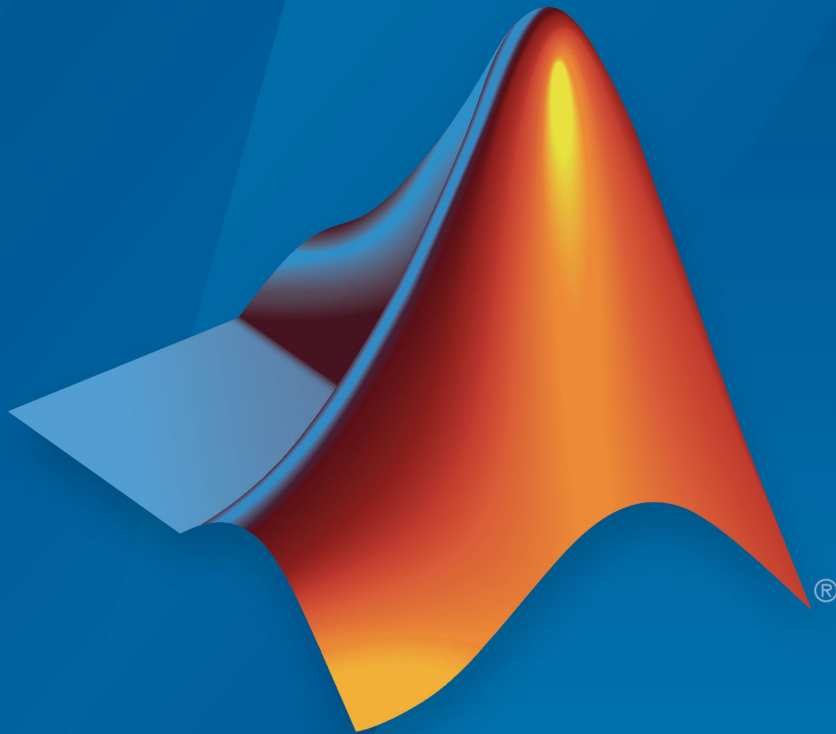


# Simscape™ Fluids™ Release Notes



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The MathWorks, Inc.  
1 Apple Hill Drive  
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# R2019a

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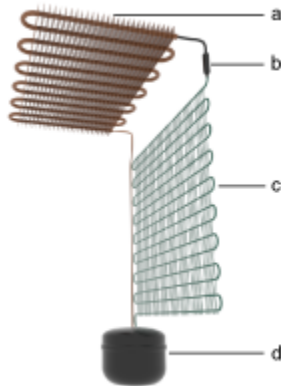
**Version: 2.6**

**New Features**

**Bug Fixes**

## Condenser Evaporator (2P-MA) Block: Model heat exchange between Two-Phase Fluid and Moist Air networks

Model a heat exchanger with working fluid susceptible to phase change. The working fluid is in the two-phase fluid domain, and it can condense or evaporate. The target fluid is in the moist air domain, and it is a gas mixture with water vapor. The water vapor can condense in bulk or as a film to drain away. The exchanger is a condenser if the working fluid turns to liquid and an evaporator if it turns to vapor. Condensers and evaporators are common in the cooling and heat cycles of air conditioning and refrigeration systems. Use the new Condenser Evaporator (2P-MA) block to model either component.



**Condenser (c) and evaporator (a) in a household refrigerator**

## E-NTU Variants of Gas Heat Exchanger Blocks: Model heat exchange in gas networks using Effectiveness-NTU method

Model the exchange of sensible heat between a gas and another fluid using the Effectiveness-NTU method. Heat exchanger blocks with at least one gas port now have two variants: **Simple Model** and **E-NTU Model**. **E-NTU Model** is the default. To change variants, right-click the block and select **Simscape > Block Choices**.

The E-NTU method determines the heat transfer rate from the effectiveness and number of transfer units, or NTU—a measure of thermal size in heat exchangers. Previously, all heat transfer calculations were based on the specific dissipation method of what is now



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the Simple Model variant. To reflect the addition of the E-NTU Model variant, heat exchanger blocks with gas ports have been renamed as follows:

- Simple Heat Exchanger (G) is now Heat Exchanger (G).
- Simple Heat Exchanger (G-G) is now Heat Exchanger (G-G).
- Simple Heat Exchanger (G-TL) is now Heat Exchanger (G-TL).

The block variants are each a composite component built from fundamental heat exchanger blocks. The Simple Model variant is based on Specific Dissipation Heat Transfer, Simple Heat Exchanger Interface (G), and, where thermal liquid serves as the second fluid, Simple Heat Exchanger Interface (TL) blocks. The E-NTU Model variant is based on E-NTU Heat Transfer, Heat Exchanger Interface (G), and, for exchangers with thermal liquid, Heat Exchanger Interface (TL) blocks. Heat Exchanger Interface (G) is a new addition to the fundamental heat exchanger components library.



**Heat exchanger (in shell-and-tube configuration)**

## **Wall Thermal Dynamics in Heat Exchanger Blocks: Capture thermal transients due to thermal mass of heat exchanger wall**

Model a heat exchanger with thermal mass for its wall. Thermal mass allows the wall to absorb heat passing through and adds to the heat transfer a slight transient delay. Heat exchanger blocks with gas or thermal liquid on each side now provide a **Wall thermal dynamics** parameter to capture that delay. Set it to On to specify the thermal mass of the wall.

The new parameters feature in the Heat Exchanger (G-G), Heat Exchanger (G-TL), and Heat Exchanger (TL-TL) blocks when configured in the default variant of E-NTU Model. The E-NTU Model variant is new to the blocks. To check and change variants, right-click the block and select **SimscapeBlock Choices**. To reflect the new variants, blocks previously named Simple Heat Exchanger (\*) are now named Heat Exchanger (\*).

# R2018b

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**Version: 2.5**

**New Features**

**Bug Fixes**

### **3-Zone Pipe (2P) Block: Model pipes containing liquid, vapor, and liquid-vapor mixtures**

Model the effects of phase change in pipe flow. The new 3-Zone Pipe (2P) block splits the fluid into up to three volumes, or *zones*—one each for liquid, vapor, and two-phase mixture. These can shrink and grow in size as condensation and evaporation take place.

The block captures the viscous friction losses that occur in the pipe as well as the convective heat transfer between each zone and the environment. Pressure and temperature are calculated from the aggregate compressibility and thermal capacity of the different zones. Temperature can vary from one zone to the next.

### **Receiver Accumulator (2P) Block: Model chambers containing liquid and vapor volumes**

Track the phase of a fluid as it evaporates and condenses inside a tank such as the receiver or accumulator of a refrigeration system. The **Two-Phase Fluid > Tanks & Accumulators** library now contains a block to model such a component: Receiver Accumulator (2P).

The tank has distinct liquid and vapor regions. These can shrink and grow, even disappear and reappear, as liquid transforms to vapor and vapor back to liquid. The phases can each enter and exit the accumulator, for which purpose the block contains two liquid ports and two vapor ports. If liquid and vapor enter at different rates, their proportions will naturally tend to change also.

### **Air Muscle Actuator (G) Block: Model actuators driven by pneumatic bladder**

Power a mechanical system with the pneumatic force of an air muscle. So that you can model this compliant actuator, the **Gas > Actuators** library now contains an Air Muscle Actuator (G) block. The block interfaces three domains: Gas, Mechanical Translational, and Thermal.

An air muscle is a linear actuator popular in robotics for its characteristics reminiscent of biological muscle. The actuator comprises an expandable bladder in a braided shell. When the bladder is pressurized, the pair widens and simultaneously shortens, producing at their end caps a contractile force. That force is calculated here using the standard Chou-Hannaford model (with two corrections applied for improved accuracy).



### **Air muscle in its relaxed (unpressurized) state**

The resemblance between air and biological muscles reflects in the shapes of their force-length curves. Those of an air muscle are the product of its sleeve properties. The number of braids in the mesh, the number of strands in a braid, the elasticity of a strand and its natural width and length—all bear on the axial force that the muscle ultimately produces. These parameters are specified in the block.

For an instance of this arrangement see the Antagonistic McKibben Muscle Actuator featured example. To open the example, at the MATLAB command prompt, enter `sscfluids_antagonistic_mckibben_actuator`.

### **Gas Valve Blocks: Model directional, flow-control, and pressure-control valves in pneumatic systems**

Control flow in a gas network using the new **Gas > Valves & Orifices** library. You can use the gas valve blocks to route flow, regulate flow rate, and control fluid pressure (or pressure differential). These blocks are similar in function to their counterparts in the **Thermal Liquid > Valves & Orifices** library. For more information, see Gas Components.

### **Thermal Liquid Properties (TL) Block: Select predefined fluid properties for diesel fuel and jet fuel**

Set the working fluid of a thermal liquid network to diesel or jet fuel without having to specify all of its physical properties. Merely connect a Thermal Liquid Properties (TL) block and select the fluid from a preset list. The block sets the fluid properties automatically, using data obtained from the CoolProp fluids database.

The preset list contains a growing number of fluids, of which the two fuels are the latest. Other presets include water and a number of aqueous mixtures common in heating and cooling applications. Every thermal liquid network must contain exactly one instance of this block or, alternatively, of the Thermal Liquid Settings (TL) block. Use the latter to manually set each of the fluid properties.

## **Pilot-Operated Check Valve (TL) block: Model pilot-operated check valves in Thermal Liquid networks**

Limit flow in a thermal liquid branch to a single direction, but only as long as the effective pressure differential across the valve is below a preset cracking pressure. The effective pressure differential is controlled in part by a pilot pressure—defined either as a gauge pressure or as a pressure differential against the inlet. The new block, Pilot-Operated Check Valve (TL), is in the **Thermal Liquid > Valves & Orifices > Directional Control Valves** library.

