

S	T	Q1	Q2
1	x	0	1
0	↑	q2	q1
0	x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q before the edge

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

T flip-flop with inverted RESET input

This T flip-flop is a T flip-flop with an additional input R (reset), via which the output Q1 can be set directly to 0. The input R is inverted, i.e. R=0 sets Q1 directly to 0.

Truth table

S	T	Q1	Q2
0	x	0	1
1	↑	q2	q1
1	x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q before the edge

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

T flip-flop with inverted SET input

This T flip-flop is a T flip-flop with an additional input S (set), via which the output Q1 can be set directly to 1. The input S is inverted, i.e. S=0 sets Q1 directly to 1.

Truth table

S	T	Q1	Q2
0	x	1	0
1	↑	q2	q1
1	x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q before the edge
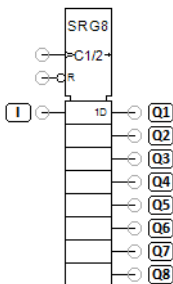
Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

Positive edge-triggered monoflop

If there is an edge from 0 to 1 at input I of the positive edge-triggered monoflop, the output Q1 is set to 1 for a time t. After expiration of t, the output is reset to 0 automatically. A distinction is made between non-retriggerable and triggerable monoflops. With retriggerable monoflops, the cycle time t restarts with a new edge.

Q1 = not Q2 always applies for the outputs.

Adjustable parameters
Delay time: 0.001 ... 10000 ms (10)
Retriggerable: ... (false)
**Voltage level (lo):** 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)

Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
**Resistance:** 0.1 ... 1000 Ohm (50)

Negative edge-triggered monoflop

If there is an edge from 1 to 0 at input I of the negative edge-triggered monoflop, the output Q1 is set to 1 for a time t. After expiration of t, the output is reset to 0 automatically. A distinction is made between non-retriggerable and triggerable monoflops. With retriggerable monoflops, the cycle time t restarts with a new edge.

Q1 = not Q2 always applies for the outputs.

Adjustable parameters
Delay time: 0.001 ... 10000 ms (10)
Retriggerable: ... (false)
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

D flip-flop with SET and RESET inputs, edge triggered

This D flip-flop is an edge-triggered D flip-flop with two additional inputs S and R. With the input S (set), the internal state can be set directly to 1. With the input R (reset), the internal state can be set directly to 0. The inputs S and R are inverted, i.e. the value 1 triggers the set or reset.   Truth table

not S	not R	C	D	Q1	Q2
0	1	x	x	1	0
1	0	x	x	0	1

0	0	x	x	1	1
1	1	↑	0	0	1
1	1	↑	1	1	0
1	1	x	x	q1	q2

Comments:

x = any (0 or 1) ↑ = positive edge from 0 to 1 q = state of output Q remains unchanged

The IC 74HC74 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)

22.6.3 Miscellaneous

Bouncing changeover switch

When the bouncing changeover switch is actuated, the required switching status is reached after multiple switching status changes within a few milliseconds.
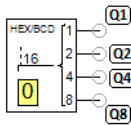
Hex switch

With the hex switch, a number x from 0 to 15 can be output bit-by-bit via the four outputs Q1, Q2, Q4 and Q8. The number x corresponds to a single-digit hexadecimal number, hence the name "hex switch". The following applies for the number x:

$$x = Q1*2^0 + Q2*2^1 + Q4*2^2 + Q8*2^3$$

Adjustable parameters
Hexadecimal value (0..F): 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F (0)
Voltage level (lo): 0 … 24 V (0)
Voltage level (hi): 0.1 … 24 V (5)
Resistance: 0.1 … 1000 Ohm (1)
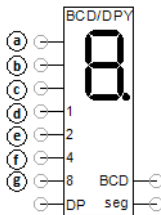
7-segment display

Decimal and hexadecimal numbers can be displayed with the 7-segment display. Depending on the additional inputs available, the individual segments and a decimal point can be controlled separately. The input DP=1 controls the decimal point.

If the input seg is available and has the value 1, the individual segments are controlled via the inputs a, b, c, d, e, f and g.

If the input seg not available or has the value 0, the number x is displayed, which is composed bit-by-bit from the inputs I1, I2, I4 and I8. If BCD=1 is also set, x is displayed as a decimal number. Otherwise it is displayed as a hexadecimal number. With decimal output, numbers greater than 9 are displayed as "-". The following applies for the number x:

$$x = I1*2^0 + I2*2^1 + I4*2^2 + I8*2^3$$

Adjustable parameters
Voltage level (lo): 0.1 … 24 V (0.8)
Voltage level (hi): 0.1 … 24 V (2)
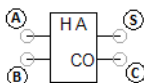
Half adder

The half adder adds two single-digit binary numbers (each 1 bit) and outputs a carry, where applicable. It has the label HA.

The two inputs A and B represent the bits to be added. The output S (sum) represents the last digit of the sum and the output C (carry) represents the carry.

Truth table

A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)
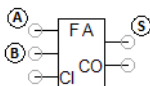
Full adder

The full adder or a cascade of full adders can be used to add multi-digit binary numbers.

The full adder has the label FA and has three inputs and two outputs. The two inputs A and B represent the bits to be added. With the input CI (carry in), a previous carry can be included in the addition.

The output S (sum) represents the last digit of the sum and the output CO (carry out) represents the carry.

The circuit diagram "TP1012_08_3_1.circ" shows a 4-bit full adder.

Truth table

A	B	CI	S	CO
0	0	0	0	0
0	1	0	1	0
1	0	0	1	0
1	1	0	0	1
0	0	1	1	0
0	1	1	0	1
1	0	1	0	1
1	1	1	1	1

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (50)
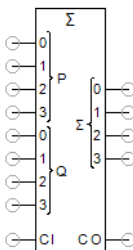
4-bit full adder

This full adder can be used to add two 4-bit numbers. With the input CI (carry in), a previous carry can be included in the addition. The sum x is calculated from the inputs as follows:

$x = CI + P0*2^0 + P1*2^1 + P2*2^2*P3*2^3 + Q0*2^0 + Q1*2^1 + Q2*2^2*Q3*2^3$

The outputs S0, S1, S2, S3 and the output CO (carry out) represent the sum x bit-by-bit, which is composed as follows:

$x = S0*2^0 + S1*2^1 + S2*2^2 + S3*2^3 + CO*2^4$

The IC 74HC283 is used as a component in the training package TP 1012 from Festo Didactic.

4-bit counter

The counter counts the number of falling edges from 1 to 0 at input I. The number is saved as a 4-bit number x and output bit-by-bit via the outputs Q0, Q1, Q2 and Q3. The counter is reset to x=0 after the value x=15 is reached. The counter can also be set to 0 with the value 1 at the input "CT=0". The counter x is output to the outputs as follows:

$$x = Q0*2^0 + Q1*2^1 + Q2*2^2 + Q3*2^3$$

The IC 74HC93 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (30)
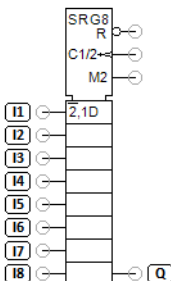
8-bit shift register, parallel-serial

With the shift register, data (8 bits) can be entered in parallel format and converted into a stream of serial bits. The bits are stored in the registers R1 to R8 and output via the output Q.

The output mode is activated when the value 1 is present at input M. The contents of each register are then shifted to the subsequent

register with each rising edge from 0 to 1 at input C. The contents of register R8 are shifted to register R1 in the ring.

The registers are loaded via the inputs I1 to I8. The registers accept the values of the inputs if the value 0 is present at input M and there is a rising edge from 0 to 1 at input C.

The shift register also has an inverted input R for reset, i.e. R=0 sets all registers to 0.

The IC 74HC166 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)
Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (55)

8-bit shift register, serial-parallel

With the shift register, a stream of serial bits can be loaded in the registers R1 to R8, which are output in parallel via the inputs Q1 to Q8.

The contents of each register are then shifted to the subsequent register with each rising edge from 0 to 1 at input C. The contents of register R1 are set to the value of input I.

The shift register also has an inverted input R for reset, i.e. R=0 sets all registers to 0.

The IC 74HC164 is used as a component in the training package TP 1012 from Festo Didactic.

Adjustable parameters
Voltage level (lo): 0.1 ... 24 V (0.8)
Voltage level (hi): 0.1 ... 24 V (2)
Voltage level (lo): 0 ... 24 V (0)

Voltage level (hi): 0.1 ... 24 V (5)
Resistance: 0.1 ... 1000 Ohm (45)

22.7 Digital technology

22.7.1 Constants and Terminals
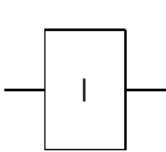
Input

Digital inputs are designated with an "I". In FluidSIM digital components can be used inside and outside a digital module. If a digital input is used inside a digital module, you can determine the input connector of the digital module in question with which the digital input shall be linked by allocating a number "I1" to "I16". If there is an analog signal of more than 10V at the chosen input of the digital module, the digital input is set to "Hi". If a digital input is used outside a digital module, there is an additional analog electrical connection at the digital input. If there is an analog signal of more than 10V at this connection, the digital input is set to "Hi". As an alternative you can click on the digital input with the left mouse button in order to set it to "Hi". Another click resets the value to "Lo".
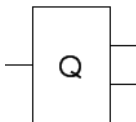
Output

Digital outputs are designated with a "Q". The output connects a digital signal through from its input to its output. In FluidSIM digital components can be used inside and outside a digital module. If a digital output is used inside a digital module, you can determine the output connector of the digital module in question with which

the digital output shall be linked by allocating a number "Q1" to "Q16". If the status of the digital output is "Hi", a potential of 24V is set at the corresponding output connector of the digital module. If a digital output is used outside a digital module, there is an additional analog electrical connection at the digital output. If the status of the digital output is "Hi", a potential of 24 V is set at this connection.
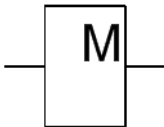
Buffer

Memory bits are designated with a "M". Memory bits are virtual outputs, with a value at their output analog to that at their input. When the simulation start is activated, you can define by using the property dialog box if the output Q shall be set to "Lo" or to "Hi", independent on the input value. After the simulation start the value at the output is set to the value of the input.

Adjustable parameters
Initial state = Hi: ...   (false)
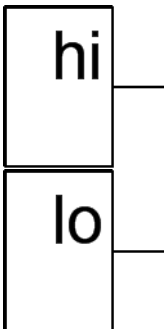
Hi Level

At the output Q you have the logic level "Hi".

Lo level

At the output Q you have the logic level "Lo".

Connection (digital)

A digital connection is a place where a digital line can be attached to. To simplify the line drawing process, a connection appears as a

small circle in Edit Mode. Note that at each digital connection its level "Lo" / "Hi" can be displayed.

Line (digital)

A digital line links two digital connections. Note that a digital connection may be a simple digital connection or a T-junction.
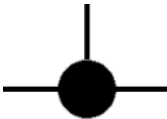
T-junction (digital)

A T-junction joins up to four digital lines, thus having a single digital level. Note that T-junctions are introduced automatically by FluidSIM when dropping the line drawing cursor onto another line in Edit Mode.

22.7.2 Basic Functions

AND
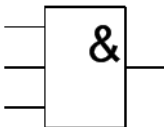
The output Q of the AND is only "Hi" when all inputs are "Hi", that is, if they are closed. If an input pin of this module is not connected, its status is automatically "Hi".

AND with edge triggering
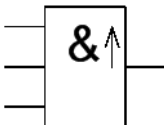
The output Q of the edge-triggered AND is only "Hi" when all inputs are "Hi" and if at least one input was "Lo" in the previous cycle. If an input pin of this block is not connected, its status is automatically "Hi".
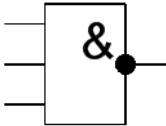
NAND

The output Q of the NAND is only "Lo", when all inputs are "Hi", that is, if they are closed. If an input pin of this block is not connected, its status is automatically "Hi".
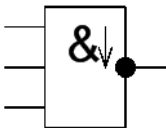
NAND with edge triggering

The output Q of the NAND with edge evaluation is only "Hi", if at least one input is "Lo" and if all inputs were "Hi" in the previous cycle. If an input pin of this block is not connected, its status is automatically "Hi".

OR
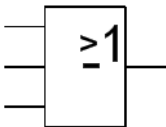
The output Q of the OR is only "Hi", if at least one input is "Hi", that is, if it is closed. If an input pin of this block is not connected, its status is automatically "Lo".
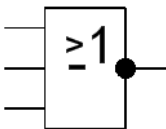
NOR

The output Q of the NOR is only "Hi" when all inputs are "Lo", that is, if they are switched off. As soon as any input is switched on (status "Hi"), the output of the NOR is set to "Lo". If an input pin of this block is not connected, its status is automatically "Lo".

XOR
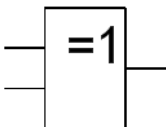
The output Q of the XOR is "Hi", if the inputs are nonequivalent. If an input pin of this block is not connected, its status is automatically "Lo".
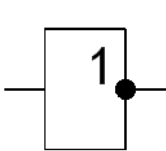
NOT

The output Q is "Hi" if the input is "Lo". The NOT block is an input status inverter.

22.7.3 Special Functions

Logic module

The digital module is used for a compact embedding of a digital switching circuit into an electropneumatic or electrohydraulic circuit. The digital module offers 8 (16) electrical inputs and outputs, which transfer their states to its digital switching circuit in the inner part. Therefore the digital switching circuit does not need much space in the electropneumatic or electrohydraulic circuit for the display of the digital module as a rectangle with a total number of 18 (34) connections.

By making a double-click with the left mouse button on the digital module you come to the digital circuit in the inner part of the module. A new window opens. It shows the digital circuit and can be handled in the usual way. The standard configuration in the inner part of a new inserted digital module is a row with 8 (16) inputs and 8 (16) outputs each. They correspond to the inputs and outputs of the module in the electropneumatic or electrohydraulic circuit. In order to be able to test the digital circuit during the setup, it can be simulated separated from the electropneumatic or electrohydraulic circuit. As soon as the processing window of the digital module is closed or the original circuit window is put into the foreground, the previously effected changes in the digital circuit are automatically adopted into the digital module of the electropneumatic or electrohydraulic circuit.

Inside the digital module only digital components can be inserted. Furthermore, an encapsulating of additional digital modules inside

a module is not possible. However, you can use several digital modules in one electropneumatic or electrohydraulic circuit. Please note that the digital circuit inside a digital module only works correctly if corresponding potentials are set at the electrical power supply units of the module (+24 V) and (0 V).

On delay
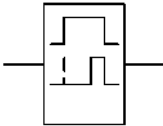
An output with on delay is not switched on until a specified time has expired. When the status of input Trg changes from "Lo" to "Hi", the on delay time starts. If the status of input Trg is "Hi" at least for the duration of the configured time, the output Q is set to "Hi" on expiration of this time. The output follows the input with on delay. The time is reset, when the status of the input changes again to "Lo" before the time has expired. The output is reset to "Lo", when the status at the input is "Lo".

Adjustable parameters
Delay time: 0 ... 100 s (3)
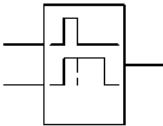
Off delay

The output is not reset until a configured time has expired. When the input status turns to "Hi", the output Q is switched instantaneously to "Hi". If the status at input Trg changes from "Hi" to "Lo", the off delay starts. After expiration of the configured time, the output is reset to "Lo" (off delay). When the input Trg is switched on and off again, the off delay restarts. The input R (Reset) is used to reset the delay time and the output before the configured time has expired.

Adjustable parameters
Delay time: 0 ... 100 s (3)
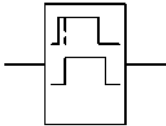
On/off delay

An output with on/off delay is switched on after a specified time and is reset on expiration of a second specified time. As soon as the status at input Trg changes from "Lo" to "Hi", the configured on delay time starts. If the status at input Trg remains "Hi" at least for the duration of the configured time, the output Q is set to "Hi" on expiration of the on delay time (the output follows the input on delayed). If the status at input Trg changes again to "Lo", before the configured on delay time has expired, the time is reset. When the status at input returns to "Lo", the configured off delay time starts. If the status at the input remains "Lo" at least for the duration of the configured off delay time, the output is set to "Lo" on expiration of that time (the output follows the input off delayed). If the status at the input returns to "Hi" before this time has expired, the time is reset.

Adjustable parameters
On delay time: 0 ... 100 s (3)
Off delay time: 0 ... 100 s (6)
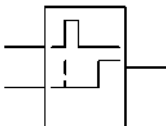
Retentive on delay

A specified time starts after an input pulse. The output is set on expiration of this time. As soon as the status at the input Trg changes from "Lo" to "Hi", the specified time starts. After expiration on the configured time, the output Q is set to "Hi". Further switching actions at input Trg have no influence on the running time. The output and the time are only reset to "Lo" when the status at input R is "Hi".

Adjustable parameters
Delay time: 0 ... 100 s (3)
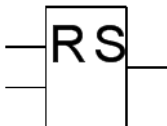
Latching relay

Input S sets output Q. Another input R resets the output Q. A latching relay is a simple logic memory. The output value depends on the input states and on the previous output status.
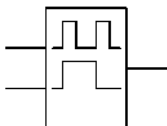
Pulse relay

A short one-shot at the input is used to set and reset the output. Output Q status is toggled at every "Lo" to "Hi" transition of the status at input Trg, that is, the output is switched on or off. Use input R to reset the pulse relay to initial state, that is, the output is set to "Lo".
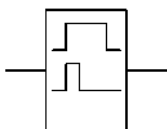
Wiping Relay - Pulse Output

An input signal generates a signal of specified length at the output. The output status is switched to "Hi" after the input Trg is set to "Hi". The configured time is started at the same time and the output remains set. After expiration of the configured time, the output is reset to the status "Lo" (pulse output). If the input status changes from "Hi" to "Lo" before the specified time has expired, also the output follows immediately with a with a "Hi" to "Lo" transition.

Adjustable parameters
Delay time: 0 ... 100 s (3)
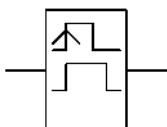
Edge-triggered wiping relay

An input signal generates a signal of specified length at the output (retriggering). The output status is switched to "Hi" after the input Trg is set to "Hi". The configured time is started at the same time. After expiration of the configured time, the output Q status is reset

to "Lo" (pulse output). If the input status changes again from "Lo" to "Hi" (retriggering), before the specified time has expired, the time is reset and the output remains switched on.

Adjustable parameters
Delay time: 0 ... 100 s (3)
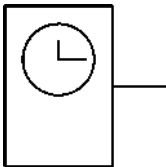
Timer switch

With the timer switch you can create timer switches referring to days, weeks and years. Upon reach of the specified on-transition time, the output Q of the timer switch is set to "Hi" and upon reach of the specified off-transition time to "Lo". If you have chosen the option "*Repeat every*", the on and off transition is repeated each time according to the specified repetition time.

Adjustable parameters
On time: 0 ... 1000 s (10)
Off time: 0.1 ... 1000 s (30)
Repeat every: 0.1 ... 1000 s (60)
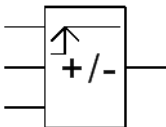
Up and down counter

Depending on the configuration of the input Dir, an internal value is counted up or down through an input pulse. The output is set when the configured count value is reached. With every status change at the input Cnt from "Lo" to "Hi", the internal counter is increased (Dir = "Lo") or decreased (Dir = "Hi") by one unit. If the internal counter is equal or larger compared to the specified value, the output Q is set to "Hi". You can use the reset input R to reset the internal count value and the output to "Lo". As long as R="Hi", also the output is "Lo" and the pulses at input Cnt are not counted.

Adjustable parameters
Counter: 0 ... 9999 (5)
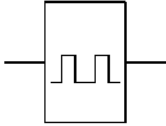
Symmetric clock generator

A timing signal with a configurable period is given at the output. Via the duration of the pulses you can determine the length of the on and off times. Via the input En (for Enable) you can switch on the clock generator, that is, the clock generator sets the output to "Hi" for the duration of the pulse, subsequent the output to "Lo" for the duration of the pulse and so on, until the input status is "Lo" again.

Adjustable parameters
Impulse time: 0.0005 ... 100 s (0.5)
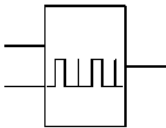
Asynchronous pulse generator

The pulse profile of the output can be changed via the configurable pulse duration and pulse pause duration. It is possible to invert the output with input INV. The input INV only negates the output, if the block is enabled via EN.

Adjustable parameters
Impulse time: 0.01 ... 100 s (3)
Impulse pause time: 0.01 ... 100 s (1)
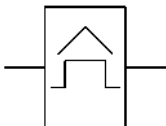
Frequency trigger

The output is switched on and off depending on two frequencies which can be specified. The threshold trigger measures the signals at input Fre. The pulses are captured across a measuring interval which can be specified. If the frequency measured within the measuring interval higher than the input frequency, the output Q is switched to "Hi". Q is switched again to "Lo" when the measured frequency has reached the value of the output frequency or if it is lower.

Adjustable parameters

On frequency: 0.01 ... 9999 Hz (6)
Off frequency: 0.01 ... 9999 Hz (2)
Time interval: 0.001 ... 100 s (5)

22.8 GRAFCET

22.8.1 GRAFCET
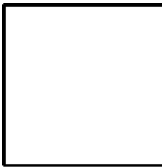
Step

The name of a step may contain the following characters: "0-9", "a-z", "A-Z" and the underscore "_". You can select from the following seven different step types: simple step, initial step, macro-step, macro input, macro output, enclosing step and initial enclosing step. Furthermore, you can give the step an activation link.
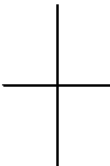
Transition

You can give a transition a name, which is shown to the left of the transition in brackets. Entering a transition condition is supported by buttons for special symbols (AND, OR, NOT, falling edge, rising edge, delay). Via $\boxed{\text{Variable}}$ you can select an existing GRAFCET variable from a list. Alternatively to the formula, you can show a descriptive text. To do this, you have to select the option "Display description instead of formula". In the "Connection ID/target information" field, you can enter a step that links to the transition's output without having to draw a connecting line. You can select an existing step from a list.

Action
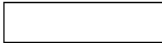
There are three types of action: assignations, allocations and compulsory commands.

For assignations and allocations, you can enter a variable or an output, whose value is changed by the action. The name of a variable may contain the following characters: "0-9", "a-z", "A-Z" and the underscore "_".

For a "conditional action" or an "*Action on event*", you can enter a condition that has to be fulfilled before the action is executed. Entering a condition is supported by buttons for special symbols (AND, OR, NOT, falling edge, rising edge, delay). Via | Variable | you can select an existing GRAFCET variable from a list. Alternatively to the formula, you can show a descriptive text. To do this, you have to select the option "Display description instead of formula".

For an allocation ("action on activation", "action on deactivation" and "action on event"), you can enter any term whose value is to be allocated to the action variable. Entering a term is supported by buttons for special symbols (AND, OR, NOT, falling edge, rising edge). Via | Variable | you can select an existing GRAFCET variable from a list. Alternatively to the formula, you can show a descriptive text. To do this, you have to select the option "Display description instead of formula".

For a "compulsory command", you can enter the name of the partial GRAFCET directly or select an existing partial GRAFCET from a list. You can also enter the relevant steps directly or select them from a list of existing steps. You have to separate the step names with commas. You can select the special commands "*" and "INIT" using the relevant buttons.

