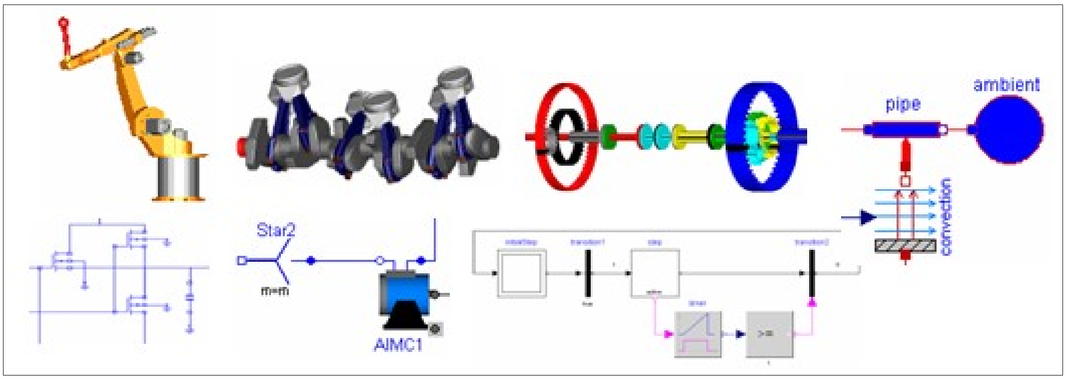
Modelica Standard Library

Version 3.0

February 2008

Tutorial and Reference



Modelica Association
http://www.Modelica.org

Modelica is a freely available, object-oriented language for modeling of large, complex, and heterogeneous physical systems. It is suited for multi-domain modeling, for example, mechatronic models in robotics, automotive and aerospace applications involving mechanical, electrical, hydraulic and control subsystems, process oriented applications and generation and distribution of electric power. Models in Modelica are mathematically described by differential, algebraic and discrete equations. No particular variable needs to be solved for manually. A Modelica tool will have enough information to decide that automatically. Modelica is designed such that available, specialized algorithms can be utilized to enable efficient handling of large models having more than one hundred thousand equations. Modelica is suited and used for hardware-in-the-loop simulations and for embedded control systems.

Modelica is developed by the Modelica Association, a non-profit organization with seat in Linköping, Sweden. The Modelica Association also develops the **free Modelica Standard Library** containing model components in many domains that are based on standardized interface definitions. This manual was automatically produced from the documentation included in the Modelica Standard Library.

The source code of the **Modelica Standard Library**, as well as this manual, is available at http://www.Modelica.org/libraries/Modelica

Links to other **free** and **commercial Modelica libraries** (utilizing the Modelica Standard Library) are available at http://www.Modelica.org/libraries.

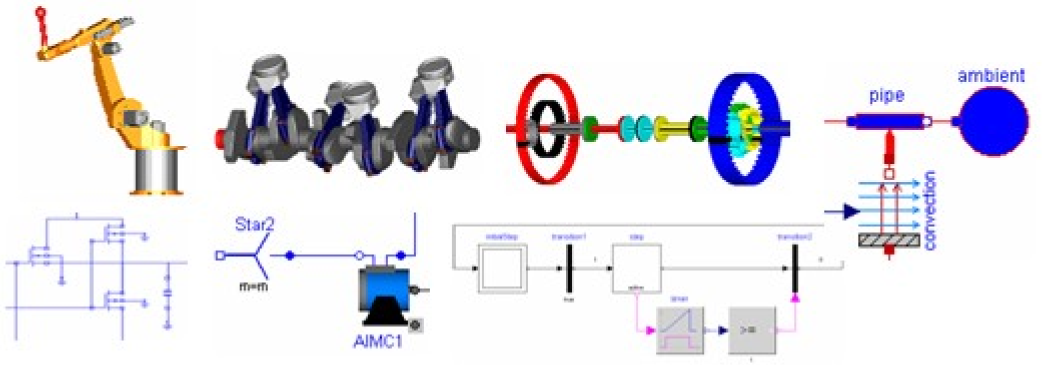
Links and short descriptions of **Modelica modeling and simulation environments** are available at http://www.Modelica.org/tools.

Modelica

Modelica Standard Library (Version 3.0)

Information

Package **Modelica** is a **standardized** and **free** package that is developed together with the Modelica language from the Modelica Association, see http://www.Modelica.org. It is also called **Modelica Standard Library**. It provides model components in many domains that are based on standardized interface definitions. Some typical examples are shown in the next figure:



For an introduction, have especially a look at:

- Overview provides an overview of the Modelica Standard Library inside the User's Guide.
- Release Notes summarizes the changes of new versions of this package.
- Contact lists the contributors of the Modelica Standard Library.
- ModelicaStandardLibrary.pdf is the complete documentation of the library in pdf format.
- The **Examples** packages in the various libraries, demonstrate how to use the components of the corresponding sublibrary.

This version of the Modelica Standard Library consists of

- **777** models and blocks, and
- **549** functions

that are directly usable (= number of public, non-partial classes).

Package Content

Name	Description
UsersGuide	User's Guide of Modelica library
Blocks	Library of basic input/output control blocks (continuous, discrete, logical, table blocks)
Constants	Library of mathematical constants and constants of nature (e.g., pi, eps, R, sigma)
Electrical	Library of electrical models (analog, digital, machines, multi-phase)
Icons	Library of icons
Math	Library of mathematical functions (e.g., sin, cos) and of functions operating on vectors and matrices
Mechanics	Library of 1-dim. and 3-dim. mechanical components (multi-body, rotational, translational)

Media	Library of media property models
SIunits	Library of type and unit definitions based on SI units according to ISO 31-1992
StateGraph	Library of hierarchical state machine components to model discrete event and reactive systems
Thermal	Library of thermal system components to model heat transfer and simple thermo-fluid pipe flow
Utilities	Library of utility functions dedicated to scripting (operating on files, streams, strings, system)

Modelica.UsersGuide

Package **Modelica** is a **standardized** and **pre-defined** package that is developed together with the Modelica language from the Modelica Association, see http://www.Modelica.org. It is also called **Modelica Standard Library**. It provides constants, types, connectors, partial models and model components in various disciplines.

This is a short **User's Guide** for the overall library. Some of the main sublibraries have their own User's Guides that can be accessed by the following links:

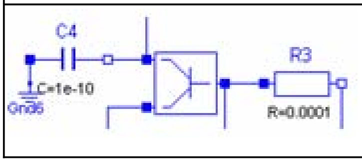
Digital	Library for digital electrical components based on the VHDL standard (2-,3-,4-,9-valued logic)
MultiBody	Library to model 3-dimensional mechanical systems
Rotational	Library to model 1-dimensional mechanical systems
Media	Property models of media
SIunits	Type definitions based on SI units according to ISO 31-1992
StateGraph	Library to model discrete event and reactive systems by hierarchical state machines
Utilities	Utility functions especially for scripting (Files, Streams, Strings, System)

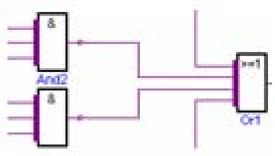
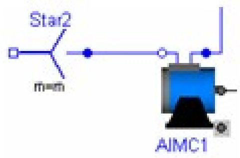
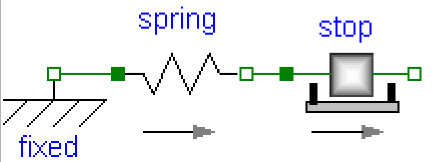
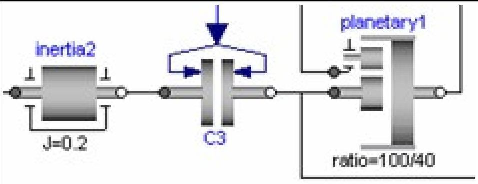
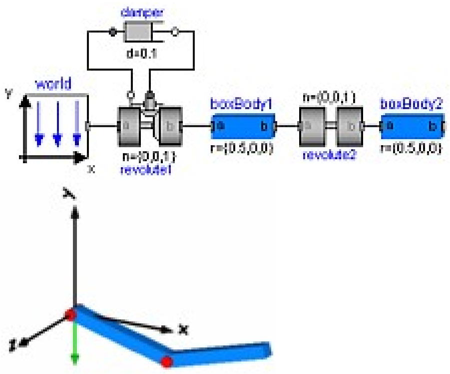
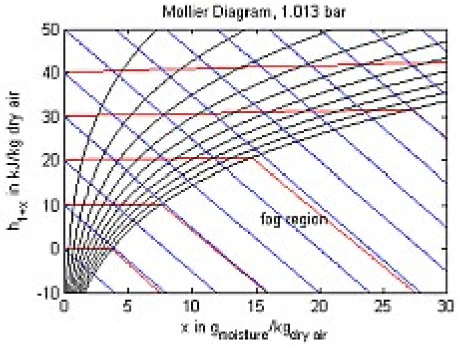
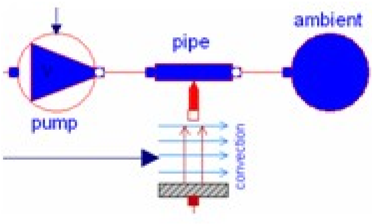
Package Content

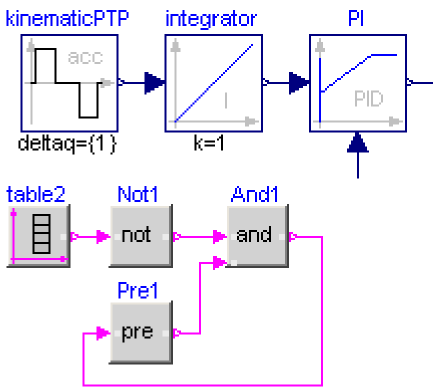
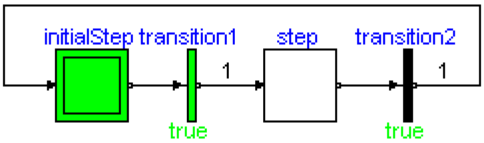
Name	Description
Overview	Overview of Modelica Library
Connectors	Connectors
Conventions	Conventions
ParameterDefaults	Parameter defaults
ReleaseNotes	Release notes
ModelicaLicense	Modelica License (Version 1.1 of June 30, 2000)
Contact	Contact

Modelica.UsersGuide.Overview

The Modelica Standard Library consists of the following main sub-libraries:

Library Components	Description
	Analog Analog electric and electronic components, such as resistor, capacitor, transformers, diodes, transistors, transmission lines, switches, sources, sensors.

	Digital Digital electrical components based on the VHDL standard, like basic logic blocks with 9-value logic, delays, gates, sources, converters between 2-, 3-, 4-, and 9-valued logic.
	Machines Electrical asynchronous-, synchronous-, and DC-machines (motors and generators) as well as 3-phase transformers.
	Translational 1-dim. mechanical, translational systems, e.g., sliding mass, mass with stops, spring, damper.
	Rotational 1-dim. mechanical, rotational systems, e.g., inertias, gears, planetary gears, convenient definition of speed/torque dependent friction (clutches, brakes, bearings, ..)
	MultiBody 3-dim. mechanical systems consisting of joints, bodies, force and sensor elements. Joints can be driven by drive trains defined by 1-dim. mechanical system library (Rotational). Every component has a default animation. Components can be arbitrarily connected together.
	Media Large media library providing models and functions to compute media properties, such as h = h(p,T), d = d(p,T), for the following media: • 1240 gases and mixtures between these gases. • incompressible, table based liquids (h = h(T), etc.). • compressible liquids • dry and moist air • high precision model for water (IF97).
	FluidHeatFlow, HeatTransfer Simple thermo-fluid pipe flow, especially to model cooling of machines with air or water (pipes, pumps, valves, ambient, sensors, sources) and lumped heat transfer with heat capacitors, thermal conductors, convection, body radiation, sources and sensors.

	Blocks Input/output blocks to model block diagrams and logical networks, e.g., integrator, PI, PID, transfer function, linear state space system, sampler, unit delay, discrete transfer function, and/or blocks, timer, hysteresis, nonlinear and routing blocks, sources, tables.
	StateGraph Hierarchical state machines with a similar modeling power as Statecharts. Modelica is used as synchronous action language, i.e. deterministic behavior is guaranteed

`A = [1,2,3;`
`     3,4,5;`
`     2,1,4];`
`b = {10,22,12};`
`x = Matrices.solve(A,b);`
`Matrices.eigenValues(A);`
	Math, Utilities
	Functions operating on vectors and matrices, such as for solving
	
	linear systems, eigen and singular values etc., and functions operating on strings, streams, files, e.g.,
	to copy and remove a file or sort a vector of strings.

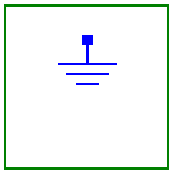
Modelica.UsersGuide.Connectors

The Modelica standard library defines the most important **elementary connectors** in various domains. If any possible, a user should utilize these connectors in order that components from the Modelica Standard Library and from other libraries can be combined without problems. The following elementary connectors are defined (potential variables are connector variables without the flow attribute, flow variables are connector variables that have the flow attribute):

domain	pot. variables	flow variables	connector definition	icons
electrical analog	electrical potential	electrical current	Modelica.Electrical.Analog.Interfaces Pin, PositivePin, NegativePin	
electrical multi-phase	vector of electrical pins		Modelica.Electrical.MultiPhase.Interfaces Plug, PositivePlug, NegativePlug	
electrical sphace phasor	2 electrical potentials	2 electrical currents	Modelica.Electrical.Machines.Interfaces SpacePhasor	
electrical digital	Integer (1..9)	---	Modelica.Electrical.Digital.Interfaces DigitalSignal, DigitalInput, DigitalOutput	
translational	distance	cut-force	Modelica.Mechanics.Translational.Interfaces Flange_a, Flange_b	
rotational	angle	cut-torque	Modelica.Mechanics.Rotational.Interfaces Flange_a, Flange_b	
3-dim. mechanics	position vector orientation object	cut-force vector cut-torque vector	Modelica.Mechanics.MultiBody.Interfaces Frame, Frame_a, Frame_b, Frame_resolve	

HeatingResistor	Temperature dependent electrical resistor
Conductor	Ideal linear electrical conductor
Capacitor	Ideal linear electrical capacitor
Inductor	Ideal linear electrical inductor
SaturatingInductor	Simple model of an inductor with saturation
Transformer	Transformer with two ports
Gyrator	Gyrator
EMF	Electromotoric force (electric/mechanic transformer)
VCV	Linear voltage-controlled voltage source
VCC	Linear voltage-controlled current source
CCV	Linear current-controlled voltage source
CCC	Linear current-controlled current source
OpAmp	Simple nonideal model of an OpAmp with limitation
VariableResistor	Ideal linear electrical resistor with variable resistance
VariableConductor	Ideal linear electrical conductor with variable conductance
VariableCapacitor	Ideal linear electrical capacitor with variable capacitance
VariableInductor	Ideal linear electrical inductor with variable inductance

Modelica.Electrical.Analog.Basic.Ground



Ground node

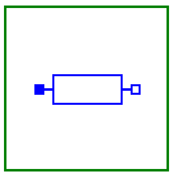
Information

Ground of an electrical circuit. The potential at the ground node is zero. Every electrical circuit has to contain at least one ground object.

Connectors

Type	Name	Description
Pin	p	

Modelica.Electrical.Analog.Basic.Resistor



Ideal linear electrical resistor

Information

The linear resistor connects the branch voltage *v* with the branch current *i* by *i*R = v*. The Resistance *R* is allowed to be positive, zero, or negative.

Parameters

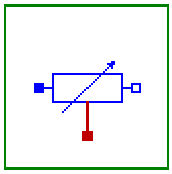
Type	Name	Default	Description

Resistance	R		Resistance [Ohm]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Basic.HeatingResistor



Temperature dependent electrical resistor

Information

This is a model for an electrical resistor where the generated heat is dissipated to the environment via connector **heatPort** and where the resistance R is temperature dependent according to the following equation:

```
R = R_ref*(1 + alpha*(heatPort.T - T_ref))
```

alpha is the **temperature coefficient of resistance**, which is often abbreviated as **TCR**. In resistor catalogues, it is usually defined as **X [ppm/K]** (parts per million, similarly to per centage) meaning **X*1.e-6 [1/K]**. Resistors are available for 1 .. 7000 ppm/K, i.e., alpha = 1e-6 .. 7e-3 1/K;

Via parameter **useHeatPort** the heatPort connector can be enabled and disabled (default = enabled). If it is disabled, the generated heat is transported implicitly to an internal temperature source with a fixed temperature of T_ref.
If the heatPort connector is enabled, it must be connected.

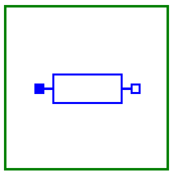
Parameters

Type	Name	Default	Description
Resistance	R_ref		Resistance at temperature T_ref [Ohm]
Temperature	T_ref		Reference temperature [K]
LinearTemperatureCoefficient	alpha		Temperature coefficient of resistance (R = R_ref*(1 + alpha*(heatPort.T - T_ref)) [1/K]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin
HeatPort_a	heatPort	

Modelica.Electrical.Analog.Basic.Conductor



Ideal linear electrical conductor

Information

The linear conductor connects the branch voltage *v* with the branch current *i* by *i* = *v**G*. The Conductance *G* is allowed to be positive, zero, or negative.

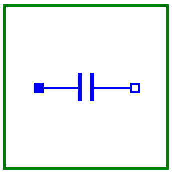
Parameters

Type	Name	Default	Description
Conductance	G		Conductance [S]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Basic.Capacitor



Ideal linear electrical capacitor

Information

The linear capacitor connects the branch voltage *v* with the branch current *i* by *i = C * dv/dt*. The Capacitance *C* is allowed to be positive, zero, or negative.

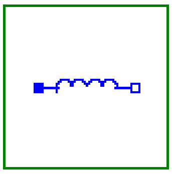
Parameters

Type	Name	Default	Description
Capacitance	C		Capacitance [F]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Basic.Inductor



Ideal linear electrical inductor

Information

The linear inductor connects the branch voltage *v* with the branch current *i* by *v = L * di/dt*. The Inductance *L* is allowed to be positive, zero, or negative.

Parameters

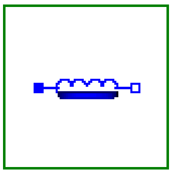
Type	Name	Default	Description
Inductance	L		Inductance [H]

Connectors

Type	Name	Description

PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Basic.SaturatingInductor



Simple model of an inductor with saturation

Information

This model approximates the behaviour of an inductor with the influence of saturation, i.e. the value of the inductance depends on the current flowing through the inductor. The inductance decreases as current increases.
The parameters are:

- Inom...nominal current
- Lnom...nominal inductance at nominal current
- Lzer...inductance near current = 0; Lzer has to be greater than Lnom
- Linf...inductance at large currents; Linf has to be less than Lnom

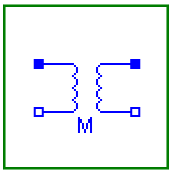
Parameters

Type	Name	Default	Description
Current	Inom		Nominal current [A]
Inductance	Lnom		Nominal inductance at Nominal current [H]
Inductance	Lzer		Inductance near current=0 [H]
Inductance	Linf		Inductance at large currents [H]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Basic.Transformer



Transformer with two ports

Information

The transformer is a two port. The left port voltage *v1*, left port current *i1*, right port voltage *v2* and right port current *i2* are connected by the following relation:

```
| v1 |         | L1   M  |  | i1' |
|    |    =    |         |  |     |
| v2 |         | M    L2 |  | i2' |
```

L1, *L2*, and *M* are the primary, secondary, and coupling inductances respectively.