## **Fan (G) block: Model fans in Gas networks**

Power a compressible flow with the action of a spinning rotor. The **Gas > Turbomachinery** library contains a new block for the rotary power source: Fan (G). The block is parameterized in terms of pressure, flow rate, efficiency, and shaft speed—performance metrics commonly reported in the technical datasheets of fans. The exact parameters used depend on the choice of fan specification. Of these, there are four, all based on tabulated data. The block calculations are based in part on fan affinity laws, which relate the performance characteristics of similar fans.

## **Pilot-Operated Check Valve block: Specify pilot pressure using new parameterization**

Specify the pilot pressure of a controlled check valve either as a gauge value (relative to the environment) or as a differential against the valve inlet. So that you can select your preferred method, the Pilot-Operated Check Valve now provides a **Pressure control specification** parameter with the options **Pressure at port X** and **Pressure differential (pX - pA)**. Note that this update refers to the Hydraulic (Isothermal Liquid) version of the block.

## **Expanded Run-Time Parameter Support: Change more block parameters during or between simulation**

The Simscape Fluids library has expanded its support for run-time parameters. These are parameters that you can set at run time—during or between simulations—without forcing the model to recompile.

You must enable this behavior explicitly for each block parameter needed as run-time. This task requires only that you select from a drop-down list the option **Run-time**. The

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drop-down list is always in line with the block parameter, adjacent to the units box or, in the case of unitless parameters, to the value box.

If you do not see the drop-down list, check that your Simscape preferences are set to show run-time parameter settings. Not all numerical parameters can be set at run time. If the drop-down list is "grayed out" and it does not respond to mouse clicks, then you can set that parameter at compile time only.

All parameters are by default **Compile-time**—even those that you can later change to **Run-time**. You can change the numerical value and physical units of a **Run-time** parameter but only before the model compiles. If you update the model thereafter, the model must recompile before it will simulate. This is the legacy behavior to which you may have grown accustomed when working with Simscape Fluids models.





# R2018a

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**Version: 2.4**

**New Features**

**Bug Fixes**

## **Orifice ISO 6358 (G) and Variable Orifice ISO 6358 (G) Blocks: Model flow restrictions per ISO standard**

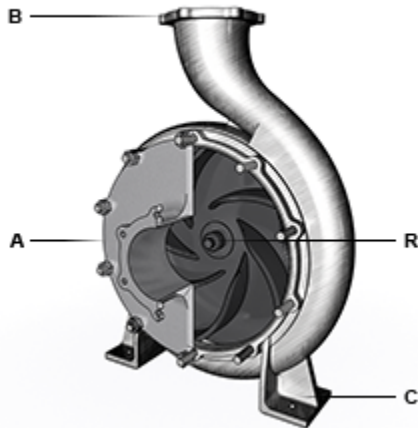
Model compressible flows across orifices of fixed and variable size using the methods of the ISO 6358 standard. The methods, variously based on sonic conductance, flow coefficient, and restriction area, form the basis for much of the measuring and reporting done on such flows. The abundance of data produced through them makes for a convenient way to characterize orifices, especially those about whose geometries little is known.

The new blocks, Orifice ISO 6358 (G) and Variable Orifice ISO 6358 (G), are the first of a Gas library aimed at the modeling of compressible flows. The blocks are based on the Simscape domain of the same name. Use them with blocks from the Foundation Gas library to create a complete gas model. Combine them with blocks from the Fluid Network Interfaces library to capture mechanical and thermal interactions with other fluids—in double-sided actuators, in multifluid heat exchangers, or in two-chamber tanks.

For more information on the Simscape Gas domain—an overview of its domain variables, a description of its gas parameterizations (perfect, semi-perfect, real), the distinction between its two component types (those with and those without internal volume), see Modeling Gas Systems.

## **Centrifugal Pump (TL) Block: Model centrifugal pump with thermal liquid working fluid**

Model the pressure rise established across a thermal liquid branch by the centrifugal action of a fanlike rotor (or impeller) inside a spiral chamber (or volute). The centrifugal pump is parameterized by head and brake power, operating characteristics often provided in technical datasheets as functions of flow capacity (a volumetric flow rate) and impeller shaft speed. Refer to the characteristic curves of the pump, if included in its datasheet, for this data.



### **Centrifugal Pump (with Ports Shown)**

The new block, Centrifugal Pump (TL), is the latest addition to the Thermal Liquid Pumps & Motors library. Consider it a complement to the variety of displacement pump blocks contained in the same library. Centrifugal pumps, among the most widespread in industry, work in such a way as to maintain a steady flow capacity even if the pressure differential across them should change. Such characteristics are captured in the tabulated data of the block.

### **Thermal Liquid Properties (TL) Block: Select predefined fluid properties for thermal liquid network**

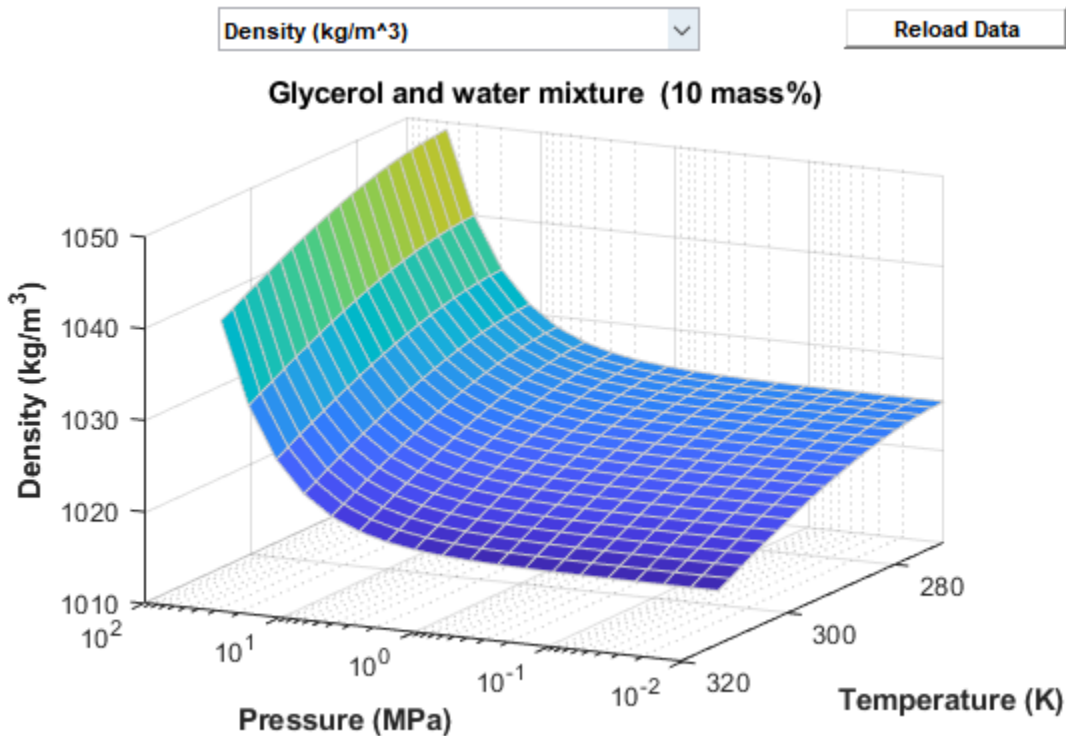
Assign a working fluid to a thermal liquid network by selecting one from a preset list. Fluids available for selection include water, seawater, and a variety of aqueous mixtures with common uses in cooling and antifreeze applications. Such mixtures include those of glycerol, ethylene glycol, and propylene glycol. The fluid can be further defined in terms of its salinity, in the case of seawater, or concentration, in the case of an aqueous mixture.

The new block, Thermal Liquid Properties (TL), features in the new Thermal Liquid Utilities library. Treat it as an alternative to the Thermal Liquid Settings (TL) block of the Foundation Thermal Liquid library. The two blocks serve the same purpose: to define the

fluid properties, among them density, viscosity, and thermal conductivity, on which thermal liquid models depend for simulation. The blocks differ only in the way in which those properties are provided.

Use the Thermal Liquid Settings (TL) block to specify—explicitly, in tabulated form—the properties of any thermal liquid. Use the new Thermal Liquid Properties (TL) block to have those properties automatically retrieved for a fluid selected from a small preset list given only a small number of parameters, such as salinity. The fluid properties are retrieved in tabulated form from data derived from Coolprop—an open-source fluids database used in industry.

For convenience, the Thermal Liquid Settings (TL) block provides a visualization utility with which to plot the properties of a fluid. Use the utility to examine the temperature and pressure dependences of those properties or to ascertain the bounds of their validity regions (given in the visualizations by the bounds of the plots). To open the visualization utility, right-click the block and, from the context-sensitive menu, select **Fluids > Plot Fluid Properties**.



**Visualization of density data for a 10% glycerol aqueous mixture**

**Pipe (TL) Block with Operating Point Parameterization:  
Specify pipe pressure drop and temperature differential  
based on operating point**

Characterize the flow through a thermal liquid pipe by specifying, in tabulated form, its pressure drop and temperature differential at one or several nominal operating points. The nominal data establishes the dependence of the pressure loss on the mass flow rate and of the temperature differential on the same. This data features in the calculation of the pressure loss coefficient, of which the friction pressure loss is a function, and of the heat transfer coefficient, on which the convective heat transfer rate—and, ultimately, temperature—depends.

The pressure parameterization, Nominal pressure drop vs. nominal mass flow rate, is available from the **Viscous friction parameterization** dropdown list of the **Viscous Friction** tab. The temperature parameterization, Nominal temperature differential vs. nominal mass flow rate, is available from the **Heat transfer parameterization** dropdown list of the **Heat Transfer** tab. A new semi-empirical parameterization, based on the Dittus-Boelter correlation accompanies the tabulated temperature parameterization. The correlation is of the form:

$$\text{Nu} = a \cdot \text{Re}^b \cdot \text{Pr}^c .$$

where Re and Pr are the average Reynolds and Prandtl numbers in the pipe and where  $a$ ,  $b$ , and  $c$  are the empirical coefficients to use in the correlation (typically 0.023, 0.8, and 0.4, respectively). For more information, refer to the Pipe (TL) block.