Synchronization

You can connect synchronizations like other FluidSIM components. However, they do not initially have any connections. You always

have to draw connecting lines to a synchronization. The corresponding connections are then generated automatically.
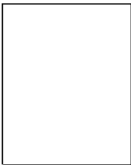
Partial GRAFCET

If you want to allocate GRAFCET elements to a specific partial GRAFCET, place the partial GRAFCET frame over the relevant GRAFCET part and give it a name. The preceding "G" is not part of the name that you have to enter; it is added automatically by FluidSIM and shown at the bottom left of the partial GRAFCET frame. You can alter the size of the partial GRAFCET frame by dragging its edges with the mouse. For the partial GRAFCET to function correctly, it is important that all its elements are completely within the frame and that the frame does not overlap with any foreign elements or other frames.
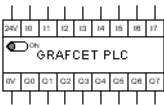
GRAFCET PLC

The GRAFCET-PLC component is similar to a SPS controller, whose behavior is described by a GRAFCET. For more information, please read the section GRAFCET-PLC-Component.

GRAFCET PLC

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GRAFCET PLC

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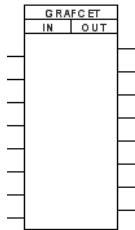
GRAFCET I/O

The GRAFCET I/O component is used to link the GRAFCET variables with the electrical part of a circuit. You can enter eight GRAFCET input variables and eight GRAFCET output variables into the GRAFCET I/O component. The actions' variables serve as outputs. The inputs can be the allocations and conditions of actions and transitions. If a potential is created as the input of the GRAFCET I/O component, the corresponding variable is set to "1". If an output variable has a value other than "0", a potential of 24V is created at the corresponding output of the GRAFCET I/O component.

22.9 Miscellaneous

22.9.1 Miscellaneous

Connection (mechanical)

A mechanical connection constitutes a place holder for the label of a valve solenoid. To simplify clicking, a mechanical connection appears as a small circle in Edit Mode.
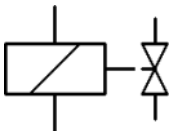
Valve solenoid

The valve solenoid switches the valve. By means of a label the valve solenoid can be linked to a valve that is solenoid operated.

Adjustable parameters
Resistance: 1 ... 10000 Ohm (90)
Minimum voltage: 0.1 ... 300 V (20)
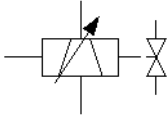
Proportional valve solenoid, position controlled

In FluidSIM the proportional valve solenoid is coupled to the respective continuous directional valve with the help of a label. The required slide position is predetermined via a voltage signal. The valve slide distance is position controlled. The control and amplifier component is integrated in the valve.

Adjustable parameters
Current (max): 0.01 ... 10 A (0.1)
Resistance: 1 ... 10000 Ohm (128)
Minimum voltage: 0.1 ... 300 V (20)
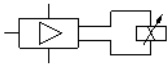
Proportional amplifier, 1-channel

The amplifier is used to control proportional valves. For this purpose, nominal values (voltage signals) from 0 V to +10 V are transformed into the necessary magnetic current for the proportional valves. In FluidSIM the amplifier is coupled to the respective valve with the help of a label. The maximum current at the amplifier output is hereby automatically adjusted in relation to the coupled valve. A step current relative to the maximum current can be specified, in order to compensate the positive overlap of proportional valves. The amplifier requires a power supply of 24 V.

Adjustable parameters
Current (max): 0.01 ... 30 A (0.1)
Jump current: 0 ... 25 % (0)
Resistance: 1 ... 10000 Ohm (100)
Minimum voltage: 0.1 ... 300 V (20)
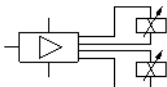
Proportional amplifier, 2-channel

The amplifier is used to control proportional valves with two magnets. For this purpose, nominal values (voltage signals) from -10 V

to +10 V are transformed into the necessary magnetic current for the proportional valves. Output A is gated at a nominal value between 0 V and -10 V, output B between 0 V and -10 V. In FluidSIM the amplifier is coupled to the respective valve with the help of two labels. The maximum currents at the amplifier outputs are hereby automatically adjusted in relation to the coupled valves. A step current relative to the maximum current can be specified, in order to compensate the positive overlap of proportional valves. The amplifier requires a power supply of 24 V.

Adjustable parameters
Current (max): 0.01 ... 30 A (0.1)
Jump current: 0 ... 25 % (0)
Resistance: 1 ... 10000 Ohm (100)
Minimum voltage: 0.1 ... 300 V (20)

Valve solenoid

The valve solenoid switches the valve. By means of a label the valve solenoid can be linked to a valve that is solenoid operated.

Adjustable parameters
Resistance: 1 ... 10000 Ohm (90)
Minimum voltage: 0.1 ... 300 V (20)

Distance rule

The distance rule is a device for attaching switches at the cylinder. The labels at the distance rule define links to the actual proximity switches or limit switches in the electrical circuit.

Status indicator

In Edit Mode, the status indicator is automatically displayed at those components that are actuated in the circuit's initial position.

Cam switch

In Edit Mode, the cam switch is automatically displayed at those mechanically operated way valves that are actuated in the circuit's initial position.

Text

Text

The concept of text components in FluidSIM gives the user a way in which to describe components in diagrams, assign identification texts, or to provide commentary on the diagram. The text and the appearance of text components can be customized to the user's liking.

State diagram

The state diagram records the state quantities of important components and depicts them graphically.

Terminal assignment diagram

The terminal assignment diagram list automatically creates terminals in the electrical circuit and displays the allocation in a table.

Functional diagram

With the functional diagram editor, functional diagrams e.g. dis-placement-step diagrams can be created.

Parts list

The parts list component creates from the components of a circuit diagram a table, which contains for each component its designation and its description.

Rectangle

Rectangles are graphic primitives, which can also be used within circuit diagrams.

Ellipse

Ellipses are graphic primitives, which can also be used within circuit diagrams.

Bitmap

In FluidSIM images, as with all other components and objects, can be inserted, positioned, moved, rotated and mirrored. In addition, images such as rectangles and ellipses are freely scalable.

Learning, Teaching, and Visualizing Technologies

Chapter 23

Beside the creation and simulation of electro-fluidic circuit diagrams, FluidSIM also supports teaching basic knowledge. This knowledge is presented in the form of texts, overview pictures, sectional views, exercises, and educational films. Functions that realize the selection of this instruction material are found under the ⊞ Didactics menu.

One group of these functions refers to information about single, selected components. Another group of functions refers to ordered overviews of the didactics material, allowing the selection of an interesting topic. Finally, it is also possible to select and link together arbitrary topics into so-called ⊞ Presentation... .

Appendix ⊞ Component Library and ⊞ Didactics Material offer a complete and concise summary of the instructional material in FluidSIM.

The following sections contain a description of the functions found under the ⊞ Didactics menu.

23.1 Information about Single Components

The first three entries under the ⊞ Didactics menu refer to selected components and are *context sensitive*. More precisely:

When a component in the current circuit diagram window is selected, or all selected components are of the same type, the menu entry ⊞ Component description will be enabled.

23.1.1 Component Descriptions

All components possess a page with a technical description. This page contains the diagram symbol for the component according to the DIN standard ("Deutsche Industrienorm"), a textual description of the component's function, the designations of the connections, and a listing of the adjustable parameters along with their value ranges.

You will find a photograph of the real-life part provided for most components. In the case that a component cannot exist singularly in a real system, FluidSIM displays a photo of the assembly group that this component belongs to. Examples for such components include the indicator light, relays, switches, and the electrical power supply. Components, which do not exist in reality, simply have no photo. Examples include the text component and the distance rule.

� Select the one-way flow control valve and click on the menu item Component description under the Didactics menu.

The following page opens:

Component library

One-way flow control valve

The one-way flow control valve is made up of a throttle valve and a check valve. The check valve stops the flow from passing in a certain direction. The flow then passes though the throttle valve. The cross-section of the throttle is adjustable via a regular screw. In the opposite direction the flow can pass through the check valve.

Adjustable parameters

Opening level:	0 … 100 %	(100)
Standard nominal flow rate:	0.1 … 5000 l/min	(100)

Related Topics

[94] One-way flow control valve

[95] Throttle valve

Throttle valve

Piloted operated check valve

Figure 23/1: Technical page of the one-way flow control valve

Component library

Component library < Hydraulic Components < Flow Control Valves < One-way flow control valve
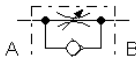
One-way flow control valve

A □—————□ B

The setting of the One-way flow control valve is set by means of a rotary knob. A check valve (see check valve) is located parallel to the throttle valve. Please note that by the rotary knob no *absolute* resistance value can be set This means that, in reality, different throttle valves can generate different resistance values despite identical settings.

Adjustable parameters

Opening level:	0 ... 100 %	(100)
Hydraulic resistance:	1e-7 ... 100 MPa*min2/l2	(0.01)

Related Topics

Throttle valve

Check valve

[144] One-way flow control valve (1)

Figure 23/2: Technical page of the throttle check valve

Under the heading *Related topics*, but also when appropriate in the component description, cross references for related instruction material and components are defined. By clicking on a cross reference, the related page will automatically be displayed.

23.1.2 Component Illustrations

Component illustrations provide useful information relating a component's function. This may include a sectional view of the component, but also illustrations of the component's usage within a circuit diagram. For several components, their sectional view can be animated like a cartoon.

----→ Select an air motor (4/2-way hand-lever valve in case of hy-draulic version) and click on $\boxed{\text{Component description}}$ under the $\boxed{\text{Didactics}}$ menu.

The following dialog box appears:

Figure 23/3: Page component-specific topics

Component library

4/2-way hand-lever valve (i)

In normal position the connection P is open to B and A to T. When manually actuated the valve is set to parallel position.

This valve is derived from a configurable 4/n way valve. You find this valve in the component library "Frequently used Way Valves", under the `Library` menu.

Related Topics

Configurable 4/n way valve

4/2-way hand-lever valve (ii)

[104] 4/2-way valve, two pistons (1)

Figure 23/4: Dialog box with component-specific topics

┈┈⟶ Please click the line with the relevant topic   **[35] Air motor** (hydraulics: **[104] 4/2-way valve, two pistons (1)**).

The following picture appears:

[35] Air motor

Devices which transform pneumatic energy into mechanical rotary motion, with the possibility of continuous motion. They are categorized into the groups of piston motors, sliding vane motors, gear motors and turbines.

→ Discuss applications for the air motor.
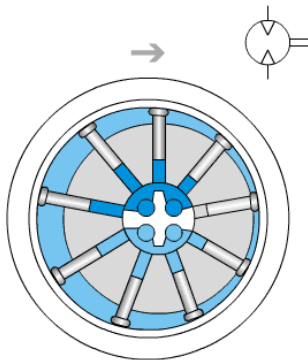
Figure 23/5: Function illustration of an air motor

[104] 4/2-way valve, two pistons (1)

The 4/2-way valve has two working ports A and B, a supply port P and a tank port T. The supply port is always connected to one of the working ports, while the second working port is routed to the tank. In the normal position, there is flow from P to B and from A to T.

→ In contrast to valves with three pistons, 4/2-way valves with two pistons do not require a leakage-oil port (see topic 106).
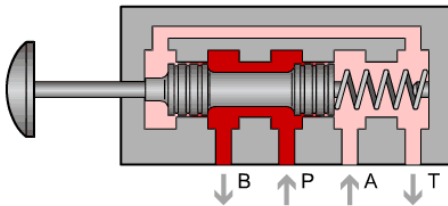
Figure 23/6: Function illustration of a 4/2-way valve

Often it is easier to understand the functional nature of a component, when its behavior is visualized through the use of animation. For this reason, several components possess different sectional views showing the component at different states. These sectional views can be animated in much the same way as a flip book.

⸱⸱⸱⸫ Please mark a quick-exhaust valve(hydraulics: 3-way pressure reducing valve)and click the menu option Didactics Component description to open the window with the component description. Now click the link with the function illustration [87] quick exhaust valve (hydraulics: [84] 3-way pressure reducing valve)

This function illustration can be animated.

⸱⸱⸱⸫ Click on ▶ or Execute Start to start the animation.

An animation can be "frozen" with ⏸ or by clicking on Pause in the Execute menu. ■ or Execute Stop stops an animation, whereas ⏮ or Execute Reset restarts an animation.

23.2 Selecting Didactics Material from a List

The entries Tutorial 'Simulating with FluidSIM' , Component Library and Didactics Material under the Didactics menu present the didactics material of FluidSIM organized in the form of overview pages. From these pages topics can be chosen and viewed independently of the current window and possibly selected components.

23.2.1 Tutorial

Below this menu option you can launch the tutorial "Simulating with FluidSIM", which contains a variety of interesting experiments and an excursus. By means of these useful examples you will get to know the possibilities of simulating with FluidSIM. Furthermore, for the most important components the mathematic models used in FluidSIM are also described.

⇢ Please click the menu option Didactics Tutorial 'Simulating with FluidSIM' to open the tutorial.
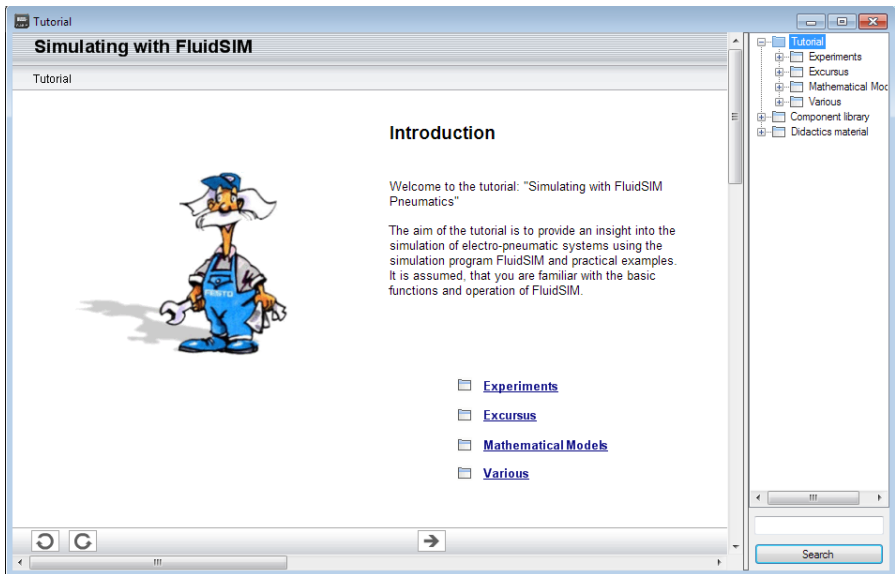
Figure 23/7: Tutorial (Pneumatics)
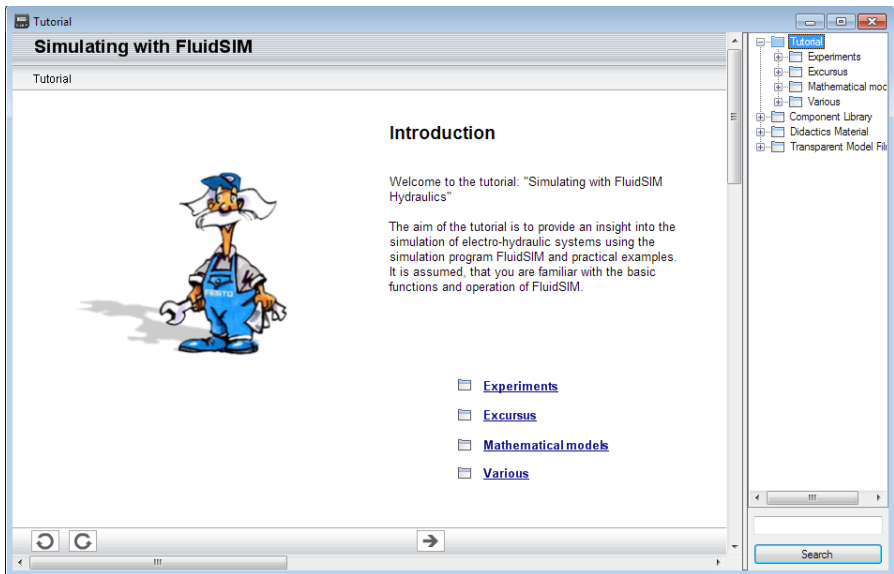
Figure 23/8: Tutorial (Hydraulics)

On the right-hand side the hierarchical directory is displayed. By double-clicking the directory symbols you may list off or close the applicable subsections. Clicking a page symbol will display the contents of the page in the open window.

23.2.2 Component Library

Below the menu option Component Library you will find descriptions and photos of all FluidSIM -components.

┈┈> Click a menu option Didactics Component Library to open the help pages of the component library.
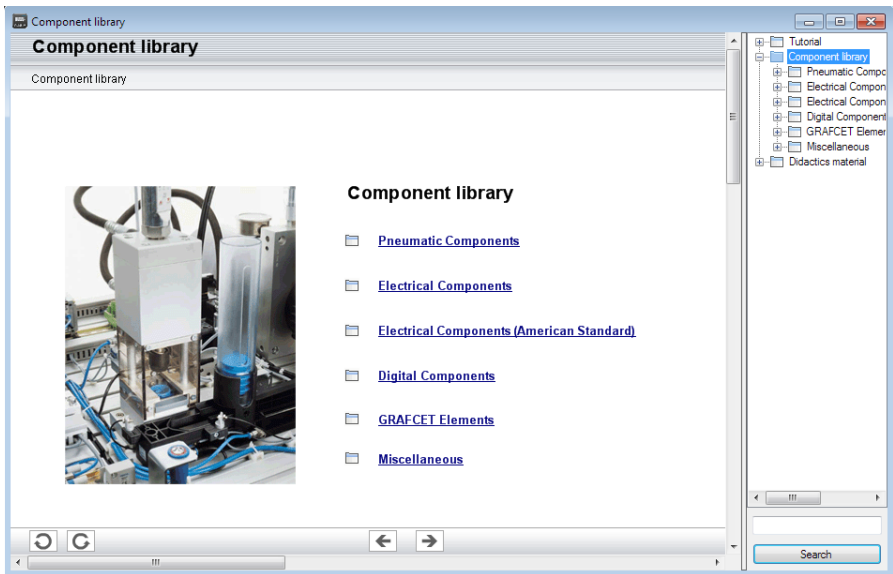
Figure 23/9: Component Library (Pneumatics)
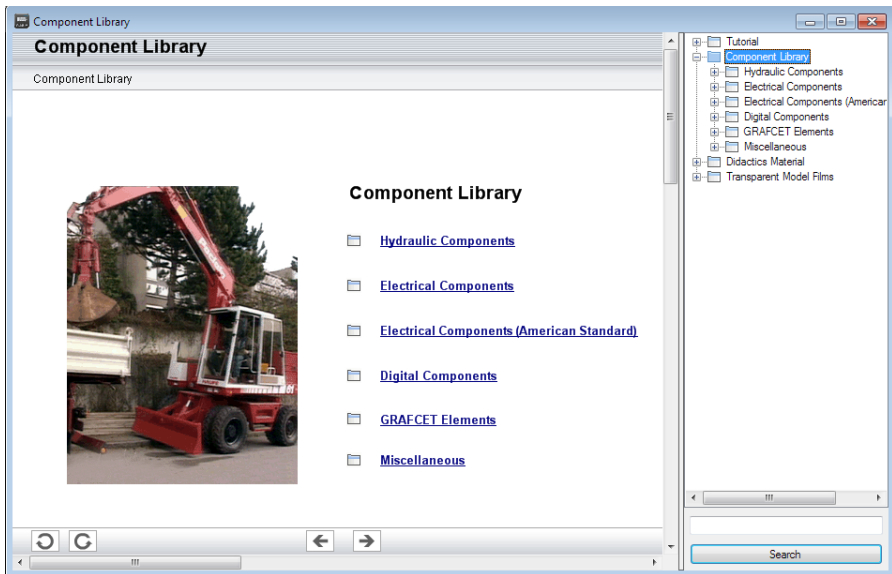
Figure 23/10: Component Library (Hydraulics)

23.2.3 Didactics Material

FluidSIM, alongside the tutorial and the component reference, contains further didactics material particularly useful for group work. Moreover, here you will find educational films, provided you have copied them onto the hard disk during the installation. If you haven't installed the film files, you may choose a chapter via the menu option Didactics Educational Film... to view the applicable film from the included video-CD.

⤑ Click the menu option Didactics Didactics Material to open the overview of the didactics material.
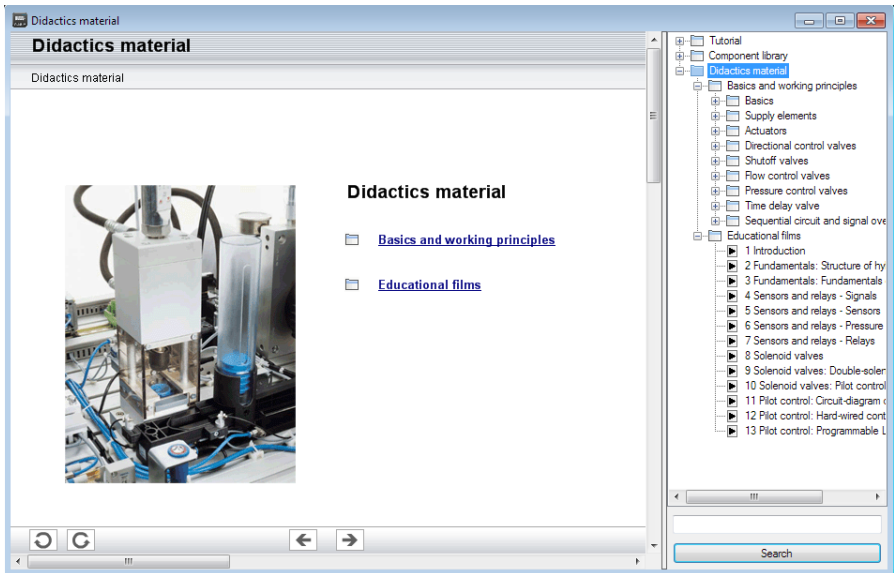
Figure 23/11: Didactics Material (Pneumatics)
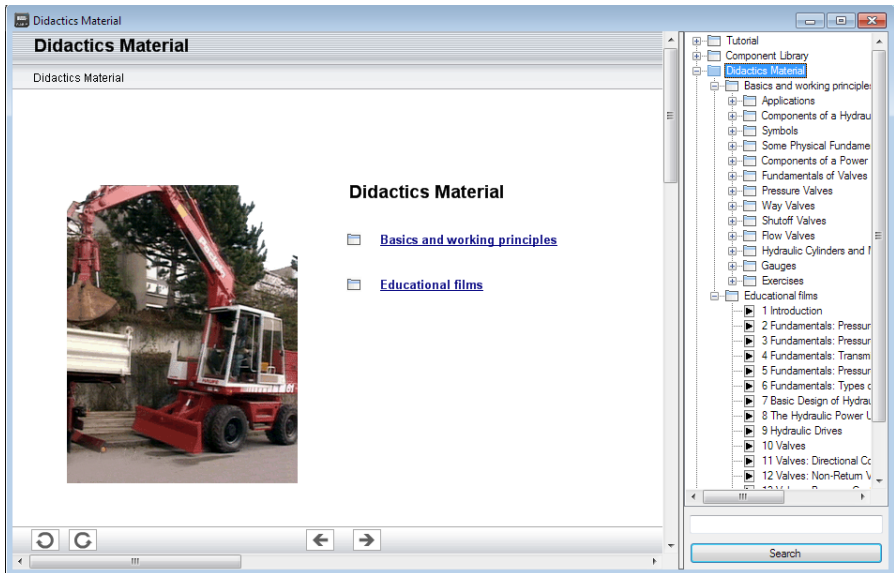
Figure 23/12: Didactics Material (Hydraulics)

23.3 Presentations: Combining Instructional Material

Sometimes you may want to examine a topic from different angles or combine individual topics into a lesson. For this purpose FluidSIM offers the concept entitled Presentation... .

There are a number of already prepared presentations, which can be found on the FluidSIM installation disks. However, editing presentations or creating new presentations is also possible with FluidSIM. All presentations can be found under Presentation... in the Didactics menu.

⤑ Click on Didactics Presentation... .