Parameters

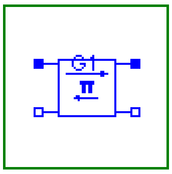
Type	Name	Default	Description

Inductance	L1		Primary inductance [H]
Inductance	L2		Secondary inductance [H]
Inductance	M		Coupling inductance [H]

Connectors

Type	Name	Description
PositivePin	p1	Positive pin of the left port (potential p1.v > n1.v for positive voltage drop v1)
NegativePin	n1	Negative pin of the left port
PositivePin	p2	Positive pin of the right port (potential p2.v > n2.v for positive voltage drop v2)
NegativePin	n2	Negative pin of the right port

Modelica.Electrical.Analog.Basic.Gyrator



Gyrator

Information

A gyrator is a two-port element defined by the following equations:

```
i1 =  G2 * v2
i2 = -G1 * v1
```

where the constants *G1*, *G2* are called the gyration conductance.

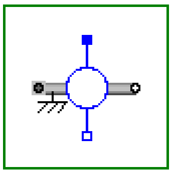
Parameters

Type	Name	Default	Description
Conductance	G1		Gyration conductance [S]
Conductance	G2		Gyration conductance [S]

Connectors

Type	Name	Description
PositivePin	p1	Positive pin of the left port (potential p1.v > n1.v for positive voltage drop v1)
NegativePin	n1	Negative pin of the left port
PositivePin	p2	Positive pin of the right port (potential p2.v > n2.v for positive voltage drop v2)
NegativePin	n2	Negative pin of the right port

Modelica.Electrical.Analog.Basic.EMF



Electromotoric force (electric/mechanic transformer)

Information

EMF transforms electrical energy into rotational mechanical energy. It is used as basic building block of an electrical motor. The mechanical connector shaft can be connected to elements of the Modelica.Mechanics.Rotational library. shaft.tau is the cut-torque, flange.phi is the angle at the rotational connection.

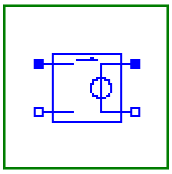
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
ElectricalTorqueConstant	k		Transformation coefficient [N.m/A]

Connectors

Type	Name	Description
PositivePin	p	
NegativePin	n	
Flange_b	flange	
Support	support	Support/housing of emf shaft

Modelica.Electrical.Analog.Basic.VCV



Linear voltage-controlled voltage source

Information

The linear voltage-controlled voltage source is a TwoPort. The right port voltage v2 is controlled by the left port voltage v1 via

```
v2 = v1 * gain.
```

The left port current is zero. Any voltage gain can be chosen.

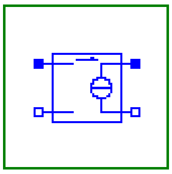
Parameters

Type	Name	Default	Description
Real	gain		Voltage gain

Connectors

Type	Name	Description
PositivePin	p1	Positive pin of the left port (potential p1.v > n1.v for positive voltage drop v1)
NegativePin	n1	Negative pin of the left port
PositivePin	p2	Positive pin of the right port (potential p2.v > n2.v for positive voltage drop v2)
NegativePin	n2	Negative pin of the right port

Modelica.Electrical.Analog.Basic.VCC



Linear voltage-controlled current source

Information

The linear voltage-controlled current source is a TwoPort. The right port current i2 is controlled by the left port voltage v1 via

```
i2 = v1 * transConductance.
```

The left port current is zero. Any transConductance can be chosen.

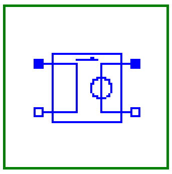
Parameters

Type	Name	Default	Description
Conductance	transConductance		Transconductance [S]

Connectors

Type	Name	Description
PositivePin	p1	Positive pin of the left port (potential p1.v > n1.v for positive voltage drop v1)
NegativePin	n1	Negative pin of the left port
PositivePin	p2	Positive pin of the right port (potential p2.v > n2.v for positive voltage drop v2)
NegativePin	n2	Negative pin of the right port

Modelica.Electrical.Analog.Basic.CCV



Linear current-controlled voltage source

Information

The linear current-controlled voltage source is a TwoPort. The right port voltage v2 is controlled by the left port current i1 via

```
v2 = i1 * transResistance.
```

The left port voltage is zero. Any transResistance can be chosen.

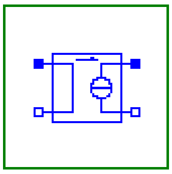
Parameters

Type	Name	Default	Description
Resistance	transResistance		Transresistance [Ohm]

Connectors

Type	Name	Description
PositivePin	p1	Positive pin of the left port (potential p1.v > n1.v for positive voltage drop v1)
NegativePin	n1	Negative pin of the left port
PositivePin	p2	Positive pin of the right port (potential p2.v > n2.v for positive voltage drop v2)
NegativePin	n2	Negative pin of the right port

Modelica.Electrical.Analog.Basic.CCC



Linear current-controlled current source

Information

The linear current-controlled current source is a TwoPort. The right port current i2 is controlled by the left port current i1 via

```
i2 = i1 * gain.
```

The left port voltage is zero. Any current gain can be chosen.

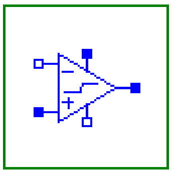
Parameters

Type	Name	Default	Description
Real	gain		Current gain

Connectors

Type	Name	Description
PositivePin	p1	Positive pin of the left port (potential p1.v > n1.v for positive voltage drop v1)
NegativePin	n1	Negative pin of the left port
PositivePin	p2	Positive pin of the right port (potential p2.v > n2.v for positive voltage drop v2)
NegativePin	n2	Negative pin of the right port

Modelica.Electrical.Analog.Basic.OpAmp



Simple nonideal model of an OpAmp with limitation

Information

The OpAmp is a simle nonideal model with a smooth out.v = f(vin) characteristic, where "vin = in_p.v - in_n.v". The characteristic is limited by VMax.v and VMin.v. Its slope at vin=0 is the parameter Slope, which must be positive. (Therefore, the absolute value of Slope is taken into calculation.)

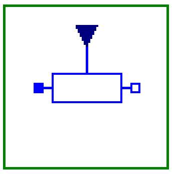
Parameters

Type	Name	Default	Description
Real	Slope		Slope of the out.v/vin characteristic at vin=0

Connectors

Type	Name	Description
PositivePin	in_p	Positive pin of the input port
NegativePin	in_n	Negative pin of the input port
PositivePin	out	Output pin
PositivePin	VMax	Positive output voltage limitation
NegativePin	VMin	Negative output voltage limitation

Modelica.Electrical.Analog.Basic.VariableResistor



Ideal linear electrical resistor with variable resistance

Information

The linear resistor connects the branch voltage *v* with the branch current *i* by

i*R = v

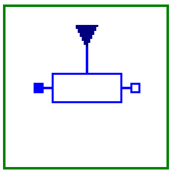
The Resistance *R* is given as input signal.

Attention!!!
It is recommended that the R signal should not cross the zero value. Otherwise depending on the surrounding circuit the probability of singularities is high.

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin
input RealInput	R	

Modelica.Electrical.Analog.Basic.VariableConductor



Ideal linear electrical conductor with variable conductance

Information

The linear conductor connects the branch voltage *v* with the branch current *i* by

i = G*v

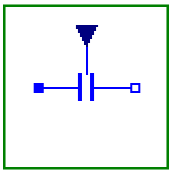
The Conductance *G* is given as input signal.

Attention!!!
It is recommended that the G signal should not cross the zero value. Otherwise depending on the surrounding circuit the probability of singularities is high.

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin
input RealInput	G	

Modelica.Electrical.Analog.Basic.VariableCapacitor



Ideal linear electrical capacitor with variable capacitance

Information

The linear capacitor connects the branch voltage *v* with the branch current *i* by

i = dQ/dt with ***Q = C * v*** .

The capacitance *C* is given as input signal.

It is required that C ≥ 0, otherwise an assertion is raised. To avoid a variable index system,
C = Cmin, if 0 ≤ C < Cmin, where Cmin is a parameter with default value Modelica.Constants.eps.

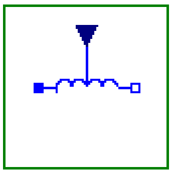
Parameters

Type	Name	Default	Description
Capacitance	Cmin	Modelica.Constants.eps	lower bound for variable capacitance [F]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin
input RealInput	C	

Modelica.Electrical.Analog.Basic.VariableInductor



Ideal linear electrical inductor with variable inductance

Information

The linear inductor connects the branch voltage *v* with the branch current *i* by

v = d Psi/dt with ***Psi = L * i*** .

The inductance *L* is as input signal.

It is required that L ≥ 0, otherwise an assertion is raised. To avoid a variable index system,
L = Lmin, if 0 ≤ L < Lmin, where Lmin is a parameter with default value Modelica.Constants.eps.

Parameters

Type	Name	Default	Description
Inductance	Lmin	Modelica.Constants.eps	lower bound for variable inductance [H]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin
input RealInput	L	

Modelica.Electrical.Analog.Ideal

Ideal electrical elements such as switches, diode, transformer, operational amplifier

Information

This package contains electrical components with idealized behaviour:

Package Content

Name	Description

Modelica.Electrical.Analog.Sources

Time-dependend and controlled voltage and current sources

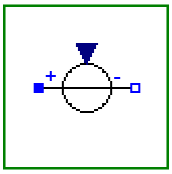
Information

This package contains time-dependend and controlled voltage and current sources.

Package Content

Name	Description
SignalVoltage	Generic voltage source using the input signal as source voltage
ConstantVoltage	Source for constant voltage
StepVoltage	Step voltage source
RampVoltage	Ramp voltage source
SineVoltage	Sine voltage source
ExpSineVoltage	Exponentially damped sine voltage source
ExponentialsVoltage	Rising and falling exponential voltage source
PulseVoltage	Pulse voltage source
SawToothVoltage	Saw tooth voltage source
TrapezoidVoltage	Trapezoidal voltage source
TableVoltage	Voltage source by linear interpolation in a table
SignalCurrent	Generic current source using the input signal as source current
ConstantCurrent	Source for constant current
StepCurrent	Step current source
RampCurrent	Ramp current source
SineCurrent	Sine current source
ExpSineCurrent	Exponentially damped sine current source
ExponentialsCurrent	Rising and falling exponential current source
PulseCurrent	Pulse current source
SawToothCurrent	Saw tooth current source
TrapezoidCurrent	Trapezoidal current source
TableCurrent	Current source by linear interpolation in a table

Modelica.Electrical.Analog.Sources.SignalVoltage



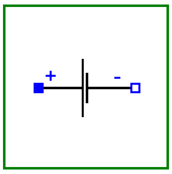
Generic voltage source using the input signal as source voltage

Connectors

Type	Name	Description
PositivePin	p	

NegativePin	n	
input RealInput	v	Voltage between pin p and n (= p.v - n.v) as input signal

Modelica.Electrical.Analog.Sources.ConstantVoltage



Source for constant voltage

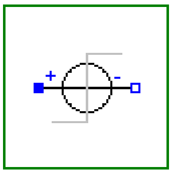
Parameters

Type	Name	Default	Description
Voltage	V		Value of constant voltage [V]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.StepVoltage



Step voltage source

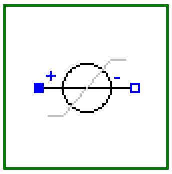
Parameters

Type	Name	Default	Description
Voltage	V		Height of step [V]
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.RampVoltage



Ramp voltage source

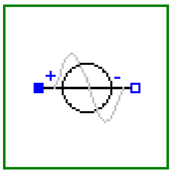
Parameters

Type	Name	Default	Description
Voltage	V		Height of ramp [V]
Time	duration		Duration of ramp [s]
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.SineVoltage



Sine voltage source

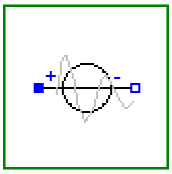
Parameters

Type	Name	Default	Description
Voltage	V		Amplitude of sine wave [V]
Angle	phase	0	Phase of sine wave [rad]
Frequency	freqHz		Frequency of sine wave [Hz]
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.ExpSineVoltage



Exponentially damped sine voltage source

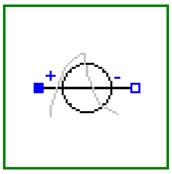
Parameters

Type	Name	Default	Description
Voltage	V		Amplitude of sine wave [V]
Frequency	freqHz		Frequency of sine wave [Hz]
Angle	phase	0	Phase of sine wave [rad]
Damping	damping		Damping coefficient of sine wave [s-1]
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.ExponentialsVoltage



Rising and falling exponential voltage source

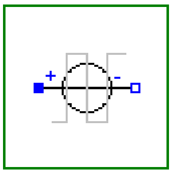
Parameters

Type	Name	Default	Description
Real	vMax		Upper bound for rising edge
Time	riseTime		Rise time [s]
Time	riseTimeConst		Rise time constant [s]
Time	fallTimeConst		Fall time constant [s]
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.PulseVoltage



Pulse voltage source

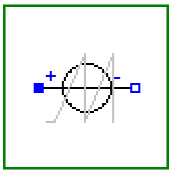
Parameters

Type	Name	Default	Description
Voltage	V		Amplitude of pulse [V]
Real	width		Width of pulse in % of period
Time	period		Time for one period [s]
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.SawToothVoltage



Saw tooth voltage source

Parameters

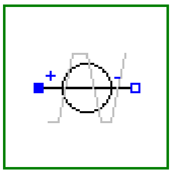
Type	Name	Default	Description
Voltage	V		Amplitude of saw tooth [V]

Time	period		Time for one period [s]
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.TrapezoidVoltage



Trapezoidal voltage source

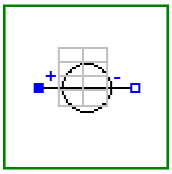
Parameters

Type	Name	Default	Description
Voltage	V		Amplitude of trapezoid [V]
Time	rising		Rising duration of trapezoid [s]
Time	width		Width duration of trapezoid [s]
Time	falling		Falling duration of trapezoid [s]
Time	period		Time for one period [s]
Integer	nperiod		Number of periods (< 0 means infinite number of periods)
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.TableVoltage



Voltage source by linear interpolation in a table

Information

This block generates a voltage source by **linear interpolation** in a table. The time points and voltage values are stored in a matrix **table[i,j]**, where the first column table[:,1] contains the time points and the second column contains the voltage to be interpolated. The table interpolation has the following properties:

- The time points need to be **monotonically increasing**.
- **Discontinuities** are allowed, by providing the same time point twice in the table.
- Values **outside** of the table range, are computed by **extrapolation** through the last or first two points of the table.
- If the table has only **one row**, no interpolation is performed and the voltage value is just returned independantly of the actual time instant, i.e., this is a constant voltage source.
- Via parameters **startTime** and **offset** the curve defined by the table can be shifted both in time and

in the voltage.
- The table is implemented in a numerically sound way by generating **time events** at interval boundaries, in order to not integrate over a discontinuous or not differentiable points.

Example:

```
   table = [0  0
            1  0
            1  1
            2  4
            3  9
            4 16]
If, e.g., time = 1.0, the voltage v =  0.0 (before event), 1.0 (after event)
    e.g., time = 1.5, the voltage v =  2.5,
    e.g., time = 2.0, the voltage v =  4.0,
    e.g., time = 5.0, the voltage v = 23.0 (i.e. extrapolation).
```

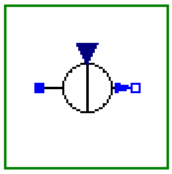
Parameters

Type	Name	Default	Description
Real	table[:, :]	[0, 0; 1, 1; 2, 4]	Table matrix (time = first column, voltage = second column)
Voltage	offset	0	Voltage offset [V]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.SignalCurrent

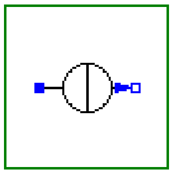


Generic current source using the input signal as source current

Connectors

Type	Name	Description
PositivePin	p	
NegativePin	n	
input RealInput	i	Current flowing from pin p to pin n as input signal

Modelica.Electrical.Analog.Sources.ConstantCurrent



Source for constant current

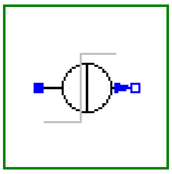
Parameters

Type	Name	Default	Description
Current	I		Value of constant current [A]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.StepCurrent



Step current source

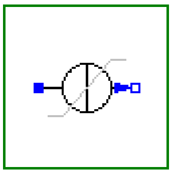
Parameters

Type	Name	Default	Description
Current	I		Height of step [A]
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.RampCurrent



Ramp current source

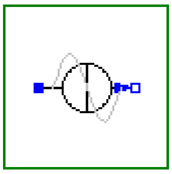
Parameters

Type	Name	Default	Description
Current	I		Height of ramp [A]
Time	duration		Duration of ramp [s]
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.SineCurrent



Sine current source

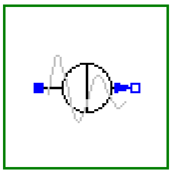
Parameters

Type	Name	Default	Description
Current	I		Amplitude of sine wave [A]
Angle	phase	0	Phase of sine wave [rad]
Frequency	freqHz		Frequency of sine wave [Hz]
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.ExpSineCurrent



Exponentially damped sine current source

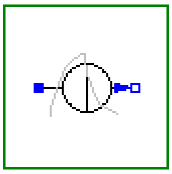
Parameters

Type	Name	Default	Description
Real	I		Amplitude of sine wave
Frequency	freqHz		Frequency of sine wave [Hz]
Angle	phase	0	Phase of sine wave [rad]
Damping	damping		Damping coefficient of sine wave [s-1]
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.ExponentialsCurrent



Rising and falling exponential current source

Parameters

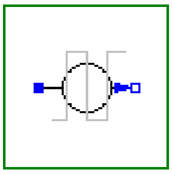
Type	Name	Default	Description
Real	iMax		Upper bound for rising edge
Time	riseTime		Rise time [s]
Time	riseTimeConst		Rise time constant [s]
Time	fallTimeConst		Fall time constant [s]
Current	offset	0	Current offset [A]

Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.PulseCurrent



Pulse current source

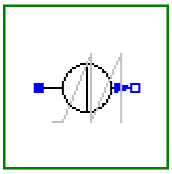
Parameters

Type	Name	Default	Description
Current	I		Amplitude of pulse [A]
Real	width		Width of pulse in % of period
Time	period		Time for one period [s]
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.SawToothCurrent



Saw tooth current source

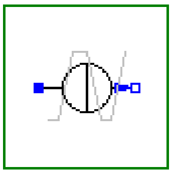
Parameters

Type	Name	Default	Description
Current	I		Amplitude of saw tooth [A]
Time	period		Time for one period [s]
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.TrapezoidCurrent



Trapezoidal current source

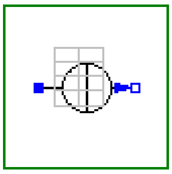
Parameters

Type	Name	Default	Description
Current	I		Amplitude of trapezoid [A]
Time	rising		Rising duration of trapezoid [s]
Time	width		Width duration of trapezoid [s]
Time	falling		Falling duration of trapezoid [s]
Time	period		Time for one period [s]
Integer	nperiod		Number of periods (< 0 means infinite number of periods)
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Analog.Sources.TableCurrent



Current source by linear interpolation in a table

Information

This block generates a current source by **linear interpolation** in a table. The time points and current values are stored in a matrix **table[i,j]**, where the first column table[:,1] contains the time points and the second column contains the current to be interpolated. The table interpolation has the following proporties:

- The time points need to be **monotonically increasing**.
- **Discontinuities** are allowed, by providing the same time point twice in the table.
- Values **outside** of the table range, are computed by **extrapolation** through the last or first two points of the table.
- If the table has only **one row**, no interpolation is performed and the current value is just returned independantly of the actual time instant, i.e., this is a constant current source.
- Via parameters **startTime** and **offset** the curve defined by the table can be shifted both in time and in the current.
- The table is implemented in a numerically sound way by generating **time events** at interval boundaries, in order to not integrate over a discontinuous or not differentiable points.