## **Directional Valves (TL) with Operating Point Parameterization: Specify mass flow rate based on opening and pressure drop**

Capture the opening characteristics of a directional control valve in the thermal liquid domain by specifying, in tabulated form, its mass flow rate. The tabulated data establishes the dependence of the mass flow rate on the position of a control member—such as a ball, spool, or diaphragm—and the pressure drop in the direction of flow. The higher-order directional valves—those that comprise two or more flow paths—provide the additional option to specify the necessary data separately for each flow path.

The new valve opening parameterization, Tabulated data - Mass flow rate vs. opening and pressure drop, is available from the **Valve parameterization** dropdown list of the block dialog box. The 2-Way Directional Valve (TL), 3-Way Directional Valve (TL), and 4-Way Directional Valve (TL) blocks all provide it, as does the Variable Area Orifice (TL) block upon which they are based. The dropdown list is named **Orifice opening** in the case of the Variable Area Orifice (TL) block.

The new option to characterize each flow path separately, Different for each flow path, is available from the **Area characteristics** dropdown list. Only directional valve blocks with multiple flow paths—that is, 3-Way Directional Valve (TL) and 4-Way Directional Valve (TL)—provide it. The **Model Parameterization** tab updates when the new option is selected to reflect the fact that the valve opening characteristics are to be specified separately.

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## **Pressure Control Valves with Operating Point Parameterization: Specify opening area based on pressure differential**

Capture the opening characteristics of a pressure control valve by specifying, in tabulated form, its opening area. The tabulated data establishes the dependence of the opening area on the pressure differential of relevance for the particular block. The new valve parameterization, **Tabulated data - Area vs. pressure**, is available from the **Valve parameterization** dropdown list of the Pressure Compensator, Pressure Reducing Valve, Pressure Reducing 3-Way Valve, and Pressure Relief Valve blocks. Use the parameterization to model valves with general, nonlinear opening characteristics in the hydraulics (isothermal liquid) domain.





# R2017b

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**Version: 2.3**

**New Features**

**Bug Fixes**

## Variable-Displacement Motor (TL) and Variable-Displacement Pump (TL) Blocks: Model motors and pumps with variable displacement

Model thermal liquid pumps and motors with variable displacement. The **Thermal Liquid > Pumps and Motors** library provides two new blocks for this purpose: Variable-Displacement Motor (TL) and Variable-Displacement Pump (TL). Exposed on each block is a physical signal port for the input of the displacement signal. Connect this port to specify the volume of fluid swept in a stroke as a function of time or as a constant.

## Thermal Liquid Pumps and Motors with Variable Losses and Efficiencies: Specify loss or efficiency as tabulated data or input signals

Specify loss or efficiency in a thermal liquid pump or motor as a variable input. Both fixed- and variable-displacement pumps and motors now include variable loss and efficiency variants. You can represent these components using the blocks provided in the **Thermal Liquid > Pumps and Motors** library:

- Fixed-Displacement Motor (TL)
- Fixed-Displacement Pump (TL)
- Variable-Displacement Motor (TL)
- Variable-Displacement Pump (TL)

Use the context-sensitive menu of the block to select a block variant. Right-click the block, then, from the **Simscape > Block Choices** menu, select **Input losses** or **Input efficiencies**. The block exposes two physical signal input ports, one for mechanical loss or efficiency, the other for volumetric loss or efficiency.

## Tank (G-TL) Block: Model tanks with both thermal liquid and gas inlets

Model a tank with thermal liquid and gas volumes. The **Fluid Network Interfaces > Tanks & Accumulators** library provides a new block for this purpose: Tank (G-TL). The thermal liquid and gas volumes are unmixed, as though separated by an impermeable membrane. Their pressures are assumed to be at equilibrium and are therefore always equal. The hydrostatic pressure differences between the liquid-gas interface and the thermal liquid inlets are included in the model.

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This block serves as an interface between the distinct Simscape domains of Thermal Liquid and Gas. Two gas ports connect to the gas volume. An optional number of thermal liquid ports, ranging from one to three, connect to the thermal liquid volume. Change the block variant to change the number of thermal liquid ports. Right-click the block and, from the **Simscape > Block Choices** menu, select **One inlet**, **Two inlets**, or **Three inlets**.

## **Simple Heat Exchanger Blocks: Model heat transfer between gas networks or gas and liquid networks using the specific dissipation method**

Model heat exchange between two gases, between a gas and a thermal liquid, or between a gas and an external fluid with properties controlled by physical signals. The **Fluid Network Interfaces > Heat Exchangers** library provides three new blocks for this purpose: Simple Heat Exchanger (G), Simple Heat Exchanger (G-G), and Simple Heat Exchanger (G-TL).

The heat transfer rate is calculated from the specific dissipation rate, a quantity defined as the ratio of the heat transfer rate to the difference in inlet temperature. The new blocks are composite components built on the new fundamental components Simple Heat Exchanger Interface (G), Simple Heat Exchanger Interface (TL), and Specific Dissipation Heat Transfer.

## **Pipe (TL) Block with Variable Elevation: Specify pipe elevation gain that varies during simulation**

Model a thermal liquid pipe with a time-varying slope. The Pipe (TL) block from the **Thermal Liquid > Pipes & Fittings** library provides a new variant for this purpose. Change the block variant to specify the elevation gain from inlet to outlet as a variable input. Right-click the block and, from the **Simscape > Block Choices** menu, select **Variable elevation**. The block exposes a physical signal input port for the elevation gain signal.

## Actuators and Cylinders with Configurable Hard Stops: Enforce motion limits with numerically smooth hard stops for faster simulation

Enforce the motion limits of actuators and cylinders using numerically smooth hard stops. The new hard stops have no zero crossings and are a suitable choice when simulation speed is of concern. They are available in actuators and cylinders of all types: isothermal liquid, thermal liquid, and multi-fluid. Use the **Hard stop model** block parameter to select a hard-stop model. Options include:

- **Stiffness and damping applied smoothly through transition region** — Scale the magnitude of the contact force from zero to its full value over a specified transition length. The scaling is polynomial in nature. The polynomial scaling function is numerically smooth and it produces no zero crossings of any kind.
- **Full stiffness and damping applied at bounds, undamped rebound** — Apply the full value of the calculated contact force when the hard-stop location is breached. The contact force is a mix of spring and damping forces during penetration and a spring force—without a damping component—during rebound. No smoothing is applied.
- **Full stiffness and damping applied at bounds, damped rebound** — Apply the full value of the calculated contact force when the hard-stop location is breached. The contact force is a mix of spring and damping forces during both penetration and rebound. No smoothing is applied. This is the hard-stop model used in previous software versions.

The new hard-stop models are available in the following blocks. In the Hydraulics (Isothermal) library:

- Double-Acting Hydraulic Cylinder
- Single-Acting Hydraulic Cylinder
- Double-Acting Rotary Actuator
- Single-Acting Rotary Actuator

In the Thermal Liquid library:

- Double-Acting Actuator (TL)
- Single-Acting Actuator (TL)

In the Fluid Network Interfaces library:

- 
- Double-Acting Actuator (IL-G)
  - Double-Acting Actuator (TL-G)



# R2017a

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**Version: 2.2**

**New Features**

**Bug Fixes**

## **Characteristic Curve Visualization: View the performance, efficiency, and loss curves for hydraulic pump and motor blocks**

You can now plot a variety of characteristic curves from the Fixed-Displacement Pump and Fixed-Displacement Motor blocks, found in the **Hydraulics (Isothermal) > Pumps and Motors** library.

The characteristic curves include performance plots that show how power and flow rate vary with the pressure difference sustained between the ports. They include also efficiency and loss plots that show how the volumetric and mechanical efficiencies and losses vary with the shaft angular speed.

The performance plots are based on simulation data. The efficiency and loss plots are based on the analytical parameters or tabular data specified in the block dialog box. Use the efficiency and loss curves to check your input data—for example, to catch data-entry errors prior to simulation.

You can generate the characteristic curves from the block context-sensitive menu by selecting **Fluids > Plot Characteristic**. This menu option opens a model harness that you can simulate without affecting the source model. Follow the steps described in the model harness to generate the characteristic curves.

For more information, see Pump and Motor Characteristic Curves.

## **Multi-Fluid Actuators: Model power generation using multiple working fluids**

Model a double-acting actuator with two types of working fluid, one being a gas and the other a hydraulic (isothermal) or thermal liquid, using the Double-Acting Actuator (IL-G) and Double-Acting Actuator (TL-G) blocks from the new **Fluid Network Interfaces > Actuators** library. The blocks serve as interfaces between the different fluid domains and the mechanical translational domain.

## **Hydraulic Directional Valves with Asymmetric Port Areas: Specify unique area characteristics for each port**

Model a hydraulic directional valve with different flow areas between its ports. You can specify the properties of each flow path separately as a function of control member



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displacement. Valve blocks with asymmetric port areas include 3-Way Directional Valve and 4-Way Directional Valve. You can find the blocks in the **Hydraulic (Isothermal) > Valves > Directional Valves** library. Set the **Area characteristics** parameter in the **Basic Parameters** tab to **Different** for each flow path to specify the properties of each flow path separately.

## Run-Time Parameters: Speed up simulation tasks and modify component parameter values without regenerating C code

Simscape Fluids software now supports run-time parameters. You can configure most numerical block parameters as **Compile-time** (default) or **Run-time** using a drop-down list that appears beside configurable parameters. The figure shows the run-time drop-down list in a 4-Way Directional Valve (TL) block dialog box. All parameters are by default **Compile-time**.