The following dialog box appears:
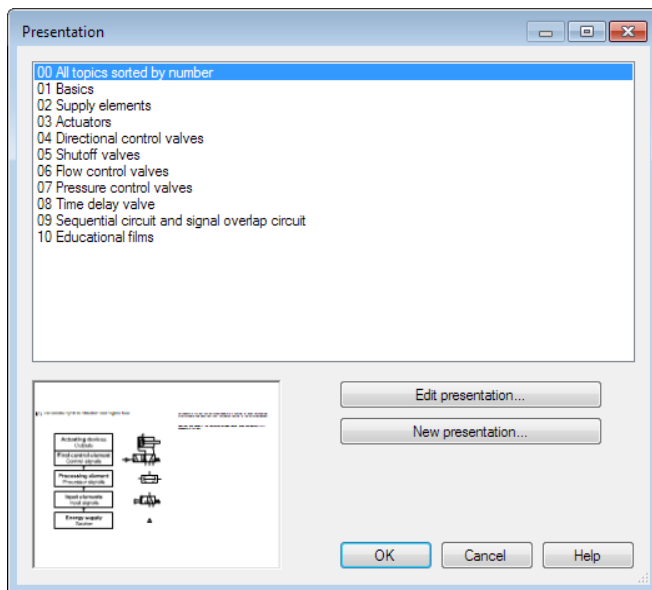
Figure 23/13: Dialog box for selecting and editing presentations (Pneumatics)
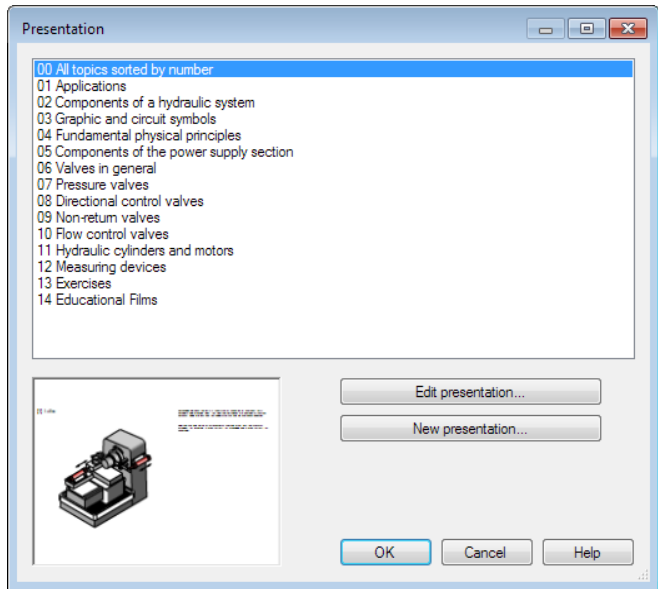
Figure 23/14: Dialog box for selecting and editing presentations (Hydraulics)

Presentations	This field contains a list of already created presentations.
New presentation...	Clicking on " New presentation... " opens a second dialog box for the creation of a new presentation.
Edit presentation...	Clicking on " Edit presentation... " opens a second dialog box to begin editing a presentation.
Preview	When the "Preview" setting is activated, the picture that pertains to the selected presentation appears underneath the topics list.

⋯⋯⋗ Click on "New Presentation" to open the following dialog box.
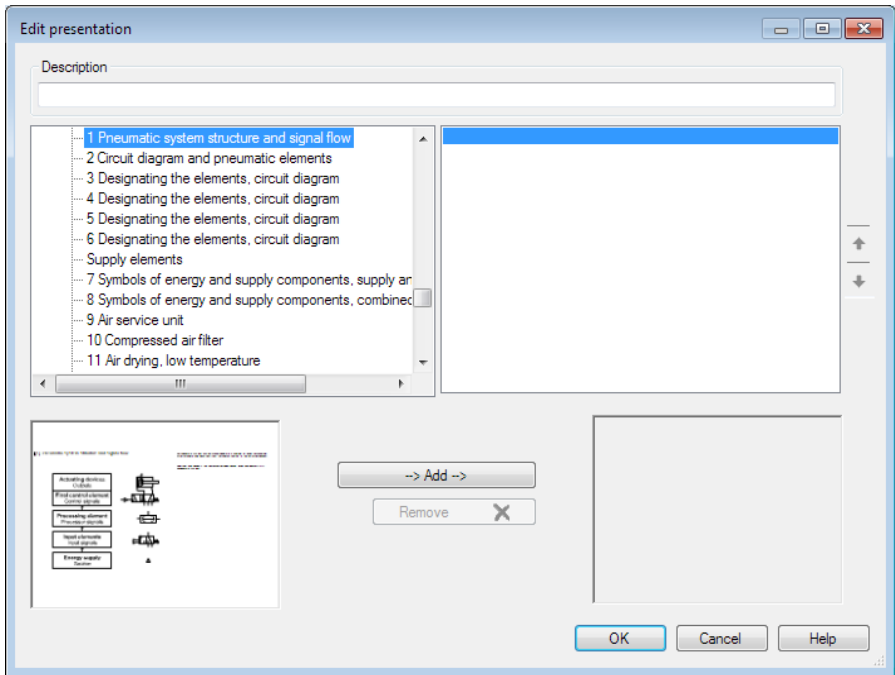
Figure 23/15: Dialog box for editing presentations (Pneumatics)
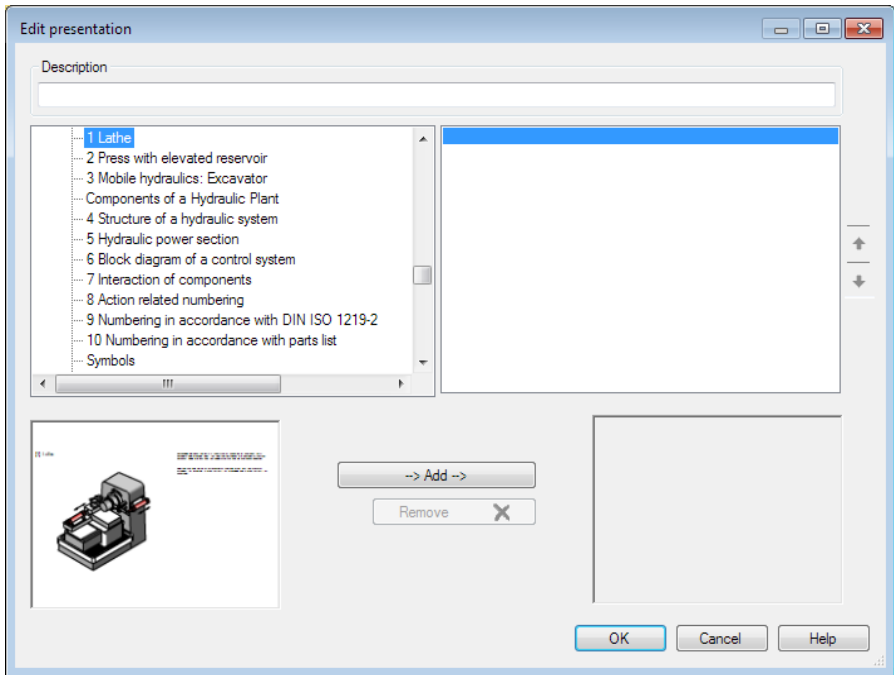
Figure 23/16: Dialog box for editing presentations (Hydraulics)

Description

In this text field a short description of the presentation can be entered. This text may consist of up to 128 characters and will appear with the other presentations, the next time the presentation dialog box is opened.

Available topics

This field contains a list of all available topics dealing with " *Pneumatics basics*", "*Hydraulics basics*", "*Working principle*", and "*Exercise*". Moreover, there exist two pictures that can be used to announce a refreshment and a lunch break respectively. A double click on a line in the "Available Topics" list inserts this line in the "*Selected topics*" list above the highlighted bar. In this way a presentation can be created or altered. Moreover, a user can integrate his own circuit diagrams, DXF files, BMP- and WMF-picture files, or even multimedia files such as sounds or video clips. To do

so, click on "*User file*": A dialog box opens that allows for the selection of the desired data source on the file system.

Selected topics

This field contains a list of topics chosen for the current presentation.

Add

Clicking on " Add " is the same as double clicking a line in the " *Available topics* " list: The selected line in " *Available topics* " will be inserted in the " *Selected topics* " list.

Delete

Clicking on " Delete " deletes the selected line of the " *Selected topics* " list.

Preview

When the " *Preview* " setting is activated, the picture that pertains to the selected topic appears underneath the respective list.

Within both topics lists the highlighted bar can be moved using the arrow keys. Maybe it will be necessary to click and select the list you want to work with. After creating a new presentation and closing the dialog box by clicking on " OK ", FluidSIM asks you to name the presentation file. Presentation files have the extension `.shw` and are located in the subdirectory `shw` under the installation directory.

23.4 Extended Presentations in the Microsoft PowerPoint Format

The hydraulics version of FluidSIM contains an additional large set of presentations written in the Microsoft PowerPoint Format. To use these presentations, PowerPoint must not be installed on your PC since FluidSIM installs the necessary viewer at its installation time.

┈┈⟶ Click on Extended Presentation... to open the dialog box of a presentation.
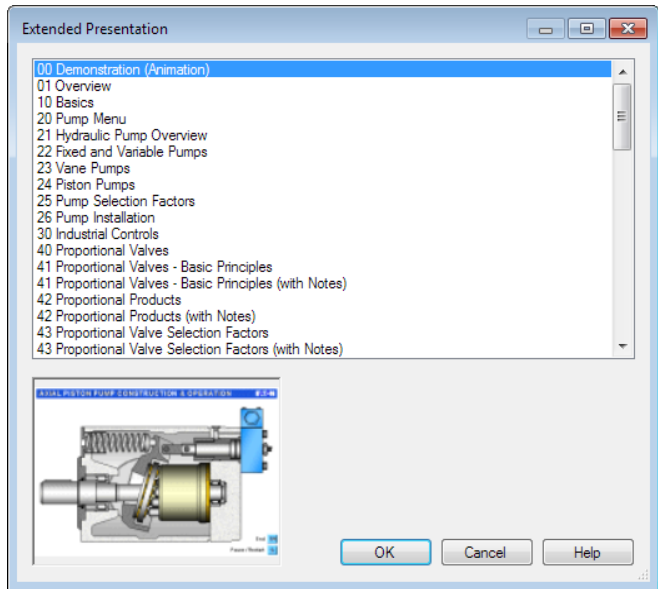
Figure 23/17: Selection of an extended presentation

┈┈> Select the item "Actuators" to open the related presentation in full screen mode.

Most of the topics form a picture sequence, which can be viewed in a single-step manner using the left mouse button or the spacebar.

┈┈> Move two single steps forward in the current presentation.
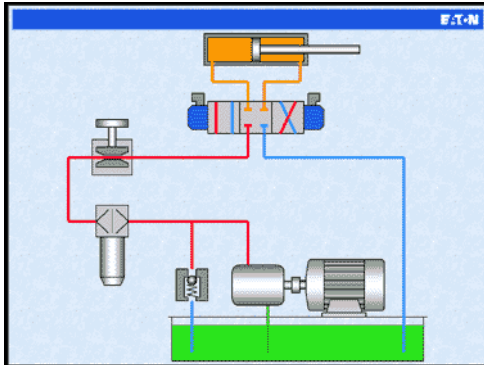
Figure 23/18: Actuators

When clicking the right mouse button, a context menu is opened by which, among others, the presentation can be closed or particular pictures picked out. The files of the extended presentations are in the subdirectory `ppx` of the FluidSIM installation. You can add new PowerPoint presentations on your own by copying the related files (format: "ppt" or "pps") into the `ppx` -directory. Like the other didactics material (illustrations of function, component photos, circuit drawings, educational films, etc.), the PowerPoint presentations can linked and used within presentations (cf. Section Presentations: Combining Instructional Material).

Didactics Material Survey (Pneumatics)

Chapter 24

This chapter provides a comprehensive listing of those parts of the didactics material in FluidSIM that are not covered by chapter The Component Library "The Component Library" . Basically, this material consists of the components' behavior illustrations, the animations, the exercises, and the educational films, which all can be activated under the Didactics menu. The subsequent sections are arranged thematically. The ▶ icon indicates that an animation exists for the related topic. The last section gives an overview of the educational films.

24.1 Basics
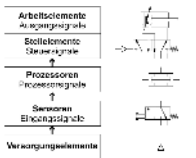
[1] Pneumatic system structure and signal flow

A pneumatic system can be broken down into a number of levels representing the hardware and signal flow from the energy source to the actuating devices.

----→ The topic highlights the relationship between signals, levels and elements in a pneumatic system.
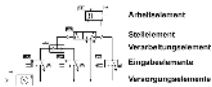
[2] Circuit diagram and pneumatic elements

Circuit diagrams are drawn in such a way that signals, for instance energy or potential values, are oriented downwards. The numbering of the components is derived from their respective function in the diagram.

----→ The topic highlights the various levels in a circuit.
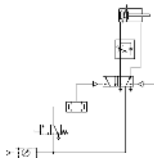
[3] Designating the elements, circuit diagram

This topic shows the relationship between levels in a circuit.
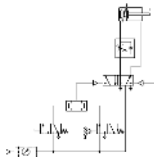
[4] Designating the elements, circuit diagram

The figures contrasts the position of a roller lever valve (initial position: actuated by the cylinder) in a circuit diagram and its physical setup in a plant.
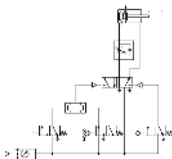
[5] Designating the elements, circuit diagram

The figures contrasts the position of a roller lever valve (initial position: not actuated) in a circuit diagram and its physical setup in a plant.
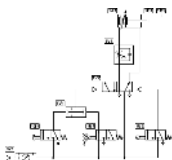
[6] Designating the elements, circuit diagram

All elements should be shown in the circuit diagram in the initial position. If valves have been drawn with an actuated initial position, this fact is indicated for example by an arrow, or for a limit switch, by drawing the cam.

----> Explain the differences between the following terms: initial position and starting position.

24.2 Supply elements

[7] Symbols of energy and supply components, supply and service equipment

The Symbols are from the DIN ISO 1219 "Circuit symbols for fluidic power components and systems". The symbols for the energy supply system can be represented as individual components or as combined elements.

⋯⋗ Compare the symbols with the combined symbols (topic 8).

[8] Symbols of energy and supply components, combined symbols
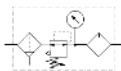
In general where specific technical details are to be given, such as requirements for non-lubricated air or micro-filtering, the complete detailed symbol should be used. If a standard and common air supply is used for all components, the simplified symbols can be used.

⋯⋗ Compare the symbols with the previous topic.

[9] Air service unit

The filter is normally combined with the pressure regulator and lubricator to form a compressed air service unit. The selection of the correct filter plays an important role in determining the quality and performance of the control system which is to be supplied with compressed air.

⋯⋗ Refer to topic 10 for construction of the filter.
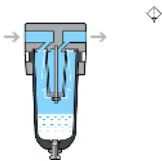
[10] Compressed air filter

The compressed air passes through a baffle plate in the filter bowl. The air is rotated, and the heavier dust particles and water droplets are spun by centrifugal force against the inner wall of the filter bowl and run down the wall of the housing. The air which has been precleaned then passes through the filter element.

┄┄⟶ The bowl must be emptied daily to prevent overflow.
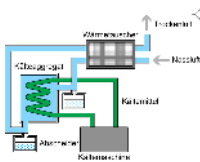
[11] Air drying, low temperature

The lower the dew point the more the water will condense and reduce the amount entrapped in the air. Using refrigeration methods, it is possible to achieve dew points of between 2º{C} and 5º{C}.

┄┄⟶ Compare with absorption and adsorption drying.
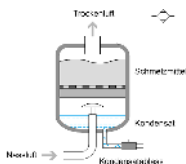
[12] Air drying, absorption

Absorption drying is a purely chemical process. The moisture in the compressed air forms a compound with the drying agent in the tank. This causes the drying agent to break down; it is then discharged as a fluid at the base of the tank. The drying agent must be replenished at a rate which is dependent on the compressed air temperature, water content and flow rate.

┄┄⟶ Compare with adsorption drying.
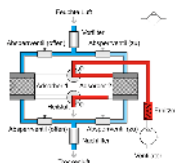
[13] Air drying, adsorption

The lowest equivalent dew points (down to -90º{C}) can be achieved by means of adsorption drying. In this process, the compressed air is passed through gel and the water is deposited on the surface, i.e. it is adsorbed.

⤳ Compare with absorption drying.
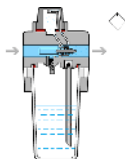
[14] Air lubricator

As a rule, the compressed air which is generated should be dry and free of oil. For some components, lubricated air is damaging, for others, it is undesirable, and for power components, it may in certain cases be necessary. Lubrication of the air should therefore be limited to the sections of the plant which require it.

⤳ Refer to picture of topic 9 for general arrangement.
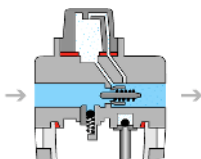
[15] Air lubricator

Air passing through the lubricator causes a pressure drop between the oil reservoir and the upper part of the lubricator. This pressure difference forces the oil upwards through a tube and it then drips into a nozzle which can be seen through an inspection glass. The oil is atomized and carried along by the air stream.

⤳ It is necessary to carefully adjust the oil discharge rate.
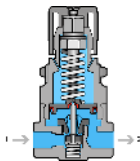
[16] Pressure regulator with vent hole

The purpose of the regulator is to maintain the operating pressure (secondary pressure) virtually constant regardless of fluctuations in the line pressure (primary pressure). When air consumption increases, the operating pressure drops and the spring opens the valve. If the pressure on the secondary side increases considerably, the center-piece of the diaphragm then opens and the compressed air can flow to atmosphere through the vent holes in the housing.
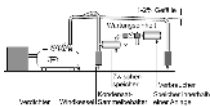
[17] Delivery

Due to the pressure losses in the system, the compressor should deliver between 650 and 700 kPa (6.5 and 7 bar). The operating components of the system should be regulated to between 500 and 600 kPa (5 and 6 bar) for economic use. The receiver is used to even out fluctuations in pressure due to demand. The drainage points are at the lowest points.

⤳ The gradient should be away from the compressor.
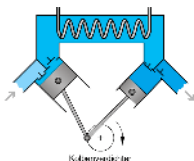
[18] Piston compressor

The piston compressor is widely used. Multi-stage compressors are required for compressing to high pressure. The drawn in air is compressed by the first piston, cooled and then compressed further by the next stage.

⤍ Discuss the advantages and disadvantages of piston compressors.
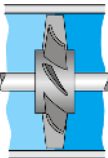
[19] Axial flow compressor

Flow compressors produce large volumes of air at small increases in stage pressure. The air is accelerated by the blades of the compressor but there is only a small increase in pressure.

⤍ The kinetic energy is converted to pressure energy.
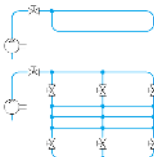
[20] Distribution

For ease of maintenance, repair or extension of the air network, it is advisable to sub-divide the network into individual sections by means of shut-off valves. Branches with T-pieces and manifolds with plug-in couplings make it possible to supply additional consuming devices as the need arises.

⤍ To discharge condensate, the pipes should be inclined 1-2 % and include water separators at low points.

[21] Absolute pressure and atmospheric pressure

Absolute pressure is calculated from the absolute zero mark. Below atmospheric pressure the pressure is in the vacuum range. The

atmospheric pressure fluctuates but is approximately 100 kPa (1 bar).

┈┈⟩ Gauge pressure is normally that component above atmospheric pressure and is not an absolute value.

24.3 Actuators
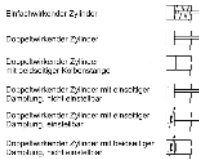
[22] Symbols for actuators, linear actuators

The single acting cylinder and the double acting cylinder form the basis for design variations. The use of cushioning to reduce loads on the end caps and mountings during deceleration of the piston is important for long-life and smooth operation.

┈┈⟩ Refer to topics 25 - 30 for construction details.
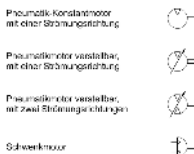
[23] Symbols for actuators, rotary motion

Rotary actuators are divided into continuous motion and limited angle of rotation. The air motor is normally a high speed device with either fixed or adjustable speed control. Units with limited angle of rotation are fixed or adjustable in angular distance. The rotary actuator may be cushioned depending on the load and speed of operation.

┈┈⟩ Refer to topics 34 and 35 for construction details.
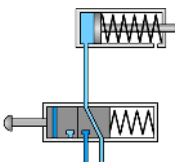
[24] Control of a single acting cylinder

The position rod of a single acting cylinder is to move forward when air is applied. A valve is to create a signal when a push-button is released. The animation shows the operation of the push-button and the extension of the cylinder. Pressure is maintained on the

piston until the push-button is released. The next stage shows retraction of the cylinder and the release of air via the exhaust port of the 3/2-way valve.

⤏ The topic can be used as an intermediate stage for explanation of the related symbols.
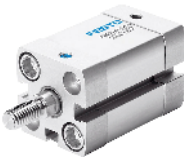
[25] Single acting cylinder

The cylinder requires one pneumatic connection and an exhaust port. The exhaust port must be clear of obstructions to ensure that the piston is not restricted by the air passage. A filter is normally fitted to the exhaust port.

⤏ Discuss the importance of selecting the size of the cylinder to match the load conditions.

[26] Single acting cylinder

With single acting cylinders, compressed air is applied on only one side of the piston face. The other side is open to atmosphere. The cylinders can perform work in only one direction. The return move-ment of the piston is effected by a built-in spring or by the applica-tion of an external force. The spring force returns the piston to its start position with a reasonably high speed under no load condi-tions. The stroke is limited by the natural length of the spring. Single acting cylinders are therefore only available in stroke lengths of up to 100 mm.

⤏ Compare the construction with the double acting type. Discuss the spring size and return speed.
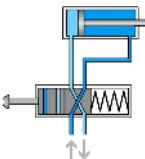
[27] Control of a double acting cylinder

The 4/2-way directional control valve is suitable for the control of a double acting cylinder. Normal practice is to use the 5/2-way valve.

The cylinder motion is controlled by air in both directions of motion. The animation shows the advance and retraction sequences as separate phases. The fully advanced position is related as long as the push-button is actuated.

⤏ The topic can be used as an intermediate stage for explanation of the related symbols.

[28] Double acting cylinder

Double acting cylinders are used particularly when the piston is required to perform a work function in both directions of motion. The construction is in general similar to the single acting cylinder.

⤏ Refer to the large number of variants, which result from the different designs, materials, etc.
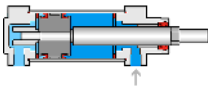
[29] Double acting cylinder

The first sequence shows the piston rod advancing. The second stage the retraction. The speed of advance and retraction are fairly constant under no load conditions.

⤏ Point at the positions of cylinder body, piston cover, cylinder cover, piston seal, piston rod, bearing bush, and scraper ring.
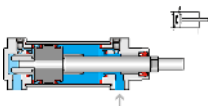
[30] Cushioned double acting cylinder

If large masses are moved by a cylinder, cushioning is used in the end positions. Before reaching the end position, a cushioning piston interrupts the direct flow of air to the outside. For the last

part of the stroke the speed is slowed to reduce impact on the cylinder.

⟶ Discuss the different concept of throttling the exhausting air by means of one-way flow control valve.
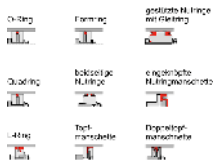
[31] Cylinder seals

The various piston seal arrangements are shown. The double-cup seal materials used are, Perbunan for -20°{C} to +80°{C} Viton for -20°{C} to +190°{C} Teflon for -80°{C} to +200°{C}.