Example:

```
   table = [0  0
            1  0
            1  1
            2  4
            3  9
            4 16]
If, e.g., time = 1.0, the current i =  0.0 (before event), 1.0 (after event)
    e.g., time = 1.5, the current i =  2.5,
    e.g., time = 2.0, the current i =  4.0,
```

```
e.g., time = 5.0, the current i = 23.0 (i.e. extrapolation).
```

Parameters

Type	Name	Default	Description
Real	table[:, :]	[0, 0; 1, 1; 2, 4]	Table matrix (time = first column, current = second column)
Current	offset	0	Current offset [A]
Time	startTime	0	Time offset [s]

Connectors

Type	Name	Description
PositivePin	p	Positive pin (potential p.v > n.v for positive voltage drop v)
NegativePin	n	Negative pin

Modelica.Electrical.Digital

Library for digital electrical components based on the VHDL standard with 9-valued logic and conversion to 2-,3-,4-valued logic

Information

This library contains packages for digital electrical components. Both, type system and models are based on the VHDL standard (IEEE Std 1076-1987 VHDL, IEEE Std 1076-1993 VHDL, IEEE Std 1164 Multivalue Logic System):

- Interfaces: Definition of signals and interfaces
- Tables: All truth tables needed
- Delay: Transport and inertial delay
- Basic: Basic logic without delay
- Gates: Basic gates composed by basic components and inertial delay
- Tristate: (not yet available)
- FlipFlops: (not yet available)
- Latches: (not yet available)
- TransferGates: (not yet available)
- Multiplexers (not yet available)
- Memory: Ram, Rom, (not yet available)
- Sources: Time-dependend signal sources
- Converters
- Examples

The logic values are coded by integer values. The following code table is necessary for both setting of input and interpreting the output values.

Code Table:

Logic value	Integer code	Meaning
'U'	1	Uninitialized
'X'	2	Forcing Unknown
'0'	3	Forcing 0
'1'	4	Forcing 1
'Z'	5	High Impedance
'W'	6	Weak Unknown

"pipe"	extra = outer-diameter / inner-diameter, i.e, extra = 1: cylinder that is completely hollow extra = 0: cylinder without a hole.
"gearwheel"	extra is the number of teeth of the gear.
"spring"	extra is the number of windings of the spring. Additionally, "height" is **not** the "height" but 2*coil-width.

Parameter **color** is an Integer vector with 3 elements, {r, g, b}, and specifies the color of the shape. {r,g,b} are the "red", "green" and "blue" color parts. Note, r g, b are given in the range 0 .. 255. The predefined type **MultiBody.Types.Color** contains a menu definition of the colors used in the MultiBody library (will be replaced by a color editor).

The variables under heading **Parameters** below are declared as (time varying) **input** variables. If the default equation is not appropriate, a corresponding modifier equation has to be provided in the model where a **Shape** instance is used, e.g., in the form

```
Visualizers.Advanced.Shape shape(length = sin(time));
```

Parameters

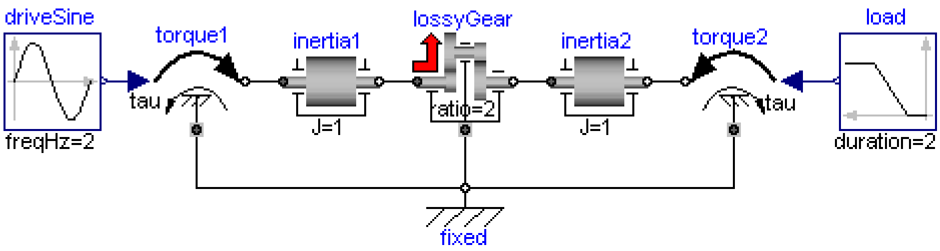
Type	Name	Default	Description
ShapeType	shapeType	"box"	Type of shape (box, sphere, cylinder, pipecylinder, cone, pipe, beam, gearwheel, spring)
Orientation	R	Frames.nullRotation()	Orientation object to rotate the world frame into the object frame
Position	r[3]	{0,0,0}	Position vector from origin of world frame to origin of object frame, resolved in world frame [m]
Position	r_shape[3]	{0,0,0}	Position vector from origin of object frame to shape origin, resolved in object frame [m]
Real	lengthDirection[3]	{1,0,0}	Vector in length direction, resolved in object frame [1]
Real	widthDirection[3]	{0,1,0}	Vector in width direction, resolved in object frame [1]
Length	length	0	Length of visual object [m]
Length	width	0	Width of visual object [m]
Length	height	0	Height of visual object [m]
ShapeExtra	extra	0.0	Additional size data for some of the shape types
Integer	color[3]	{255,0,0}	Color of shape
SpecularCoefficient	specularCoefficient	0.7	Reflection of ambient light (= 0: light is completely absorbed)

Modelica.Mechanics.Rotational

Library to model 1-dimensional, rotational mechanical systems

Information

Library **Rotational** is a **free** Modelica package providing 1-dimensional, rotational mechanical components to model in a convenient way drive trains with frictional losses. A typical, simple example is shown in the next figure:



For an introduction, have especially a look at:

- Rotational.UsersGuide discusses the most important aspects how to use this library.
- Rotational.Examples contains examples that demonstrate the usage of this library.

In version 3.0 of the Modelica Standard Library, the basic design of the library has changed: Previously, bearing connectors could or could not be connected. In 3.0, the bearing connector is renamed to "support" and this connector is enabled via parameter "useSupport". If the support connector is enabled, it must be connected, and if it is not enabled, it must not be connected.

Package Content

Name	Description
UsersGuide	User's Guide of Rotational Library
Examples	Demonstration examples of the components of this package
Components	Components for 1D rotational mechanical drive trains
Sources	Sources to drive 1D rotational mechanical components
Sensors	Sensors to measure variables in 1D rotational mechanical components
Interfaces	Connectors and partial models for 1D rotational mechanical components

Modelica.Mechanics.Rotational.UsersGuide

Library **Rotational** is a **free** Modelica package providing 1-dimensional, rotational mechanical components to model in a convenient way drive trains with frictional losses.

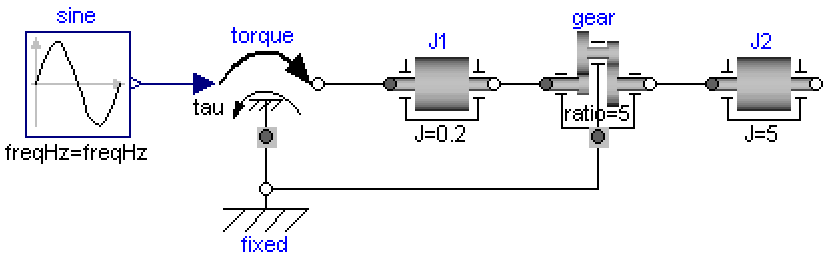
Package Content

Name	Description
Overview	Overview
FlangeConnectors	Flange Connectors
SupportTorques	Support Torques
SignConventions	Sign Conventions
UserDefinedComponents	User Defined Components
RequirementsForSimulationTool	Requirements for Simulation Tools
Contact	Contact

Modelica.Mechanics.Rotational.UsersGuide.Overview

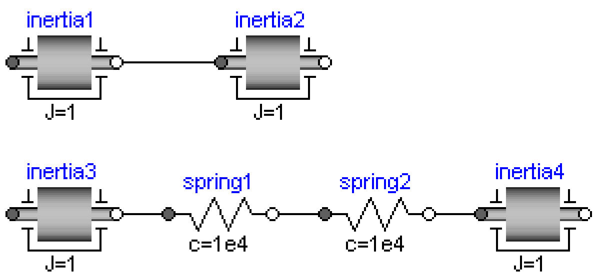
This package contains components to model **1-dimensional rotational mechanical** systems, including different types of gearboxes, shafts with inertia, external torques, spring/damper elements, frictional elements, backlash, elements to measure angle, angular velocity, angular acceleration and the cut-torque of a flange. In sublibrary **Examples** several examples are present to demonstrate the usage of the elements. Just open the corresponding example model and simulate the model according to the provided description.

A unique feature of this library is the **component-oriented** modeling of **Coulomb friction** elements, such as friction in bearings, clutches, brakes, and gear efficiency. Even (dynamically) coupled friction elements, e.g., as in automatic gearboxes, can be handeled **without** introducing stiffness which leads to fast simulations. The underlying theory is new and is based on the solution of mixed continuous/discrete systems of equations, i.e., equations where the **unknowns** are of type **Real**, **Integer** or **Boolean**. Provided appropriate numerical algorithms for the solution of such types of systems are available in the simulation tool, the simulation of (dynamically) coupled friction elements of this library is **efficient** and **reliable**.



A simple example of the usage of this library is given in the figure above. This drive consists of a shaft with inertia J1=0.2 which is connected via an ideal gearbox with gear ratio=5 to a second shaft with inertia J2=5. The left shaft is driven via an external, sinusoidal torque. The **filled** and **non-filled grey squares** at the left and right side of a component represent **mechanical flanges**. Drawing a line between such squares means that the corresponding flanges are **rigidly attached** to each other. By convention in this library, the connector characterized as a **filled** grey square is called **flange_a** and placed at the left side of the component in the "design view" and the connector characterized as a **non-filled** grey square is called **flange_b** and placed at the right side of the component in the "design view". The two connectors are completely **identical**, with the only exception that the graphical layout is a little bit different in order to distinguish them for easier access of the connector variables. For example, `J1.flange_a.tau` is the cut-torque in the connector `flange_a` of component `J1`.

The components of this library can be **connected** together in an **arbitrary** way. E.g., it is possible to connect two springs or two shafts with inertia directly together, see figure below.



Modelica.Mechanics.Rotational.UsersGuide.FlangeConnectors

A flange is described by the connector class Interfaces.**Flange_a** or Interfaces.**Flange_b**. As already noted, the two connector classes are completely identical. There is only a difference in the icons, in order to easier identify a flange variable in a diagram. Both connector classes contain the following variables:

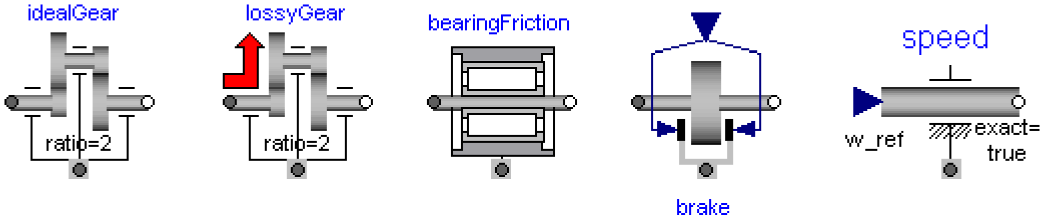
```
Modelica.SIunits.Angle       phi  "Absolute rotation angle of flange";
flow Modelica.SIunits.Torque tau  "Cut-torque in the flange";
```

If needed, the angular velocity `w` and the angular acceleration `a` of a flange connector can be determined by differentiation of the flange angle `phi`:

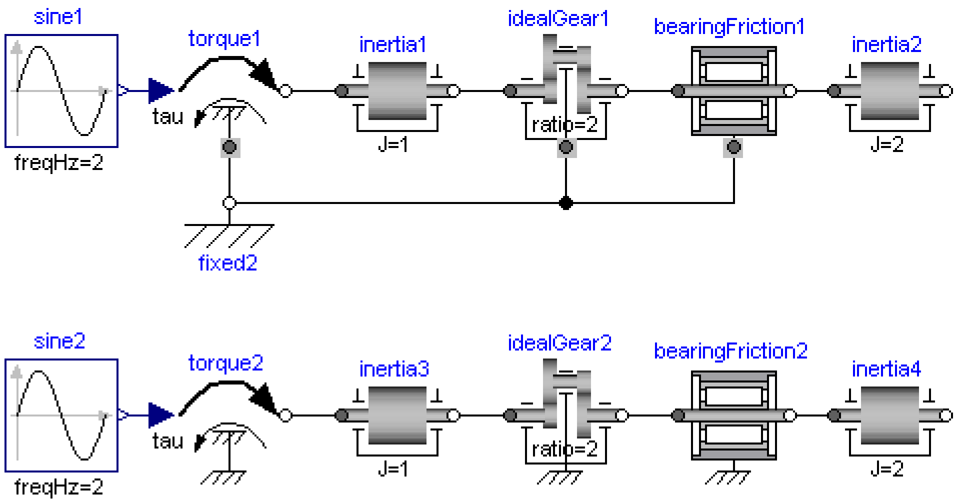
```
w = der(phi);     a = der(w);
```

Modelica.Mechanics.Rotational.UsersGuide.SupportTorques

The following figure shows examples of components equipped with a support flange (framed flange in the lower center), which can be used to fix components on the ground or on other rotating elements or to combine them with force elements. Via Boolean parameter **useSupport**, the support torque is enabled or disabled. If it is enabled, it must be connected. If it is disabled, it must not be connected. Enabled support flanges offer, e.g., the possibility to model gearboxes mounted on the ground via spring-damper-systems (cf. example ElasticBearing).

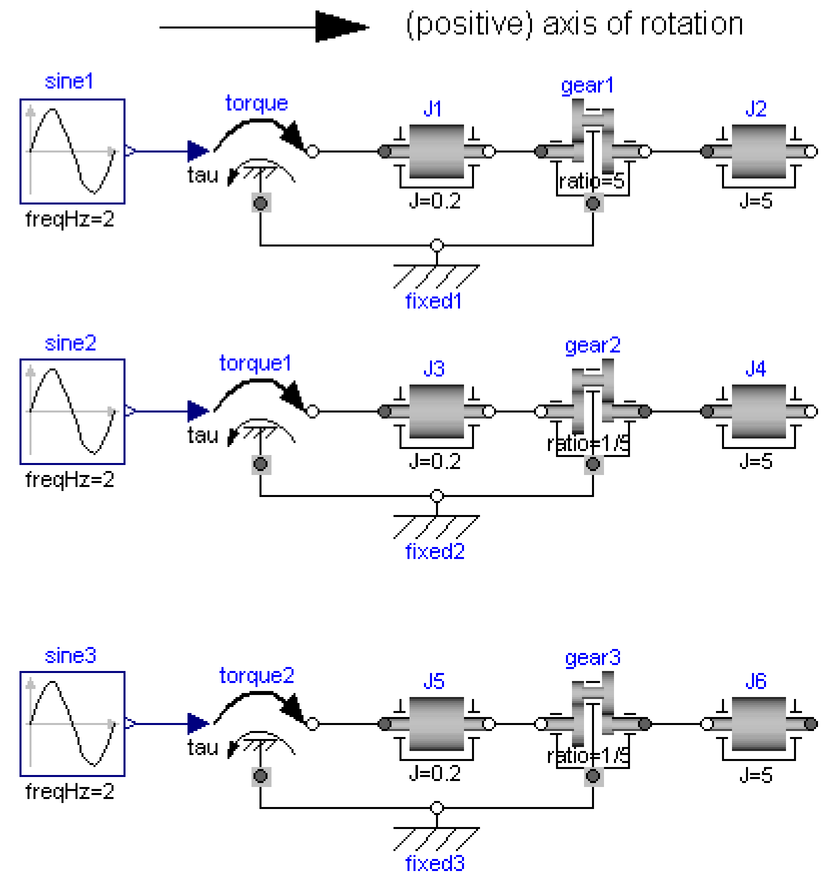


Depending on the setting of **useSupport**, the icon of the corresponding component is changing, to either show the support flange or a ground mounting. For example, the two implementations in the following figure give identical results.