Parameters	Valve Opening Offsets
Between ports P and A:	<input type="text" value="0"/> <input type="text" value="m"/> <input type="text" value="Compile-time"/>
Between ports B and T:	<input type="text" value="0"/> <input type="text" value="m"/> <input type="text" value="Run-time"/>
Between ports P and B:	<input type="text" value="0"/> <input type="text" value="m"/> <input type="text" value="Compile-time"/>
Between ports A and T:	<input type="text" value="0"/> <input type="text" value="m"/> <input type="text" value="Compile-time"/>

**Compile-time** parameters update in value only when you recompile the model. Use them when performing tasks that rely on inlined parameters such as model optimization. **Run-time** parameters update in value without the need for extra compilations. Use them when tuning parameter values in Fast Restart mode or when simulating models that rely at least in part on generated C code.

To set a parameter as **Run-time** from the block dialog box, you must configure your Simscape preferences. Open the MATLAB® Preferences window, select the **Simscape** node, and check the **Show run-time parameter settings** check box. Parameters without a run-time option or with a run-time option that is inactive (i.e., “grayed out”) cannot be configured.

For more information about Simscape run-time parameters, see About Simscape Run-Time Parameters (Simscape).

## Hydraulic Tank Block Updates

Three hydraulic tank blocks have merged into a single block named Tank. The merged blocks include Variable Head Tank, Variable Head Two-Arm Tank, and Variable Head Three-Arm Tank. The new Tank block provides three Simscape variants corresponding to the merged blocks—these differing in their numbers of ports, which ranged from one to three.

You can select a Simscape variant from the context-sensitive menu of the block. Right-click the block to open the menu and select **Simscape > Block Choices** to pick a variant. The `One inlet` variant corresponds to the old Variable Head Tank block, the `Two inlets` variant to the old Variable Head Two-Arm Tank block, and the `Three inlets` variant to the old Variable Head Three-Arm Tank block.

## Hydraulic Ball Valve Block Updates

Two hydraulic ball valve blocks have merged into a single block named Ball Valve. The merged blocks include Ball Valve and Ball Valve with Conical Seat. The updated Ball Valve block provides two block parameterizations corresponding to the merged blocks—these differing in their valve seat geometries.

Use the **Valve seat specification** parameter to select a valve seat geometry. The `Sharp-edged` parameterization corresponds to the previous version of the Ball Valve block. The `Conical` parameterization corresponds to the previous version of the Ball Valve with Conical Seat block.

# R2016b

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**Version: 2.1**

**New Features**

**Bug Fixes**

## **Numerical Enhancements in Hydraulic Pump and Motor Blocks: Transition robustly between pumping and motoring regimes**

Pump and motor blocks from the Hydraulics (Isothermal) library support new operation modes. The updated blocks can each operate as forward pumps, reverse pumps, forward motors, and reverse motors. The pressure difference between the hydraulic ports and the rotational velocity at the mechanical rotational port determine the actual operation mode. Hyperbolic Tanh functions smooth the transitions between the modes.

## **Loss Parameterizations in Hydraulic Pump and Motor Blocks: Specify variable losses and efficiencies using physical signals or lookup tables**

Pump and motor blocks from the Hydraulics (Isothermal) library provide new ways of accounting for power losses. You can now specify mechanical and volumetric efficiencies and losses using physical signals or 2D lookup tables. To change the specification method, you must change the block variant using the block context-sensitive menu. Right-click the block and, from the **Simscape > Block choices** menu, select the appropriate option. The blocks with the new variants are:

- Fixed-Displacement Motor
- Fixed-Displacement Pump
- Variable-Displacement Motor
- Variable-Displacement Pump

## **Interface (TL-IL) Block: Connect thermal liquid and isothermal liquid networks**

The Fluid Network Interfaces library provides a new block, Interface (TL-IL). Use the new block to connect a thermal liquid network to a hydraulic (isothermal liquid) network. The block matches the pressure and mass flow rates at the interface while keeping the network fluid properties separate. Heat transfer occurs between the thermal liquid and the interface but not between the interface and the hydraulic fluid.

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## **Mass Flow Rate Measurements: Log and sense mass flow rates through pump and motor blocks**

Pump and motor blocks from the Hydraulics (Isothermal) library now use mass flow rate as an explicit variable. You can sense the new variable using the updated Hydraulic Flow Rate Sensor block, which now senses mass flow rates directly. You can also use Simscape logging to access the mass flow rate data for a hydraulic node.

## **Hydraulics (Isothermal) Library: Motor blocks combined and renamed**

The Fixed-Displacement Motor (External Efficiencies) block has been combined with the Hydraulic Motor block and renamed Fixed-Displacement Motor. The updated block comprises three block variants that preserve and expand the functionality of the original blocks. To access the block variants, right-click the block and select **Simscape > Block choices**.



# R2016a

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**Version: 2.0**

**New Features**

**Bug Fixes**

## **SimHydraulics renamed to Simscape Fluids**

The SimHydraulics® product is now named Simscape Fluids. The product library is located in the Simscape node of the Simulink® library browser under the name Fluids. You can open the product library at the MATLAB command prompt using the new `SimscapeFluids_lib` command.

## **Thermal Liquid Library: Model systems containing liquids whose properties vary with temperature**

A new Thermal Liquid library enables you to capture the effects of temperature change on liquid properties. You can use the Thermal Liquid library to model any liquid system where thermal effects are important. Applications include power transmission systems such as hydraulic actuators, liquid transport systems such as oil pipelines, and heating and cooling systems such as HVAC units.

The new library provides specialized components not found in the Simscape Foundation Thermal Liquid library. These include detailed models of actuators, accumulators, valves, pumps, and motors. A separate library named Fluid Network Interfaces enables you to model heat exchange between separate fluid subsystems. The new blocks are based on the existing Simscape Thermal Liquid domain.

For a tutorial showing how to model a simple thermal liquid system, see [Model a Thermal Liquid Pipeline](#).

## **Thermal Liquid Examples**

The following featured examples show some applications of the new Thermal Liquid library:

- Engine Cooling System
- Hydraulic Oil System with Thermal Control
- Reciprocal Actuator with Differential Cylinders



# R2015b

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**Version: 1.17**

**New Features**

**Bug Fixes**

## Pneumo-Hydraulic Actuator block with two mechanical ports

The Pneumo-Hydraulic Actuator block can now have either one or two mechanical translational ports:

- Use the variant with one mechanical port to model just the load on the piston. In this case, the cylinder is assumed to be grounded.
- Use the variant with two mechanical ports to model the load on the actuator cylinder, as well as the piston. This variant also lets you include liquid compressibility on the hydraulic side of the actuator.

By default, the block has one mechanical port. To switch to the two-port variant, right-click on the block in your model and then, from the context menu, select **Simscape > Block choices > Two mechanical ports**. The block icon displays the additional port, and the block dialog changes to include the additional parameters on the **Hydraulic Side** tab.

# R2015a

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**Version: 1.16**

**New Features**

**Bug Fixes**

## Variable-Displacement Hydraulic Machine (External Efficiencies) block

The new Variable-Displacement Hydraulic Machine (External Efficiencies) block in the Pumps and Motors library represents a reversible, variable positive-displacement hydraulic machine with volumetric and mechanical efficiencies provided externally to the block through physical signal ports EV and EM, respectively. The machine displacement is controlled by the signal provided through the physical signal port C. The block can work as a pump or a motor, depending on the direction of mechanical and hydraulic power flow. To ensure continuity at the instance when the machine switches its operational mode, the block implements a small transition region, defined by the power threshold value. This transition region helps avoid a discontinuity and improve numerical convergence.

## Valve opening dynamics in directional and pressure control valves

The following blocks now have an additional parameter that lets you consider valve opening dynamics:

- Check Valve
- Pilot-Operated Check Valve
- Hydraulically Operated Remote Control Valve
- Shuttle Valve
- Pressure Compensator
- Pressure Reducing 3-Way Valve
- Pressure Reducing Valve
- Pressure Relief Valve

The default block behavior is unchanged, that is, the valve sets its opening area directly as a function of pressure. However, as the area changes instantaneously, so does the flow equation, often by many orders of magnitude. Adding valve opening dynamics provides continuous behavior that is more physically realistic, and is particularly helpful in situations with rapid valve opening and closing.

If you set the new **Opening dynamics** parameter to `Include valve opening dynamics`, two additional parameters become available:

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- **Opening time constant** — The time constant for the first order response of the valve opening.
  - **Initial area** — The initial opening area of the valve.

The orifice passage area depending on pressure  $A(p)$  in the block equations then becomes the steady-state area, calculated exactly as before, and the instantaneous orifice passage area is calculated as

$$area.der = (steady-state\ area - area) / opening\ time\ constant,$$

with  $area = initial\ area$  at  $t = 0$ .

Use this feature in hydraulic simulations with the local solver for real-time simulation. This feature is also helpful if you are interested in valve opening dynamics in variable step simulations.

## Accumulator blocks with improved hard stops

The Gas-Charged Accumulator and Spring-Loaded Accumulator blocks are each equipped with two hard stops, used to restrict the fluid volume between zero and the full fluid chamber capacity. In R2014b, these hard stops were modeled as absolutely plastic. As a result, the fluid volume could drift below zero or above fluid chamber capacity in some situations.

Starting in R2015a, the hard stop model in the accumulator blocks includes both a stiffness term and a damping term to prevent the nonphysical values from occurring. When the hard stops are modeled with finite stiffness and damping, it is still possible for the fluid volume to become slightly negative or slightly greater than the fluid chamber capacity. This represents the deflection in the hard stops.

As a result of these changes, both blocks now have a new parameter, **Hard-stop stiffness coefficient**, which accounts for the stiffness term in the hard-stop equations. The old parameter **Penetration coefficient** has been renamed to **Hard-stop damping coefficient**, and some other block parameters have been renamed for clarity. See the block reference pages for details.

When you upgrade from R2014b, the blocks in existing models automatically assume a value of zero for the **Hard-stop stiffness coefficient** parameter value to preserve the existing behavior. When you upgrade from R2014a or earlier, the blocks in existing

models automatically assume the new default values for the **Hard-stop stiffness coefficient** and **Hard-stop damping coefficient** parameters.