⟶ Emphasize correct temperature range selection for reliability.
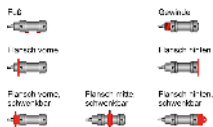
[32] Mounting arrangements for cylinders

The type of mounting is determined by the manner in which the cylinder is to be fitted to a machine or fixture. The cylinder can be designed with a permanent type of mounting if it does not have to be altered at any time. Alternatively, the cylinder can utilize adjustable types of mounting which can be altered by using suitable accessories on the modular construction principle.

⟶ Discuss application examples for each type of mounting.
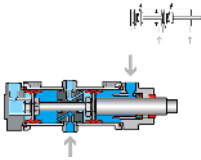
[33] Tandem double acting cylinder

This design features the characteristics of two double acting cylinders forming a single unit. This increases the effective piston area of the unit for high force applications. It is suitable for applications where a large force is required but the cylinder diameter is restricted.

---→ Compare the double acting cylinder in topic 29.
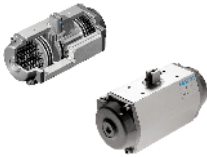
[34] Semi-rotary actuator

The rotary actuator is compact with high torque ratings. The force is transmitted to the drive shaft by a rotary vane. The range of angular movement is adjustable with end stops. The angle can be adjusted between 0º and 180º. The adjustable stop system is separate to the rotary vanes. This allows force to be absorbed by the stop blocks. At the end positions, impacts are cushioned by elastic cushioning rings.

---→ Discuss the mounting arrangements for the actuator. Discuss applications for the rotary actuator.
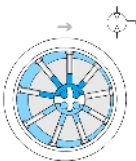
[35] Air motor

Devices which transform pneumatic energy into mechanical rotary motion, with the possibility of continuous motion. They are categorized into the groups of piston motors, sliding vane motors, gear motors and turbines.

----> Discuss applications for the air motor.

24.4 Directional control valves

[36] Symbols for directional control valves (1)

The directional control valve is represented by the number of ports and the number of switching positions. Additional information is required to fully describe the symbol function, including the methods of actuation and special flow path characteristics.

----> Compare the full range of symbols for directional control valves.

[37] Symbols for directional valves (2)

Each valve position is shown as a separate square. The designation of the ports is important when interpreting the circuit symbols and the valve as fitted to the physical system.

----> Compare the full range of symbols for directional control valves.

[38] Designation of connections
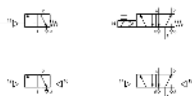
The designations for directional control valves are in accordance with ISO 5599-3, edition 1990. Prior to this a lettering system was utilized.

----> Discuss the examples and emphasize the numbering systems.

[39] Methods of actuation (1)

The methods of actuation of pneumatic directional control valves are dependent upon the application. The methods of actuation include manual, mechanical, pneumatic, electrical and combined.

----> Discuss the actuation and return actuation methods.

[40] Methods of actuation (2)

When applied to a directional control valve, consideration must be given to the method of initial actuation of the valve and also the method of return actuation. They are both shown on the symbol either side of the position boxes. There may also be additional methods such as manual overrides separately indicated.

----> Discuss the actuation and return actuation methods.
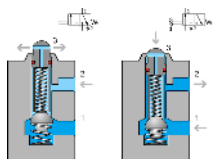
[41] 3/2-way valve, ball seat

A spring forces a hemisphere against the valve seat preventing the compressed air from flowing from the air connection 1 to the working line 2. Initially port 1 is blocked and the output port 2 is exhausted through the stem of the plunger. Actuation of the valve plunger causes the sealing element to be forced away from the seat. In doing this, the opposing force of the reset spring and that generated from the compressed air must be overcome. The air supply is then open to the output side of the valve and a signal is generated.

----> Compare the symbol and the valve construction. Compare the construction of the disc seat valve.

[42] 3/2-way valve, ball seat

The ball seat valve is compact with the possibility of fitting various types of actuating heads. The limitation for directly actuated valves is the force required to operate the stem. If the flow rate required is very high, the valve ball will have a large working area. This requires a large operating force. This limits the size of valve for this design.

⤏ The load on the stem is dependent on the size of valve.
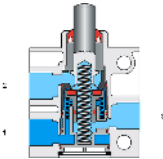
[43] 3/2-way valve, disc seat, normally closed

The valve is constructed on the disc seat principle. The response time is short and a small movement results in a large area being available for air flow. Valves of the single disc seat type are non-overlapping. Using this topic, discuss the term "blocked normal position". When operated slowly, there is no loss of air. A 3/2-way valve with flow blocked between ports 1 and 2 in the normal condition, is referred to as a normally closed valve. The valves are insensitive to dirt and thus have a long service life. Explain the term "non-overlapping" with this figure and the animation.

⤏ The animation sequence shows the operation of the 3/2 way valve. The first sequence describes the actuation and the supply of a signal from 1 to 2. The second sequence shows the closing of the disc seat and the release of air from 2 to 3 which exhausts to atmosphere.
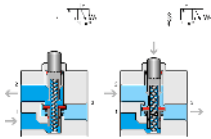
[44] 3/2-way valve, disc seat, normally open

A 3/2-way valve with free flow between ports 1 and 2 in the normal condition, is referred to as normally open. Valves can be operated manually, mechanically, electrically or pneumatically. The configuration of the valve head is changed to meet the actuation method. Upon operation of the actuating stem, the disc seat is sealed and air supply port 1 is blocked. The air at port 2 is exhausted to atmosphere via port 3.

---⇢ Note the change of construction compared to the normally closed valve topic 43.
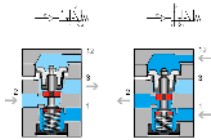
[45] 3/2-way valve, single pilot, normally closed

The pneumatically operated 3/2-way valve is operated by a directly acting signal at port 12. This is referred to as a single pilot valve since there is only one control signal and the valve has a spring return. A signal is applied at port 12 and the valve plunger is moved against the reset spring. The connections 1 and 2 are then interconnected creating a signal 2. The pressure at port 12 must be sufficient to move the disc against the supply pressure.

---⇢ Note the pneumatic symbol shows direct application of the signal at port 12. Compare the construction of the valve to the 3/2-way disc seat valve topic 43.

[46] 3/2-way valve, single pilot

The valve ports are labeled to ensure the correct connections are made. The pilot valve is available in a range of sizes depending upon the flow rate.

⋯⋗ Note the need to designate and label the ports.

[47] 3/2-way valve, internal pilot, roller operated

This type of valve can be used as either a normally closed valve or as a normally open valve by exchanging connections 1 and 3 and rotating the actuating head 180 degrees. The force required on the roller lever is small due to the pilot operation.

⋯⋗ Show the requirements to alter the valve configuration.
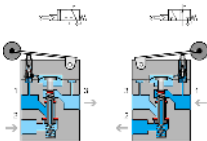
[48] 3/2-way valve, internal pilot, normally closed

To avoid high actuating force, mechanically controlled directional valves can be equipped with an internal pilot valve to assist opening. A small hole connects the pressure connection 1 and the pilot valve. If the roller is operated, the pilot valve opens. Compressed air flows to the main piston and actuates the main valve disc.

⋯⋗ The symbol shows the roller operating a pilot signal.

[49] 4/2-way valve, disc seat

The valve is robust. Two stems directly operate the disc seats. The load required to move the stems may be large for high flow rate valves.

┄┄> Compare the construction with the 3/2-way valve.

[50] 4/2-way valve, disc seat
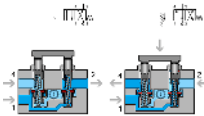
The 4/2-way valve has four ports and two positions. A disc seat 4/2-way valve is similar in characteristic to the combination of two 3/2-way valves, one valve normally closed and the other normally open. The plungers can be operated by an auxiliary mounted device such as a roller lever or push-button. When the two plungers are actuated simultaneously, 1 to 2 and 4 to 3 are closed by the first movement. By pressing the valve plungers further against the discs, opposing the reset spring force, the passages between 1 and 4 and from 2 to 3 are opened.

┄┄> Show the similarities to the 3/2-way valve construction. Discuss the valve overlap.

[51] 4/3-way valve, mid-position closed
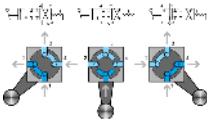
The 4/3-way valve has four ports and three positions. An example of the 4/3-way valve is the plate slide valve with hand or foot actuation. By turning two discs, channels are interconnected with one another.

┄┄> Compare the symbol with the valve construction.
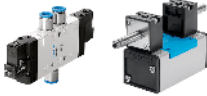
[52] 5/2-way valve, longitudinal slide valve

The valve can be mounted onto a common sub-base for supply and exhaust air. This compact arrangement also ensures adequate flow is available to the valve.

---> Discuss the DIN ISO 5599/1 standard for 5 port valves.
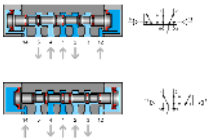
[53] 5/2-way valve, longitudinal slide valve

The 5/2-way valve has five ports and two positions. The 5/2-way valve is used for the control of cylinders primarily as a final control element. In pneumatic valves, the gap between spool and housing bore should not exceed 0.002–0.004 mm. The valve is shown here with pilot pressure applied at port 12. To avoid damage to seals, the ports can be distributed around the circumference of the housing. The actuation travel is considerably larger than with seat valves. The valve is shown here with pilot pressure at 14.

---> Discuss the load conditions on the O-rings. Compare the construction with the disc seat valve.
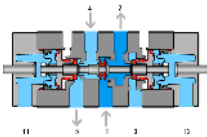
[54] 5/2-way valve, suspended disc seat

A method of sealing the 5/2-way valve is to use a suspended disc seat with a relatively small switching movement. The disc seat seal connects the 1 port to either the 2 port or the 4 port. The 5/2-way double air pilot valve has the characteristic of memory control. The last switched position is retained until a new switching position is initiated by a unique pilot signal from the opposite side. There are

two manual override buttons to manually operate valve spool. The animation shows the two switched positions. The air pilot signals are applied from both directions. The manual override operations are also shown. The manual overrides are used to manually actuate the valve or initialize the valve position.

----→ Compare the suspended disc seat construction to the longitudinal slide principle topic 53. Explain the working principle of the manual override button and its related diagram symbol.
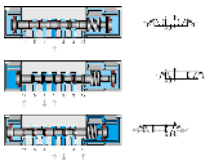
[55] 5/3-way valve

The 5/3-way valve has five ports and three positions. Signals applied at ports 14 or 12 operate the valve. If the valve is not actuated it is closed in the mid-position. After actuation via a pilot signal at port 14 air flows from 1 to 4. Port 2 exhausts via 3. After actuation via a pilot signal at port 12 air flows from 1 to 2. Port 4 exhausts via port 5.

----→ Show the three valve positions.
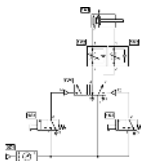
[56] Memory circuit, 5/2-way bistable valve

The piston rod of a double acting cylinder is to advance when a 3/2-way push-button valve is actuated. The cylinder is to remain extended until a second push-button is actuated. The cylinder is to then return to the initial position. The speed of the cylinder is to be adjustable in both directions.

----→ Discuss the memory characteristic of the bistable valve.

[57] Memory circuit, 5/2-way bistable valve

Signals initiated by the push-button signaling devices can be of short or pulse duration due to the memory characteristics of the bistable valve. Upon operation of push-button 1S1, a 1-signal is generated at port 14 of the control valve 1V3. The 5/2-way memory valve switches and the cylinder 1A1 advances.
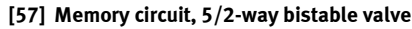
⟶ The circuit is shown at the first operation of the button.

[58] Memory circuit, 5/2-way bistable valve

When the push-button 1S1 is released, the signal at port 14 is exhausted. The valve 1V3 remains in the current position. The last position is retained until a new input signal is given.

⟶ Compare the sequence of operation.

[59] Memory circuit, 5/2-way bistable valve

The valve 1V3 remains in the current position until the push-button 1S2 is operated. The cylinder then retracts. The cylinder remains retracted until a new signal is generated at port 14 by the valve 1S1.

⟶ Compare the sequence of operation.

[60] Memory circuit, 5/2-way bistable valve

The flow control valves throttle the exhausting air in both directions of piston motion. The cylinder remains retracted until a start signal is generated at port 14 by the valve 1S1. The 5/2-way valve remains in the current position with air supplied continuously to the return side of the cylinder.

⟶ Discuss the situation when both 1S1 and 1S2 are operated together.
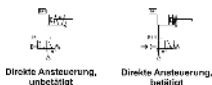
[61] Direct control, unactuated

A single acting cylinder of 25 mm diameter is to clamp a component when a push-button is pressed. As long as the push-button is operated, the cylinder is to remain in the clamped position. Since the cylinder is the only working element or actuator in the circuit, it is designated 1A1. The final control element that advances the cylinder is designated 1S1.

⤑ Discuss the circuit layout standard, numbering and operation. Note the circuit is shown in the initial state.
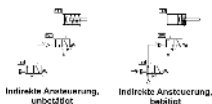
[62] Indirect control (unactuated)

A large diameter single acting cylinder is to extend upon operation of a push-button valve. The valve is situated at a remote and distant position. The cylinder is to retract once the remote push-button is released. The signal at the pilot port 12 remains as long as the push-button is held down. This is an indirect push-button control of the cylinder. If the push-button is released, the spring return closes the 3/2-way valve and removes the pilot signal at the control valve.

⤑ Discuss the circuit layout standard, numbering and operation. Note the circuit is shown in the initial state.

[63] Exercise: Direct control of a double acting cylinder – Problem
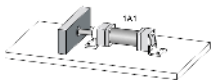
A double acting cylinder is to advance when a push-button is operated. Upon release of the push-button, the cylinder is to retract. The cylinder is of small bore (25 mm diameter) requiring a small flow rate to operate at the correct speed.

[64] Exercise: Direct control of a double acting cylinder – Solution

The control valve for a double acting cylinder can be selected as a 4/2 way or a 5/2 way valve. In this case, since the cylinder has a

small capacity, the operation can be directly controlled by a push-button control valve with spring return. On operating the push-button, the air passes through the valve from port 1 to the port 4 and advances the piston rod. On release of the push-button, the valve spring returns the control valve to its initial position and the cylinder retracts. Air escapes from the cylinder via the exhaust port. Since the cylinder is the only working element or actuator in the circuit, it is designated 1A1. The final control element that advances the cylinder is designated 1S1.
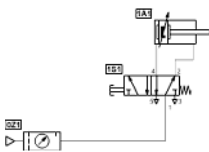
[65] Exercise: Direct control of a double acting cylinder – Note

---> If the push-button is pressed for a very short period, the cylinder only partially advances and then retracts, since the spring resets the control valve as soon as the push-button is released. In order to achieve full extension in this case, the push-button must be held down until the cylinder moves fully forward.
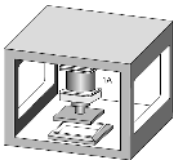
[66] Exercise: Indirect control of a double acting cylinder – Problem

A double acting cylinder is to advance when a push-button is operated. Upon release of the push-button the cylinder is to retract. The cylinder is 250 mm diameter and consumes a large volume of air. For controlling cylinders at high speed or of large diameter large size control valves should be used. The operating force to actuate the valve may be relatively large and in this case indirect control is preferable.

[67] Exercise: Indirect control of a double acting cylinder – Solution

Operating valve 1S1 supplies a pilot signal to port 14 of control valve 1V1. This generates a 1-signal at the outlet 4 and the cylinder advances. If the push-button is released the return signal is supplied via port 2 of valve 1V1 and the return air is vented via exhaust port 5. If the push-button is released before the cylinder fully ad-

vances, the cylinder immediately returns to the initial position. The
control valve requires a sustained signal for it to remain operated.

---→ Explain the benefits of indirect control: The required actuating
force is reduced, the working lines can be kept short, since the
actuator can be mounted close to the cylinder, and the signal-
ing element can be small since it has to generate only the sig-
nal for actuating the control valve.
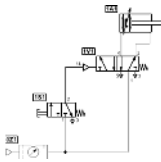
[68] Exercise: Indirect control of a double acting cylinder – Note

---→ The supply line can be short since the control valve can be
mounted close to the cylinder. The other advantage is that the
signal element (i.e. push-button 3/2 way valve) can be small,
as it only provides a signal to operate the control valve and is
not required to operate the cylinder directly.

24.5 Shutoff valves

[69] Non-return valves

The non-return or check valve will open due to the supply pressure
exceeding the resistance of the spring (if fitted) and the inertia of
the valve. The non-return valve is the basis for development of
many combined components. The shuttle valve, two pressure valve
and quick exhaust valve incorporate features of the non-return
valve.

---→ Indicate the valves that include the non-return function.

[70] Non return valve

Non return valves can stop the flow completely in one direction. In
the opposite direction the flow is free with a minimal pressure drop

due to the resistance of the valve. The one-way blocking action can be effected by cones, balls, plates or diaphragms.

⋯⋯⟩ Discuss the relationship between pressure to open and the spring size.
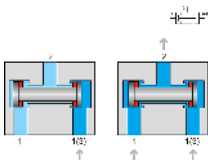
[71] Two pressure valve

The two pressure valve has two inputs 1 and one output 2. The two pressure valve is used mainly for interlocking controls, safety controls, check functions or logic operations. The application of a signal at a single input produces no pressure at output 2. If pressure is applied at both inputs 1, the signal which is last applied passes to the output 2. The two pressure circuit is equivalent to two input signaling devices in series, i.e. one after the other.

⋯⋯⟩ Refer to topics 72 - 74 for the circuit example. Discuss the advantages of the shown solution against series connection.
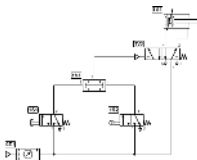
[72] Circuit: Two pressure valve I

The piston rod of a double acting cylinder is to advance when a 3/2-way push-button valve and a roller lever valve are actuated. If either of the actuations is released, then the cylinder is to return to the initial position.

⋯⋯⟩ Discuss the circuit layout standard, numbering and operation.
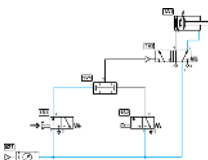
[73] Circuit: Two pressure valve II

The inputs of the two pressure valve are connected to the outputs of the two 3/2-way valves. Upon operation of the push-button 1S1, a signal is generated at the left side of input 1 of the two pressure valve. The signal is blocked by the two pressure valve. No output is given at 2.

→ Discuss the logic function "AND". Refer to the for additional conditions.
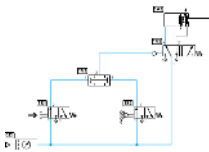
[74] Circuit: Two pressure valve III

If the roller lever valve 1S2 is also operated, then the two pressure valve will produce a 1-signal at port 2 which operates the control valve, via pilot port 1V1, against the return spring and the cylinder advances.

→ Compare this topic to .
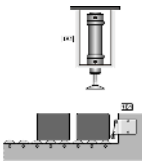
[75] Exercise: The logic AND function, the two pressure valve – Problem

A transfer station removes a product from a conveyor belt. If the product is detected as present and if the operator presses the push-button, the pick-up cylinder 1A1 advances. The product is sensed by a 3/2 way roller lever valve. Upon release of the push-button, cylinder 1A1 is to retract to the initial position. The operating condition for the pick-up cylinder to advance is a logic AND function between the product sensor and the operator push-button. Therefore if a two pressure valve is used to combine the signals from the sensor and push-button the logic conditions can be met.

[76] Exercise: The logic AND function, the two pressure valve – Solution

The two pressure valve is connected between the outlet lines of the two 3/2 way valves. Operating the push-button, a 1-signal is generated at left input 1 of the two pressure valve. Once the part is sensed as present, the 3/2 way roller valve generates a second 1-signal, this time at the right input 1 of the two pressure valve. A signal is passed through to port 2. This signal operates the control valve pilot signal 14 against the spring return and the cylinder advances. If either of the two signals created by the 3/2 way valves is set to zero, the two pressure valve will release the 14 signal back through the exhaust port of one of the 3/2 way valves. The return

spring in the control valve then switches the control valve to the initial position. The control valve outlet port 2 is active and with outlet port 4 exhausted to atmosphere the cylinder retracts. The control valve can be a 4/2 or 5/2 way valve and can be sized to suit the flow rate required for the cylinder speed.
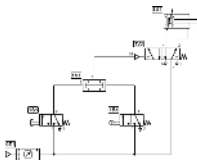
### [77] Exercise: The logic AND function, the two pressure valve – Note

Discuss also the advantages of the shown solution against series connection.

[78] Shuttle valve

This non-return element has two inputs 1 and one output 2. If compressed air is applied to one input, the valve seat seals off the opposing input and air flows to output 2. Note the similarity in construction to the two pressure valve.

⤑ Compare the two pressure valve construction topic 71.
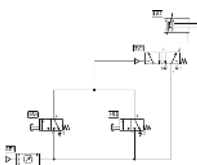
[79] Circuit: Shuttle valve I

If the condition states that either of two push-buttons is to advance a cylinder, the inexperienced designer may attempt to use a junction for the output signals of 1S1 and 1S2. The circuit is not functional due to the escape of air through the exhaust ports of the valves.

⤑ Discuss the sequence of circuits for the shuttle valve.
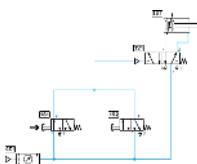
[80] Circuit: Shuttle valve II

If push-button 1S1 is operated, the air escapes to atmosphere through the exhaust port of 1S2. The air takes the easiest path and the pressure will be very low and inadequate to operate the valve

1V1. This is an inadequate solution to the problem. A shuttle valve is required.

⋯⟩ Compare the topic with the .
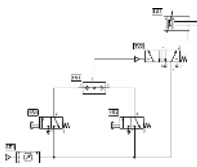
[81] Circuit: Shuttle valve III

The piston rod of a double acting cylinder is to advance when either of two 3/2-way push-buttons is actuated. If both push-buttons are then released, the cylinder is to retract. The shuttle valve is incorporated at the junction and the circuit now functions correctly.

⋯⟩ Note the function of the ball in the shuttle valve acting as a non-return valve.
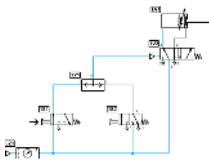
[82] Circuit: Shuttle valve IV

The shuttle valve is connected to the junction between the two 3/2-way push-button valves. Upon operation of one of the push-buttons, a signal is generated at the X or Y port of the shuttle valve and an output signal is emitted at port 2. The cylinder advances.

⋯⟩ Compare the topic with the .
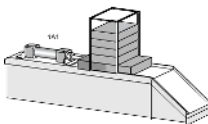
[83] Exercise: The logic OR function, the shuttle valve – Problem

A cylinder is used to transfer parts from a magazine. If either a push-button or a foot pedal is operated, then the cylinder is to advance. Once the cylinder has fully advanced, it is to retract to the initial position. A 3/2 way roller lever valve is to be used to detect forward end position of the cylinder.
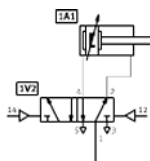
[84] Exercise: The logic OR function, the shuttle valve – Solution

The shuttle valve is connected to the junction between the two manual 3/2 way valves. Upon operation of one of the manual 3/2 way valves, a 1-signal is generated at either input 1 of the shuttle

valve. This signal passes through the shuttle valve and is emitted at port 2. This operates the control valve via pilot port 14, and the cylinder advances. A limit valve 1S2 senses that the cylinder has fully extended. Pilot signal 2 from valve 1S2 actuates the 5/2 way valve via port 12 and the cylinder retracts. The signal at port 12 is only effective, if the opposing signal at port 14 is released. If both of the signals produced via the push-button valves are set to zero, then the shuttle valve will release the pilot signal 14 back through the exhaust port of one of the 3/2 way valves. In other words, both the push-button and the foot pedal must be inactive for retraction to occur. The control valve can be a 4/2 way or 5/2 way valve and can be sized to suit the flow rate required for the cylinder speed.
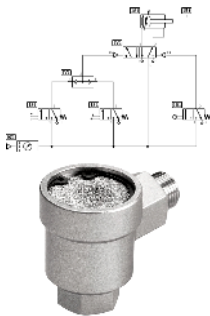
[85] Exercise: The logic OR function, the shuttle valve – Note

┈┈> The necessity of the shuttle valve can be explained with topic 79.