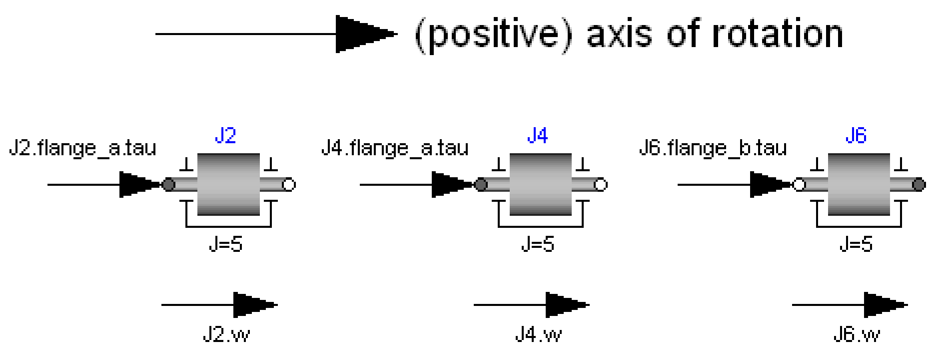


Modelica.Mechanics.Rotational.UsersGuide.SignConventions

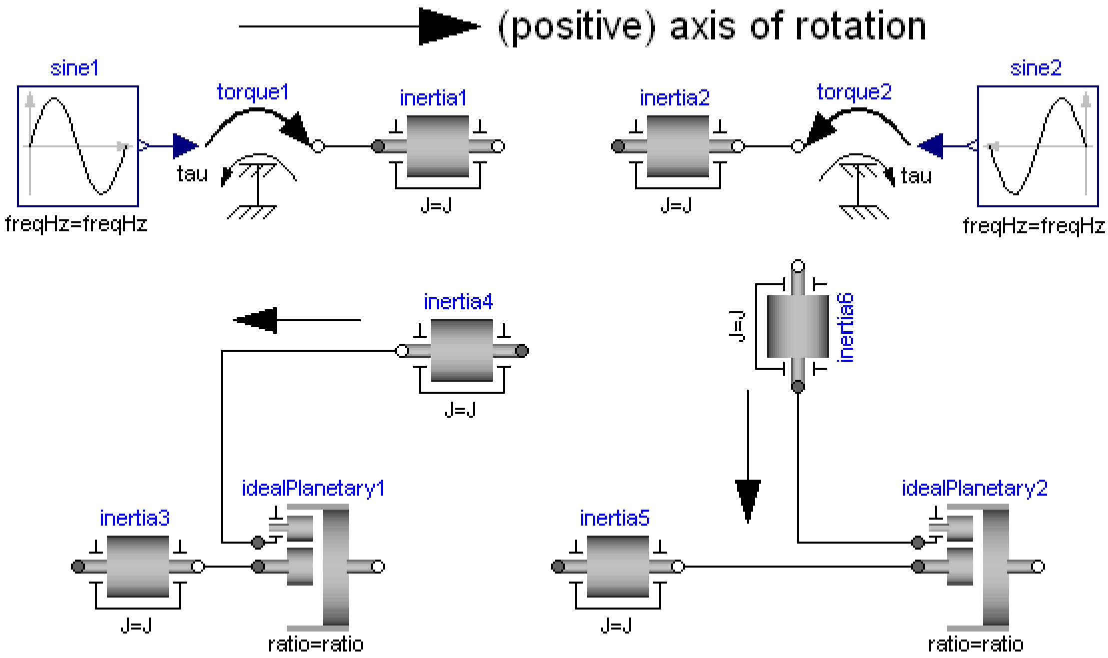
The variables of a component of this library can be accessed in the usual way. However, since most of these variables are basically elements of **vectors**, i.e., have a direction, the question arises how the signs of variables shall be interpreted. The basic idea is explained at hand of the following figure:



In the figure, three identical drive trains are shown. The only difference is that the gear of the middle drive train and the gear as well as the right inertia of the lower drive train are horizontally flipped with regards to the upper drive train. The signs of variables are now interpreted in the following way: Due to the 1-dimensional nature of the model, all components are basically connected together along one line (more complicated cases are discussed below). First, one has to define a **positive** direction of this line, called **axis of rotation**. In the top part of the figure this is characterized by an arrow defined as `axis of rotation`. The simple rule is now: If a variable of a component is positive and can be interpreted as the element of a vector (e.g. torque or angular velocity vector), the corresponding vector is directed into the positive direction of the axis of rotation. In the following figure, the right-most inertias of the figure above are displayed with the positive vector direction displayed according to this rule:



The cut-torques `J2.flange_a.tau, J4.flange_a.tau, J6.flange_b.tau` of the right inertias are all identical and are directed into the direction of rotation if the values are positive. Similiarily, the angular velocities `J2.w, J4.w, J6.w` of the right inertias are all identical and are also directed into the direction of rotation if the values are positive. Some special cases are shown in the next figure:



In the upper part of the figure, two variants of the connection of an external torque and an inertia are shown. In both cases, a positive signal input into the torque component accelerates the inertias `inertia1`, `inertia2` into the positive axis of rotation, i.e., the angular accelerations `inertia1.a`, `inertia2.a` are positive and are directed along the "axis of rotation" arrow. In the lower part of the figure the connection of inertias with a planetary gear is shown. Note, that the three flanges of the planetary gearbox are located along the axis of rotation and that the axis direction determines the positive rotation along these flanges. As a result, the positive rotation for `inertia4`, `inertia6` is as indicated with the additional grey arrows.

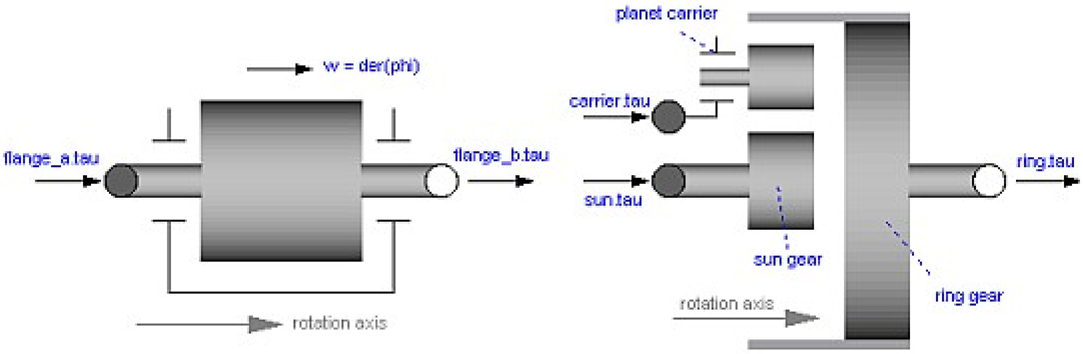
Modelica.Mechanics.Rotational.UsersGuide.UserDefinedComponents

In this section some hints are given to define your own 1-dimensional rotational components which are compatible with the elements of this package. It is convenient to define a new component by inheritance from one of the following base classes, which are defined in sublibrary Interfaces:

Name	Description
PartialRigid	Rigid connection of two rotational 1-dim. flanges (used for elements with inertia).
PartialCompliant	Compliant connection of two rotational 1-dim. flanges (used for force laws such as a spring or a damper).
PartialGear	Partial model for a 1-dim. rotational gear consisting of the flange of an input shaft, the flange of an output shaft and the support.
PartialTorque	Partial model of a torque acting at the flange (accelerates the flange).
PartialTwoFlanges	General connection of two rotational 1-dim. flanges.
PartialAbsoluteSensor	Measure absolute flange variables.
PartialRelativeSensor	Measure relative flange variables.

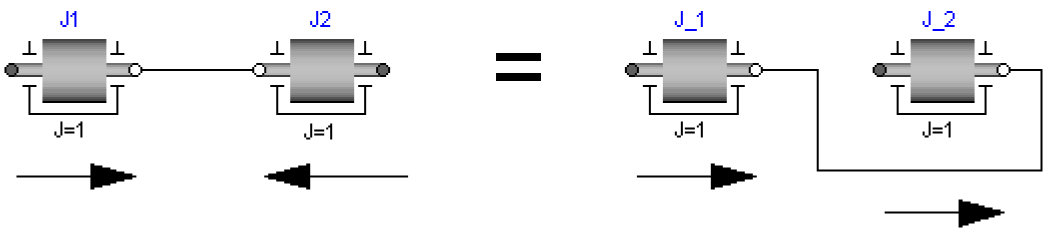
The difference between these base classes are the auxiliary variables defined in the model and the relations between the flange variables already defined in the base class. For example, in model **PartialRigid** the flanges flange_a and flange_b are rigidly connected, i.e., flange_a.phi = flange_b.phi, whereas in model **PartialCompliant** the cut-torques are the same, i.e., flange_a.tau + flange_b.tau = 0.

The equations of a mechanical component are vector equations, i.e., they need to be expressed in a common coordinate system. Therefore, for a component a **local axis of rotation** has to be defined. All vector quantities, such as cut-torques or angular velocities have to be expressed according to this definition. Examples for such a definition are given in the following figure for an inertia component and a planetary gearbox:



As can be seen, all vectors are directed into the direction of the rotation axis. The angles in the flanges are defined correspondingly. For example, the angle `sun.phi` in the flange of the sun wheel of the planetary gearbox is positive, if rotated in mathematical positive direction (= counter clock wise) along the axis of rotation.

On first view, one may assume that the selected local coordinate system has an influence on the usage of the component. But this is not the case, as shown in the next figure:



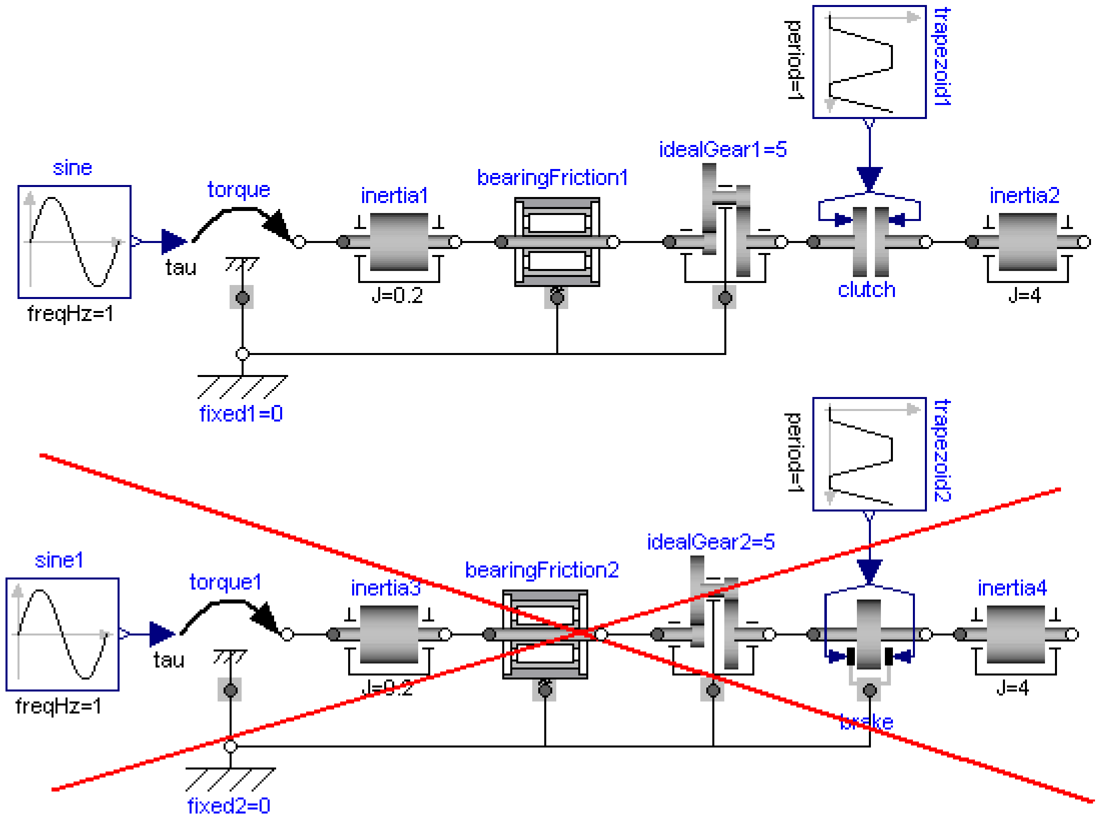
In the figure the **local** axes of rotation of the components are shown. The connection of two inertias in the left and in the right part of the figure are completely equivalent, i.e., the right part is just a different drawing of the left part. This is due to the fact, that by a connection, the two local coordinate systems are made identical and the (automatically) generated connection equations (= angles are identical, cut-torques sum-up to zero) are also expressed in this common coordinate system. Therefore, even if in the left figure it seems to be that the angular velocity vector of `J2` goes from right to left, in reality it goes from left to right as shown in the right part of the figure, where the local coordinate systems are drawn such that they are aligned. Note, that the simple rule stated in section 4 (Sign conventions) also determines that the angular velocity of `J2` in the left part of the figure is directed from left to right.

To summarize, the local coordinate system selected for a component is just necessary, in order that the equations of this component are expressed correctly. The selection of the coordinate system is arbitrary and has no influence on the usage of the component. Especially, the actual direction of, e.g., a cut-torque is most easily determined by the rule of section 4. A more strict determination by aligning coordinate systems and then using the vector direction of the local coordinate systems, often requires a re-drawing of the diagram and is therefore less convenient to use.

Modelica.Mechanics.Rotational.UsersGuide.RequirementsForSimulationTool

This library is designed in a fully object oriented way in order that components can be connected together in every meaningful combination (e.g. direct connection of two springs or two inertias). As a consequence, most models lead to a system of differential-algebraic equations of **index 3** (= constraint equations have to be differentiated twice in order to arrive at a state space representation) and the Modelica translator or the simulator has to cope with this system representation. According to our present knowledge, this requires that the Modelica translator is able to symbolically differentiate equations (otherwise it is e.g. not possible to provide consistent initial conditions; even if consistent initial conditions are present, most numerical DAE integrators can cope at most with index 2 DAEs).

The elements of this library can be connected together in an arbitrary way. However, difficulties may occur, if the elements which can **lock** the **relative motion** between two flanges are connected **rigidly** together such that essentially the **same relative motion** can be locked. The reason is that the cut-torque in the locked phase is not uniquely defined if the elements are locked at the same time instant (i.e., there does not exist a unique solution) and some simulation systems may not be able to handle this situation, since this leads to a singularity during simulation. Currently, this type of problem can occur with the Coulomb friction elements **BearingFriction, Clutch, Brake, LossyGear** when the elements become stuck:



In the figure above two typical situations are shown: In the upper part of the figure, the series connection of rigidly attached BearingFriction and Clutch components are shown. This does not hurt, because the BearingFriction element can lock the relative motion between the element and the housing, whereas the clutch element can lock the relative motion between the two connected flanges. Contrary, the drive train in the lower part of the figure may give rise to simulation problems, because the BearingFriction element and the Brake element can lock the relative motion between a flange and the housing and these flanges are rigidly connected together, i.e., essentially the same relative motion can be locked. These difficulties may be solved by either introducing a compliance between these flanges or by combining the BearingFriction and Brake element into one component and resolving the ambiguity of the frictional torque in the stuck mode. A tool may handle this situation also **automatically**, by picking one solution of the infinitely many, e.g., the one where the difference to the value of the previous time instant is as small as possible.

Modelica.Mechanics.Rotational.UsersGuide.Contact

Library Officer

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Modelica.Mechanics.Rotational.Examples

Demonstration examples of the components of this package

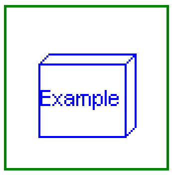
Information

This package contains example models to demonstrate the usage of the Modelica.Mechanics.Rotational package. Open the models and simulate them according to the provided description in the models.

Package Content

Name	Description
First	First example: simple drive train
FirstGrounded	First example: simple drive train with grounded elments
Friction	Drive train with clutch and brake
CoupledClutches	Drive train with 3 dynamically coupled clutches
LossyGearDemo1	Example to show that gear efficiency may lead to stuck motion
LossyGearDemo2	Example to show combination of LossyGear and BearingFriction
ElasticBearing	Example to show possible usage of support flange
Backlash	Example to demonstrate backlash
RollingWheel	Demonstrate coupling Rotational - Translational

Modelica.Mechanics.Rotational.Examples.First



First example: simple drive train

Information

The drive train consists of a motor inertia which is driven by a sine-wave motor torque. Via a gearbox the rotational energy is transmitted to a load inertia. Elasticity in the gearbox is modeled by a spring element. A linear damper is used to model the damping in the gearbox bearing.

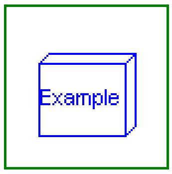
Note, that a force component (like the damper of this example) which is acting between a shaft and the housing has to be fixed in the housing on one side via component Fixed.

Simulate for 1 second and plot the following variables:
angular velocities of inertias inertia2 and 3: inertia2.w, inertia3.w

Parameters

Type	Name	Default	Description
Torque	amplitude	10	Amplitude of driving torque [N.m]
Frequency	freqHz	5	Frequency of driving torque [Hz]
Inertia	Jmotor	0.1	Motor inertia [kg.m2]
Inertia	Jload	2	Load inertia [kg.m2]
Real	ratio	10	Gear ratio
Real	damping	10	Damping in bearing of gear

Modelica.Mechanics.Rotational.Examples.FirstGrounded



First example: simple drive train with grounded elments

Information

The drive train consists of a motor inertia which is driven by a sine-wave motor torque. Via a gearbox the rotational energy is transmitted to a load inertia. Elasticity in the gearbox is modeled by a spring element. A linear damper is used to model the damping in the gearbox bearing.

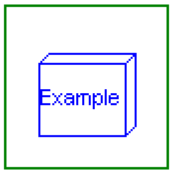
Note, that a force component (like the damper of this example) which is acting between a shaft and the housing has to be fixed in the housing on one side via component Fixed.

Simulate for 1 second and plot the following variables:
angular velocities of inertias inertia2 and 3: inertia2.w, inertia3.w

Parameters

Type	Name	Default	Description
Torque	amplitude	10	Amplitude of driving torque [N.m]
Frequency	freqHz	5	Frequency of driving torque [Hz]
Inertia	Jmotor	0.1	Motor inertia [kg.m2]
Inertia	Jload	2	Load inertia [kg.m2]
Real	ratio	10	Gear ratio
Real	damping	10	Damping in bearing of gear

Modelica.Mechanics.Rotational.Examples.Friction



Drive train with clutch and brake

Information

This drive train contains a frictional **clutch** and a **brake**. Simulate the system for 1 second using the following initial values (defined already in the model):

```
inertia1.w =  90 (or brake.w)
inertia2.w =  90
inertia3.w = 100
```

Plot the output signals

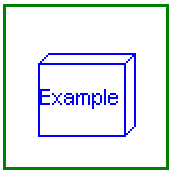
```
tMotor      Torque of motor
tClutch     Torque in clutch
tBrake      Torque in brake
tSpring     Torque in spring
```

as well as the absolute angular velocities of the three inertia components (inertia1.w, inertia2.w, inertia3.w).

Parameters

Type	Name	Default	Description
Time	startTime	0.5	Start time of step [s]

Modelica.Mechanics.Rotational.Examples.CoupledClutches



Drive train with 3 dynamically coupled clutches

Information

This example demonstrates how variable structure drive trains are handeled. The drive train consists of 4 inertias and 3 clutches, where the clutches are controlled by input signals. The system has 2^3=8 different configurations and 3^3 = 27 different states (every clutch may be in forward sliding, backward sliding or locked mode when the relative angular velocity is zero). By invoking the clutches at different time instances, the switching of the configurations can be studied.

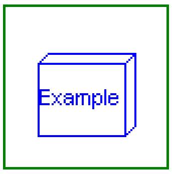
Simulate the system for 1.2 seconds with the following initial values:
J1.w = 10.

Plot the following variables:
angular velocities of inertias (J1.w, J2.w, J3.w, J4.w), frictional torques of clutches (clutchX.tau), frictional mode of clutches (clutchX.mode) where mode = -1/0/+1 means backward sliding, locked, forward sliding.

Parameters

Type	Name	Default	Description
Frequency	freqHz	0.2	frequency of sine function to invoke clutch1 [Hz]
Time	T2	0.4	time when clutch2 is invoked [s]
Time	T3	0.9	time when clutch3 is invoked [s]

Modelica.Mechanics.Rotational.Examples.LossyGearDemo1



Example to show that gear efficiency may lead to stuck motion

Information

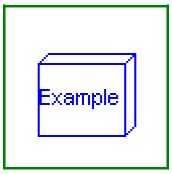
This model contains two inertias which are connected by an ideal gear where the friction between the teeth of the gear is modeled in a physical meaningful way (friction may lead to stuck mode which locks the motion of the gear). The friction is defined by an efficiency factor (= 0.5) for forward and backward driving condition leading to a torque dependent friction loss. Simulate for about 0.5 seconds. The friction in the gear will take all modes (forward and backward rolling, as well as stuck).

You may plot:

```
Inertia1.w,
```

```
Inertia2.w : angular velocities of inertias
powerLoss  : power lost in the gear
gear.mode  :  1 = forward rolling
              0 = stuck (w=0)
             -1 = backward rolling
```

Modelica.Mechanics.Rotational.Examples.LossyGearDemo2



Example to show combination of LossyGear and BearingFriction

Information

This model contains bearing friction and gear friction (= efficiency). If both friction models are stuck, there is no unique solution. Still a reliable Modelica simulator, such as Dymola, should be able to handle this situation.

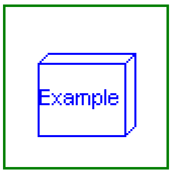
Simulate for about 0.5 seconds. The friction elements are in all modes (forward and backward rolling, as well as stuck).