## **New examples**

The following example has been introduced in this version:

- Hydraulic System with Priority Valve

# R2014b

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**Version: 1.15**

**New Features**

**Bug Fixes**

## **Flow Divider-Combiner block**

The new Flow Divider-Combiner block in the Flow Control Valves library models a valve that divides the direct flow (incoming to port P) between two outlets, and also maintains a specified proportion between return flows through ports A and B in the total flow rate through port P. In other words, the valve works in two distinctive modes: flow divider for direct flow and flow combiner for reverse flow. The existing Flow Divider block, also available in the Flow Control Valves library, cannot be used as a flow combiner.

## **Variable Orifice Between Round Holes block**

The new Variable Orifice Between Round Holes block in the Orifices library simulates a variable orifice created by two interacting round holes, which can be of different diameters. One hole is located in the sleeve, while the other is drilled in the case, with the sleeve sliding along the case. Use this block in cartridge valve models.



# R2014a

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**Version: 1.14**

**New Features**

**Bug Fixes**

**Compatibility Considerations**

## Removal of laminar-turbulent zero-crossings in flow rate equations

Flow rate equations used in orifices, valves, local resistances, and low-pressure blocks have been modified so that they no longer produce zero-crossings upon transition between the laminar and turbulent regimes during simulation. This enhancement increases simulation efficiency for hydraulic models. Numerical simulation results are essentially the same.

## Improvement of mass conservation for cylinders with fluid compressibility

The schematics of the cylinder and rotary actuator blocks no longer include the Hydraulic Piston Chamber block. Instead, they are now using the updated hydro-mechanical converter blocks from the Simscape Foundation library, which let you account for fluid compressibility inside the converter block. For more information see the Simscape Release Notes item, Hydro-mechanical converter blocks with fluid compressibility option.

## Gate Valve equations change

The equations used to calculate the instantaneous area of the valve opening have changed, to increase the fidelity of simulation. The area is now computed with the same equation for the whole working range,  $0 < h \leq 2D$ :

$$A(h) = D^2 \cdot \left( \frac{\alpha}{2} - \sin(2\alpha) \right) / 4.$$

The angle  $\alpha$  is computed as  $\alpha = \arccos(1 - h / D)$  for the first half of the working range,  $0 < h \leq D$ , and as  $\alpha = \arccos(h / D - 1)$  for the second half,  $D < h \leq 2D$ .

## Compatibility Considerations

Numerical simulation results for legacy models containing this block may change slightly because of the change in the block equations.

# R2013b

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**Version: 1.13**

**New Features**

**Bug Fixes**

## Cylinder Cushion block

The new Cylinder Cushion block in the Hydraulic Cylinders library models a hydraulic cylinder cushion, the device that decelerates the cylinder rod as it approaches the end of stroke by restricting flow rate leaving the cylinder chamber.

## Pressure-Compensated 3-Way Flow Control Valve block

The new Pressure-Compensated 3-Way Flow Control Valve block in the Flow Control Valves library simulates a pressure-compensated 3-way flow control valve. The valve includes a variable orifice and a normally closed pressure-control valve, connected in parallel with the orifice. The purpose of the pressure-control valve is to maintain a preset pressure differential across the orifice by diverting some flow from port A to tank (through port R) if pressure differential exceeds the setting.

## Pressure Reducing 3-Way Valve block

The new Pressure Reducing 3-Way Valve block in the Pressure Control Valves library simulates a pressure reducing 3-way valve, sometimes also referred to as a pressure reducing/relieving valve. The valve reduces inlet pressure to a preset value, similar to a conventional pressure-reducing valve, but, additionally, starts working as a pressure-relief valve if the pressure continues to rise.

## Nominal fluid density parameter for pump and motor blocks

The **Nominal fluid density** parameter lets you specify a value for fluid density, to allow more flexibility and accuracy in modeling the working fluid. Previously, only fluid viscosity was adjustable. The parameter has been added for the following blocks in the Pumps and Motors library:

- Variable-Displacement Pressure-Compensated Pump
- Variable-Displacement Pump
- Variable-Displacement Motor
- Fixed-Displacement Pump
- Hydraulic Motor

# R2013a

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**Version: 1.12**

**New Features**

**Bug Fixes**

## Flow Divider block

The Flow Divider block simulates a hydraulic two-path flow divider, which consists of a spring-centered spool installed in a case. The flow from the source enters the valve and is split into two paths. Each path contains a fixed orifice and a variable orifice. The fixed orifices must be precisely matched to divide flow in equal parts, or arranged in a certain proportion if unequal division is required. The purpose of variable orifices is to maintain a constant pressure drop across the fixed orifices, regardless of pressure fluctuations at valve outlets. The load increase on any outlet causes the pressure drop across the spool (and across fixed orifices) to change, and thus shift the spool. As a result, the passage areas of variable orifices change until the pressure drop values across the fixed orifices even out.

The Hydraulic System with Flow Divider example illustrates using a Flow Divider block to split the flow equally between two consumers, represented by Orifice with Variable Area Slot blocks.

## Fixed Orifice with Fluid Inertia block

The Fixed Orifice with Fluid Inertia block models a hydraulic fixed orifice that accounts for the fluid inertia, in addition to the static pressure loss. Fluid inertia plays a noticeable role in orifices with large ratio of orifice length to the orifice hydraulic diameter ( $L / D_H$ ), or in sharp-edged short orifices when the rate of change of flow rate (fluid acceleration) is relatively large. The model accounts for the laminar and turbulent flow regimes by monitoring the Reynolds number ( $Re$ ) and comparing its value with the critical Reynolds number ( $Re_{cr}$ ). The transition between laminar and turbulent regimes is assumed to be sharp and taking place exactly at  $Re=Re_{cr}$ .

## Double-Acting Servo Cylinder block

The Double-Acting Servo Cylinder block models a hydraulic double-acting servo cylinder implemented as a spring-centered plunger. Changing pressure at ports A and B shifts the plunger from neutral position proportionally to the pressure differential. Use the servo cylinder for control purposes.

## Partially Filled Vertical Pipe LP block

The Partially Filled Vertical Pipe LP block models a vertical pipe connecting two tanks, with the possibility that the top tank gets emptied, and therefore the top port of the pipe

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can be exposed. The fluid level in the pipe then settles at some intermediate position depending on pressures at both ports. The block models pipes with circular and noncircular cross sections. The block accounts for friction losses, variable fluid level in the pipe, and resulting variable heads at the ports.

## **Spool Orifice Hydraulic Force block that now supports round hole orifices**

The Spool Orifice Hydraulic Force block simulates the steady-state axial hydraulic force exerted on the spool by fluid flowing through the orifice. In previous releases, the orifice was supposed to be rectangular. Now you have two parameterization options:

- A rectangular slot
- A round hole, or a set of round holes

The spool is assumed to be sharp-edged. The orifice width, or diameter, must be considerably larger than the radial clearance between the spool and the sleeve.

## **Improved conservation of mass for cylinders with fluid compressibility**

The four cylinder blocks that account for fluid compressibility have been changed to include custom translational or rotational hydro-mechanical converters, instead of the corresponding standard blocks from the Simscape Foundation library. The custom hydro-mechanical converters take into account pressure-induced density variations to give increased accuracy. The affected blocks are:

- Double-Acting Hydraulic Cylinder
- Double-Acting Rotary Actuator
- Single-Acting Hydraulic Cylinder
- Single-Acting Rotary Actuator

## **New examples**

The following example has been introduced in this version:

- Hydraulic System with Flow Divider





# R2012b

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**Version: 1.11**

**New Features**

**Bug Fixes**

## **Journal Bearing Pressure-Fed block**

The new Journal Bearing Pressure-Fed block in the Orifices library simulates the hydraulic portion of a pressure-fed journal bearing. Connections A and B are hydraulic conserving ports associated with the bearing inlet and outlet, respectively. The journal radial displacement, which controls the bearing eccentricity, is imported through the physical signal port J. The flow regime is assumed to be laminar due to small clearances. Use this block in lubrication system simulation to assess the flow consumption through the pressure-fed journal bearing.

## **Fixed Orifice Empirical block**

The new Fixed Orifice Empirical block in the Orifices library models a fixed orifice in hydraulic systems with data obtained from experimental testing. The data required for characterization is the set of pressure differentials across the orifice, together with associated flow rates determined for a particular fluid and temperature. The block operates as a one-dimensional table lookup, with three interpolation and two extrapolation methods.

## **Fixed-Displacement Motor (External Efficiencies) block**

The new Fixed-Displacement Motor (External Efficiencies) block in the Pumps and Motors library represents a fixed-displacement hydraulic motor with both mechanical and volumetric efficiencies provided through the external physical signal ports. Hydraulic losses are implemented as a leakage between hydraulic ports, while mechanical losses are introduced through the friction imposed on the driving shaft. Both the leakage and the friction are determined by the efficiency values.

## **Pneumo-Hydraulic Actuator block**

The new Pneumo-Hydraulic Actuator block in the Cylinders library simulates a pneumo-hydraulic actuator, implemented as a double-acting cylinder with one side connected to a hydraulic power supply and another side operated by pneumatic power. The hydraulic part of the model accounts only for fluid consumption associated with the piston velocity. The pneumatic part of the model is built with the ideal gas relationships. To simulate the limit on the piston motion, the hard stop is included in the model. The piston effective area is constant.

The model is suitable for building pneumo-hydraulic or hydro-pneumatic pumps, intensifiers, and similar devices. You can simulate piston loading (such as inertia, springs,

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friction) by modeling the load externally and connecting it to port L. Similarly, simulate the heat exchange with the environment through the external thermal port E, which corresponds to the gas in the chamber. Use blocks from the Simscape Foundation library, such as Convective Heat Transfer, Conductive Heat Transfer, Thermal Mass, and so on, depending on the actual system configuration.