[86] Quick exhaust valve

To reduce resistance to flow, the air is expelled to atmosphere through a large orifice thus increasing cylinder piston speed. The valve is normally silenced so as to reduce exhaust air noise.
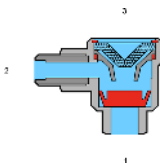
[87] Quick exhaust valve

Quick exhaust valves are used to increase the piston speed of cylinders. Lengthy return times can be avoided, particularly with single acting cylinders. To reduce resistance to flow, the air is expelled to atmosphere close to the cylinder and through a large orifice. In the direction 1 to 2 the air is passed freely via the open-ing of the non-return seal. Port 3 is blocked by the disc. If air is supplied to port 2, the disc seals port 1. Air is expelled to atmos-phere through the large orifice 3. Mount the quick exhaust valve directly on the cylinder, or as near as possible.

┈┈> Refer to topic 88 for the circuit example.
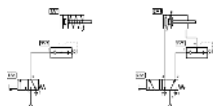
[88] Circuit: Quick exhaust valve

A cylinder piston rod is to travel at an increased speed, utilizing the quick exhaust valve. The forward motion of the piston rod is assisted by the release of exhausting air at the quick exhaust valve. The return stroke is unchanged due to the bypass non-return valve.

⤏ Refer to topic 70 for construction of the valve.
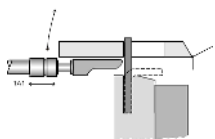
[89] Exercise: The quick exhaust valve – Problem

A cylinder advances a forming tool on an edge-folding device. If a sheet is detected as present and if a push-button is pressed, then the cylinder is to advance. For rapid forward travel, the circuit utilizes a quick exhaust valve. The forward movement folds the edge of a flat sheet. If the push-button is released, the double acting cylinder is to return slowly to the initial position.
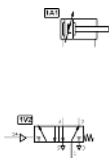
[90] Exercise: The quick exhaust valve – Solution

Initial position: In the initial state, the cylinder assumes the retracted position. If both of the 3/2 way valves are actuated, pressure is present at the output port 2 of the two pressure valve 1V4. This reverses the 5/2 way control valve. The cylinder advances with air being supplied via an unrestricted passage through the one-way flow control valve 1V1. The actuator travels rapidly to its forward end position since the pressure space on the piston rod side is rapidly exhausted through the quick exhaust valve. If both 3/2 way valves remain actuated, the cylinder remains in the forward end position. If the push-button is released, the actuator is no longer pressurized, since the control valve reverses via the return spring. The actuator travels to its initial position under conditions of restricted flow (valve 1V1) and therefore at a reduced speed.
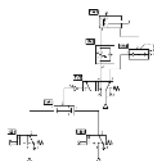
[91] Exercise: The quick exhaust valve – Note

┄┄> The quick exhaust valve should be fitted as near as possible to the connection of the cylinder to reduce resistance to flow.

24.6 Flow control valves

[92] Flow control valves

One-way flow control valve

Flow control valve adjustable

Most flow control valves are adjustable. If the non-return valve is fitted, then the element is a one-way flow control valve.

┄┄> Discuss the flow in both directions in both cases.

[93] One-way flow control valve

The valve is generally mounted as close to the cylinder as possible. The valve is usually provided with a locking nut to allow finite adjustments to be regulated and then set.
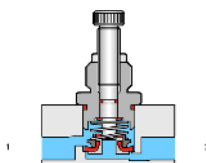
[94] One-way flow control valve

One-way flow control valves influence the volumetric flow of the compressed air. One-way flow control valves are normally adjustable and the setting can be locked in position. The influence of speed control is in one direction only. The first sequence of the animation shows the total cross section of the one-way flow control valve. The animation will be shown in detail by zooming into the air passage area.

┄┄> Refer to topic 96 for the circuit example.
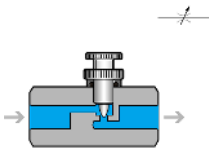
[95] Throttle valve

Throttle valves are normally adjustable and the setting can be locked in position. These valves are used to regulate the speed regulation of actuators and if possible, should be mounted directly on the cylinder.

┈┈⟶ Compare the flow control with throttle valves and one-way flow control valve topic 94.
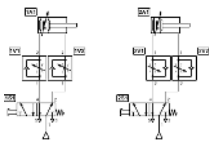
[96] Supply and exhaust air throttling

Exhaust air throttling should be used with double acting cylinder circuits. For supply air throttling, the flow valves are installed so that the air entering the cylinder is throttled. With exhaust air throttling, the supply air flows freely to the cylinder and the exhaust air is throttled.

┈┈⟶ Discuss the numbering system. Even numbers relate to advancing signals and odd numbers to the retracting signals.

24.7 Pressure control valves
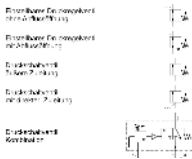
[97] Pressure control valves

The pressure control valves are generally adjustable against a compression spring. The sensing line for regulators is at the valve outlet and for sequence valves the sensing is before the valve, i.e. that pressure which is to be measured.

┄┈➤ Compare the sensing line positions and flow arrows.
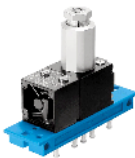
[98] Adjustable pressure sequence valve

The adjusting screw normally incorporates a look nut to set the desired position. The valve body is fitted to a sub-base which can frame mounted with other compact valves. Some applications for the valve are clamping, pressing, gluing and safety interlocks.
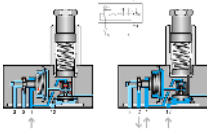
[99] Adjustable pressure sequence valve (unactuated)

Sequence valves are installed in pneumatic controls where a specific pressure is required for a switching operation. The output signal is transmitted only after the required operation pressure has been reached. If the signal pressure at port 12 exceeds that set on the spring, the valve opens. Outlet port 2 is opened only if a preset pressure has built up in pilot line 12. A pilot spool opens the passage between ports 1 to 2.

┄┈➤ Discuss the two elements in the control symbol. Discuss the adjustment required to set the desired operation pressure. A pressure gauge is required.
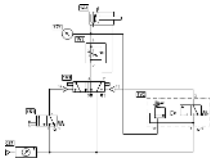
[100] Circuit: Pressure sequence valve

A plastic component is embossed using a die powered by a double acting cylinder. The die is to advance and emboss the plastic when a push-button is operated. The return of the die is to be effected when a preset pressure is reached. The pressure is to be adjustable.

[101] Exercise: Pressure dependent control, embossing of plastic – Problem

A plastic component is embossed using a die and a double acting cylinder. The die is to advance and emboss the plastic when a push-button is operated. The return of the die is to occur when the cylinder rod has fully advanced to the embossing position and a preset pressure is reached. A roller limit valve is to be used to confirm full extension. The embossing pressure is adjustable and is indicated on a pressure gauge.
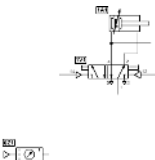
[102] Exercise: Pressure dependent control, embossing of plastic – Solution

The cylinder advances if valve 1V1 is switched by push-button valve 1S1. The pressure on the advancing side of the cylinder is fed from a junction to the limit valve 1S2 and then in series to the sequence valve. The signal port 12 at the sequence valve acts against the preset compression of the adjustable spring. If the limit valve 1S2 is operated due to full extension of the cylinder and the preset value is reached, then the sequence valve opens from 1 to 2 and sends a pilot signal to port 12 of the control valve 1V1. The memory valve switches and the cylinder retracts. At the same time the air from port 4 is exhausted and the pilot signal at the sequence valve is relieved through the limit valve.
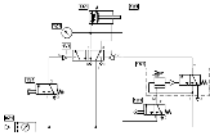
[103] Exercise: Pressure dependent control, embossing of plastic – Note

┈┈⟩ If the pressure does not reach the preset limit, then the cylinder will remain advanced. If the cylinder is obstructed during extension to the forward position, the cylinder will not retract due to the dependency upon operation of the limit vale 1S2. The power circuit must be initialized by operating the 5/2 way memory valve manually (via the manual overrides) with the air off. The air can then be turned on.

24.8 Time delay valve

[104] Time delay valve, normally closed

The valve has a lock-able adjusting screw for setting time. The valve is sized to meet the flow requirements.

┈┈⟩ Discuss the accuracy of the time delay valve.
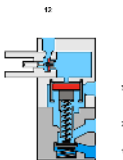
[105] Time delay valve, normally closed

The time delay valve is a combinational valve consisting of a 3/2-way valve, throttle relief valve and an air reservoir. The 3/2-way valve can be a valve with normal position open or closed. The delay time is generally 0-30 seconds for both types of valves. By using additional reservoirs, the time can be extended. When the necessary control pressure from 12 has built up in the air reservoir, the pilot spool of the 3/2-way valve is actuated. An accurate switch-over time is assured if the air is clean and the pressure constant.

┈┈⟩ Discuss the need for clean and stable air for accuracy. Discuss the relationship between time delay and the reservoir size.

[106] Circuit: Time delay valve

A double acting cylinder is to glue components. The push-button operates the clamping cylinder and trips a roller lever valve. The cylinder is to remain fully extended for a time of 6 seconds and then immediately retracts to the initial position. A new start cycle is only possible after the cylinder has fully retracted. The cylinder advance is to be slow and the retraction adjustable but fast.
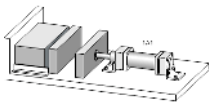
[107] Exercise: The time delay valve – Problem

A double acting cylinder is used to press together glued compo-nents. Upon operation of a push-button, the clamping cylinder advances and trips a roller lever valve. Once the forward end posi-tion is reached, the cylinder is to remain for 6 seconds and then immediately retract to the initial position. A new start cycle is only possible after the cylinder has fully retracted and after a delay of 5 seconds. The cylinder extension is to be slow and the retraction adjustable, but relatively fast.
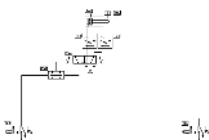
[108] Exercise: The time delay valve – Solution

The start conditions are the actuation of roller limit valve 1S3, a delay of 5 seconds after the end of cycle and the operation of 1S1. The two pressure valve 1V4 actuates the 5/2 way memory valve at port 14. The cylinder advances at a preset speed via the flow con-trol valve 1V2. The limit switch 1S3 is deactivated and therefore even if the start button is still held, the signal at port 14 is exhaust-ed by the removal of the limit switch signal, which resets the timer 1V6 until the cylinder has retracted again. The cylinder reaches the limit valve 1S2 and produces a pilot signal for the time delay valve 1V5. The time delay valve opens port 2 if the preset time is reached.

A pilot signal is produced 6 seconds after the limit valve 1S2 is operated. The 5/2 way valve switches to the initial position and the cylinder retracts and with speed controlled by the valve 1V1. The roller limit valve 1S2 is deactivated and the pilot signal to the timer 1V5 is cut-off, removing the signal at port 12 of the 5/2 way valve.

[109] Exercise: The time delay valve – Note

⤍ The memory valve must be positioned manually before air is supplied to the circuit to ensure that the cylinder will be retracted initially.
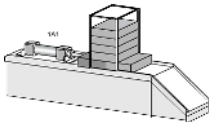
[110] Exercise: Memory circuit and speed control of a cylinder – Problem

A double acting cylinder is to fully advance when a push-button is actuated and to retract after full extensions is reached (confirmed by a roller lever valve). The cylinder is to continue forward even if the push-button is released. Speed of the cylinder is to be adjustable.

[111] Exercise: Memory circuit and speed control of a cylinder – Solution

Operating the push-button 1S1 then advances the cylinder 1A1. Operation of valve 1V3 produces pressure at port 14 which switches the air to port 4. Once the cylinder travels to the limit valve 1S2, a pilot signal is sent to port 12 of the control valve switching the control valve if the push-button valve is released. If the push-button is held operated after the cylinder has fully advanced, it will remain advanced until valve 1S1 is released. The final control element 1V3 is a memory valve and the last position is retained until a unique opposing signal is received. The speed of advance and retraction is controlled by the throttle valves 1V1 and 1V2 and in both cases the speed control is by exhaust air throttling. If the roller lever valve is fitted at the mid-stroke position of the cylinder, it will advance up to the limit valve and then retract.
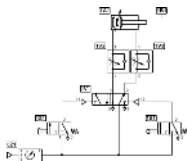
[112] Exercise: Memory circuit and speed control of a cylinder – Note

The memory control valve 1V3 when first fitted could be in either of two positions 14 or 12. It is not easy to predict the position of the valve when fitted. If a manual override button is available the valve should be manually set to the 12 position before turning on the air to ensure that the cylinder remains retracted initially.

24.9 Sequential circuit and signal overlap circuit
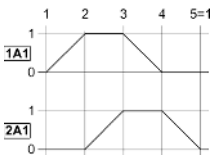
[113] Sequential circuit, distance-step diagram

Confirmation is required that cylinder 2A1 is retracted before start of the cycle. The sequence is, A+ B+ A- B-. The valves 2S2 and 1S3 are initially operated. There is no signal overlap at the final control elements 1V2 and 2V2.

┄┄> Discuss the relationship between the circuit and the distance-step diagram.
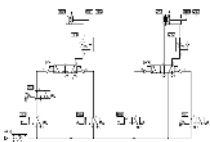
[114] Sequential circuit

A sequential circuit has the following characteristics; when a 3/2-way push-button valve is operated, cylinder 1A1 extends. Confirmation is required at each step of the sequence. The sequence is A+ B+ A- B-.

┄┄> There is no signal overlap with the circuit.
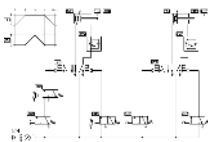
[115] Signal overlap circuit I

It is necessary to identify the points in the circuit where signal overlap occurs on the 5/2-way valves 1V2 and 2V2. With this distance step diagram the circuit design using roller valves cannot operate due to signal overlap.

---⟩ Refer to the next topics for the overlap conditions.
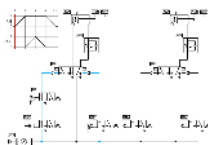
[116] Signal overlap circuit II

The first overlap condition occurs at the start. The pilot signals at the valve 1V2 from the valves 1S3 and 1S2 are opposed. The bistable valve cannot move due to overlap.

---⟩ Discuss the options for removal of overlap.

[117] Signal overlap circuit III

The second overlap condition occurs in the third step. The valve 2V2 has signals generated by 2S1 and 2S2 opposing each other and causing a signal overlap condition.

---⟩ Review the control diagram topic 118.
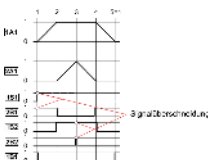
[118] Control diagram, signal overlap

The first control valve 1V2 has an overlap problem in the first step. The first of these signals must be out short and therefore valve 1S2 could be an idle return roller lever valve. The second overlap problem is with valve 2V2 in step 3, when the cylinder 2A1 is fully advanced. Valve 2S1 could be an idle return roller valve only active in step 2 for a short duration.

---⟩ Idle return roller valves are not a recommended solution.

[119] Idle return roller valve solution

The idle return roller limit switch can be used to remove the signal overlap points, i.e. replace the roller lever limit switches identified, with an idle return roller lever valve. Valves 1S2 and 2S1 generated the signal overlap and therefore these valves should be idle return roller valves.

⤑ Idle return roller valves are not a recommended solution.

[120] Reversing valve solution

An alternative method of shortening the duration of signals is to remove the air supply to the two signal valves, except at the steps required. Using the reversing valve 1V2, lines S1 and S2 can be activated consecutively and the signals are prevented from overlapping at the memory valves 1V1 and 2V1.

⤑ Emphasize the increased reliability of the circuit.

24.10 Educational Films

24.10.1   Educational Films

No.	Title	Length
1	Introduction	2:42
2	Fundamentals: Structure of hybrid systems	4:32
3	Fundamentals: Fundamentals of electricity	10:26
4	Sensors and relays – Signals	0:48
5	Sensors and relays – Sensors	3:24

6	Sensors and relays – Pressure switches	2:41
7	Sensors and relays – Relays	3:34
8	Solenoid valves	2:48
9	Solenoid valves: Double-solenoid valves	1:47
10	Solenoid valves: Pilot control	3:58
11	Pilot control: Circuit-diagram conventions	4:14
12	Pilot control: Hard-wired controllers	4:58
13	Pilot control: Programmable Logic Controllers	2:25

24.11 Standard Presentations

For several topics useful presentations have been provided within FluidSIM. The following table lists the titles of the predefined presentations.

24.11.1 Presentations

Presentation Title
All topics sorted by number
Basics
Supply elements
Actuators
Directional control valves
Shutoff valves
Flow control valves
Pressure control valves
Time delay valve

| Sequential circuit and signal overlap circuit |
| Educational films |

Didactics Material Survey (Hydraulics)

Chapter 25

This chapter provides a comprehensive listing of those parts of the didactics material in FluidSIM that are not covered by chapter The Component Library "The Component Library". Basically, this material consists of the components' behavior illustrations, the animations, the exercises, and the educational films, which all can be activated under the Didactics menu. The subsequent sections are arranged thematically. The ▶ icon indicates that an animation exists for the related topic. The last section gives an overview of the educational films.

25.1 Applications
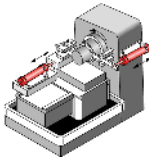
[1] Lathe

Machine-tool construction is a typical area of application of hydraulics. With modern CNC machine tools, the tools and workpieces are clamped by hydraulic means. Feed motions and the spindle drive can also be hydraulically powered.

⌁⟶ This can also serve as an example of hydraulic circuit with two pressure ranges, for example, 3 MPa (30 bar) for machining and 9 MPa (90 bar) for clamping.
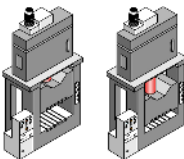
[2] Press with elevated reservoir

This is an application in which extremely high forces are required. Due to the suspended cylinder and the tractive load, special measures are required for the activation of the advance stroke. This in turn requires specially-designed press drives.

⌁⟶ A special feature is the elevated reservoir, which utilizes the static pressure in the pressure medium.
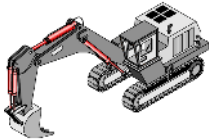
[3] Mobile hydraulics: Excavator

On this hydraulic excavator, not only all working movements (linear drives) but also the propulsion of the vehicle (rotary drive) is hydraulically powered. The primary drive of the excavator is an internal-combustion engine.

---≳ A model calculation can be used here to demonstrate an advantage of hydraulics - large forces with relatively small components.

25.2 Components of a Hydraulic Plant
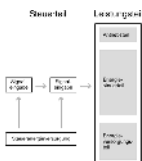
[4] Structure of a hydraulic system

This simplified block diagram shows the division of hydraulic systems into a signal control section and a hydraulic power section. This signal control section is used to activate the valves in the power control section.

---≳ The material depicted in these electronic slides is concerned in the main with the hydraulic power section and the three "levels" of this which are shown.
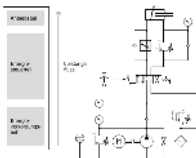
[5] Hydraulic power section

The diagram of the hydraulic power section is complemented in this case by a circuit diagram to allow correlation of the various function groups; the power supply section contains the hydraulic pump and drive motor and the components for the preparation of the hydraulic fluid. The energy control section consists of the various valves used to provide control and regulate the flow rate, pressure and

direction of the hydraulic fluid. This drive section consists of cylinders or hydraulic motors, depending on the application in question.
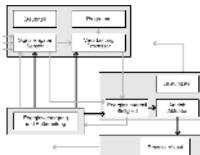
[6] Block diagram of a control system

In analyzing and planning an actual control task, it can be helpful to use a differentiated block diagram showing the actual levels to be found on the machine.

⸺⸺> The light arrows show the signal flow, while the solid dark arrows show the energy flow.
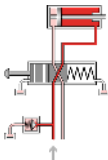
[7] Interaction of components

The animations show the sequences in a basic hydraulic circuit in simplified form - the actuation and spring return of the final control element (4/2-way valve), the advance and return of the drive component (double acting cylinder) and the opening and closing of the pressure relief valve.

⸺⸺> The representations of the actuator and final control element are based on the relevant circuit symbols. This can be used as a preparation for the introduction of circuit symbols.
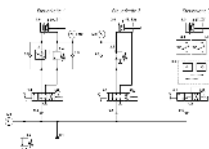
[8] Action related numbering

First of all the control chain is numbered sequentially according to the principle. The first actuator is given the supplementary number.0 and the associated final control element the supplementary number.1. The remaining elements get even numbers if they influence the advance stroke and uneven numbers if they influence the return stroke.

⸺⸺> The numbering should always be entered in the circuit diagram and also on the machine to enable systematic fault-finding.
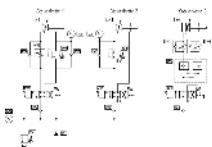
[9] Numbering in accordance with DIN ISO 1219-2

The DIN ISO Standard 1219-2 defines the code structure of the components as a string consisting of the following four parts: number of the plant, number of the circuit, component designation, and component number. If the entire system consists of a single plant only, the plant number may be dropped.
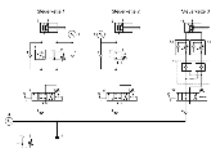
[10] Numbering in accordance with parts list

Another method used in practice is to number all the components in a hydraulic system consecutively. The numbers then correspond to the numbers in the parts list.

----> This method is used particularly with complex controls systems, for which a control-chain-related numbering system cannot be used due the overlaps involved.

25.3 Symbols

[11] Circuit symbols for energy transfer (1)

The symbols shown are used in circuit diagrams for energy transfer and hydraulic-fluid preparation.

----> In the interests of clarity, the lines in the circuit diagram should be drawn without cross-overs as far as possible.

reservoir	
filter	
cooler	
heater	
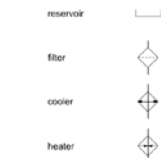
[12] Circuit symbols for energy transfer (2)

The direction of the arrows in the circuit symbols for the heater and cooler correspond to the direction of heat flow.

Konstant-Hydropumpe mit einer Stromrichtung	
Konstant-Hydropumpe mit zwei Stromrichtungen	
Elektromotor	
Wärmekraftmaschine	
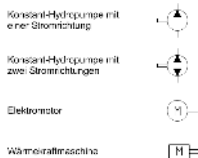
[13] Circuit symbols for energy conversion

Hydraulic pumps are shown by a circle with a part representation of a drive shaft. Triangles in the circles show the direction of flow. The triangles are shown solid, since pressure fluid is used in hydraulics.

> If the pressure medium is gaseous, as in the case of pneumatics, the triangles are shown in outline.
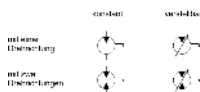
[14] Circuit symbols for hydraulic motors

	constant	verstellbar
mit einer Drehrichtung		
mit zwei Drehrichtungen		

The symbols for hydraulic motors are distinguished from the symbols for hydraulic pumps by the fact that the arrows showing the direction of flow are the other way round.
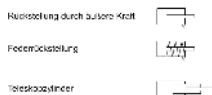
[15] Circuit symbols for single acting cylinders

Rückstellung durch äußere Kraft	
Federrückstellung	
Teleskopzylinder	

Single acting cylinders have one port, i.e. pressure fluid can be applied only to the piston side. With these cylinders, the return stroke is produced either by external force, shown in the symbol by an opening bearing cap, or by a spring is shown within the symbol in this latter case.

[16] Circuit symbols for double acting cylinders

Mit einfacher Kolbenstange	
Mit beidseitiger Kolbenstange	
Differenzialzylinder	
Tandemzylinder	
Mit beidseitiger einstellbarer Endlagendämpfung	

Double acting cylinders have two ports to allow pressure fluid to be applied to both cylinder chambers. The symbol for a differential cylinder is distinguished from the symbol for a double acting cylin-

der by the two lines added to the end of the piston rod. The area ratio is generally 2:1. In the case of cylinders with double- ended piston rods, the symbol shows that the piston areas are of equal size (synchronous cylinders).