You may plot:

```
Inertia1.w,
Inertia2.w           : angular velocities of inertias
powerLoss            : power lost in the gear
bearingFriction.mode:  1 = forward rolling
                       0 = stuck (w=0)
                      -1 = backward rolling
gear.mode            :  1 = forward rolling
                       0 = stuck (w=0)
                      -1 = backward rolling
```

Note: This combination of LossyGear and BearingFriction is not recommended to use, as component LossyGear includes the functionality of component BearingFriction (only *peak* not supported).

Modelica.Mechanics.Rotational.Examples.ElasticBearing



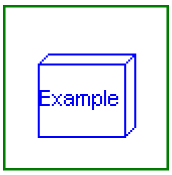
Example to show possible usage of support flange

Information

This model demonstrates the usage of the bearing flange. The gearbox is not connected rigidly to the ground, but by a spring-damper-system. This allows examination of the gearbox housing dynamics.

Simulate for about 10 seconds and plot the angular velocities of the inertias `housing.w`, `shaft.w` and `load.w`.

Modelica.Mechanics.Rotational.Examples.Backlash

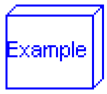


Example to demonstrate backlash

Information

This model demonstrates the effect of a backlash on eigenfrequency, and also that the damping torque does not lead to unphysical pulling torques (since the ElastoBacklash model takes care of it).

Modelica.Mechanics.Rotational.Examples.RollingWheel



Demonstrate coupling Rotational - Translational

Information

This model demonstrates the coupling between rotational and translational components:
A torque (step) accelerates both the inertia (of the wheel) and the mass (of the vehicle).
Du to a speed dependent force (like driving resistance), we find an eqilibrium at 5 m/s after approx. 5 s.

Modelica.Mechanics.Rotational.Components

Components for 1D rotational mechanical drive trains

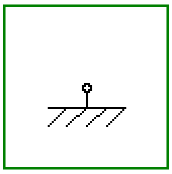
Information

This package contains basic components 1D mechanical rotational drive trains.

Package Content

Name	Description
Fixed	Flange fixed in housing at a given angle
Inertia	1D-rotational component with inertia
Disc	1-dim. rotational rigid component without inertia, where right flange is rotated by a fixed angle with respect to left flange
Spring	Linear 1D rotational spring
Damper	Linear 1D rotational damper
SpringDamper	Linear 1D rotational spring and damper in parallel
ElastoBacklash	Backlash connected in series to linear spring and damper (backlash is modeled with elasticity)
BearingFriction	Coulomb friction in bearings
Brake	Brake based on Coulomb friction
Clutch	Clutch based on Coulomb friction
OneWayClutch	Series connection of freewheel and clutch
IdealGear	Ideal gear without inertia
LossyGear	Gear with mesh efficiency and bearing friction (stuck/rolling possible)
IdealPlanetary	Ideal planetary gear box
Gearbox	Realistic model of a gearbox (based on LossyGear)
IdealGearR2T	Gearbox transforming rotational into translational motion
IdealRollingWheel	Simple 1-dim. model of an ideal rolling wheel without inertia
InitializeFlange	Initializes a flange with pre-defined angle, speed and angular acceleration (usually, this is reference data from a control bus)
RelativeStates	Definition of relative state variables

Modelica.Mechanics.Rotational.Components.Fixed



Flange fixed in housing at a given angle

Information

The **flange** of a 1D rotational mechanical system is **fixed** at an angle phi0 in the **housing**. May be used:

- to connect a compliant element, such as a spring or a damper, between an inertia or gearbox component and the housing.
- to fix a rigid element, such as an inertia, with a specific angle to the housing.

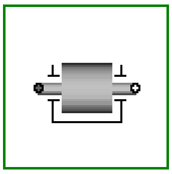
Parameters

Type	Name	Default	Description
Angle	phi0	0	Fixed offset angle of housing [rad]

Connectors

Type	Name	Description
Flange_b	flange	(right) flange fixed in housing

Modelica.Mechanics.Rotational.Components.Inertia



1D-rotational component with inertia

Information

Rotational component with **inertia** and two rigidly connected flanges.

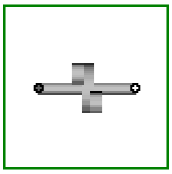
Parameters

Type	Name	Default	Description
Inertia	J		Moment of inertia [kg.m2]
Initialization			
Angle	phi.start		Absolute rotation angle of component [rad]
AngularVelocity	w.start		Absolute angular velocity of component (= der(phi)) [rad/s]
AngularAcceleration	a.start		Absolute angular acceleration of component (= der(w)) [rad/s2]
Advanced			
StateSelect	stateSelect	StateSelect.default	Priority to use phi and w as states

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of shaft
Flange_b	flange_b	Right flange of shaft

Modelica.Mechanics.Rotational.Components.Disc



1-dim. rotational rigid component without inertia, where right flange is rotated by a fixed angle with respect to left flange

Information

Rotational component with two rigidly connected flanges without **inertia**. The right flange is rotated by the fixed angle "deltaPhi" with respect to the left flange.

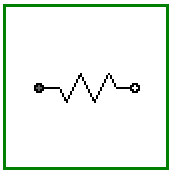
Parameters

Type	Name	Default	Description
Angle	deltaPhi	0	Fixed rotation of left flange with respect to right flange (= flange_b.phi - flange_a.phi) [rad]

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft

Modelica.Mechanics.Rotational.Components.Spring



Linear 1D rotational spring

Information

A **linear 1D rotational spring**. The component can be connected either between two inertias/gears to describe the shaft elasticity, or between a inertia/gear and the housing (component Fixed), to describe a coupling of the element with the housing via a spring.

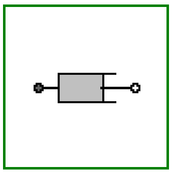
Parameters

Type	Name	Default	Description
RotationalSpringConstant	c		Spring constant [N.m/rad]
Angle	phi_rel0	0	Unstretched spring angle [rad]
Initialization			
Angle	phi_rel.start	0	Relative rotation angle (= flange_b.phi - flange_a.phi) [rad]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component

Modelica.Mechanics.Rotational.Components.Damper



Linear 1D rotational damper

Information

Linear, velocity dependent damper element. It can be either connected between an inertia or gear and the housing (component Fixed), or between two inertia/gear elements.

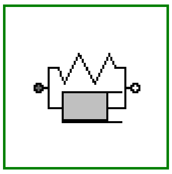
Parameters

Type	Name	Default	Description
RotationalDampingConstant	d		Damping constant [N.m.s/rad]
Initialization			
Angle	phi_rel.start	0	Relative rotation angle (= flange_b.phi - flange_a.phi) [rad]
AngularVelocity	w_rel.start	0	Relative angular velocity (= der(phi_rel)) [rad/s]
AngularAcceleration	a_rel.start	0	Relative angular acceleration (= der(w_rel)) [rad/s2]
Advanced			
Angle	phi_nominal	1e-4	Nominal value of phi_rel (used for scaling) [rad]
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component

Modelica.Mechanics.Rotational.Components.SpringDamper



Linear 1D rotational spring and damper in parallel

Information

A **spring** and **damper** element **connected in parallel**. The component can be connected either between two inertias/gears to describe the shaft elasticity and damping, or between an inertia/gear and the housing (component Fixed), to describe a coupling of the element with the housing via a spring/damper.

Parameters

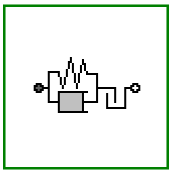
Type	Name	Default	Description
RotationalSpringConstant	c		Spring constant [N.m/rad]
RotationalDampingConstant	d		Damping constant [N.m.s/rad]
Angle	phi_rel0	0	Unstretched spring angle [rad]
Initialization			
Angle	phi_rel.start	0	Relative rotation angle (= flange_b.phi - flange_a.phi) [rad]
AngularVelocity	w_rel.start	0	Relative angular velocity (= der(phi_rel)) [rad/s]
AngularAcceleration	a_rel.start	0	Relative angular acceleration (= der(w_rel)) [rad/s2]

Advanced			
Angle	phi_nominal	1e-4	Nominal value of phi_rel (used for scaling) [rad]
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component

Modelica.Mechanics.Rotational.Components.ElastoBacklash



Backlash connected in series to linear spring and damper (backlash is modeled with elasticity)

Information

This element consists of a **backlash** element **connected in series** to a **spring** and **damper** element which are **connected in parallel**. The spring constant shall be non-zero, otherwise the component cannot be used.

In combination with components IdealGear, the ElastoBacklash model can be used to model a gear box with backlash, elasticity and damping.

During initialization, the backlash characteristic is replaced by a continuous approximation in the backlash region, in order to reduce problems during initialization, especially for inverse models.

If the backlash b is smaller as 1e-10 rad (especially, if b=0), then the backlash is ignored and the component reduces to a spring/damper element in parallel.

In the backlash region (-b/2 ≤ flange_b.phi - flange_a.phi - phi_rel0 ≤ b/2) no torque is exerted (flange_b.tau = 0). Outside of this region, contact is present and the contact torque is basically computed with a linear spring/damper characteristic:

desiredContactTorque = c*phi_contact + d***der**(phi_contact) phi_contact = phi_rel - phi_rel0 - b/2 **if** phi_rel - phi_rel0 > b/2 = phi_rel - phi_rel0 + b/2 **if** phi_rel - phi_rel0 < -b/2 phi_rel = flange_b.phi - flange_a.phi;

This torque characteristic leads to the following difficulties:

1. If the damper torque becomes larger as the spring torque and with opposite sign, the contact torque would be "pulling/sticking" which is unphysical, since during contact only pushing torques can occur.
2. When contact occurs with a non-zero relative speed (which is the usual situation), the damping torque has a non-zero value and therefore the contact torque changes discontinuously at phi_rel = phi_rel0. Again, this is not physical because the torque can only change continuously. (Note, this component is not an idealized model where a steep characteristic is approximated by a discontinuity, but it shall model the steep characteristic.)

In the literature there are several proposals to fix problem (2). However, there seems to be no proposal to avoid sticking. For this reason, the most simple approach is used in the ElastoBacklash model, to fix both problems by slight changes to the linear spring/damper characteristic:

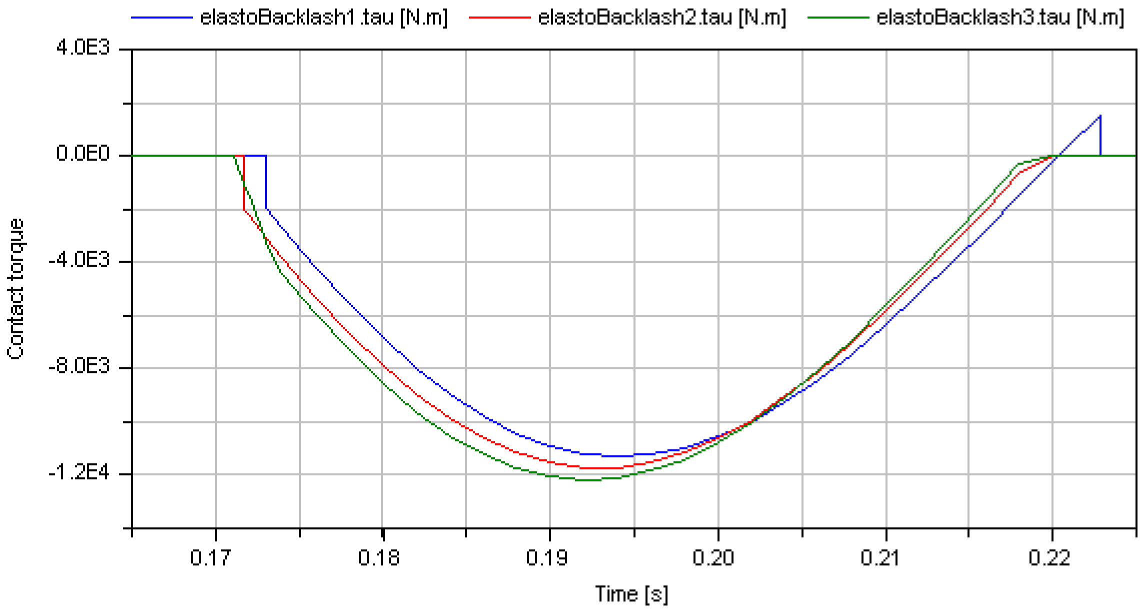
```
// Torque characteristic when phi_rel > phi_rel0
if phi_rel - phi_rel0 < b/2 then
   tau_c = 0;          // spring torque
   tau_d = 0;          // damper torque
   flange_b.tau = 0;
else
   tau_c = c*(phi_rel - phi_rel0);     // spring torque
   tau_d = d*der(phi_rel);             // damper torque
   flange_b.tau = if tau_c + tau_d ≤ 0 then 0 else tau_c + min( tau_c, tau_d
```

```
);
    end if;
```

Note, when sticking would occur (tau_c + tau_d ≤ 0), then the contact torque is explicitly set to zero. The "min(tau_c, tau_d)" part in the if-expression, limits the damping torque when it is pushing. This means that at the start of the contact (phi_rel - phi_rel0 = b/2), the damping torque is zero and is continuous. The effect of both modifications is that the absolute value of the damping torque is always limited by the absolute value of the spring torque: |tau_d| ≤ |tau_c|.

In the next figure, a typical simulation with the ElastoBacklash model is shown (Examples.Backlash) where the different effects are visualized:

1. Curve 1 (elastoBacklash1.tau) is the unmodified contact torque, i.e., the linear spring/damper characteristic. A pulling/sticking torque is present at the end of the contact.
2. Curve 2 (elastoBacklash2.tau) is the contact torque, where the torque is explicitly set to zero when pulling/sticking occurs. The contact torque is discontinuous at begin of contact.
3. Curve 3 (elastoBacklash3.tau) is the ElastoBacklash model of this library. No discontinuity and no pulling/sticking occurs.



Parameters

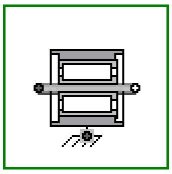
Type	Name	Default	Description
RotationalSpringConstant	c		Spring constant (c > 0 required) [N.m/rad]
RotationalDampingConstant	d		Damping constant [N.m.s/rad]
Angle	b	0	Total backlash [rad]
Angle	phi_rel0	0	Unstretched spring angle [rad]
Initialization			
Angle	phi_rel.start	0	Relative rotation angle (= flange_b.phi - flange_a.phi) [rad]
AngularVelocity	w_rel.start	0	Relative angular velocity (= der(phi_rel)) [rad/s]
AngularAcceleration	a_rel.start	0	Relative angular acceleration (= der(w_rel)) [rad/s2]
Advanced			

Angle	phi_nominal	1e-4	Nominal value of phi_rel (used for scaling) [rad]
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component

Modelica.Mechanics.Rotational.Components.BearingFriction



Coulomb friction in bearings

Information

This element describes **Coulomb friction** in **bearings**, i.e., a frictional torque acting between a flange and the housing. The positive sliding friction torque "tau" has to be defined by table "tau_pos" as function of the absolute angular velocity "w". E.g.

```
  w | tau
---+-----
  0 |   0
  1 |   2
  2 |   5
  3 |   8
```

gives the following table:

```
tau_pos = [0, 0; 1, 2; 2, 5; 3, 8];
```

Currently, only linear interpolation in the table is supported. Outside of the table, extrapolation through the last two table entries is used. It is assumed that the negative sliding friction force has the same characteristic with negative values. Friction is modelled in the following way:

When the absolute angular velocity "w" is not zero, the friction torque is a function of w and of a constant normal force. This dependency is defined via table tau_pos and can be determined by measurements, e.g. by driving the gear with constant velocity and measuring the needed motor torque (= friction torque).

When the absolute angular velocity becomes zero, the elements connected by the friction element become stuck, i.e., the absolute angle remains constant. In this phase the friction torque is calculated from a torque balance due to the requirement, that the absolute acceleration shall be zero. The elements begin to slide when the friction torque exceeds a threshold value, called the maximum static friction torque, computed via:

```
maximum_static_friction = peak * sliding_friction(w=0)   (peak >= 1)
```

This procedure is implemented in a "clean" way by state events and leads to continuous/discrete systems of equations if friction elements are dynamically coupled which have to be solved by appropriate numerical methods. The method is described in:

Otter M., Elmqvist H., and Mattsson S.E. (1999):
Hybrid Modeling in Modelica based on the Synchronous Data Flow Principle. CACSD'99, Aug. 22.-26, Hawaii.

More precise friction models take into account the elasticity of the material when the two elements are "stuck", as well as other effects, like hysteresis. This has the advantage that the friction element can be completely described by a differential equation without events. The drawback is that the system becomes stiff (about 10-20 times slower simulation) and that more material constants have to be supplied which requires more sophisticated identification. For more details, see the following references, especially (Armstrong and Canudas de Witt 1996):

Armstrong B. (1991):
Control of Machines with Friction. Kluwer Academic Press, Boston MA.

Armstrong B., and Canudas de Wit C. (1996):
Friction Modeling and Compensation. The Control Handbook, edited by W.S.Levine, CRC Press, pp. 1369-1382.

Canudas de Wit C., Olsson H., Astroem K.J., and Lischinsky P. (1995):
A new model for control of systems with friction. IEEE Transactions on Automatic Control, Vol. 40, No. 3, pp. 419-425.

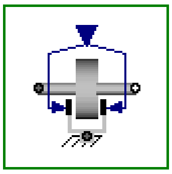
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Real	tau_pos[:, 2]	[0, 1]	[w,tau] Positive sliding friction characteristic (w>=0)
Real	peak	1	peak*tau_pos[1,2] = Maximum friction torque for w==0
Initialization			
Boolean	startForward.start	**false**	true, if w_rel=0 and start of forward sliding
Boolean	startBackward.start	**false**	true, if w_rel=0 and start of backward sliding
Boolean	locked.start	false	true, if w_rel=0 and not sliding
Advanced			
AngularVelocity	w_small	1.0e10	Relative angular velocity near to zero if jumps due to a reinit(..) of the velocity can occur (set to low value only if such impulses can occur) [rad/s]

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Components.Brake



Brake based on Coulomb friction

Information

This component models a **brake**, i.e., a component where a frictional torque is acting between the housing and a flange and a controlled normal force presses the flange to the housing in order to increase friction. The normal force fn has to be provided as input signal f_normalized in a normalized form (0 ≤ f_normalized ≤ 1), fn = fn_max*f_normalized, where fn_max has to be provided as parameter. Friction in the brake is modelled in the following way:

When the absolute angular velocity "w" is not zero, the friction torque is a function of the velocity dependent friction coefficient mue(w) , of the normal force "fn", and of a geometry constant "cgeo" which takes into account the geometry of the device and the assumptions on the friction distributions:

```
frictional_torque = cgeo * mue(w) * fn
```

Typical values of coefficients of friction:

```
dry operation   :  mue = 0.2 .. 0.4
operating in oil:  mue = 0.05 .. 0.1
```

When plates are pressed together, where **ri** is the inner radius, **ro** is the outer radius and **N** is the number of friction interfaces, the geometry constant is calculated in the following way under the assumption of a uniform rate of wear at the interfaces:

```
cgeo = N*(r0 + ri)/2
```

The positive part of the friction characteristic **mue**(w), w >= 0, is defined via table mue_pos (first column = w, second column = mue). Currently, only linear interpolation in the table is supported.