## **Counterbalance Valve and Hydraulically Operated Remote Control Valve blocks**

Two new blocks extend the valve modeling capabilities:

- The Counterbalance Valve block in the Flow Control Valves library models an internally-externally piloted counterbalance valve. The purpose of a counterbalance valve is to control an overriding or suspended load by creating additional pressure in the discharge line of a hydraulic actuator. The block is essentially a data-sheet-based model that lets you characterize the valve by data usually provided in manufacturer catalogs or data sheets.
- The Hydraulically Operated Remote Control Valve block in the Directional Valves library represents a remote control valve where the valve control member (spool, poppet, and so on) can be shifted from its initial position after pressure at the pilot port exceeds the cracking pressure limit. The valve passage area is directly proportional to pilot pressure. The model covers both normally closed and normally open valve configurations.

## **New examples**

The following example has been introduced in this version:

- Hydraulic System with Counterbalance Valve



# R2012a

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**Version: 1.10.1**

**Bug Fixes**



# R2011b

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**Version: 1.10**

**New Features**

## New Gate Valve Block

The new Gate Valve block in the Flow Control Valves library models a valve consisting of a round orifice in the valve housing and a flat gate, which moves perpendicular to the orifice axis. The orifice in the gate has the same diameter as the orifice in the housing. As the gate moves, it opens or closes the valve passage. The flow rate through the valve is proportional to the orifice opening and to the pressure differential across the orifice.

## Swash Plate Block Enhancement

The Swash Plate block in the Pumps and Motors library now has the **Piston offset from the plate** parameter, which lets you specify the offset between the piston tip and the plate. The default value is 0, which corresponds to the block implementation in the previous version.

## Segmented Pipe Block Enhancement

Additional parameters in the Segmented Pipeline block let you specify the initial condition for pressure inside the pipe segments. You have two options:

- **The same initial pressure for all nodes** — The initial pressure in all pipe segments is the same, and is specified by the **Initial pressure** parameter value. This is the default.
- **Custom** — Lets you specify initial pressure individually for each pipe segment, by using the **Initial pressure vector** parameter. The vector size must be equal to the number of pipe segments, defined by the **Number of segments** parameter value.



# R2011a

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**Version: 1.9**

**New Features**

**Bug Fixes**

## New Swash Plate Block

The new Swash Plate block in the Pumps and Motors library models a swash plate mechanism used in axial-piston machines to convert translational motion of a piston into rotational motion of a drive shaft. For details, see the block reference page and the new Hydraulic Axial-Piston Pump with Load-Sensing and Pressure-Limiting Control (sh\_hydraulic\_axial\_piston\_pump) demo.

## New Porting Plate Variable Orifice Block

The new Porting Plate Variable Orifice block in the Pumps and Motors library models a variable orifice located between the piston chamber and a crescent-shaped slot on a porting plate in hydraulic axial-piston machines. For details, see the block reference page and the new Hydraulic Axial-Piston Pump with Load-Sensing and Pressure-Limiting Control (sh\_hydraulic\_axial\_piston\_pump) demo.

## New Angle Sensor Block

The new Angle Sensor block in the Pumps and Motors library models an ideal angle sensor with measuring range from zero to 360 degrees. With the sensor probe connected to a mechanical rotational port, the output is a value between 0 and  $2\pi$ , regardless of the number of revolutions performed by the probe and direction of rotation. For an example of block usage, see the new Hydraulic Axial-Piston Pump with Load-Sensing and Pressure-Limiting Control (sh\_hydraulic\_axial\_piston\_pump) demo.

## Changes to SimHydraulics Demos

The following demo has been added in Version 1.9:

Demo Name	Description
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<p>Hydraulic Axial-Piston Pump with Load-Sensing and Pressure-Limiting Control (sh_hydraulic_axial_piston_pump)</p>	<p>The demo models a test rig designed to investigate interaction between an axial-piston pump and a typical control unit, simultaneously performing the load-sensing and pressure-limiting functions. To assure required accuracy, the model of the pump must account for such features as interaction between pistons, swash plate, and porting plate, which makes it necessary to build a detailed pump model.</p>
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# R2010b

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**Version: 1.8**

**New Features**

**Bug Fixes**

## New Jet Pump Block

The new Jet Pump block in the Pumps and Motors library models a jet liquid-liquid pump operating with identical primary and secondary fluids containing no gas. For details, see the block reference page and the new Well Jet Pump (sh\_well\_jet\_pump) demo.

## Hydraulic Pipeline Block Enhancement

The Hydraulic Pipeline block now contains an additional parameter that lets you set the initial pressure inside the pipe at the start of simulation. See the block reference page for details.

## Changes to SimHydraulics Demos

The following demos have been added in Version 1.8:

Demo Name	Description
Rotating Hydraulic Actuator (sh_rotating_hydraulic_actuator)	Simulates a typical hydraulic cylinder actuator used to operate friction clutches, brakes and other devices installed on rotating shafts.
Well Jet Pump (sh_well_jet_pump)	Simulates a well jet pump installation, consisting of a surface-mounted centrifugal pump and a jet pump installed in the well below water level.

# R2010a

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**Version: 1.7**

**New Features**

**Bug Fixes**

**Compatibility Considerations**

## Simplified Blocks for Real-Time Simulation

The following new blocks implement simplified models that reproduce only basic functionality in exchange for better numerical efficiency:

- Single-Acting Hydraulic Cylinder (Simple) block represents a simplified version of a single-acting hydraulic cylinder. The model assumes fluid compressibility, friction, and leakages to be negligible. The hard stops are assumed to be fully inelastic, to eliminate any possible oscillations at the end of the stroke.
- Double-Acting Hydraulic Cylinder (Simple) block represents a simplified version of a double-acting hydraulic cylinder. The model assumes fluid compressibility, friction, and leakages to be negligible. The hard stops are assumed to be fully inelastic, to eliminate any possible oscillations at the end of the stroke.
- 4-Way Ideal Valve block represents a 4-way critically-centered valve. Initial openings of all orifices are set to 0, which significantly simplifies the model.
- Valve Actuator block represents a simplified version of a valve actuator, built as a first-order lag.

Use these blocks for real-time and HIL (hardware-in-the-loop) simulation, if such simplifications are acceptable.

## Low-Pressure Blocks with Variable Elevations

Additional blocks in the Low-Pressure Blocks library incorporate elevation information and let you specify elevations as input signals, rather than as block parameters:

- Resistive Pipe LP with Variable Elevation block represents a hydraulic pipeline which accounts for friction losses and port elevations.
- Hydraulic Pipe LP with Variable Elevation block represents a hydraulic pipeline with resistive, fluid compressibility, and elevation properties.

Use these blocks for low-pressure system simulation in which the pipe ends change their positions with respect to the reference plane.

## Cartridge Valve Modeling Blocks

Two new blocks extend the cartridge valve modeling capabilities:



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- Cartridge Valve Insert with Conical Seat block represents an insert of a hydraulic cartridge valve consisting of a poppet interacting with the conical seat.
  - Hydraulic 4-Port Cartridge Valve Actuator block represents double-acting hydraulic valve actuator driven by four pressures. Use this block as a pilot actuator for cartridge valves, as well as pilot-operated pressure and control valves, in applications where all the forces, except spring and pressure forces, and flow consumption can be neglected.

There are also additional parameters in the Hydraulic Cartridge Valve Actuator block that account for initial conditions and dynamic properties of the model. See the block reference page for details.

## Lubrication System Modeling Blocks

The following blocks have been added to facilitate modeling lubrication systems:

- Centrifugal Force in Rotating Cylinder block simulates centrifugal forces exerted by fluid on a piston if the cylinder rotates about its symmetry axis. Such cylinders are used in control mechanisms of various friction clutches, brakes, square-jaw positive clutches, dog clutches, and so on. No inertial effects are considered in the model. In other words, the angular velocity is assumed to be constant or changing at very low speed.
- Rotating Pipe block models a hydraulic pipeline represented as a short bore drilled through a shaft at some angle to its axis, or as a short pipe that connects actuator or bearings, mounted on the shaft, with the channel inside the shaft. Such connections are typical for lubrication systems and for hydraulically-operated clutches and mechanisms. The shaft angular velocity is assumed to be constant or changing at very low speed.

## Centrifugal Pump Enhancement

The Centrifugal Pump block now contains additional parameters that let you simulate operation at zero angular velocity. See the block reference page for details.

## Initial Piston Position in the Single-Acting Hydraulic Cylinder Block

The **Piston initial position** parameter in the block dialog box has been renamed to **Initial distance between piston and cap**, and the way it is used in the block output has been changed.

In previous versions, the **Piston initial position** parameter let you specify the distance that the piston is extended at the beginning of simulation by setting the piston initial position to any point within its stroke, but this value was not included in calculating the rod displacement. In other words, the rod displacement output at the block's physical signal port was with respect to the initial piston position.

In the current version, the **Initial distance between piston and cap** parameter value is included in calculating the rod displacement output by the block:

$$x_{pst} = x_0 + x_p$$

where

$x_{pst}$	Rod displacement output by the physical signal port
$x_0$	Initial distance between piston and cap
$x_p$	Rod displacement with respect to its initial position

For details, see the block reference page.

## Compatibility Considerations

The block output changes because of the new way it calculates rod displacement. It used to start out at zero but now starts out at the initial position. If you have used this block with nonzero initial position in your models, the block output will differ by this value:

$$x_{new} = x_0 + x_{old}$$

where

$x_{new}$	Rod displacement output by the physical signal port in the current version
$x_{old}$	Rod displacement output by the physical signal port in the previous version
$x_0$	Piston initial position value

## Changes to SimHydraulics Demos

The following demos have been added in Version 1.7:

Demo Name	Description
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Diesel Engine In-Line Injection System (sh_diesel_engine_in_line_injection_system)	Simulates an in-line multi-element injection system. The objective of the simulation is to investigate the entire system operation.
Fuel Supply System with Variable Elevation (sh_fuel_supply_system_with_variable_elevations)	Simulates a three-tank fuel supply system where side tanks periodically change elevations during the simulation cycle.
Hydraulic Actuation System with Cartridge Valves (sh_actuation_system_cartridge_valve)	Simulates a complex actuation system equipped with cartridge valves.
Hydraulic Closed-Loop Actuator with Fixed-Step Integration (sh_hydraulic_closed_loop_actuator_fixed_step)	Represents two versions of the same closed-loop hydraulic actuator. In the second version, standard SimHydraulics blocks are replaced with their simplified versions and the model is optimized for fixed-step integration.