Wegeventil	Ruhestellung	Symbol
2/2	Gesperrt (P, A)	
2/2	Durchfluss (P → A)	
3/2	Gesperrt (P, A → T)	
3/2	Durchfluss (P → A, T)	

[17] Circuit symbols for directional control valves (1)

Designations for directional control valves always give firstly the number of ports and then the number of switching positions. Directional control valves always have at least two ports and at least two switching positions. The number of squares shows the number of possible switching positions of a valve. Arrows within the squares show the direction of flow. Lines show how the ports are interconnected in the various switching positions of the valve. The designations always relate to the normal position of the valve.

[18] Circuit symbols for directional control valves (2)

Wegeventil	Ruhestellung	Symbol
4/2	Durchfluss (P → B, A → T)	
5/2	Durchfluss (A → R, P → B, B → T)	

This illustration shows the circuit symbols for 4/2- and 5/2-way valves.

‑‑‑→ There are two general methods for the designation of ports, using either the letters P, T, R, A, B and L or consecutively using A, B, C, D etc.; the first method is the preferred one in the relevant standard.

[19] Circuit symbols for directional control valves (3)

Wegeventil	Mittelstellung	Symbol
4/3	Gesperrt (P, A, B, T)	
4/3	Pumpenumlauf (P → T, A, B)	
4/3	Hebhebstellung (P → A → B → T)	
4/3	Ablaufabfangungumschaltet (P, A, B, T)	
4/3	Umschaltung (P → A → B → T)	

The illustration shows the circuit symbols for 4/3-way valves with various mid-positions.

[20] Circuit symbols for manual operation

Allgemeine Symbol, mit Federrückstellung und Endentastetelles

Handtaster und Federrückstellung

Handhebel und Rasterung

Pedal und Federrückstellung

The switching position of a directional control valve can be changed by various actuation methods. The symbol for the valve is accord-

ingly supplemented by a symbol indicating the actuation methods shown, such as pushbuttons and pedals, a spring is always necessary for resetting. Resetting can, however, also be achieved by actuating the valve a second time, for example in the case of valves with hand levers and detents.

⟶ The various actuating methods possible are listed in DIN ISO 1219.

[21] Circuit symbols for mechanical actuation

stem or push button

spring

roller stem

This illustration shows the symbols for stem or push button, spring and roller stem.

[22] Circuit symbol for pressure valves

Druckbegrenzungsventil

2-Wege-Druckregelventil

3-Wege-Druckregelventil

Pressure valves are represented using squares. The flow direction is indicated by an arrow. The valve ports can be designated as P (supply port) and T (tank return port) or as A and B. The position of the arrow within the square indicates whether the valve is normally open or normally closed. Adjustable pressure valves are indicated by a diagonal arrow through the spring. Pressure valves are divided into pressure relief valves and pressure regulators.

[23] Circuit symbols for flow control valves

A distinction is made in flow control valves between types which are affected by viscosity and those which are unaffected. Flow control valves unaffected by viscosity are termed orifices. A 2-way flow control valve consists of restrictors, one adjustable restrictor which is unaffected by viscosity (orifice) and a regulating restrictor (pressure compensator). These valves are represented by a rectangle containing the symbol for the adjustable restrictor and an arrow to represent the pressure compensator. The diagonal arrow through the rectangle indicates that the valve is adjustable.

[24] Circuit symbols for non-return valves

The symbol for non-return valves is a ball which is pressed against a seat. Delockable non-return valves are shown by a square containing the symbol for a non- return valve. The pilot control for unlocking the non- return valve is indicated by a broken line at the pilot port. The pilot port is designated by the letter X.

[25] Circuit symbols for measuring devices

The illustration shows the symbols for measuring devices used in hydraulics.

25.4 Some Physical Fundamentals

[26] Hydrostatic pressure

Hydrostatic pressure is the pressure created above a certain level within a liquid as a result of the weight of the liquid mass. Hydrostatic pressure is not dependent on the shape of the vessel concerned but only on the height and density of the column of liquid.

⸱⸱⸱⸱⸱⸱⸱> Hydrostatic pressure can generally be ignored for the purpose of studying hydraulics (exception: see topic 2).
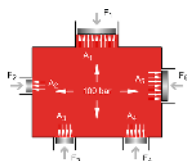
[27] Pressure propagation

If a force F acts on an area A of an enclosed liquid, a pressure p is produced which acts throughout the liquid (Pascal's Law).
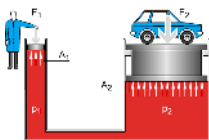
[28] Power transmission

If a force F_1 is applied to an area A_1 of a liquid, a pressure p results. If, as in this case, the pressure acts on a larger surface A_2, then a larger counter-force F_2 must be maintained. If A_2 is three times as large as A1, then F_2 will also be three times as large as F_1.

⤳ Hydraulic power transmission is comparable to the mechanical law of levers.
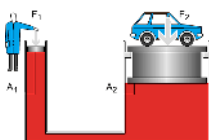
[29] Displacement transmission (1)

If the input piston of the hydraulic press travels a distance s_1, a volume of fluid will be displaced. This same volume displaces the output piston by the distance s_2. If the area of this piston is larger than that of the input piston, the distance s_2 will be shorter than s_1.

⤳ Hydraulic displacement transmission is comparable to the mechanical law of levers.
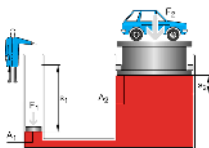
[30] Displacement transmission (2)

See topic 29
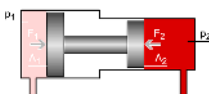
[31] Pressure transfer (1)

The fluid pressure p_1 exerts a force F_1 on the surface A_1 which is transferred via the piston rod to the small piston. The force F_1 thus acts on the surface A_2 and produces the fluid pressure p2. Since the piston area A_2 is smaller than the piston area A_1, the pressure p_2 must be larger than the pressure p_1.

⤏ The pressure-transfer (pressure-intensification) effect is put to practical use in pneumatic/hydraulic pressure intensifiers and also in purely hydraulic systems when extremely high pressures are required which a pump cannot deliver.

[32] Pressure transfer (2)
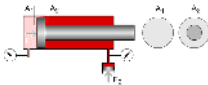
A pressure-transfer effect also occurs in conventional double acting cylinders with single piston rod.

⤏ This effect also causes problems in hydraulics. If, for example, an exhaust flow control is fitted to a differential cylinder for the advance stroke, a pressure- intensification effect results in the piston-rod chamber.

[33] Types of flow

A distinction is made between laminar flow and turbulent flow. In the case of laminar flow, the hydraulic fluid moves through the pipe in ordered cylindrical layers. If the flow velocity of the hydraulic fluid rises above a critical speed, the fluid particles at the center of the pipe break away to the side, and turbulence results.

⤏ Turbulent flow should be avoided in hydraulic circuits by ensuring they are adequate sized.

[34] Diesel effect

A pressure drop to the level of vacuum may occur at points of restriction, causing precipitation of the air dissolved in the oil. When the pressure rises again, oil bursts into the gas bubbles and spontaneous ignition of the oil/air mixture may occur.

[35] Cavitation
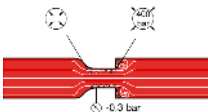
Motion energy is required for an increase in the flow velocity of the oil at a restriction. This motion energy is derived from the pressure energy. If the vacuum which results is smaller than -30 kPa (-0.3

bar), air dissolved in the oil is precipitated out. When the pressure rises again due to a reduction in speed, the oil bursts into the gas bubbles.

⌁→ Cavitation is a significant factor in hydraulic systems as a cause of wear in devices and connections.

[36] Cavitation
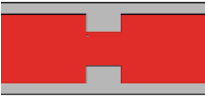
Local pressure peaks occur during cavitation. This causes the erosion of small particles from the wall of the pipe immediately after the reduced cross-section, leading to material fatigue and often also to fractures. This effect is accompanied by considerable noise.
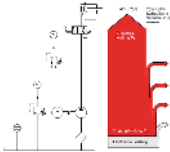
[37] Input and output power

Various losses occur at the individual devices within a hydraulic control chain. These consist essentially of mechanical, electrical and volumetric losses.

⌁→ After an installation has been in service for some time, there will be a change in particular in the volumetric efficiency of the pump, as the result, for example, of cavitation (see topic 35).

25.5 Components of a Power Unit
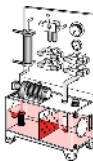
[38] Hydraulic power unit

The hydraulic power unit (power supply unit) provides the energy required for the hydraulic installation. It's most important components are the reservoir (tank) , drive (electric motor), hydraulic pump, pressure relief valve (safety valve), filter and cooler. The

hydraulic power unit may also act as a carrier for other devices (gauges, directional control valves).
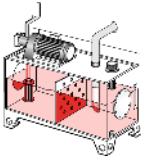
[39] Hydraulic power unit: Reservoir

The hydraulic reservoir contains the hydraulic fluid required to operate the installation. Within the reservoir, air, water and solid matter are separated out of the hydraulic fluid.

⟶ The size of the reservoir will depend on the practical application involved; for stationary systems, the volume of fluid delivered by the pump in 3 to 5 minutes can be taken as a guide. In mobile hydraulic systems, on the other hand, the reservoir contains only the maximum quantity of hydraulic fluid required.
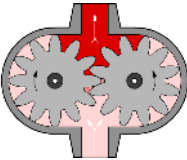
[40] Externally toothed gear pump

The increase in volume which results when a tooth moves out of mesh produces a vacuum in the suction area. The hydraulic fluid is conveyed into the pressure area. The hydraulic fluid is then forced out of the tooth gaps by the meshing of the teeth and displaced into the above supply line.
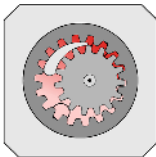
[41] Internally toothed gear pump

The inner gear is driven by a motor. The teeth of the inner wheel drive the outer gear wheel. The rotary motion creates a vacuum in the gaps between the teeth, causing hydraulic fluid to be sucked in. On the other side, the teeth engage once more and oil is displaced from the tooth chambers.

⟶ The design can deliver pressures of up to approx. 17.5 MPa (175 bar). Hydraulic motors represent the reverse of the function principle.
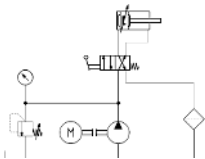
[42] Circuit diagram: Return flow filter

An oil filter situated in the return line to the tank has the advantage that the filter is thus easy to maintain. A disadvantage, however, is that contamination is removed from the hydraulic fluid only after it has passed through the hydraulic components.

⤏ This configuration is often used.
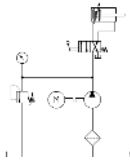
[43] Circuit diagram : Pump inlet filter

With this configuration, the pump is protected from contamination. The filter is, on the other hand, less easily accessible.

⤏ If these filters have a too fine mesh, suction problems and cavitation effects may occur. Additional coarse filters upstream of the pump are recommended.
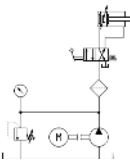
[44] Circuit diagram: Pressure line filter

Pressure filters can be installed selectively upstream of valves which are sensitive to contamination; this also enables smaller mesh sizes to be used.

⤏ A pressure-resistant housing is required, which makes this configuration more expensive.
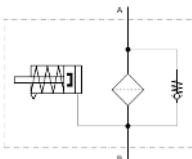
[45] Circuit diagram: Contamination indicator

It is important that the effectiveness of a filter can be checked by a contamination indicator. The contamination of a filter is measured by the pressure drop; as the contamination increases, the pressure upstream of the filter increases. The pressure acts on a spring-loaded piston. As the pressure increases, the piston is pushed against a spring.

→ There are a number of different display methods. Either the piston movement is directly visible or it is converted into an electrical or visual indication by electrical contacts.

[46] Water cooler
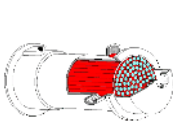
With this design of cooler, hydraulic fluid is fed through tubes over which coolant (water) flows. The heat which is discharged can be re-used.

→ The operating temperature in hydraulic installations should not exceed 50 - 60º{C}, since this would cause an unacceptable reduction in viscosity, leading to premature aging of the fluid. In comparison with air cooling, operating costs a higher due to the required coolant and the susceptibility to corrosion. Temperature difference of up to approx. 35º{C} can be handled.

[47] Air cooler

Hydraulic fluid from the return line flows through a coiled pipe which is cooled by a fan.

→ The advantages here are simplicity of installation and low operating costs. The noise of the fan may be a nuisance (see also topic 46).

[48] Heating element

Heaters are often required to ensure that the optimum operating temperature is reached quickly. Heating elements or flow preheaters are used for heating and pre-heating hydraulic fluid.

→ If the viscosity is too high, the resulting increase in friction and cavitation leads to greater wear.
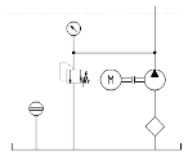
[49] Circuit diagram: Hydraulic power unit

The illustration shows the detailed circuit symbol for a hydraulic power unit.

⤏ Since this is a combination unit, a dot/dash line is placed around the symbols representing the individual units.

25.6 Fundamentals of Valves
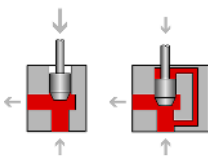
[50] Actuating force

With some types of poppet valves, the actuating force, which is dependent on pressure and area, may be very high. In order to avoid this, pressure compensation may be provided at the valves.
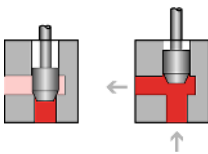
[51] Poppet principle

Valves are based either on the poppet principle or slide principle. In poppet valves, a ball, a cone or a disc is pressed by a spring against the seat of a passage. The high pressure per unit area which is created, means that valves of this kind provide a very efficient seal. The illustration shows a cone used as a sealing element.
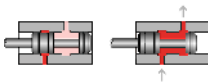
[52] Slide principle

This illustration shows the principle of a longitudinal slide valve. In order to allow the piston to move, it has a certain clearance and floats in hydraulic fluids. Ring grooves ensure an even film of oil and thus pressure equilibrium. The piston can thus be moved with minimal frictional losses.

⤏ This type of valve cannot provide a perfect seal, which means that there is always a certain oil leakage.

[53] Poppet valves
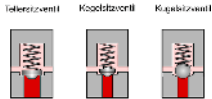
In poppet valves, a ball, cone or occasionally a disk is pressed against a seat area to act as a sealing element. Valves of this type provide a very efficient seal.

[54] Piston overlap
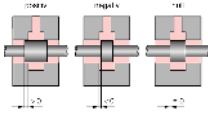
The switching characteristics of a valve are governed by, among other things, its piston overlap. A distinction is made between positive, negative and zero overlap. In the case of positive overlap, the port in question is completely covered by the piston, while with negative overlap it is less than completely covered. In the case of zero overlap, the distances between the control edges of the piston and of the port are exactly the same.

> ····⫯ The individual control edges of the pilot piston can have different overlaps.
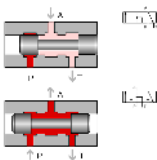
[55] Negative switching overlap

In the case of negative overlap, flow from A to T is not quite closed when the inlet P is opened. This means that the pressure at port A rises slowly and the piston starts gently.

> ····⫯ In manufacturers' data sheets, overlap positions are shown within dotted lines between the switching positions, or the overlap positions are shown in color or with a patterned background.
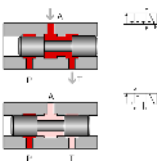
[56] Positive switching overlap

In the case of positive overlap, the left-hand piston does not open the passage from P to A until the tank has been completely isolated by the other piston. Pressure is immediately fed to the load device (cylinder or hydraulic motor) with the result that this starts abruptly.

[57] Control edges

The control edges of the pistons are often either sharp, chamfered or notched. The profiling of the control edges means that the throttling action of the flow when switching is gradual rather than abrupt.

┄┄> See also the example in topic 144.
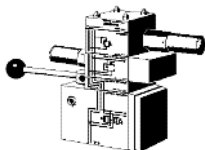
[58] Vertical interconnection system

Vertical interconnection systems ("modular hydraulics") mean that less space is required and that no piping is needed between the components. The circuit symbols directly marked on the components give greater clarity in the installation.

25.7 Pressure Valves
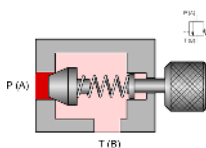
[59] Pressure relief valve (1)

In this design incorporating a poppet valve, a seal is pressed against the inlet port P by a pressure spring when the valve is in its normal position.

┄┄> In this situation, for example, an unloaded piston rod is executing an advance stroke and the entire pump delivery is flowing to the cylinder.
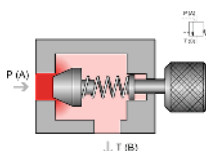
[60] Pressure relief valve (2)

As soon as the force exerted by the inlet pressure at A exceeds the opposing spring force, the valve begins to open.

⋯⋯> In this situation, for example, the piston rod is fully advanced; the entire pump delivery is flowing at the preset system pressure to the tank.
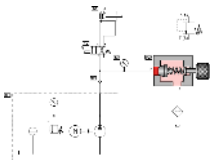
[61] PRV used to limit system pressure

This illustration shows a pressure relief valve within a basic hydraulic circuit (used to control a double acting cylinder).

⋯⋯> The resistances at the outlet (tank line, filter) must be added to the force of the spring in the pressure relief valve. See also the animation "Interaction of components" (topic 7).
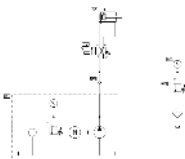
[62] Circuit diagram: PRV used to limit system pressure

This illustration shows the same circuit as the previous illustration, but with the cut-away view of the PRV replaced by the appropriate circuit symbol.
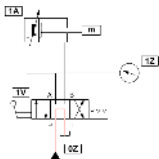
[63] Circuit without brake valve

One application of pressure relief valves is as brake valves; these prevent pressure peaks which may otherwise occur as the result of mass moments of inertia when a directional control valve is suddenly closed. The animation shows an (incorrect) circuit in schematic form in which the working line on the exhaust side has fractured due to the absence of a brake valve.

⋯⋯> The next animation (topic 64) shows the correct circuit.
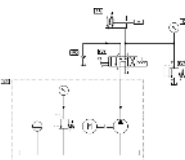
[64] Circuit diagram: Brake valve

This illustration shows the correct circuit for the problem in topic 63. This circuit incorporates not only a brake valve on the piston-rod side but also a non-return valve on the inlet side via which oil can be taken in from a reservoir during the vacuum phase following the closure of the directional control valve.

·····> The following animation shows the events which occur in the two working lines.
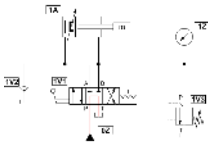
[65] Circuit with brake valve

First the animation shows in schematic form the behavior of the PRV during the braking phase, then it shows the behavior of the non-return valve (NRV) in the supply line.

·····>
The necessity of the brake valve can be demonstrated by .
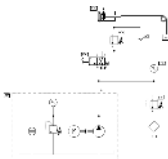
[66] Circuit diagram: PRV as back-pressure valve

Back-pressure valves counteract mass moments of inertia with tractive loads. The illustration shows a circuit with a back-pressure valve on the piston-rod side. On the return stroke, the PRV is by-passed by an NRV.

·····> The PRV must be pressure-compensated and the tank port must be capable of carrying a pressure load.
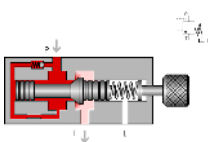
[67] PRV, internally controlled, cushioned

Pressure relief valves often incorporate cushioning pistons or flow control valves. The cushioning device shown provides fast opening and slow closing of the valve. This prevents damage caused by pressure shocks (smooth valve operation).

·····> Pressure shock arise, for example, when the pump delivers oil in an almost unpressurized condition and the supply port of the load device is abruptly closed by a directional control valve.
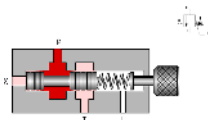
[68] PRV, externally controlled (1)

This pressure relief valve controls the flow in accordance with an external pressure setting. This pressure acts against an adjustable

spring force. The passage from the supply port P to the tank port T remains closed as long as no load acts on the pilot piston.

[69] PRV, externally controlled (2)
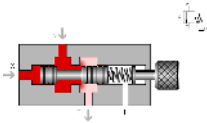
Pressure can be fed to the pilot piston via the pilot port X. As soon as the pressure force at the pilot piston exceeds the preset spring force, the pilot piston is displaced, allowing free flow.

[70] Sequence valve
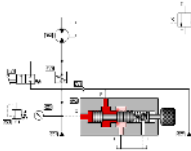
The example shows a circuit with a pressure relief valve used as a pressure sequence valve. The pressure at the pilot piston of the PRV rises via the pressure regulator. The PRV opens and the high-pressure pump delivers directly to the tank. As soon as the 2/2-way valve opens, the pressure drops. The pressure relief valve closes and the high pressure pump is connected to the system.

[71] Circuit diagram: Sequence valve
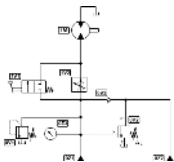
This illustration shows the same circuit as the previous illustration, but with the cut-away view of the sequence valve replaced by the appropriate circuit symbol.

[72] Pressure relief valve

Actual photograph of a pressure relief valve.

[73] 2-way pressure regulator (1)
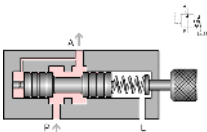
This valve is normally open. The outlet pressure (A) acts via a pilot line on the left-hand surface of the pilot piston against an adjustable spring force.

┄┄⟶ Pressure regulators reduce the inlet pressure to an adjustable outlet pressure. It is appropriate to use these in hydraulic installations only if different pressures are required.

[74] 2-way pressure regulator (2)
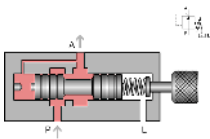
When the pressure rises at outlet A, the force at the left-hand surface of the pilot piston becomes greater, the piston is displaced to the right and the throttle gap becomes narrower. This causes a pressure drop.

┄┄⟶ In the case of slide valves, it is also possible to design the control edges in such way that the opening gap increases only slowly. This gives greater control precision.

[75] 2-way pressure regulator (3)
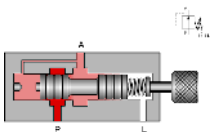
When the preset maximum pressure is reached, the throttle point closes completely; the pressure set on the pressure relief valve is produced at the inlet P.

[76] 2-way pressure regulator (4)
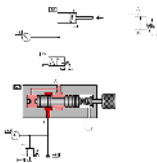
In the circuit illustrated, the piston rod of the cylinder is executing an advance stroke. The pressure at the outlet A of the pressure regulator is less than the system pressure at P and constant.

[77] 2-way pressure regulator (5)
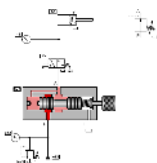
The piston rod of the cylinder is now in its forward end position. The pressure at outlet A thus continues to rise and the throttle point closes completely.
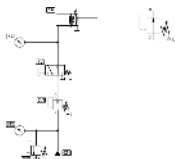
[78] Circuit diagram: 2-way pressure regulator

The illustration shows the same circuit as the previous illustration, but with the 2-way pressure regulator in the form of a circuit symbol.
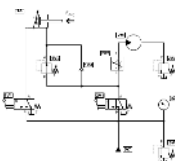
[79] Circuit diagram: 2-way pressure regulator

It is appropriate to use PRVs only when different pressures are required in an installation. The mode of operation of pressure regulator will thus be explained here by taking an example with two control circuits. The first control circuit acts via a flow control valve on a hydraulic motor which drives a roller. This roller is used to stick together multi-layered printed circuit boards. The second control circuit acts on a hydraulic cylinder which draws the roller towards the boards at an adjustable reduced pressure.