When the absolute angular velocity becomes zero, the elements connected by the friction element become stuck, i.e., the absolute angle remains constant. In this phase the friction torque is calculated from a torque balance due to the requirement, that the absolute acceleration shall be zero. The elements begin to slide when the friction torque exceeds a threshold value, called the maximum static friction torque, computed via:

```
frictional_torque = peak * cgeo * mue(w=0) * fn   (peak >= 1)
```

This procedure is implemented in a "clean" way by state events and leads to continuous/discrete systems of equations if friction elements are dynamically coupled. The method is described in:

Otter M., Elmqvist H., and Mattsson S.E. (1999):
Hybrid Modeling in Modelica based on the Synchronous Data Flow Principle. CACSD'99, Aug. 22.-26, Hawaii.

More precise friction models take into account the elasticity of the material when the two elements are "stuck", as well as other effects, like hysteresis. This has the advantage that the friction element can be completely described by a differential equation without events. The drawback is that the system becomes stiff (about 10-20 times slower simulation) and that more material constants have to be supplied which requires more sophisticated identification. For more details, see the following references, especially (Armstrong and Canudas de Witt 1996):

Armstrong B. (1991):
Control of Machines with Friction. Kluwer Academic Press, Boston MA.

Armstrong B., and Canudas de Wit C. (1996):
Friction Modeling and Compensation. The Control Handbook, edited by W.S.Levine, CRC Press, pp. 1369-1382.

Canudas de Wit C., Olsson H., Astroem K.J., and Lischinsky P. (1995):
A new model for control of systems with friction. IEEE Transactions on Automatic Control, Vol. 40, No. 3, pp. 419-425.

Parameters

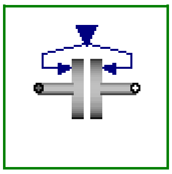
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Real	mue_pos[:, 2]	[0, 0.5]	[w,mue] positive sliding friction coefficient (w_rel>=0)
Real	peak	1	peak*mue_pos[1,2] = maximum value of mue for w_rel==0
Real	cgeo	1	Geometry constant containing friction distribution assumption
Force	fn_max		Maximum normal force [N]

Initialization			
Boolean	startForward.start	**false**	true, if w_rel=0 and start of forward sliding
Boolean	startBackward.start	**false**	true, if w_rel=0 and start of backward sliding
Boolean	locked.start	false	true, if w_rel=0 and not sliding
Advanced			
AngularVelocity	w_small	1.0e10	Relative angular velocity near to zero if jumps due to a reinit(..) of the velocity can occur (set to low value only if such impulses can occur) [rad/s]

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component
input RealInput	f_normalized	Normalized force signal 0..1 (normal force = fn_max*f_normalized; brake is active if > 0)

Modelica.Mechanics.Rotational.Components.Clutch



Clutch based on Coulomb friction

Information

This component models a **clutch**, i.e., a component with two flanges where friction is present between the two flanges and these flanges are pressed together via a normal force. The normal force fn has to be provided as input signal f_normalized in a normalized form (0 ≤ f_normalized ≤ 1), fn = fn_max*f_normalized, where fn_max has to be provided as parameter. Friction in the clutch is modelled in the following way:

When the relative angular velocity is not zero, the friction torque is a function of the velocity dependent friction coefficient mue(w_rel) , of the normal force "fn", and of a geometry constant "cgeo" which takes into account the geometry of the device and the assumptions on the friction distributions:

```
frictional_torque = cgeo * mue(w_rel) * fn
```

Typical values of coefficients of friction:

```
dry operation   :  mue = 0.2 .. 0.4
operating in oil:  mue = 0.05 .. 0.1
```

When plates are pressed together, where **ri** is the inner radius, **ro** is the outer radius and **N** is the number of friction interfaces, the geometry constant is calculated in the following way under the assumption of a uniform rate of wear at the interfaces:

```
cgeo = N*(r0 + ri)/2
```

The positive part of the friction characteristic **mue**(w_rel), w_rel >= 0, is defined via table mue_pos (first column = w_rel, second column = mue). Currently, only linear interpolation in the table is supported.

When the relative angular velocity becomes zero, the elements connected by the friction element become stuck, i.e., the relative angle remains constant. In this phase the friction torque is calculated from a torque balance due to the requirement, that the relative acceleration shall be zero. The elements begin to slide when the friction torque exceeds a threshold value, called the maximum static friction torque, computed via:

```
frictional_torque = peak * cgeo * mue(w_rel=0) * fn   (peak >= 1)
```

This procedure is implemented in a "clean" way by state events and leads to continuous/discrete systems of equations if friction elements are dynamically coupled. The method is described in:

Otter M., Elmqvist H., and Mattsson S.E. (1999):
Hybrid Modeling in Modelica based on the Synchronous Data Flow Principle. CACSD'99, Aug. 22.-26, Hawaii.

More precise friction models take into account the elasticity of the material when the two elements are "stuck", as well as other effects, like hysteresis. This has the advantage that the friction element can be completely described by a differential equation without events. The drawback is that the system becomes stiff (about 10-20 times slower simulation) and that more material constants have to be supplied which requires more sophisticated identification. For more details, see the following references, especially (Armstrong and Canudas de Witt 1996):

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Armstrong B., and Canudas de Wit C. (1996):
Friction Modeling and Compensation. The Control Handbook, edited by W.S.Levine, CRC Press, pp. 1369-1382.

Canudas de Wit C., Olsson H., Astroem K.J., and Lischinsky P. (1995):
A new model for control of systems with friction. IEEE Transactions on Automatic Control, Vol. 40, No. 3, pp. 419-425.

Parameters

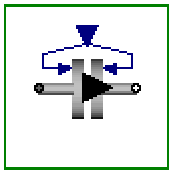
Type	Name	Default	Description
Real	mue_pos[:, 2]	[0, 0.5]	[w,mue] positive sliding friction coefficient (w_rel>=0)
Real	peak	1	peak*mue_pos[1,2] = maximum value of mue for w_rel==0
Real	cgeo	1	Geometry constant containing friction distribution assumption
Force	fn_max		Maximum normal force [N]
Initialization			
Angle	phi_rel.start	0	Relative rotation angle (= flange_b.phi - flange_a.phi) [rad]
AngularVelocity	w_rel.start	0	Relative angular velocity (= der(phi_rel)) [rad/s]
AngularAcceleration	a_rel.start	0	Relative angular acceleration (= der(w_rel)) [rad/s2]
Boolean	startForward.start	**false**	true, if w_rel=0 and start of forward sliding
Boolean	startBackward.start	**false**	true, if w_rel=0 and start of backward sliding
Boolean	locked.start	false	true, if w_rel=0 and not sliding
Advanced			
Angle	phi_nominal	1e-4	Nominal value of phi_rel (used for scaling) [rad]
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states
AngularVelocity	w_small	1.0e10	Relative angular velocity near to zero if jumps due to a reinit(..) of the velocity can occur (set to low value only if such impulses can occur)

			[rad/s]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component
input RealInput	f_normalized	Normalized force signal 0..1 (normal force = fn_max*f_normalized; clutch is engaged if > 0)

Modelica.Mechanics.Rotational.Components.OneWayClutch



Series connection of freewheel and clutch

Information

This component models a **one-way clutch**, i.e., a component with two flanges where friction is present between the two flanges and these flanges are pressed together via a normal force. These flanges maybe sliding with respect to each other Parallel connection of ClutchCombi and of FreeWheel. The element is introduced to resolve the ambiguity of the constraint torques of the elements.

A one-way-clutch is an element where a clutch is connected in parallel to a free wheel. This special element is provided, because such a parallel connection introduces an ambiguity into the model (the constraint torques are not uniquely defined when both elements are stuck) and this element resolves it by introducing **one** constraint torque and not two.

Note, initial values have to be chosen for the model, such that the relative speed of the one-way-clutch >= 0. Otherwise, the configuration is physically not possible and an error occurs.

The normal force fn has to be provided as input signal f_normalized in a normalized form (0 ≤ f_normalized ≤ 1), fn = fn_max*f_normalized, where fn_max has to be provided as parameter. Friction in the clutch is modelled in the following way:

When the relative angular velocity is positive, the friction torque is a function of the velocity dependent friction coefficient mue(w_rel) , of the normal force "fn", and of a geometry constant "cgeo" which takes into account the geometry of the device and the assumptions on the friction distributions:

```
frictional_torque = cgeo * mue(w_rel) * fn
```

Typical values of coefficients of friction:

```
dry operation   :  mue = 0.2 .. 0.4
operating in oil:  mue = 0.05 .. 0.1
```

When plates are pressed together, where **ri** is the inner radius, **ro** is the outer radius and **N** is the number of friction interfaces, the geometry constant is calculated in the following way under the assumption of a uniform rate of wear at the interfaces:

```
cgeo = N*(r0 + ri)/2
```

The positive part of the friction characteristic **mue**(w_rel), w_rel >= 0, is defined via table mue_pos (first column = w_rel, second column = mue). Currently, only linear interpolation in the table is supported.

When the relative angular velocity becomes zero, the elements connected by the friction element become stuck, i.e., the relative angle remains constant. In this phase the friction torque is calculated from a torque balance due to the requirement, that the relative acceleration shall be zero. The elements begin to slide when the friction torque exceeds a threshold value, called the maximum static friction torque, computed via:

```
frictional_torque = peak * cgeo * mue(w_rel=0) * fn   (peak >= 1)
```

This procedure is implemented in a "clean" way by state events and leads to continuous/discrete systems of equations if friction elements are dynamically coupled. The method is described in:

Otter M., Elmqvist H., and Mattsson S.E. (1999):
Hybrid Modeling in Modelica based on the Synchronous Data Flow Principle. CACSD'99, Aug. 22.-26, Hawaii.

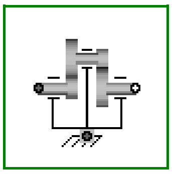
Parameters

Type	Name	Default	Description
Real	mue_pos[:, 2]	[0, 0.5]	[w,mue] positive sliding friction coefficient (w_rel>=0)
Real	peak	1	peak*mue_pos[1,2] = maximum value of mue for w_rel==0
Real	cgeo	1	Geometry constant containing friction distribution assumption
Force	fn_max		Maximum normal force [N]
Initialization			
Angle	phi_rel.start	0	Relative rotation angle (= flange_b.phi - flange_a.phi) [rad]
AngularVelocity	w_rel.start	0	Relative angular velocity (= der(phi_rel)) [rad/s]
AngularAcceleration	a_rel.start	0	Relative angular acceleration (= der(w_rel)) [rad/s2]
Advanced			
Angle	phi_nominal	1e-4	Nominal value of phi_rel (used for scaling) [rad]
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states
AngularVelocity	w_small	1e10	Relative angular velocity near to zero if jumps due to a reinit(..) of the velocity can occur (set to low value only if such impulses can occur) [rad/s]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component
input RealInput	f_normalized	Normalized force signal 0..1 (normal force = fn_max*f_normalized; clutch is engaged if > 0)

Modelica.Mechanics.Rotational.Components.IdealGear



Ideal gear without inertia

Information

This element characterices any type of gear box which is fixed in the ground and which has one driving shaft and one driven shaft. The gear is **ideal**, i.e., it does not have inertia, elasticity, damping or backlash. If these effects have to be considered, the gear has to be connected to other elements in an appropriate way.

Parameters

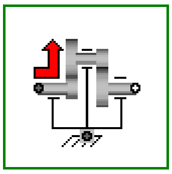
Type	Name	Default	Description

Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Real	ratio		Transmission ratio (flange_a.phi/flange_b.phi)

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Components.LossyGear



Gear with mesh efficiency and bearing friction (stuck/rolling possible)

Information

This component models the gear ratio and the **losses** of a standard gear box in a **reliable** way including the stuck phases that may occur at zero speed. The gear boxes that can be handeled are fixed in the ground, have one input and one output shaft, and are essentially described by the equations:

```
  flange_a.phi  = i*flange_b.phi
(-flange_b.tau) = i*(eta_mf*flange_a.tau - tau_bf)
```

where

- **i** is the constant **gear ratio**,
- **eta_mf** = eta_mf(w) is the **mesh efficiency** due to the friction between the teeth of the gear wheels,
- **tau_bf** = tau_bf(w) is the **bearing friction torque**, and
- **w_a** = der(flange_a.phi) is the speed of flange_a

The loss terms "eta_mf" and "tau_bf" are functions of the *absolute value* of the input shaft speed w_a and of the energy flow direction. They are defined by parameter **lossTable[:,5]** where the columns of this table have the following meaning:

|w_a|	eta_mf1	eta_mf2	|tau_bf1|	|tau_bf2|
...	...	...	...	...
...	...	...	...	...

with

|w_a|	Absolute value of angular velocity of input shaft flange_a
eta_mf1	Mesh efficiency in case of input shaft driving
eta_mf2	Mesh efficiency in case of output shaft driving
|tau_bf1|	Absolute bearing friction torque in case of input shaft driving
|tau_bf2|	Absolute bearing friction torque in case of output shaft driving

With these variables, the mesh efficiency and the bearing friction are formally defined as:

```
if flange_a.tau*w_a > 0 or flange_a.tau==0 and w_a > 0 then
   eta_mf := eta_mf1
   tau_bf := tau_bf1
elseif flange_a.tau*w_a < 0 or flange_a.tau==0 and w_a < 0 then
   eta_mf := 1/eta_mf2
   tau_bf := tau_bf2
else // w_a == 0
   eta_mf and tau_bf are computed such that der(w_a) = 0
end if;
```

Note, that the losses are modeled in a physically meaningful way taking into account that at zero speed the movement may be locked due to the friction in the gear teeth and/or in the bearings. Due to this important property, this component can be used in situations where the combination of the components Modelica.Mechanics.Rotational.IdealGear and Modelica.Mechanics.Rotational.GearEfficiency will fail because, e.g., chattering occurs when using the Modelica.Mechanics.Rotational.GearEfficiency model.

Acknowledgement: The essential idea to model efficiency in this way is from Christoph Pelchen, ZF Friedrichshafen.

For detailed information:

Pelchen C., Schweiger C., and Otter M.: "Modeling and Simulating the Efficiency of Gearboxes and of Planetary Gearboxes," in *Proceedings of the 2nd International Modelica Conference, Oberpfaffenhofen, Germany,* pp. 257-266, The Modelica Association and Institute of Robotics and Mechatronics, Deutsches Zentrum für Luft- und Raumfahrt e. V., March 18-19, 2002.

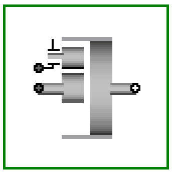
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Real	ratio		Transmission ratio (flange_a.phi/flange_b.phi)
Real	lossTable[:, 5]	[0, 1, 1, 0, 0]	Array for mesh efficiencies and bearing friction depending on speed

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Components.IdealPlanetary



Ideal planetary gear box

Information

The IdealPlanetary gear box is an ideal gear without inertia, elasticity, damping or backlash consisting of an inner **sun** wheel, an outer **ring** wheel and a **planet** wheel located between sun and ring wheel. The bearing of the planet wheel shaft is fixed in the planet **carrier**. The component can be connected to other elements at the sun, ring and/or carrier flanges. It is not possible to connect to the planet wheel. If inertia shall not be neglected, the sun, ring and carrier inertias can be easily added by attaching inertias (= model Inertia) to the corresponding connectors. The inertias of the planet wheels are always neglected.

The icon of the planetary gear signals that the sun and carrier flanges are on the left side and the ring flange is on the right side of the gear box. However, this component is generic and is valid independantly how the flanges are actually placed (e.g. sun wheel may be placed on the right side instead on the left side in reality).

The ideal planetary gearbox is uniquely defined by the ratio of the number of ring teeth zr with respect to the number of sun teeth zs. For example, if there are 100 ring teeth and 50 sun teeth then ratio = zr/zs = 2. The number of planet teeth zp has to fulfill the following relationship:

```
zp := (zr - zs) / 2
```

Therefore, in the above example zp = 25 is required.

According to the overall convention, the positive direction of all vectors, especially the absolute angular velocities and cut-torques in the flanges, are along the axis vector displayed in the icon.

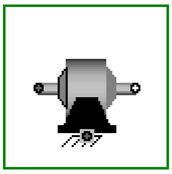
Parameters

Type	Name	Default	Description
Real	ratio		number of ring_teeth/sun_teeth (e.g. ratio=100/50)

Connectors

Type	Name	Description
Flange_a	sun	Flange of sun shaft
Flange_a	carrier	Flange of carrier shaft
Flange_b	ring	Flange of ring shaft

Modelica.Mechanics.Rotational.Components.Gearbox



Realistic model of a gearbox (based on LossyGear)

Information

This component models the essential effects of a gearbox, in particular

- in component **lossyGear**
  - gear **efficiency** due to friction between the teeth
  - **bearing friction**
- in component **elastoBacklash**
  - gear **elasticity**
  - **damping**
  - **backlash**

The inertia of the gear wheels is not modeled. If necessary, inertia has to be taken into account by connecting components of model Inertia to the left and/or the right flange of component Gearbox.

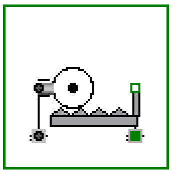
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Real	ratio		transmission ratio (flange_a.phi/flange_b.phi)
Real	lossTable[:, 5]	[0, 1, 1, 0, 0]	Array for mesh efficiencies and bearing friction depending on speed (see docu of LossyGear)
RotationalSpringConstant	c		Gear elasticity (spring constant) [N.m/rad]
RotationalDampingConstant	d		(relative) gear damping [N.m.s/rad]
Angle	b	0	Total backlash [rad]
Advanced			
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Components.IdealGearR2T



Gearbox transforming rotational into translational motion

Information

This is an ideal mass- and inertialess gearbox which transforms a 1D-rotational into a 1D-translational motion. If elasticity, damping or backlash has to be considered, this ideal gearbox has to be connected with corresponding elements. This component defines the kinematic constraint:

```
(flangeR.phi - internalSupportR.phi) = ratio*(flangeT.s - internalSupportT.s);
```

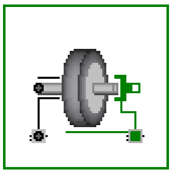
Parameters

Type	Name	Default	Description
Boolean	useSupportR	false	= true, if rotational support flange enabled, otherwise implicitly grounded
Boolean	useSupportT	false	= true, if translational support flange enabled, otherwise implicitly grounded
Real	ratio		Transmission ratio (flange_a.phi/flange_b.s) [rad/m]

Connectors

Type	Name	Description
Flange_a	flangeR	Flange of rotational shaft
Flange_b	flangeT	Flange of translational rod
Support	supportR	Rotational support/housing of component
Support	supportT	Translational support/housing of component

Modelica.Mechanics.Rotational.Components.IdealRollingWheel



Simple 1-dim. model of an ideal rolling wheel without inertia

Information

A simple kinematic model of a rolling wheel which has no inertia and no rolling resistance. This component defines the kinematic constraint:

```
    (flangeR.phi - internalSupportR.phi)*wheelRadius = (flangeT.s -
internalSupportT.s);
```

Parameters

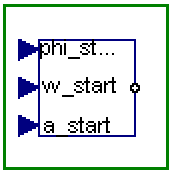
Type	Name	Default	Description
Boolean	useSupportR	false	= true, if rotational support flange enabled, otherwise implicitly grounded
Boolean	useSupportT	false	= true, if translational support flange enabled, otherwise implicitly grounded
Distance	radius		Wheel radius [m]

Connectors

Type	Name	Description
Flange_a	flangeR	Flange of rotational shaft

Flange_b	flangeT	Flange of translational rod
Support	supportR	Rotational support/housing of component
Support	supportT	Translational support/housing of component

Modelica.Mechanics.Rotational.Components.InitializeFlange



Initializes a flange with pre-defined angle, speed and angular acceleration (usually, this is reference data from a control bus)

Information

This component is used to optionally initialize the angle, speed, and/or angular acceleration of the flange to which this component is connected. Via parameters use_phi_start, use_w_start, use_a_start the corresponding input signals phi_start, w_start, a_start are conditionally activated. If an input is activated, the corresponding flange property is initialized with the input value at start time.