# R2009b

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**Version: 1.6**

**New Features**

**Bug Fixes**

## **Additional 4-Way and 6-Way Directional Valve Configurations**

Nine 4-way directional valve blocks and one 6-way directional valve block have been added to the Directional Valves library, and the original 4-Way Directional Valve block has been modified, to enable additional valve configurations. For more information, see Modeling Directional Valves, as well as individual block reference pages.

## **Additional Low-Pressure Blocks**

The following blocks have been added to the Low-Pressure Blocks library:

- Variable Head Two-Arm Tank block represents a tank with constant pressurization and volume-dependent fluid level. The tank has two hydraulic ports and a physical signal port, which exports the volume of fluid in the tank.
- Variable Head Three-Arm Tank block represents a tank with constant pressurization and volume-dependent fluid level. The tank has three hydraulic ports and a physical signal port, which exports the volume of fluid in the tank.

Both blocks account for the fluid level change caused by the volume variation, as well as for pressure loss in the connecting pipes that can be caused by a filter, fittings, or some other local resistance. You can specify pipeline diameter, pressure loss coefficient, and elevation information for each hydraulic port separately.

## **New Ball Valve with Conical Seat Block**

The new Ball Valve with Conical Seat block in the Flow Control Valves library models a ball valve created by a spherical ball and a conical seat. The valve is characterized by the ball diameter, cone angle, and orifice diameter.

# R2009a

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**Version: 1.5**

**New Features**

**Bug Fixes**

## New Low-Pressure Blocks Library

The Low-Pressure Blocks library, added in this release, contains five new blocks that incorporate elevation information:

- Constant Head Tank block represents a tank where pressurization and fluid level remain constant regardless of volume change. The block accounts for the fluid level elevation with respect to the tank bottom, as well as for pressure loss in the connecting pipe that can be caused by a filter, fittings, or some other local resistance.
- Variable Head Tank block represents a tank with constant pressurization and volume-dependent fluid level. The block accounts for the fluid level change caused by the volume variation, as well as for pressure loss in the connecting pipe that can be caused by a filter, fittings, or some other local resistance.
- Resistive Pipe LP block represents a hydraulic pipeline which accounts for friction losses and port elevations.
- Hydraulic Pipe LP block represents a hydraulic pipeline with resistive, fluid compressibility, and elevation properties.
- Segmented Pipe LP block represents a hydraulic pipeline with resistive, fluid inertia, fluid compressibility, and elevation properties.

These blocks enable additional applications, such as low-pressure fluid transportation system simulation.

## Changes to SimHydraulics Demos

The following demos have been added in Version 1.5:

Demo Name	Description
Water Supply System (sh_water_supply_system)	The water supply system modeled in the demo consists of three pumping stations located at 45, 25, and 30 m with respect to the reference plane, respectively. All three stations are expected to pump water in a tank located at 61 m. The objective of simulation is to determine steady-state flow rates and pressures.



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Fluid Transportation System with Three Tanks (sh_three_tanks)	The demo illustrates a classical problem of fluid transportation: to determine flow rates, pressures, and fluid volumes in a system built of three constant head tanks. The tanks are located at different elevations and connected with pipelines combined together in a common node. The pipelines are simulated with the Segmented Pipeline LP block, which accounts for hydraulic losses, fluid inertia, and the head due to different node elevations.
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# R2008b

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**Version: 1.4**

**New Features**

**Bug Fixes**

## Explicit Solvers Now Available for SimHydraulics Models

Using explicit solvers has been implemented for models that include Simscape and SimHydraulics blocks. For more information, see Setting Up Solvers for Physical Models in the Simscape documentation.

## New Variable-Displacement Hydraulic Machine Block

The Variable-Displacement Hydraulic Machine block, able to work as a pump or a motor, enables modeling variable-efficiency machines based on manufacturer's data sheets. The machine displacement is controlled by the signal provided through the physical signal port C. The machine efficiency is simulated by implementing regime-dependable leakage and friction torque based on the experimentally established correlations between the machine efficiencies and pressure, angular velocity, and displacement.

## Improved Usability of the 4-Way Directional Valve Block

The 4-Way Directional Valve block dialog box has been reorganized using tabs to improve usability. Use the **Initial openings** tab to set all the initial orifice openings. The **Basic parameters** tab contains the model parameterization options and the corresponding parameters. The parameters themselves have not changed.

## Changes to SimHydraulics Demos

The following demos have been added in Version 1.4:

Demo Name	Description
Hydraulic Drill-Ream Actuator (sh_drill_ream_actuator)	The actuator is intended to drive a machine tool working unit performing a sequence of three technological operations: coarse drilling, fine drilling, and reaming. The actuator speed is controlled by one of three pressure-compensated flow control valves metering out return flow from the cylinder. The selection of an appropriate flow control is performed by directional valves that are activated by a control unit.

<p>Front-Loader Actuation System (sh_front_loader_actuation_system)</p>	<p>The model shows a simplified version of an actuation system consisting of the lift and tilt cylinders. Each of the cylinders is controlled by an open center, 5-way, 3-position directional valve. The valves are connected in series through their unloading branch in such a way that the system pump is unloaded when both command levers are in neutral position. If either tilt or lift command is applied, the unloading path is closed.</p>
<p>Pipeline System with Centrifugal Pump (sh_pipeline_system_centrifugal_pump)</p>	<p>The demo represents a typical pipeline system with the centrifugal pump. The system is built of three manifolds connected with hoses. The combination of valves installed inside manifolds allows flow rate to be directed through different branches. The manifold models account for local resistances, elbows, and cylindrical channels.</p>

Also, the Variable Volume Chamber Test Rig (sh\_variable\_chamber\_test\_rig) demo has been renamed to Variable Volume Piston Chamber Test Rig, and all the Variable Volume Chamber blocks in it have been replaced with Piston Chamber blocks.



# R2008a

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**Version: 1.3**

**New Features**

**Bug Fixes**

## Trimming Now Available for SimHydraulics Models

Finding and managing operating points by trimming has been implemented for models that include Simscape and SimHydraulics blocks. Simulink Control Design™ product is required for using this functionality. For more information, see Trimming Simscape Models in the Simscape documentation.

## New Cartridge Valve Insert and Hydraulic Cartridge Valve Actuator Blocks

Two new blocks facilitate modeling cartridge valves:

- Cartridge Valve Insert block in the Directional Valves library represents an insert of a hydraulic cartridge valve consisting of a poppet interacting with the sleeve seat. The poppet position is determined by pressures at ports A, B, and X and force of the spring. This is a structural model based on a Variable Orifice block and a Hydraulic Cartridge Valve Actuator block, described below.
- Hydraulic Cartridge Valve Actuator block in the Valve Actuators library represents a double-acting hydraulic valve actuator driven by three pressures. Use this block as a pilot actuator for cartridge valves, as well as pilot-operated pressure and control valves in applications where all the forces, except spring and pressure forces, and flow consumption can be neglected.

## Additional Configurations for the Centrifugal Pump Block

The Centrifugal Pump block represents a centrifugal pump of any type as a data-sheet-based model. Depending on data listed in the manufacturer's catalogs or data sheets for your particular pump, you can now choose one of the following model parameterization options:

- By approximating polynomial — Provide values for the polynomial coefficients. These values can be determined analytically or experimentally, depending on the data available. This is the default method, equivalent to the implementation available in the previous release.
- By two 1D characteristics: P-Q and N-Q — Provide tabulated data of pressure differential and brake power versus pump delivery characteristics. The pressure differential and brake power are determined by one-dimensional table lookup. You have a choice of three interpolation methods and two extrapolation methods.



- 
- By two 2D characteristics: P-Q-W and N-Q-W — Provide tabulated data of pressure differential and brake power versus pump delivery characteristics at different angular velocities. The pressure differential and brake power are determined by two-dimensional table lookup. You have a choice of three interpolation methods and two extrapolation methods.

## **Additional Fluids Available in the Hydraulic Fluid Block**

The following predefined fluids have been added to the Hydraulic Fluid block:

- ISO VG 22 (ESSO UNIVIS N 22)
- ISO VG 46 (ESSO UNIVIS N 46)
- Brake fluid DOT3
- Brake fluid DOT4
- Brake fluid DOT5
- Water

See the block reference page for more information. The Examples section shows how you can get information on the fluids and their properties.



# R2007b

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**Version: 1.2.1**

**New Features**

**Bug Fixes**

## **Code Generation Now Available for SimHydraulics Models**

Code generation has been implemented for models that include Simscape and SimHydraulics blocks. For more information, see Code Generation in the Simscape documentation.

# R2007a

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**Version: 1.2**

**New Features**

**Bug Fixes**

**Compatibility Considerations**

## **SimHydraulics Now Requires Simscape**

SimHydraulics now depends on and requires Simscape, the platform for all Physical Modeling products, which includes common Physical Modeling utilities and block libraries.

## **Block Libraries Moved from SimHydraulics to Simscape**

The Foundation and Utilities block libraries that used to be included in SimHydraulics (V1.0 and V1.1) are now part of Simscape product.

## **Sharing Models Using the Simscape Editing Modes**

When working with SimHydraulics models, you now have a selection of two Simscape editing modes that allow full or restricted editing of models.

- The Restricted mode requires SimHydraulics software to be installed, but does not require a license. It allows you change a limited set of model parameters, but not the blocks or connections, in a SimHydraulics model.
- The Full mode requires SimHydraulics software to be installed with a license. It allows you to change anything in a SimHydraulics model.