····> This example can be used as a preliminary stage to the introduction of the 3-way PR. If the 2-way PR is closed due to the fact that the preset maximum pressure has been reached, thickening of the material of the workpieces would cause an increase in the pressure on the outlet side of the PR to a higher value than desired. (See also the animation for topic 84.)
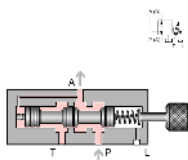
[80] 3-way pressure regulator (1)

The 3-way pressure regulator can be regarded as a combination of a 2-way PR and a pressure relief valve (PRV). The PR is in its normal position here; only a low pressure has built up at the outlet A.
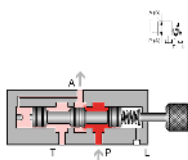
[81] 3-way pressure regulator (2)

When the pressure at A rises the result of external conditions, this pressure acts via a pilot line on the left-hand piston surface of the pilot piston against an adjustable spring force. Every pressure

increase causes the throttle gap to become narrower, resulting in a pressure drop.
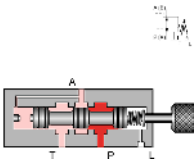
[82] 3-way pressure regulator (3)

When the maximum preset pressure is reached, the throttle point closes completely. The pressure set on the system-pressure limiter is produced at the inlet P.
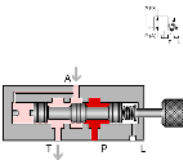
[83] 3-way pressure regulator (4)

If the pressure rises above the preset value as the result of an external load at outlet A, the valve opens to allow flow from A to the tank port T (pressure-limiter function).

---> 3-way pressure regulators are available with both positive and negative piston overlap. If a 3-way pressure regulator is created by combining a 2-way pressure regulator and a pressure relief valve, the "overlap" is adjustable.
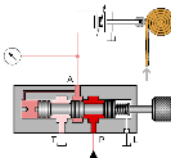
[84] 3-way pressure regulator

The animation shows both the pressure-regulator and pressure-limiter function of a 3-way pressure regulator through the example of a roller which exerts a constant pressure on moving material of variable thickness.

---> The final control element which is normally interposed has been omitted here in the interests of clarity.
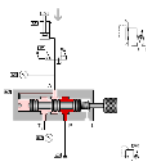
[85] 3-way pressure regulator (5)

A 3-way PR is shown here in a functional representation, incorporated into a model circuit diagram. The piston rod of the cylinder is subject to external force and the pressure regulator provides a pressure-limiter function.
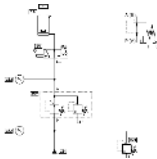
[86] 3-way pressure regulator (6)

The illustration shows the same circuit as the previous illustration, but with the functional representation of the 3-way pressure regulator replaced by a "detailed" circuit symbol.

┈┈> 3-way pressure regulators are available with both positive and negative piston overlap. If a 3-way pressure regulator is created by combining a 2-way pressure regulator and a pressure relief valve, the "overlap" is adjustable.
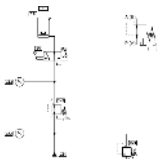
[87] Circuit diagram: 3-way pressure regulator

The illustration shows the same circuit as the previous illustration, but with the standard circuit symbol for a 3-way pressure regulator.

25.8 Way Valves

[88] 2/2-way valve (1)
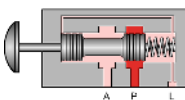
The 2/2-way valve has a working port A, a supply port P and a leakage-oil port L. In the case of the valve shown here, of slide design, flow from P to A is closed in the normal position.

┈┈> A relief line leading to the leakage-oil port is provided to prevent a build-up of pressure in the spring and piston chambers.

[89] 2/2-way valve (2)
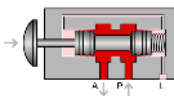
The 2/2-way valve is actuated and the passage from P to A is open.

┈┈> 2/2-way valves are also available which are normally open from P to A.
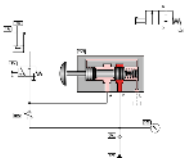
[90] 2/2-way valve as by-pass valve

This example shows a 2/2-way valve used as a by-pass valve; when the 2/2-way valve is actuated, the flow control valve 0V2 is by-passed, causing the piston rod of the cylinder to advance at maximum speed.
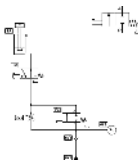
[91] Circuit diagram: 2/2-way valve as by-pass valve

The illustration shows the same circuit as the previous illustration, but with the functional representation of the 2/2-way valve replaced by a circuit symbol.

[92] Circuit diagram: 2/2-way valve as final control element

In its initial position, the cylinder is advanced. If the 2/2- way valve 0V1 is actuated, the entire volumetric flow passes to the tank and piston rod of the cylinder is reset by the external load m. If 0V1 is not actuated, the system pressure set on the pressure limiter 0V2 builds up and the piston rod advances.

⋯⋯> In the initial position, the pump operates against the preset system pressure, which has an unfavorable effect on the power balance of the circuit shown.
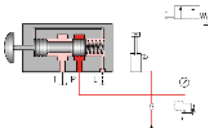
[93] 2/2-way valve as final control element

The animations show the actuation and release of the 2/2-way valve, which causes the piston rod of the cylinder to advance and retract.
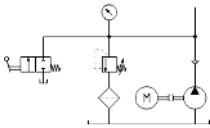
[94] Circuit diagram for pressure-less pump recirculation

The part circuit diagram shows a 2/2-way valve used as a by-pass valve to achieve pressure-less pump recirculation; if the valve is actuated, the pump no longer needs to operate against the preset system pressure.

---> One application of this circuit is with 4/3-way valves which are closed in their mid-position in cases where, with the installation operational, it is desired to switch to pump recirculation (see also topic 116).
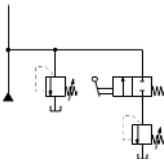
[95] Circuit diagram: Pressure stage circuit

The part circuit diagram shows a 2/2-way valve used as a selector switch for one of two preset system pressures ("pressure levels"); if the 2/2-way valve is actuated, flow is enabled to a second system-pressure limiter.
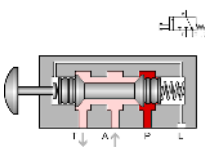
[96] 3/2-way valve (poppet principle) (1)

The 3/2-way valve has working port A, a supply port P and a tank port T. Volumetric flow can be routed from the supply port to the working port or from the working port to the tank port. The third port in each case is closed. In the normal position shown, P is closed and flow released from A to T.

---> See also topic 101 (slide principle).
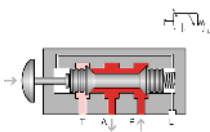
[97] 3/2-way valve (poppet principle) (2)

The 3/2-way valve is actuated; flow is released from P to A, the outlet T is closed.

---> 3/2-way valves which are normally open from P to A and T closed are also available.
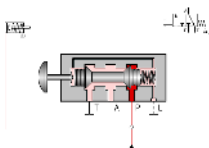
[98] 3/2-way valve as final control element

The circuit shows the 3/2-way valve in a functional representation as a final control element of a single acting cylinder.

⤍ The non-return valve protects the pump in cases where the 3/2-way valve is actuated and the piston rod is subject to an external load.
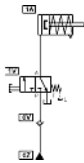
[99] Circuit diagram: 3/2-way valve as final control element

The illustration shows the same circuit as the previous illustration, but with the circuit symbol for the 3/2-way valve.
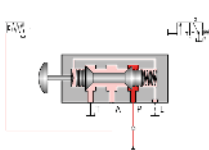
[100] 3/2-way valve

The animations show the actuation and release of the manual pushbutton for a 3/2-way valve, which causes the piston rod of the cylinder to advance and retract.
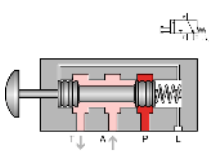
[101] 3/2-way valve (slide principle) (1)

The 3/2-way valve has a working port A, a supply port P and a tank port T. The volumetric flow can be routed from the supply port to the working port, or from the working port to the tank port. The third port in each case is closed. In the normal position shown, P is closed and flow is released from A to T.

⤍ See also the 3/2-way valve designed on the poppet principle (Topic 96).
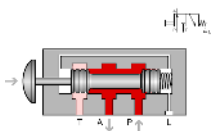
[102] 3/2-way valve (slide principle) (2)

The 3/2-way valve is actuated; flow is released from P to A, and the outlet T is closed.

⤏ 3/2-way valves which are normally closed from P to A and T are also available.
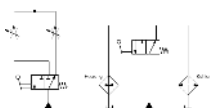
[103] 3/2-way valves as diverter

In addition to their application as final control elements, 3/2-way valves can also be used as diverters. In this case, port T is connected to a further device, to which a switch-over can then be made. The part circuit diagrams show the facility to switch between the flow control valves with different settings and between heating and cooling.

⤏ The circuit symbol is drawn reversed to simplify the representation of the circuit diagram.
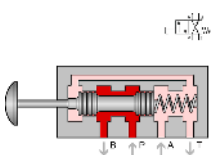
[104] 4/2-way valve, two pistons (1)

The 4/2-way valve has two working ports A and B, a supply port P and a tank port T. The supply port is always connected to one of the working ports, while the second working port is routed to the tank. In the normal position, there is flow from P to B and from A to T.

⤏ In contrast to valves with three pistons, 4/2-way valves with two pistons do not require a leakage-oil port (see topic 106).
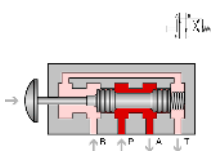
[105] 4/2-way valve, two pistons (2)

The 4/2-way valve is actuated, and there is flow from P to A and from B to T.

⤏ 4/2-way valves are also available which are normally open from P to A and from B to T.
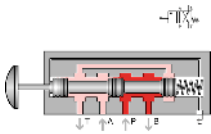
[106] 4/2-way valve, three pistons (1)

This 4/2-way valve has two working ports A and B, a supply port P and a tank port T. The supply port is always connected to one of the working ports, while the second working port is routed to the tank. In the neutral position, there is flow from P to B and from A to T.

---> 4/2-way valves with three pistons require a leakage-oil port, since hydraulic fluid would otherwise be trapped within the valve.
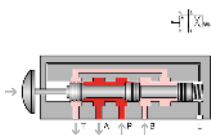
[107] 4/2-way valve, three pistons (2)

The 4/2-way valve is actuated, and there is flow from P to A and from B to T.
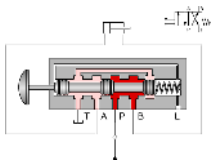
[108] 4/2-way valve, three pistons (3)

The circuit shows the 4/2-way valve in functional representation as a final control element of a double acting cylinder.

---> The non-return valve protects the pump in cases where the piston rod of the cylinder is subject to an external load.
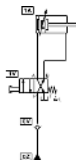
[109] Circuit diagram: 4/2-way valve

The illustration shows the same circuit as the previous illustration, but with the 4/2-way valve as a circuit symbol.
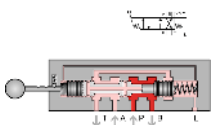
[110] 4/3-way valve with pump bypass (1)

From the logic point of view, 4/3-way valves are 4/2- way valves with an additional mid-position. There are various versions of this mid-position (in the mid-position in the example shown, the supply

port P is directly connected to the tank T, see next illustration). In the switching position shown, there is flow from P to B and from A to T.

----> 4/3-way valves are easy to construct as slide valves and of complex design as poppet valves.

[111] 4/3-way valve with pump bypass (2)
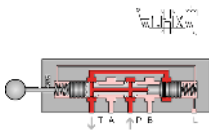
The 4/3-way valve is in its mid-position; there is flow from P to T, while A and B are closed. Since the output from the pump flows to the tank, this switching position is called pump bypass or also pump recirculation.
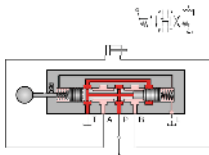
----> In the case of pump bypass, the pump needs to operate only against the resistance of the valve, which has a favorable effect on the power balance.

[112] 4/3-way valve with pump bypass (3)
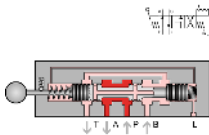
The valve is in its left-hand switching position; there is flow from P to A and from B to T.

**[113] 4/3-way valve with pump bypass (4)**

The circuit shows the 4/3-way valve in functional representation as a final control element of a double acting cylinder. The valve is in its mid-position; the pump delivery flows via the by-pass line within the pilot piston to the tank.

----> The non-return valve protects the pump in cases where the piston rod of the cylinder is subject to an external load.

[114] Circuit diagram: 4/3-way valve with pump bypass

The illustration shows the same circuit as the previous illustration, but with the 4/3-way valve as a circuit symbol.
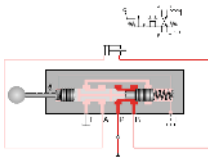
[115] 4/3-way valve with pump bypass

The animations show the switching of the 4/3-way valve into the three switching positions and the corresponding cylinder movements. During the advance stroke, movement can be halted by switching to the mid- position.

---> As appropriate to the application in question, a circuit of this kind must be equipped with a brake valve to prevent damage to the installation when the valve is switched to the mid-position (see also topic 64).
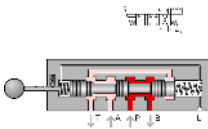
[116] 4/3-way valve with closed mid-position (1)

From the logic point of view, 4/3-way valves are 4/2- way valves with an additional mid-position. There are various versions of this mid-position (in the mid-position in the example shown, all ports are closed in the mid- position, see next illustration). In the switching position shown, there is flow from P to B and from A to T.
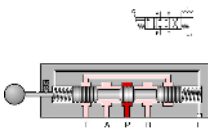
[117] 4/3-way valve with closed mid-position (2)

The 4/3-way valve is in its mid-position; all ports apart from the leakage-oil port are closed.

---> In this mid-position, the pump is operating against the system pressure set on the pressure relief valve.
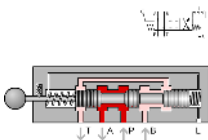
[118] 4/3-way valve with closed mid-position (3)

The valve is in its left-hand switching position; there is flow from P to A and from B to T.
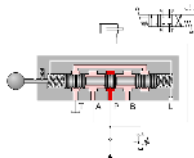
[119] 4/3-way valve with closed mid-position (4)

The circuit shows the 4/3-way valve in functional representation as a final control element of a double acting cylinder. The valve is in its mid-position; the pump is operating against the system pressure set on the PRV.

⤏ If, with an operational installation, it is desired to switch to pump recirculation, this can be achieved by using an additional 2/2-way valve as a changeover valve (see part circuit-diagram in topic 94).
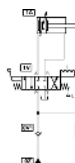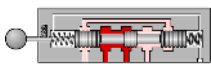
[120] Circuit diagram: 4/3-way valve with closed mid-position

The illustration shows the same circuit as the previous illustration, but with the 4/3-way valve as a circuit symbol.

[121] 4/3-way valve: overlap positions (1)

The illustration shows the left-hand overlap position of a 4/3-way valve with positive overlap in the mid-position (closed mid-position). This overlap position is a mixture of positive and negative overlap; P is connected to A, B and T are closed.

⤏ With 4/3-way valves, the types of overlap positions are generally specified in the data sheet.

[122] 4/3-way valve: overlap positions (2)
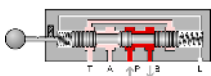
The illustration shows the "right-hand" overlap position of a 4/3-way valve with positive overlap in the mid- position (closed mid-position). This overlap position, too, is a mixture of positive and negative overlap; P is connected to B, A and T are closed.

[123] Way valve

Actual photograph of a directional control valve with lever actuation.
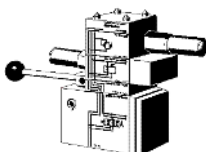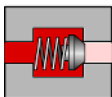

[124] 4/3-way module

This 4/3-way module with hand-lever actuation is used in vertical interconnection systems ("modular hydraulics").

⋯⋯⋙ See also the illustration in topic 58.

25.9 Shutoff Valves

[125] Non-return valve (1)

Non-return valves block flow in one direction and allow free flow in the other. In the direction of flow shown, the sealing element is pressed against a seat by a spring and the hydraulic fluid.

⋯⋯⋙ These valves are also available in designs without springs. Since there must be no leaks in the closed position, these valves are generally of poppet design.

[126] Non-return valve (2)
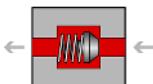
In the direction of flow shown, the valve is opened by the hydraulic fluid, which lifts the sealing element from the seat.
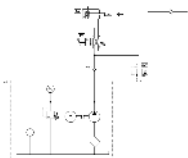
**[127] Circuit diagram: Pump protection**

In this circuit, the non-return valve is used to protect the pump. This prevents a load pressure from driving the pump in reverse when the electric motor is switched off. Pressure peaks do not affect the pump but are discharged via the pressure relief valve.
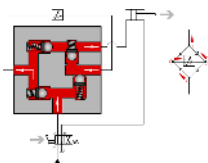
[128] Graetz block (1)

In the Graetz rectifier circuit (Graetz block), four non- return valves are combined to form a function unit. The circuit diagram shows how this operates in conjunction with a flow control valve; flow passes through this valve from left to right during both the advance and return strokes of the cylinder. The situation during the advance stroke is shown.
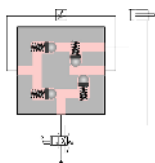
⌁⟶ During the advance stroke shown here, flow control is carried out on the inlet side.
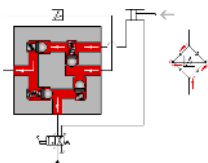
[129] Graetz block (2)

The cylinder is on its return stroke. The rectifier circuit means that flow once again passes through the flow control valve from left to right.
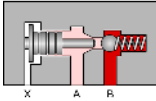
⌁⟶ During the return stroke shown here, flow control is carried out on the outlet side.

[130] Graetz block

The animation shows the actuation and spring return of a 4/2-way valve and the flow through the Graetz block during the advance and return strokes.

⌁⟶ Similar rectifier circuits are also used in conjunction with line filters or brake valves.

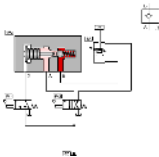### [131] Delockable non-return valve (1)

In the cases of delockable non-return valves, flow in the closed direction can be released by means of an additional pilot port (X). The illustration shows the valve in its normal position; flow from B to A is closed.
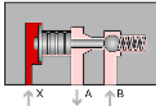
[132] Delockable non-return valve (2)

The released piston is pressurized via pilot port X. This lifts the sealing element from its seat and releases flow from B to A.

····> In order to release the valve reliably, the effective area of the pilot piston must always be greater than the effective area of the sealing element. Piloted non-return valves are also available with lockable non-return function.

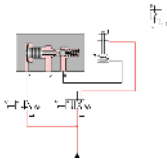### [133] Delockable non-return valve (3)

The model circuit diagram shows how a load can be positioned by holding a cylinder using a suitable delockable non-return valve. The valve becomes active in the return stroke whereby the restriction on the piston side is released by actuation of the 3/2-way valve.

····> See also the animation 135 on this topic.


[134] Circuit diagram: Delockable non-return valve

The illustration shows the same circuit as the previous illustration, but with the piloted non-return valve as a circuit symbol.
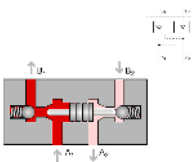
[135] Delockable non-return valve

The 4/2-way valve is actuated, the hydraulic fluid passes through the non-return valve against the force of the return spring and the piston rod advances. When the 4/2-way valve is reset, the outlet on the piston side is closed by the non-return valve, and the cylinder remains advanced. The 3/2-way valve is now actuated, the pilot piston is reversed and the outlet flow released; the piston rod begins to retract. During the return stroke, the 3/2-way valve is brought temporarily into its normal position. This causes the outlet to be closed again, and the piston rod and load remain in their current position. When the 3/2-way valve is actuated again, the piston rod travels to its retracted end position.
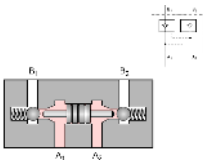
[136] Delockable double non-return valve (1)

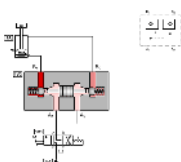Delockable double non-return valves allow a load to be positioned reliably with the cylinder at a standstill, even if eternal leaks exist around the cylinder piston. When, as in the case, neither of the inlets A_1 or A_2 is pressurized, B_1 and B_2 are closed.

[137] Delockable double non-return valve (2)

When A_1 is pressurized, the left-hand sealing element is lifted from its seat, enabling flow to B_1. At the same time, the pilot piston is displaced to the right, releasing flow from B_2 to A_2.

⤑ The opposite is true when inlet A_2 is pressurized.

[138] Delockable double non-return valve (3)

The model circuit diagram shows a delockable double non-return valve used in conjunction with a 4/3-way valve to allow the vertical positioning of a load. In the mid-position of the final control element shown, ports A and B are connected to the tank. This means

that the inlets A_1 and A_2 of the double non-return valve are pressure-less and both cylinder supply lines are closed.
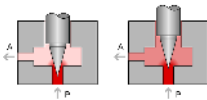

[139] Circuit diagram: Delockable double non-return valve

The illustration shows the same circuit as the previous illustration, but with the delockable double non-return valve as a circuit symbol.

25.10 Flow Valves

[140] Needle restrictor

Throttle and orifice valves are used to achieve a certain pressure drop. This is done by creating a specific flow resistance. The needle flow control valve shown generates considerable friction due to its long narrowing. This means that the action of the flow control valve is difficult to adjust due to the fact that a small adjustment produces a large change in cross-section.

⤐ One advantage is the simple and inexpensive design. Needle flow control valves can be used if the above- mentioned negative properties can be ignored for the purposes of a given control task.

[141] Gap restrictor with helix
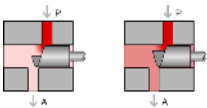
Its short narrowing means that the action of this gap flow control valve is virtually independent of viscosity. The helix provides precise adjustability, since adjustment from fully opened to fully closed requires a 360° turn. The helix is, however, very costly to produce.
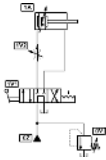
**[142] Circuit diagram: Flow division using restrictor**

Throttle and orifice valves control the volumetric flow rate in conjunction with a pressure relief valve. The PRV opens when the resistance of the flow control valve becomes greater than that of the opening pressure set on the PRV. This produces a division of flow.

⤑ The volumetric flow to the load device varies, i.e. the action of flow control valves is load-dependent.

[143] Throttle valve

Actual photograph of a flow control valve.
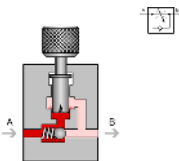
[144] One-way flow control valve (1)

The one-way flow control valve is a combination of an orifice or throttle valve and a non-return valve. In the closed direction shown of the non-return valve, the volumetric flow passes via the variable throttle gap, which creates a considerable resistance.

⤑ Speed reduction can be achieved by using a one-way flow control valve in conjunction with a pressure relief valve or a variable-delivery pump. The pressure rises upstream of the flow control valve until the PRV opens and routes part of the flow to the tank.
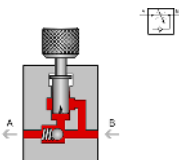
[145] One-way flow control valve (2)

In the reverse direction, from B to A, flow is unrestricted, since the ball in the one-way flow control valve allows free flow (non-return function).

⤑ One-way flow control valves are available with a fixed restrictor and with variable flow control.
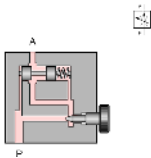
[146] 2-way flow control valve (1)

Flow control valves have the task of providing constant volumetric flow independently of pressure changes at the inlet or outlet of the valve. This is achieved firstly by means of an adjustable restrictor which is set to the desired volumetric flow. In order to keep the pressure drop across the throttle point constant, a second regulating restrictor (pressure compensator) is also required. The illustration shows the valve in its normal position.