For example, if "use_phi_start = true", then flange.phi is initialized with the value of the input signal "phi_start" at the start time.

Additionally, it is optionally possible to define the "StateSelect" attribute of the flange angle and the flange speed via paramater "stateSelection".

This component is especially useful when the initial values of a flange shall be set according to reference signals of a controller that are provided via a signal bus.

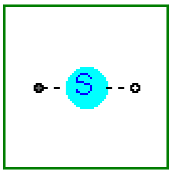
Parameters

Type	Name	Default	Description
Boolean	use_phi_start	true	= true, if initial angle is defined by input phi_start, otherwise not initialized
Boolean	use_w_start	true	= true, if initial speed is defined by input w_start, otherwise not initialized
Boolean	use_a_start	true	= true, if initial angular acceleration is defined by input a_start, otherwise not initialized
StateSelect	stateSelect	StateSelect.default	Priority to use flange angle and speed as states

Connectors

Type	Name	Description
input RealInput	phi_start	Initial angle of flange
input RealInput	w_start	Initial speed of flange
input RealInput	a_start	Initial angular acceleration of flange
Flange_b	flange	Flange that is initialized

Modelica.Mechanics.Rotational.Components.RelativeStates



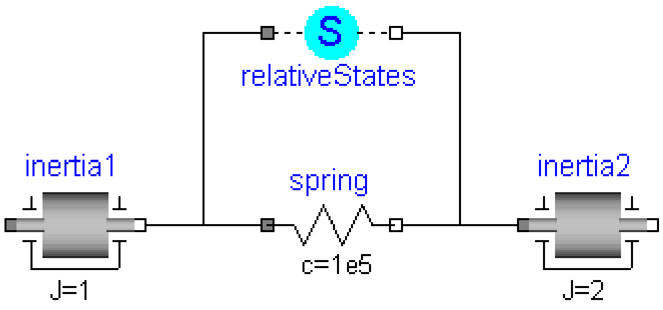
Definition of relative state variables

Information

Usually, the absolute angle and the absolute angular velocity of Modelica.Mechanics.Rotational.Inertia models are used as state variables. In some circumstances, relative quantities are better suited, e.g., because it may be easier to supply initial values. In such cases, model **RelativeStates** allows the definition of state variables in the following way:

- Connect an instance of this model between two flange connectors.
- The **relative rotation angle** and the **relative angular velocity** between the two connectors are used as **state variables**.

An example is given in the next figure



Here, the relative angle and the relative angular velocity between the two inertias are used as state variables. Additionally, the simulator selects either the absolute angle and absolute angular velocity of model inertia1 or of model inertia2 as state variables.

Parameters

Type	Name	Default	Description
StateSelect	stateSelect	StateSelect.prefer	Priority to use the relative angle and relative speed as states

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft

Modelica.Mechanics.Rotational.Sources

Sources to drive 1D rotational mechanical components

Information

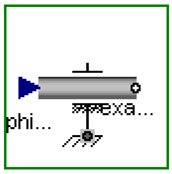
This package contains ideal sources to drive 1D mechanical rotational drive trains.

Package Content

Name	Description
Position	Forced movement of a flange according to a reference angle signal
Speed	Forced movement of a flange according to a reference angular velocity signal
Accelerate	Forced movement of a flange according to an acceleration signal
Move	Forced movement of a flange according to an angle, speed and angular acceleration signal

Torque	Input signal acting as external torque on a flange
Torque2	Input signal acting as torque on two flanges
LinearSpeedDependentTorque	Linear dependency of torque versus speed
QuadraticSpeedDependentTorque	Quadratic dependency of torque versus speed
ConstantTorque	Constant torque, not dependent on speed
ConstantSpeed	Constant speed, not dependent on torque
TorqueStep	Constant torque, not dependent on speed

Modelica.Mechanics.Rotational.Sources.Position



Forced movement of a flange according to a reference angle signal

Information

The input signal **phi_ref** defines the **reference angle** in [rad]. Flange **flange** is **forced** to move according to this reference motion relative to flange support. According to parameter **exact** (default = **false**), this is done in the following way:

1. **exact=true**
   The reference angle is treated **exactly**. This is only possible, if the input signal is defined by an analytical function which can be differentiated at least twice. If this prerequisite is fulfilled, the Modelica translator will differentiate the input signal twice in order to compute the reference acceleration of the flange.
2. **exact=false**
   The reference angle is **filtered** and the second derivative of the filtered curve is used to compute the reference acceleration of the flange. This second derivative is **not** computed by numerical differentiation but by an appropriate realization of the filter. For filtering, a second order Bessel filter is used. The critical frequency (also called cut-off frequency) of the filter is defined via parameter **f_crit** in [Hz]. This value should be selected in such a way that it is higher as the essential low frequencies in the signal.

The input signal can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Sources.

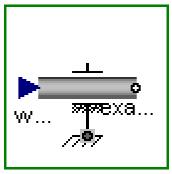
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Boolean	exact	false	true/false exact treatment/filtering the input signal
Frequency	f_crit	50	if exact=false, critical frequency of filter to filter input signal [Hz]

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component
input RealInput	phi_ref	Reference angle of flange with respect to support as input signal [rad]

Modelica.Mechanics.Rotational.Sources.Speed



Forced movement of a flange according to a reference angular velocity signal

Information

The input signal **w_ref** defines the **reference speed** in [rad/s]. Flange **flange** is **forced** to move relative to flange support according to this reference motion. According to parameter **exact** (default = **false**), this is done in the following way:

1. **exact=true**
   The reference speed is treated **exactly**. This is only possible, if the input signal is defined by an analytical function which can be differentiated at least once. If this prerequisite is fulfilled, the Modelica translator will differentiate the input signal once in order to compute the reference acceleration of the flange.
2. **exact=false**
   The reference angle is **filtered** and the second derivative of the filtered curve is used to compute the reference acceleration of the flange. This second derivative is **not** computed by numerical differentiation but by an appropriate realization of the filter. For filtering, a first order filter is used. The critical frequency (also called cut-off frequency) of the filter is defined via parameter **f_crit** in [Hz]. This value should be selected in such a way that it is higher as the essential low frequencies in the signal.

The input signal can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Sources.

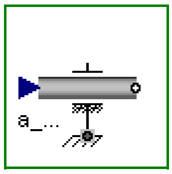
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Boolean	exact	false	true/false exact treatment/filtering the input signal
Frequency	f_crit	50	if exact=false, critical frequency of filter to filter input signal [Hz]

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component
input RealInput	w_ref	Reference angular velocity of flange with respect to support as input signal

Modelica.Mechanics.Rotational.Sources.Accelerate



Forced movement of a flange according to an acceleration signal

Information

The input signal **a** defines an **angular acceleration** in [rad/s2]. Flange **flange** is **forced** to move relative to flange support with this acceleration. The angular velocity **w** and the rotation angle **phi** of the flange are automatically determined by integration of the acceleration.

The input signal can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Sources.

Parameters

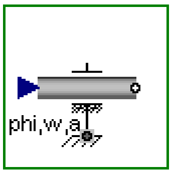
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component
input RealInput	a_ref	Absolute angular acceleration of flange with respect to support as input signal

---

Modelica.Mechanics.Rotational.Sources.Move



Forced movement of a flange according to an angle, speed and angular acceleration signal

Information

Flange **flange** is **forced** to move relative to flange support with a predefined motion according to the input signals:

```
u[1]: angle of flange
u[2]: angular velocity of flange
u[3]: angular acceleration of flange
```

The user has to guarantee that the input signals are consistent to each other, i.e., that u[2] is the derivative of u[1] and that u[3] is the derivative of u[2]. There are, however, also applications where by purpose these conditions do not hold. For example, if only the position dependent terms of a mechanical system shall be calculated, one may provide angle = angle(t) and set the angular velocity and the angular acceleration to zero.

The input signals can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Sources.

Parameters

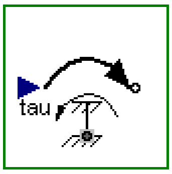
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component
input RealInput	u[3]	Angle, angular velocity and angular acceleration of flange with respect to support as input signals

---

Modelica.Mechanics.Rotational.Sources.Torque



Input signal acting as external torque on a flange

Information

The input signal **tau** defines an external torque in [Nm] which acts (with negative sign) at a flange connector, i.e., the component connected to this flange is driven by torque **tau**.

The input signal can be provided from one of the signal generator blocks of Modelica.Blocks.Sources.

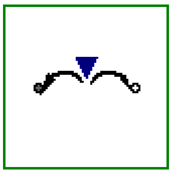
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component
input RealInput	tau	Accelerating torque acting at flange (= -flange.tau)

Modelica.Mechanics.Rotational.Sources.Torque2



Input signal acting as torque on two flanges

Information

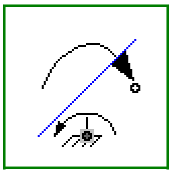
The input signal **tau** defines an external torque in [Nm] which acts at both flange connectors, i.e., the components connected to these flanges are driven by torque **tau**.

The input signal can be provided from one of the signal generator blocks of Modelica.Blocks.Sources.

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
input RealInput	tau	Torque driving the two flanges (a positive value accelerates the flange)

Modelica.Mechanics.Rotational.Sources.LinearSpeedDependentTorque



Linear dependency of torque versus speed

Information

Model of torque, linearly dependent on angular velocity of flange.
Parameter TorqueDirection chooses whether direction of torque is the same in both directions of rotation or not.

Parameters

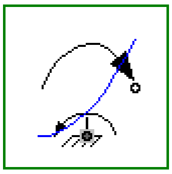
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Torque	tau_nominal		Nominal torque (if negative, torque is acting as load) [N.m]

Boolean	TorqueDirection	true	Same direction of torque in both directions of rotation
AngularVelocity	w_nominal		Nominal speed [rad/s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Sources.QuadraticSpeedDependentTorque



Quadratic dependency of torque versus speed

Information

Model of torque, quadratic dependent on angular velocity of flange.
Parameter TorqueDirection chooses whether direction of torque is the same in both directions of rotation or not.

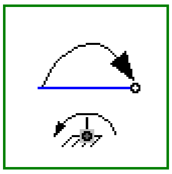
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Torque	tau_nominal		Nominal torque (if negative, torque is acting as load) [N.m]
Boolean	TorqueDirection	true	Same direction of torque in both directions of rotation
AngularVelocity	w_nominal		Nominal speed [rad/s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Sources.ConstantTorque



Constant torque, not dependent on speed

Information

Model of constant torque, not dependent on angular velocity of flange.
Positive torque acts accelerating.

Parameters

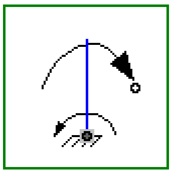
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Torque	tau_constant		Constant torque (if negative, torque is acting as load) [N.m]

Connectors

Type	Name	Description

Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Sources.ConstantSpeed



Constant speed, not dependent on torque

Information

Model of **fixed** angular verlocity of flange, not dependent on torque.

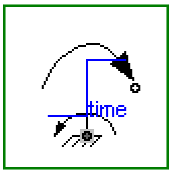
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
AngularVelocity	w_fixed		Fixed speed [rad/s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Sources.TorqueStep



Constant torque, not dependent on speed

Information

Model of a torque step at time .
Positive torque acts accelerating.

Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Torque	stepTorque		Height of torque step (if negative, torque is acting as load) [N.m]
Torque	offsetTorque		Offset of torque [N.m]
Time	startTime	0	Torque = offset for time < startTime [s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Sensors

Sensors to measure variables in 1D rotational mechanical components

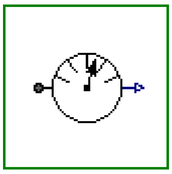
Information

This package contains ideal sensor components that provide the connector variables as signals for further processing with the Modelica.Blocks library.

Package Content

Name	Description
AngleSensor	Ideal sensor to measure the absolute flange angle
SpeedSensor	Ideal sensor to measure the absolute flange angular velocity
AccSensor	Ideal sensor to measure the absolute flange angular acceleration
RelAngleSensor	Ideal sensor to measure the relative angle between two flanges
RelSpeedSensor	Ideal sensor to measure the relative angular velocity between two flanges
RelAccSensor	Ideal sensor to measure the relative angular acceleration between two flanges
TorqueSensor	Ideal sensor to measure the torque between two flanges (= flange_a.tau)
PowerSensor	Ideal sensor to measure the power between two flanges (= flange_a.tau*der(flange_a.phi))

Modelica.Mechanics.Rotational.Sensors.AngleSensor



Ideal sensor to measure the absolute flange angle

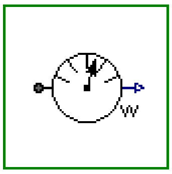
Information

Measures the **absolute angle phi** of a flange in an ideal way and provides the result as output signal **phi** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange	Flange of shaft from which sensor information shall be measured
output RealOutput	phi	Absolute angle of flange

Modelica.Mechanics.Rotational.Sensors.SpeedSensor



Ideal sensor to measure the absolute flange angular velocity

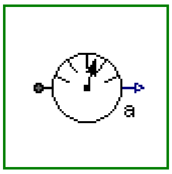
Information

Measures the **absolute angular velocity w** of a flange in an ideal way and provides the result as output signal **w** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange	Flange of shaft from which sensor information shall be measured
output RealOutput	w	Absolute angular velocity of flange

Modelica.Mechanics.Rotational.Sensors.AccSensor



Ideal sensor to measure the absolute flange angular acceleration

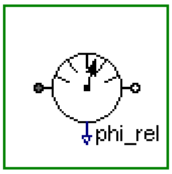
Information

Measures the **absolute angular acceleration a** of a flange in an ideal way and provides the result as output signal **a** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange	Flange of shaft from which sensor information shall be measured
output RealOutput	a	Absolute angular acceleration of flange

Modelica.Mechanics.Rotational.Sensors.RelAngleSensor



Ideal sensor to measure the relative angle between two flanges

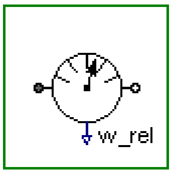
Information

Measures the **relative angle phi_rel** between two flanges in an ideal way and provides the result as output signal **phi_rel** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of shaft
Flange_b	flange_b	Right flange of shaft
output RealOutput	phi_rel	Relative angle between two flanges (= flange_b.phi - flange_a.phi)

Modelica.Mechanics.Rotational.Sensors.RelSpeedSensor



Ideal sensor to measure the relative angular velocity between two flanges

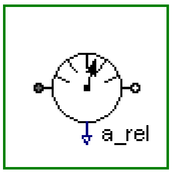
Information

Measures the **relative angular velocity w_rel** between two flanges in an ideal way and provides the result as output signal **w_rel** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of shaft
Flange_b	flange_b	Right flange of shaft
output RealOutput	w_rel	Relative angular velocity between two flanges (= der(flange_b.phi) - der(flange_a.phi))

Modelica.Mechanics.Rotational.Sensors.RelAccSensor



Ideal sensor to measure the relative angular acceleration between two flanges

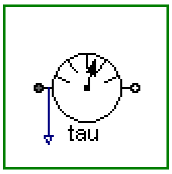
Information

Measures the **relative angular acceleration a_rel** between two flanges in an ideal way and provides the result as output signal **a_rel** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of shaft
Flange_b	flange_b	Right flange of shaft
output RealOutput	a_rel	Relative angular acceleration between two flanges

Modelica.Mechanics.Rotational.Sensors.TorqueSensor



Ideal sensor to measure the torque between two flanges (= flange_a.tau)

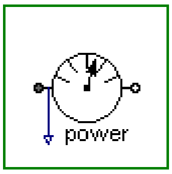
Information

Measures the **cut-torque between two flanges** in an ideal way and provides the result as output signal **tau** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of shaft
Flange_b	flange_b	Right flange of shaft
output RealOutput	tau	Torque in flange flange_a and flange_b (tau = flange_a.tau = -flange_b.tau)

Modelica.Mechanics.Rotational.Sensors.PowerSensor



Ideal sensor to measure the power between two flanges (= flange_a.tau*der(flange_a.phi))

Information

Measures the **power between two flanges** in an ideal way and provides the result as output signal **power** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of shaft
Flange_b	flange_b	Right flange of shaft
output RealOutput	power	Power in flange flange_a

Modelica.Mechanics.Rotational.Interfaces

Connectors and partial models for 1D rotational mechanical components

Information

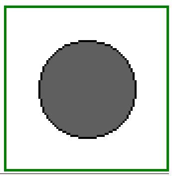
This package contains connectors and partial models for 1-dim. rotational mechanical components. The components of this package can only be used as basic building elements for models.

Package Content

Name	Description
Flange_a	1-dim. rotational flange of a shaft (filled square icon)
Flange_b	1-dim. rotational flange of a shaft (non-filled square icon)
Support	Support/housing of a 1-dim. rotational shaft
InternalSupport	Adapter model to utilize conditional support connector
PartialTwoFlanges	Partial model for a component with two rotational 1-dim. shaft flanges
PartialOneFlangeAndSupport	Partial model for a component with one rotational 1-dim. shaft flange and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components
PartialTwoFlangesAndSupport	Partial model for a component with two rotational 1-dim. shaft flanges and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components
PartialCompliant	Partial model for the compliant connection of two rotational 1-dim. shaft flanges
PartialCompliantWithRelativeStates	Partial model for the compliant connection of two rotational 1-dim. shaft flanges where the relative angle and speed are used as preferred states
PartialElementaryOneFlangeAndSupport	Partial model for a component with one rotational 1-dim. shaft flange and a support used for textual modeling, i.e., for elementary models
PartialElementaryTwoFlangesAndSupport	Partial model for a component with two rotational 1-dim. shaft flanges and a support used for textual modeling, i.e., for elementary models
PartialElementaryRotationalToTranslational	Partial model to transform rotational into translational motion
PartialTorque	Partial model of a torque acting at the flange (accelerates the flange)
PartialAbsoluteSensor	Partial model to measure a single absolute flange variable
PartialRelativeSensor	Partial model to measure a single relative variable between two flanges
PartialFriction	Partial model of Coulomb friction elements

Modelica.Mechanics.Rotational.Interfaces.Flange_a

1-dim. rotational flange of a shaft (filled square icon)



Information

This is a connector for 1-dim. rotational mechanical systems and models the mechanical flange of a shaft. The following variables are defined in this connector:

phi	Absolute rotation angle of theshaft flange in [rad]
tau	Cut-torque in the shaft flange in [Nm]

There is a second connector for flanges: Flange_b. The connectors Flange_a and Flange_b are completely identical. There is only a difference in the icons, in order to easier identify a flange variable in a diagram. For a discussion on the actual direction of the cut-torque tau and of the rotation angle, see section Sign Conventions in the user's guide of Rotational.