## **New SimHydraulics Blocks**

The new blocks introduced in Version 1.2 are listed below:

- Centrifugal Pump
- Single-Acting Rotary Actuator
- Double-Acting Rotary Actuator
- Hydraulic Single-Acting Valve Actuator
- Hydraulic Double-Acting Valve Actuator
- Valve Hydraulic Force
- Spool Orifice Hydraulic Force

## **Initial Conditions Added for Certain Blocks**

Several blocks now have a parameter that specifies the initial condition for use in computing the block's initial state at the beginning of a simulation run. Note that some of

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these blocks, which used to be included in SimHydraulics (V1.0 and V1.1), are now part of Simscape product. The following is a complete list of blocks where you can specify an initial condition through the block dialog box:

- Gas-Charged Accumulator
- Spring-Loaded Accumulator
- Constant Volume Chamber
- Variable Volume Chamber
- Fluid Inertia
- Inertia
- Mass
- PS Integrator
- Rotational Spring
- Translational Spring

For details, see the block reference pages.

## **Compatibility Considerations**

In this version, there is a difference in the way the initial conditions are computed, and as a result, the blocks that have an initial condition parameter work differently than they used to in the previous version.

## **Block Library Links Must Be Resolved**

All SimHydraulics blocks in your models must now have resolved block library links. You can neither disable nor break these library links. This is a global requirement of Simscape modeling environment. Consult the Simscape documentation for further details.

## **Compatibility Considerations**

If you have an existing SimHydraulics model with disabled or broken links from SimHydraulics blocks to the SimHydraulics block library, you must restore all the broken block library links for your model to be valid.

If you have disabled or broken the SimHydraulics library link for blocks that you have customized and want to keep these modified blocks in your model, you must move these

modified blocks to your own custom library or libraries, then copy the block instances that you need to your model.

You must still restore the block link to its parent library, whether that parent library is SimHydraulics or your own.

## Changes to SimHydraulics Demos

The following demos have been added in Version 1.2:

Demo Name	Description
Hydraulic Actuator with Two-Chamber Snubbers (sh_actuator_with_2_chamber_snubbers)	The reciprocal actuator demonstrated in this model is equipped with snubbers (cushions) on both sides of the cylinder.
Digital Hydraulic Actuator (sh_digital_hydraulic_actuator)	The digital hydraulic actuator consists of three double-acting cylinders mounted in the same shell and interconnected through the hard stops.
Hydraulic Actuator with Load-Sensing Variable-Displacement Pump (sh_hydraulic_actuator_load_sensing_pump)	The circuit demonstrates usage of a load-sensing and pressure-limiting unit in a conventional reciprocal system with variable load on the forward stroke.
Hydraulic Actuator with Telescopic Cylinder (sh_hydraulic_actuator_telescopic_cylinder)	The actuator is built around a telescopic hydraulic cylinder, which is equipped with three rods interacting with each other through hard stops.
Closed-Circuit Reciprocal Actuator (sh_hydraulic_closed_circuit_reciprocal_actuator)	The demo illustrates a closed-circuit electrohydraulic actuator driven by a variable-velocity electrical motor.
Power-Assisted Steering Mechanism (sh_hydraulic_power_assisted_steering)	The model represents a simplified version of a power-assisted steering mechanism showing all its major parts.
Hydraulic System with Servo-Valve (sh_hydraulic_system_with_servo_valve)	The demo represents the model of a two-stage servo-valve with a 4-way, 3-position spool valve in the power stage and a flapper-nozzle amplifier in the pilot stage.



Hydraulic Transmission with Secondary Control (sh_hydraulic_transmission_secondary_control)	The system demonstrates usage of the so-called secondary control in hydrostatic transmissions with a variable-displacement motor.
Hydrostatic Transmission with Shuttle Valve (sh_hydrostatic_transmission_shuttle_valve)	The circuit demonstrates a hydrostatic transmission with a shuttle valve in the control unit.
Hydraulic Circuit with Load-Sensing Velocity Control (sh_load_sensing_velocity_control)	The circuit is equipped with the load-sensing velocity regulator installed between the pump and directional valve.
Oscillating Hydraulic Mechanism (sh_oscillating_hydraulic_mechanism)	The oscillating hydraulic mechanism consists of a single-acting hydraulic rotary actuator, winch, flow control valve, two-position electrohydraulic valve, and power and control units.
Reciprocal Actuator with Counterbalance Valves (sh_reciprocal_actuator_cntrb_valves)	The actuator is built of a double-acting cylinder, directional valve, flow control, block of counterbalance valves, power unit, replenishment arrangement, and a control unit.
Sequencing Circuit with Rotary Actuators (sh_sequencing_circuit_rotary_actuators)	The sequence circuit is based on four check valves installed in both pressure and return lines of the second rotary actuator.

The following demos that used to be in SimHydraulics 1.1 are now part of Simscape product:

<b>Demo Name</b>	<b>Description</b>
Simple Mechanical System (ssc_simple_mechanical_system)	This model is built of both rotational and translational mechanical blocks to illustrate their use in a system.
Mechanical System with Translational Friction (ssc_mechanical_system_translational_friction)	The demo illustrates a mass loaded with a spring and viscous damper.
Mechanical System with Translational Hard Stop (ssc_mechanical_system_translational_hardstop)	The demo illustrates two masses interacting through a hard stop.

Mechanical Rotational System with Stick-Slip Motion (ssc_rot_system_stick_slip)	This model demonstrates a mechanical rotational system, where a load is driven by a velocity source with a friction element between them, and stick-slip motion is developed in the regions of constant velocities.
Linkage Mechanism (ssc_linkage_mechanism)	The model demonstrates the use of the Lever block in a linkage mechanism.

# R2006b

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**Version: 1.1**

**New Features**

**Bug Fixes**

## Linearization Support

The Simulink `linmod` and `dlinmod` commands create continuous- or discrete-time linear time-invariant (LTI) state-space models from Simulink models. You can now use these commands to generate an LTI state-space model from a model containing SimHydraulics components.

There are two basic ways `linmod` and `dlinmod` can be used, and the behavior of linearization differs depending on which method is chosen. If `linmod mdl` is called (that is, the arguments for time, state, and input are not provided), then consistent initial conditions are solved for in the same way as on the first step of a simulation. If you call `linmod mdl, t, x, u`, it is particularly important to provide it with a consistent state to linearize about. For more information, see *Linearizing at an Operating Point* in the Simscape User's Guide.

## New Solver Option Allows Starting Transient Analysis from a Steady State

A new solver option allows you to specify that simulation starts from a steady state. Steady state means that the system variables are no longer changing with time.

If you select the **Start simulation from steady state** check box in the Solver block dialog, the solver attempts to find the steady state that would result if the inputs to the system were held constant for a sufficiently large time, starting from the initial state obtained from the initial conditions computation. Although the solver tries to find the particular steady state resulting from the given initial conditions, it is not guaranteed to do so. All that is guaranteed is that if the steady-state solve succeeds, the state found is a steady state (within tolerance). Simulation then starts from this steady state.

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**Note** If the simulation fails at or near the start time when you use the **Start simulation from steady state** option, consider clearing the check box and simulating with the plain initial conditions computation only.

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## Extended Functionality for Working with Physical Units

Version 1.1 provides the following commands that help you specify the physical units for your system:

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- `pm_adddimension`
  - `pm_addunit`
  - `pm_getunits`

Unit names are defined in the `pm_units.m` file, which is shipped with the product. You can open this file to see how the physical units are defined, and also as an example when adding your own units. This file is located in the directory `matlabroot\toolbox\physmod\pm_util\pm_util`.

Use the `pm_getunits` command to get an up-to-date list of units currently defined in your unit registry. Use the `pm_adddimension` and `pm_addunit` commands to define additional units.

## **New SimHydraulics Blocks**

The new blocks introduced in Version 1.1 are listed below:

- Annular Orifice
- Cylinder Friction
- Reservoir
- Elbow
- Pipe Bend
- T-junction
- Gradual Area Change
- Sudden Area Change
- Variable-Displacement Motor
- Variable-Displacement Pump
- Shuttle Valve
- PS Product
- PS Divide



# R2006a+

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**Version: 1.0**

**New Features**

## Product Introduction

SimHydraulics software is a modeling environment for the engineering design and simulation of hydraulic power and control systems within Simulink and MATLAB. It is based on the Physical Network approach and contains a comprehensive library of hydraulic blocks, as well as one-dimensional translational and rotational mechanical elements and utility blocks.

SimHydraulics software key features are:

- Enables modeling and simulation of hydraulic power and control systems in Simulink
- Provides intuitive and convenient description of multidomain models based on physical networks
- Includes a library of hydraulic components, such as pumps, valves, accumulators, and pipelines, that account for effects such as fluid compressibility, turbulence transition, and fluid inertia
- Provides foundation library of hydraulic building blocks, as well as fundamental mechanical and mathematical elements, to enable efficient extension and customization of models
- Provides customizable library of hydraulic fluids

SimHydraulics software employs a network approach to model building. Components in the network correspond to physical elements, such as pumps, motors, valves, etc. The lines that join the components correspond to physical connections that transmit power between components. Unlike traditional Simulink block diagrams, these connections are non-directional and do not require the user to resolve the causality of the system while building the model. SimHydraulics libraries contain more than 75 models of hydraulic and mechanical components. All the models were developed to be easily characterized by data normally available in manufacturer's catalogs or data sheets. Building a model of a system is analogous to assembling the actual physical system with off-the-shelf components. The end result is a hydraulic circuit schematic in concurrence with ISO 1219 Fluid Power Standard.

SimHydraulics limitations are:

- Explicit solvers are not currently supported. Only the following solvers are supported: `ode15s`, `ode23t`, and `ode14x`.
- A SimHydraulics physical network should not exist within a Simulink algebraic loop. This means that you should not directly connect an output of a PS-Simulink Converter block to an input of a Simulink-PS Converter block of the same physical network.



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- Code generation is not currently supported.