····> 2-way flow control valves always operate in conjunction with a pressure relief valve. The part of the flow which is not required is discharged via the PRV.
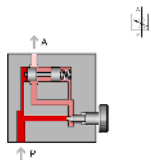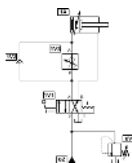
[147] 2-way flow control valve (2)

When fluid flows through the valve, the pressure drop across the adjustable restrictor is kept constant by the pressure compensator, which varies the resistance at the upper throttle point in accordance with the load at the inlet or outlet.

····> See also the animation 150 for this topic.
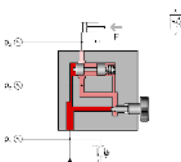
[148] 2-way flow control valve (3)

In the case of this flow control valve, the pressure difference is kept constant by an adjustable restrictor, i.e. between p_1 and p_2. If the pressure p_3 rises as the result of an external load, the overall resistance of the valve is reduced by opening the regulating restrictor.
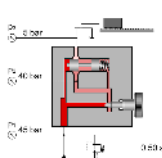
[149] Circuit diagram: 2-way flow control valve

The model circuit diagram shows the arrangement of a 2-way flow control valve in the piston-side supply line in order to achieve a constant feed speed even under varying load. A non-return valve is

fitted in the by-pass to allow the flow control valve to be by-passed on the return stroke.

[150] 2-way flow control valve

The advancing piston rod encounters a load half-way through its stroke. The flow control valve nonetheless ensures that the advance speed remains constant. From 0 to 2 seconds (shown at bottom right) the piston rod is unloaded and the pressure conditions remain constant. When the piston rod encounters the load, the pressure p_3 rises at the outlet of the flow control valve. (In order to allow the rapid control operations to be shown more clearly, the time scale now changes to 1/100ths of a second.) The flow control valve briefly raises the pressure p_2 downstream of the adjustable restrictor. Following this, the regulating restrictor moves to the left, and p_2 falls back to its original value, i.e. the pressure difference between p_1 and p_2 remains constant. The regulating operation shown is repeated a number of times, as the result of which p_3 increases to 2.5 MPa (25 bar) in several steps and the regulating restrictor opens more and more. (At the point at which 2.5 MPa (25 bar) is reached, the time scale changes back to 0.1 seconds.) The piston rod now travels under load just as fast as previously without load.

25.11 Hydraulic Cylinders and Motors
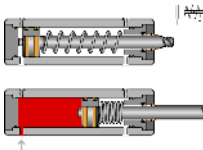
[151] Single acting cylinder

In the case of a single acting cylinder, only the piston side is pressurized with hydraulic fluid. The cylinder can thus carry out work only in one direction. The fluid which flows into the piston chamber causes a pressure to build up the surface of the piston. The piston travels into its forward end position. The return stroke is affected by a spring, the dead weight of the piston rod or an external load.
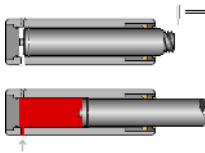
[152] Plunger cylinder

In the case of plunger cylinders, the piston and rod form a single component. Due to the design of the cylinder, the return stroke can only be affected by external forces. The cylinders can therefore generally be installed only vertically.
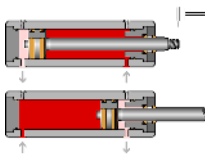
[153] Double acting cylinder

In the case of double acting cylinders, both piston surfaces can be pressurized. A working movement can thus be performed in both directions.

---> With double acting cylinders with a single-sided piston rod, different forces and speeds are obtained on the advance and return strokes due to the difference in area between the piston surface and annular piston surface.
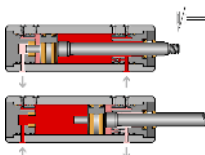
[154] Double acting cylinder with end position cushioning

Cylinders with end position cushioning are used to break high stroke speeds smoothly and prevent hard impacts at the end of the stroke. Shortly before the end position is reached, the cross- section for the outflow of fluid is reduced by the built-in cushioning pistons and then finally closed. The hydraulic fluid is then forced to escape through a flow control valve.
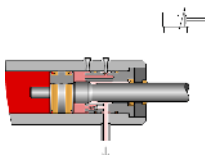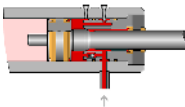
[155] End position cushioning (1)

The piston is a short distance before its end position; the hydraulic fluid on the piston-rod side must escape via the adjustable flow control valve above the piston rod

⟶ This type of end position cushioning is used for stroke speed between 6 m/min and 20 m/min. At higher speed, additional cushioning or braking devices must be used.
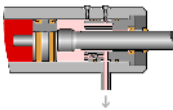
[156] End position cushioning (2)

The piston rod is on its return stroke; in this flow direction, the non-return valve below the piston rod is opened, thus by-passing the flow control valve. The piston rod retracts at maximum speed.

[157] End position cushioning

The illustration shows first the advance of the piston rod from a mid-position to the forward end position, with cushioning at the end of the advance movement. The non-return valve is open during the return stroke.

⟶ In addition the animation shows the opening of the pressure limiter after a certain pressure has been built up on the outlet side by the cushioning piston.

[158] Double acting cylinder

Actual photograph of a double acting cylinder.
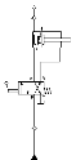
[159] Automatic bleed valve

When the cylinder is retracted, the piston of the bleed valve is closed. It is lifted as the piston rod advances. Air can then escape via the bleed hole until the hydraulic fluid reaches the piston and pushes it upwards. In the forward end position, the piston is pushed fully upwards by the hydraulic fluid and thus provides an external seal.

⟶ Bleed valves should be fitted at the highest point in a piping system, since this is where any trapped air will collect.

25.12 Gauges

[160] Piston pressure gauge
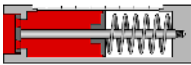
Pressure gauges operate on the principle that pressure acting on a given area will produce a given force. In the case of piston pressure gauges, the pressure acts on a piston against the force of a spring. The pressure value is now shown on a scale either by the piston itself or by a pointer driven magnetically by the piston.
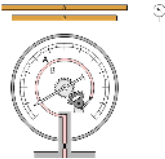

[161] Bourdon-tube pressure gauge

Most pressure gauges operate on the principle of a Bourdon tube. When hydraulic fluid flows into the tube, an identical pressure is produced throughout. Due to the difference in area between the outer and inner curved surfaces, the tube is bent. This movement is transferred to a pointer.

·····> This type of gauge is not protected against overload. A cushioning restrictor must be installed in the inlet connection prevent pressure surges from damaging the tube.

[162] Flow meter
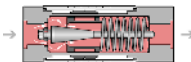
The flow of oil to be measured passes through a movable orifice. The orifice consists of a fixed cone and a hollow piston mounted on a spring. The piston is pressed against the spring in proportion to the flow rate concerned. The measuring error of this type of flow meter is approx. 4%. Measuring turbines, oval disk meters or toothed-wheel gauges are used when higher accuracy is required.

25.13 Exercises
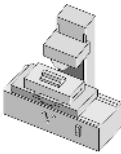
[163] Exercise: Horizontal grinding machine (pump delivery)

The slide on a horizontal grinding machine is hydraulically actuated. A machine operator determines that the reciprocating movement of the machine is no longer reaching the desired speed. A possible cause of this is reduced pump delivery. To investigate this, it is necessary to plot a characteristic curve for the pump and compare this with the values achieved during initial commissioning. As an additional exercise, the circuit diagram and parts list for the necessary test assembly should be prepared.

  In order to draw the characteristic curve for the pump, the volumetric flow of hydraulic fluid delivered by the pump (Q) is plotted against the operating pressure achieved (p). The manufacturer's characteristic curve exhibits a slight downward gradient, since the new pump manifests increasing internal leakage losses as necessary to provide internal lubrication. The newly-plotted curve shows a clear deviation; the leakage oil losses have become greater at higher operating pressures, the volumetric efficiency has become worse. The main reason for this is pump wear. Regarding the circuit diagram for the test assembly: The adjustable flow control valve 1V3 is adjusted in such a way that the pressure gauge 1Z1 shows the desired system pressure. The pressure relief valve 1V2 is used to limit the system pressure, while valve 1V1 acts as a safety valve for the pump.

⟶ The measured values taken as the basis for this exercise do not allow for the characteristic curve of the electric motor. The motor characteristic thus forms part of the calculated error.

[164] Exercise: Bending machine (directly-controlled pressure relief valve)

A bending machine is used to bend steel plates. The bending tools are driven by hydraulic cylinders. It is now desired to use the bending machine for considerably thicker steel plates than before. This requires a hydraulic system pressure of 45 bar against the previous 30 bar. According to the manufacturer's data, the pump used is suitable for the higher operating pressure. Testing reveals, however, that the bending process is now much too slow. In this case, leakage losses in the piping or directional control valve are ruled out as the cause of the problem. A directly-controlled pressure relief valve (PRV) is installed as a safety valve. Measurements of the volumetric flow (Q) as a function of pressure (p) are available for this valve. A characteristic curve can then be used to determine whether the loss of speed in the bending process is due to the PRV.

  The volumetric flow which is discharged to the tank when the PRV opens is entered on the horizontal axis. The characteristic curve shows that the opening point of the PRV is 44 bar, although it is set to 50 bar. This means that part of the pump delivery is diverted at pressures greater than 44 bar. Pressures of more than 44 bar are achieved during the bending process. Since, however, the flow is divided from 44 bar onwards, the volumetric flow to the cylinder is reduced from this point and the bending process slows down. Measure to be taken: The PRTV can be set to 60 bar if the overall installation has been designed for this higher pressure. Flow diversion will then take place from a pressure of 54 bar onwards.

····⟶ An alternative solution would be to use a valve with a different response pressure.
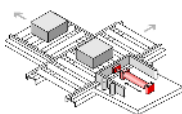
[165] Exercise: Roller conveyor (flow resistance)

Steel blocks are transported on a roller conveyor. A hydraulic transfer station makes it possible to transfer blocks from one track

to another. A pressure of at least 30 bar is required for the transfer of blocks by means of hydraulic cylinders. Every component through which the hydraulic fluid flows represents a resistance and causes a constant pressure loss. The question is, what pressure is to be set at the pressure relief valve.

The total resistance is the sum of all the individual resistances. The resistance must be determined separately for the advance and return strokes. The overall balances do not include data for the pressure losses at the 4/2-way valve. These can be determined from the flow characteristic for the 4/2-way valve, based on a volumetric flow of 8 l/min. In the calculation, allowance must be made for the resistance of the directional control valve on the inlet and outlet sides respectively. Allowance must also be made for the pressure intensification factor of 2:1 in the case of the differential cylinder. This enables values to be calculated as shown in the solution figure. In the case of the advance stroke, 6 bar hysteresis for the PRV (see exercise 164) must be added to the calculated 42.5 bar in order to ensure that the opening pressure is higher than the required operating pressure. The value finally chosen is 50 bar in order to make allowance for unknown variables such as pipe elbows and the static friction in the cylinder.

⤳ In order to keep pressure losses in large installations to a minimum, it is advisable to select valves on the basis of their flow characteristics. It is better to select a valve which is one size too large than to accept large pressure losses. This furthermore reduces wear resulting from cavitation in the valves.
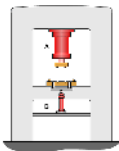

[166] Exercise: Embossing press (activation of a single acting cylinder)

Additional hydraulic components are to be added to an embossing press to eject the finished workpieces. A single acting cylinder (1A) is to be fitted for this purpose. A proposed solution in the form of a circuit diagram with a 2/2-way valve is to be examined to see if it is suitable for this control problem. Following this, a circuit diagram with a 3/2-way valve as final control element is to be developed

and a parts list prepared. A comparison is to be made of the behavior of these two circuits during the advance and return strokes.

  When a 2/2-way valve is used to activate a single acting cylinder, the final control element must be reversed and the hydraulic power unit switched off in order to retract the piston rod. The load acting on the piston rod must be larger than the resistance of the directional control valve. This solution cannot be used due to the presence of the second control chain (embossing cylinder). If a 3/2-way valve is used, a direct switch-over can be made from the advance stroke to the return stroke without switching off the hydraulic power unit. Halting at overlap positions, on the other hand (which are not required here), would be possible only by switching off the hydraulic power unit.

⤳ The non-return valve fitted in each case protects the pump against oil back-pressure. This is necessary in case the hydraulic power unit is switched off with the cylinder advanced and under load.
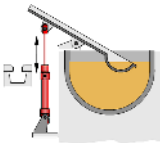
### [167] Exercise: Ladle (activation of a double acting cylinder)

Liquid aluminum is transferred from a holding furnace into a channel leading to a die-casting machine. A ladle is required for this. A double acting cylinder is used to enable the ladle to carry out the appropriate movements. A circuit diagram is provided for the activation of the cylinder with a 4/2-way valve as final control element. This must be examined to see if it is suitable for the control task concerned. The ladle must not be allowed to dip into the furnace when the valve is not actuated. A circuit diagram with a back-pressure valve must be developed to cater for the case in which the ladle is very heavy.

  The requirements of the exercise are met by the first circuit diagram only if the ladle represents a light load. If the ladle is very heavy, the advance speed could rise to an unacceptably high level during the advance stroke of the piston rod (ladle moving towards furnace), and the ladle could as a result plunge too quickly into the

molten metal. This can be prevented by installing a back- pressure valve in the B line between the valve and cylinder (tractive load).

┄┄⇥ If, as is required in this exercise, the power component must positively assume a defined end position when the installation is at rest, valves with spring return must be used, as in this case. Here, a 4/2-way valve with spring return has been used, since this ensures that the cylinder remains in the desired position if the hydraulic power unit is switched on unexpectedly. The required cylinder diameter and the return speed of the piston rod can also be calculated as additional optional tasks in the exercise: see the model calculations in the textbook.
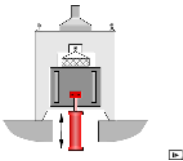
[168] Exercise: Paint drying oven (4/3-way valve)

Workpieces are fed continuously through a paint drying oven on a conveyor belt. In order to minimize the heat loss through the door, this should be opened only as much as required by the height of the workpieces. The hydraulic control system should be designed so that the door can be held reliably in position for a long period of time without slipping down. Firstly, a 4/3-way valve with suitable mid-position functions should be selected as a final control element. Secondly, a delockable non-return valve should be provided in the circuit diagram to act as a hydraulic safety device to prevent slippage of the door under load (i.e. its own weight) over a long period of time as the result of leakage losses in the directional control valve. The question is, which type of 4/3-way valve has a suitable mid-position function?

A 4/3-way valve with an "all ports closed" mid-position will solve the problem only if a poppet valve is used. If a slide valve would be used, the oven door would slip down slowly as the result of internal leakage losses.

┄┄⇥ The second solution would be to fit a delockable non- return valve in the supply line to the piston rod side of the cylinder downstream of the directional control valve. In order to ensure that the non-return valve closes immediately when the door

stops, both the outlets A and B of the directional control valve to the tank must be de-pressurized (A, B and T connected, P closed).
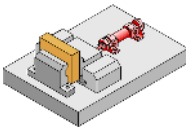
[169] Exercise: Clamping device (closing speed)

Workpieces are clamped by a hydraulic cylinder. The closing speed must be reduced in order to prevent damage to the workpieces. The opening speed must, however, be maintained. The question here is how to incorporate the necessary one-way flow control valve in the circuit. Possible solutions must be examined to see what thermal side- effects occur and to determine the pressure load placed on the components concerned.

  The advance stroke can as a general principle be made slower by using either inlet or outlet flow control. Either solution can be used in this control; in comparison with outlet flow control, inlet flow control has the advantage that no pressure intensification will take place. The oil heated at the throttle point will, however, then pass through the power component. The resulting expansion of material is not, however, of significance for this simple vice. If the solution with outlet flow control is selected, it should be borne in mind that pressure intensification will take place in accordance with the area ratio of the differential cylinder of 2:1. The pressure relief valve will respond, i.e. flow division will occur, only when a pressure has built up on the piston-rod side which is approximately twice as high as the system pressure set on the PRV. The cylinder, flow control valve and connectors used must therefore be suitable for this intensified pressure.

⤑ Precision drives for machine tools are a good example of cases in which it is essential to make allowance for expansion of the material of power components due to the passage through these of heated oil.
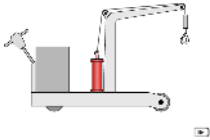
[170] Exercise: Hydraulic crane (speed reduction)

Press tools of varying weights are inserted into a press by means of a hydraulic crane. A double acting cylinder raises and lowers the load. During the commissioning of the hydraulic crane, it has become apparent that the advance speed of the piston rod is too high. The solutions have been proposed to reduce this speed; a circuit with exhaust flow control and a circuit with a back-pressure valve. A suitable solution must be selected and reasons stated for this choice. Since the second solution is not capable of operating in this form, this must be rectified by correcting the circuit diagram.

If the solution with exhaust flow control is selected, it must be borne in mind that the cylinder, flow control valve and connectors must be suitable for this intensified pressure. The solution chosen is the circuit with the back-pressure valve; in this case, the load is clamped hydraulically and a pressure-intensification effect does not occur, since the pressure can be adjustable by means of the pressure relief valve as appropriate to the load. A non-return valve must be installed to provide a by-pass on the return stroke.

⤑ Inlet flow control cannot be used to control a tractive load; the load forces oil out of the piston-rod chamber faster than oil can flow into the piston chamber. Vacuum is created and air will escape.
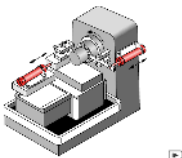
[171] Exercise: Feed control for a lathe (speed control)

The feed movement of a lathe has previously been carried out manually. In future, this is to be performed automatically by a hydraulic control system. The feed movement must be adjustable and remain constant even with changing tool loads. Since a simple throttle valve is not able to provide a constant feed speed under changing load, a 2-way flow control valve must be used. On the basis of a circuit diagram with data for the no-load situation, values for pressures, pressure differences and feed speed under load

must be added. The circuit diagram must be modified to ensure that the flow control valve is not operative on the return stroke. Finally, the relationship must be investigated between Q of the PRV and the feed speed and between p_2 and the volumetric flow to the load device.

In order to prevent the flow control valve from acting as a resistance on the return stroke, a non-return valve is installed parallel to this as a by-pass. The pressure at the PRV remains constant despite the effect of the load. The outlet flow from this is therefore a constant 7 l/min. A constant volumetric flow Q at the PRV in turn means a constant volumetric flow to the load device and thus constant feed speed. Regarding the last question: No matter whether operation is with or without a load, the pressure drop p_2 at the adjustable throttle remains constant. A constant pressure drop means a constant volumetric flow.

---⟩ Regarding the necessity for the non-return valve in the by-pass: When flow passes through 2-way flow control valves in the reverse direction, they act either as flow control valves if the regulating restrictor is fully open or non-return valves if the regulating restrictor is closed.
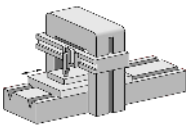
[172] Exercise: Planing machine (by-pass circuit)

The sliding bed of a parallel planing machine is actuated with the aid of a hydraulic control system. The power section of this hydraulic control system consists of a double acting differential cylinder. The area ratio of the full piston surface of this cylinder to the annular piston surface is 2:1. Since the piston-rod chamber is only half the volume of the piston chamber, the return stroke is twice as fast as the advance stroke. Machining has previously been carried out only during the advance stroke. In future, working movements are to be carried out in both directions. To make this possible, the hydraulic control system must be modified so that forward and return strokes are at the same speed. The speed should now also be adjustable. The connecting lines should be added to the given circuit diagram. The mode of operation of the circuit in the three

switching positions should be described and the various piston speeds and forces compared.

  In order to achieve the same speed on the advance and return strokes, a differential circuit (by-pass circuit) can be used with differential cylinders with an area ratio of 2:1. Picture 116.2 The second picture shows the principle of a by-pass circuit with a 3/2-way valve. In the case of the parallel planing machine, the necessary differential circuit can be achieved by using the mid-position of a 4/3-way valve (A, B and P connected, T closed). In this switching position (advance stroke), the piston speed and force are twice as high as in the right-hand switching position (return stroke). In the left-hand switching position, on the other hand, the advance stroke is half as fast and the force twice as great as in the other two switching positions. The speed for the advance and return strokes can be adjusted by means of a flow control valve fitted upstream.

···⟩ It should also be noted that only half the force is available on the advance stroke at the mid-position. In the case of a tractive load, the by-pass position has the advantage that the piston is hydraulically clamped. Differential circuits are used not only as synchronization circuits but also as rapid-traverse circuits when, for example, different speeds are required in the same direction with constant pump delivery. If it is desired to calculate forces and piston speeds using concrete values, the model values given in the TP 501 textbook can be used for this purpose.
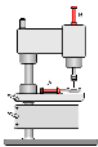
[173] Exercise: Drilling machine (pressure regulator)

The drill feed and clamping device of a drilling machine are hydraulically actuated. The hydraulic control system contains two cylinders, a clamping cylinder 1A and a feed cylinder 2A. The clamping pressure at cylinder 1A must be adjustable, since different workpiece clamping forces are required. A pressure regulator is used for this. The return stroke of the clamping cylinder must be at maximum speed. The drilling feed must be adjustable for various feed speeds, which must however remain constant under varying

load. It should also be noted that the drive spindle fitted to the piston rod of the drilling cylinder acts as a tractive load. The return stroke of the drilling cylinder should also be at maximum speed. A circuit should be drafted with the above-mentioned characteristics.

Pressure regulators can, as general principle, be used to reduce the general system pressure in a part of a hydraulic installation. If we consider the two control chains for the drilling machine without pressure regulation, we can observe the following undesirable effects: When 1V1 is actuated, the workpiece is first clamped at full system pressure. If 2V1 is now actuated, the system pressure will drop to the operating pressure of the drilling cylinder. The same applies to the pressure at the clamping cylinder. If the circuit is expanded to include the pressure regulator 1V3, this enables the clamping pressure to be adjusted. The system pressure upstream of the PRV will, however, continue to fall during the advance stroke of 2A. In order to maintain the preset clamping pressure at outlet A of the PRV reliably, the pressure at inlet P must be higher than this. This can be achieved by fitting the additional flow control valve 0V2 upstream of the final control element 2V1. Maximum return-stroke speed is achieved for the clamping cylinder by means of 1V2, which is used to by-pass 1V3. The flow control valve 2V3 means that the advance-stroke speed of the drilling cylinder is independent of load and adjustable. Due to the tractive load of the attached spindle, however, an additional PRV must be fitted as a back-pressure valve. The non-return valves 2V2 and 2V5 provide a by-pass during the return stroke and allow maximum speed to be achieved during this.

···⇥ A parts list can be specified to help in the drafting of this circuit.

25.14 Educational Films

25.14.1   Educational Films

No.	Title	Length
1	Introduction	3:20
2	Fundamentals: Pressure fluids	2:02
3	Fundamentals: Pressure and Flow Rate	2:41
4	Fundamentals: Transmission of Force and Displacement	1:35
5	Fundamentals: Pressure Transmission	0:53
6	Fundamentals: Types of Flow	2:10
7	Basic Design of Hydraulic Systems	1:13
8	The Hydraulic Power Unit	3:26
9	Hydraulic Drives	6:58
10	Valves	3:12
11	Valves: Directional Control Valves	10:39
12	Valves: Non-Return Valves	1:59
13	Valves: Pressure Control Valves	4:24
14	Valves: Flow Control Valves	4:23
15	Representation of Hydraulic Systems in Circuit Diagrams	2:58

25.15 Standard Presentations

For several topics useful presentations have been provided within FluidSIM. The following table lists the titles of the predefined presentations.

25.15.1   Presentations

Presentation Title
All topics sorted by number
Applications
Components of a hydraulic system
Graphic and circuit symbols
Fundamental physical principles
Components of the power supply section
Valves in general
Pressure valves
Directional control valves
Non-return valves
Flow control valves
Hydraulic cylinders and motors
Measuring devices
Exercises

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