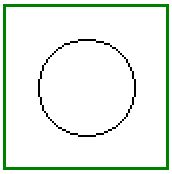
If needed, the absolute angular velocity w and the absolute angular acceleration a of the flange can be determined by differentiation of the flange angle phi:

```
w = der(phi);    a = der(w)
```

Contents

Type	Name	Description
Angle	phi	Absolute rotation angle of flange [rad]
flow Torque	tau	Cut torque in the flange [N.m]

Modelica.Mechanics.Rotational.Interfaces.Flange_b



1-dim. rotational flange of a shaft (non-filled square icon)

Information

This is a connector for 1-dim. rotational mechanical systems and models the mechanical flange of a shaft. The following variables are defined in this connector:

phi	Absolute rotation angle of the shaft flange in [rad]
tau	Cut-torque in the shaft flange in [Nm]

There is a second connector for flanges: Flange_a. The connectors Flange_a and Flange_b are completely identical. There is only a difference in the icons, in order to easier identify a flange variable in a diagram. For a discussion on the actual direction of the cut-torque tau and of the rotation angle, see section Sign Conventions in the user's guide of Rotational.

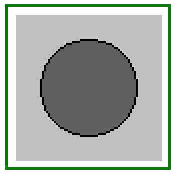
If needed, the absolute angular velocity w and the absolute angular acceleration a of the flange can be determined by differentiation of the flange angle phi:

```
w = der(phi);    a = der(w)
```

Contents

Type	Name	Description
Angle	phi	Absolute rotation angle of flange [rad]
flow Torque	tau	Cut torque in the flange [N.m]

Modelica.Mechanics.Rotational.Interfaces.Support



Support/housing of a 1-dim. rotational shaft

Information

This is a connector for 1-dim. rotational mechanical systems and models the support or housing of a shaft. The following variables are defined in this connector:

phi	Absolute rotation angle of the support/housing in [rad]
tau	Reaction torque in the support/housing in [Nm]

The support connector is usually defined as conditional connector. It is most convenient to utilize it

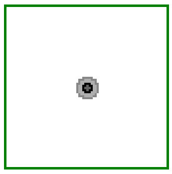
- For models to be build graphically (i.e. the model is build up by drag-and-drop from elementary components):
  PartialOneFlangeAndSupport,
  PartialTwoFlangesAndSupport,

- For models to be build textually (i.e. elementary models):
  PartialElementaryOneFlangeAndSupport,
  PartialElementaryTwoFlangesAndSupport,
  PartialElementaryRotationalToTranslational.

Contents

Type	Name	Description
Angle	phi	Absolute rotation angle of the support/housing [rad]
flow Torque	tau	Reaction torque in the support/housing [N.m]

Modelica.Mechanics.Rotational.Interfaces.InternalSupport



Adapter model to utilize conditional support connector

Information

This is an adapter model to utilize a conditional support connector in an elementary component, i.e., where the component equations are defined textually:

- If *useSupport* = *true*, the flange has to be connected to the conditional support connector.
- If *useSupport* = *false*, the flange has to be connected to the conditional fixed model.

Variable **tau** is defined as **input** and must be provided when using this component as a modifier (computed via a torque balance in the model where InternalSupport is used). Usually, model InternalSupport is utilized via the partial models:

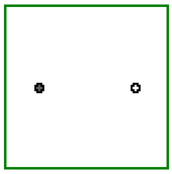
PartialElementaryOneFlangeAndSupport,
PartialElementaryTwoFlangesAndSupport,
PartialElementaryRotationalToTranslational.

Note, the support angle can always be accessed as internalSupport.phi, and the support torque can always be accessed as internalSupport.tau.

Connectors

Type	Name	Description
Flange_a	flange	Internal support flange (must be connected to the conditional support connector for useSupport=true and to conditional fixed model for useSupport=false)

Modelica.Mechanics.Rotational.Interfaces.PartialTwoFlanges



Partial model for a component with two rotational 1-dim. shaft flanges

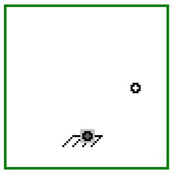
Information

This is a 1-dim. rotational component with two flanges. It is used e.g. to build up parts of a drive train consisting of several components.

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft

Modelica.Mechanics.Rotational.Interfaces.PartialOneFlangeAndSupport



Partial model for a component with one rotational 1-dim. shaft flange and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components

Information

This is a 1-dim. rotational component with one flange and a support/housing. It is used e.g. to build up parts of a drive train graphically consisting of several components.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

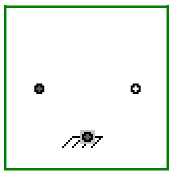
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Interfaces.PartialTwoFlangesAndSupport



Partial model for a component with two rotational 1-dim. shaft flanges and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components

Information

This is a 1-dim. rotational component with two flanges and a support/housing. It is used e.g. to build up parts of a drive train graphically consisting of several components.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally

fixed to ground.

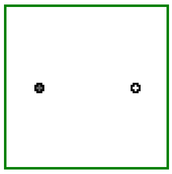
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Interfaces.PartialCompliant



Partial model for the compliant connection of two rotational 1-dim. shaft flanges

Information

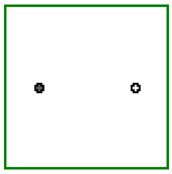
This is a 1-dim. rotational component with a compliant connection of two rotational 1-dim. flanges where inertial effects between the two flanges are neglected. The basic assumption is that the cut-torques of the two flanges sum-up to zero, i.e., they have the same absolute value but opposite sign: flange_a.tau + flange_b.tau = 0. This base class is used to built up force elements such as springs, dampers, friction.

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component

---

Modelica.Mechanics.Rotational.Interfaces.PartialCompliantWithRelativeStates



Partial model for the compliant connection of two rotational 1-dim. shaft flanges where the relative angle and speed are used as preferred states

Information

This is a 1-dim. rotational component with a compliant connection of two rotational 1-dim. flanges where inertial effects between the two flanges are neglected. The basic assumption is that the cut-torques of the two flanges sum-up to zero, i.e., they have the same absolute value but opposite sign: flange_a.tau + flange_b.tau = 0. This base class is used to built up force elements such as springs, dampers, friction.

The relative angle and the relative speed are defined as preferred states. The reason is that for some drive trains, such as drive trains in vehicles, the absolute angle is quickly increasing during operation. Numerically, it is better to use relative angles between drive train components because they remain in a limited size. For this reason, StateSelect.prefer is set for the relative angle of this component.

In order to improve the numerics, a nominal value for the relative angle can be provided via parameter **phi_nominal** in the Advanced menu. The default ist 1e-4 rad since relative angles are usually in this order and the step size control of an integrator would be practically switched off, if a default of 1 rad would be used. This nominal value might also be computed from other values, such as "phi_nominal = tau_nominal / c" for a rotational spring, if tau_nominal and c are more meaningful for the user.

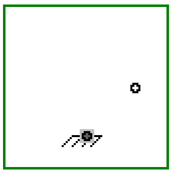
Parameters

Type	Name	Default	Description
Advanced			
Angle	phi_nominal	1e-4	Nominal value of phi_rel (used for scaling) [rad]
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. rotational component
Flange_b	flange_b	Right flange of compliant 1-dim. rotational component

Modelica.Mechanics.Rotational.Interfaces.PartialElementaryOneFlangeAndSupport



Partial model for a component with one rotational 1-dim. shaft flange and a support used for textual modeling, i.e., for elementary models

Information

This is a 1-dim. rotational component with one flange and a support/housing. It is used to build up elementary components of a drive train with equations in the text layer.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

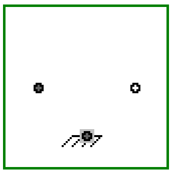
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Interfaces.PartialElementaryTwoFlangesAndSupport



Partial model for a component with two rotational 1-dim. shaft flanges and a support used for textual modeling, i.e., for elementary models

Information

This is a 1-dim. rotational component with two flanges and a support/housing. It is used to build up elementary components of a drive train with equations in the text layer.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

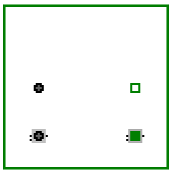
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Interfaces.PartialElementaryRotationalToTranslational



Partial model to transform rotational into translational motion

Information

This is a 1-dim. rotational component with

- one rotational flange,
- one rotational support/housing,
- one translational flange, and
- one translatinal support/housing

This model is used to build up elementary components of a drive train transforming rotational into translational motion with equations in the text layer.

If *useSupportR=true*, the rotational support connector is conditionally enabled and needs to be connected.
If *useSupportR=false*, the rotational support connector is conditionally disabled and instead the rotational part is internally fixed to ground.
If *useSupportT=true*, the translational support connector is conditionally enabled and needs to be connected.
If *useSupportT=false*, the translational support connector is conditionally disabled and instead the translational part is internally fixed to ground.

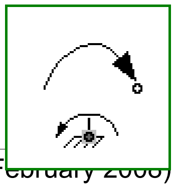
Parameters

Type	Name	Default	Description
Boolean	useSupportR	false	= true, if rotational support flange enabled, otherwise implicitly grounded
Boolean	useSupportT	false	= true, if translational support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_a	flangeR	Flange of rotational shaft
Flange_b	flangeT	Flange of translational rod
Support	supportR	Rotational support/housing of component
Support	supportT	Translational support/housing of component

Modelica.Mechanics.Rotational.Interfaces.PartialTorque



Partial model of a torque acting at the flange (accelerates the flange)

Information

Partial model of torque that accelerates the flange.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

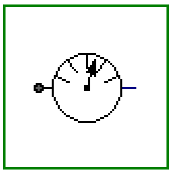
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of shaft
Support	support	Support/housing of component

Modelica.Mechanics.Rotational.Interfaces.PartialAbsoluteSensor



Partial model to measure a single absolute flange variable

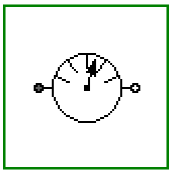
Information

This is a partial model of a 1-dim. rotational component with one flange of a shaft in order to measure an absolute kinematic quantity in the flange and to provide the measured signal as output signal for further processing with the blocks of package Modelica.Blocks.

Connectors

Type	Name	Description
Flange_a	flange	Flange of shaft from which sensor information shall be measured

Modelica.Mechanics.Rotational.Interfaces.PartialRelativeSensor



Partial model to measure a single relative variable between two flanges

Information

This is a partial model for 1-dim. rotational components with two rigidly connected flanges in order to measure relative kinematic quantities between the two flanges or the cut-torque in the flange and to provide the measured signal as output signal for further processing with the blocks of package Modelica.Blocks.

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of shaft
Flange_b	flange_b	Right flange of shaft

Modelica.Mechanics.Rotational.Interfaces.PartialFriction

Partial model of Coulomb friction elements

Information

Basic model for Coulomb friction that models the stuck phase in a reliable way.

Parameters

Type	Name	Default	Description
Advanced			
AngularVelocity	w_small	1.0e10	Relative angular velocity near to zero if jumps due to a reinit(..) of the velocity can occur (set to low value only if such impulses can occur) [rad/s]

Modelica.Mechanics.Translational

Library to model 1-dimensional, translational mechanical systems

Information

This package contains components to model *1-dimensional translational mechanical* systems.

The *filled* and *non-filled green squares* at the left and right side of a component represent *mechanical flanges*. Drawing a line between such squares means that the corresponding flanges are *rigidly attached* to each other. The components of this library can be usually connected together in an arbitrary way. E.g. it is possible to connect two springs or two sliding masses with inertia directly together.

The only *connection restriction* is that the Coulomb friction elements (e.g. MassWithStopAndFriction) should be only connected together provided a compliant element, such as a spring, is in between. The reason is that otherwise the frictional force is not uniquely defined if the elements are stuck at the same time instant (i.e., there does not exist a unique solution) and some simulation systems may not be able to handle this situation, since this leads to a singularity during simulation. It can only be resolved in a "clean way" by combining the two connected friction elements into one component and resolving the ambiguity of the frictional force in the stuck mode.

Another restriction arises if the hard stops in model MassWithStopAndFriction are used, i. e. the movement of the mass is limited by a stop at smax or smin. **This requires the states Stop.s and Stop.v** . If these states are eliminated during the index reduction the model will not work. To avoid this any inertias should be connected via springs to the Stop element, other sliding masses, dampers or hydraulic chambers must be avoided.

In the *icon* of every component an *arrow* is displayed in grey color. This arrow characterizes the coordinate system in which the vectors of the component are resolved. It is directed into the positive translational direction (in the mathematical sense). In the flanges of a component, a coordinate system is rigidly attached to the flange. It is called *flange frame* and is directed in parallel to the component coordinate system. As a result, e.g., the positive cut-force of a "left" flange (flange_a) is directed into the flange, whereas the positive cut-force of a "right" flange (flange_b) is directed out of the flange. A flange is described by a Modelica connector containing the following variables:

```
Modelica.SIunits.Position s    "Absolute position of flange";
flow Modelica.SIunits.Force f  "Cut-force in the flange";
```

This library is designed in a fully object oriented way in order that components can be connected together in every meaningful combination (e.g. direct connection of two springs or two shafts with inertia). As a consequence, most models lead to a system of differential-algebraic equations of *index 3* (= constraint equations have to be differentiated twice in order to arrive at a state space representation) and the Modelica translator or the simulator has to cope with this system representation. According to our present knowledge, this requires that the Modelica translator is able to symbolically differentiate equations (otherwise it is e.g. not possible to provide consistent initial conditions; even if consistent initial conditions are present, most numerical DAE integrators can cope at most with index 2 DAEs).

Library Officer
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Package Content

Name	Description
Examples	Demonstration examples of the components of this package
Components	Components for 1D translational mechanical drive trains
Sources	Sources to drive 1D translational mechanical components
Sensors	Sensors for 1-dim. translational mechanical quantities
Interfaces	Interfaces for 1-dim. translational mechanical components

Modelica.Mechanics.Translational.Examples

Demonstration examples of the components of this package

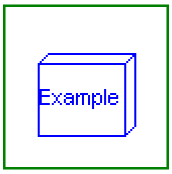
Information

This package contains example models to demonstrate the usage of the Translational package. Open the models and simulate them according to the provided description in the models.

Package Content

Name	Description
SignConvention	Examples for the used sign conventions.
InitialConditions	Setting of initial conditions
WhyArrows	Use of arrows in Mechanics.Translational
Accelerate	Use of model accelerate.
Damper	Use of damper models.
Oscillator	Oscillator demonstrates the use of initial conditions.
Sensors	Sensors for translational systems.
Friction	Use of model Stop
PreLoad	Preload of a spool using ElastoGap models.
ElastoGap	Demonstrate usgae of ElastoGap

Modelica.Mechanics.Translational.Examples.SignConvention



Examples for the used sign conventions.

Information

If all arrows point in the same direction a positive force results in a positive acceleration a, velocity v and position s.

For a force of 1 N and a mass of 1 Kg this leads to

```
a = 1 m/s2
v = 1 m/s after 1 s (SlidingMass1.v)
s = 0.5 m after 1 s (SlidingMass1.s)
```

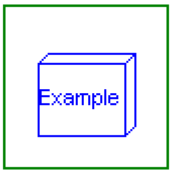
The acceleration is not available for plotting.

System 1) and 2) are equivalent. It doesn't matter whether the force pushes at flange_a in system 1 or pulls at flange_b in system 2.

It is of course possible to ignore the arrows and connect the models in an arbitrary way. But then it is hard see in what direction the force acts.

In the third system the two arrows are opposed which means that the force acts in the opposite direction (in the same direction as in the two other examples).

Modelica.Mechanics.Translational.Examples.InitialConditions



Setting of initial conditions

Information

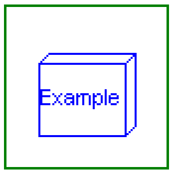
There are several ways to set initial conditions. In the first system the position of the mass m3 was defined by using the modifier s(start=4.5), the position of m4 by s(start=12.5). These positions were chosen such that the system is a rest. To calculate these values start at the left (Fixed1) with a value of 1 m. The spring has an unstreched length of 2 m and m3 an length of 3 m, which leads to

```
1   m (fixed1)
```

```
+ 2   m (spring s2)
+ 3/2 m (half of the length of mass m3)
-------
  4,5 m = s(start = 4.5) for m3
+ 3/2 m (half of the length of mass m3)
+ 4   m (springDamper 2)
+ 5/2 m (half of length of mass m4)
-------
 12,5 m = s(start = 12.5) for m4
```

This selection of initial conditions has the effect that Dymola selects those variables (m3.s and m4.s) as state variables. In the second example the length of the springs are given as start values but they cannot be used as state for pure springs (only for the spring/damper combination). In this case the system is not at rest.

Modelica.Mechanics.Translational.Examples.WhyArrows

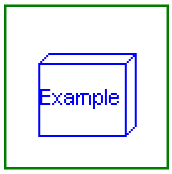


Use of arrows in Mechanics.Translational

Information

When using the models of the translational sublibrary it is recommended to make sure that all arrows point in the same direction because then all component have the same reference system. In the example the distance from flange_a of Rod1 to flange_b of Rod2 is 2 m. The distance from flange_a of Rod1 to flange_b of Rod3 is also 2 m though it is difficult to see that. Without the arrows it would be almost impossible to notice. That all arrows point in the same direction is a sufficient condition for an easy use of the library. There are cases where horizontally flipped models can be used without problems.

Modelica.Mechanics.Translational.Examples.Accelerate

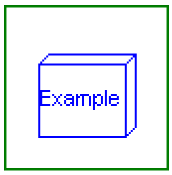


Use of model accelerate.

Information

Demonstrate usage of component Sources.Accelerate by moving a massing with a predefined acceleration.

Modelica.Mechanics.Translational.Examples.Damper

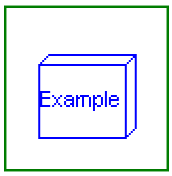


Use of damper models.

Information

Demonstrate usage of damper components in different variants.

Modelica.Mechanics.Translational.Examples.Oscillator



Oscillator demonstrates the use of initial conditions.

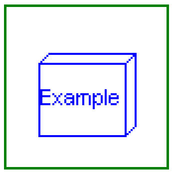
Information

A spring - mass system is a mechanical oscillator. If no damping is included and the system is excited at resonance frequency infinite amplitudes will result. The resonant frequency is given by omega_res = sqrt(c / m) with:

```
c spring stiffness
m mass
```

To make sure that the system is initially at rest the initial conditions s(start=0) and v(start=0) for the SlindingMass are set. If damping is added the amplitudes are bounded.

Modelica.Mechanics.Translational.Examples.Sensors



Sensors for translational systems.

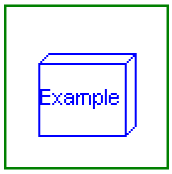
Information

These sensors measure

```
force f in N
position s in m
velocity v in m/s
acceleration a in m/s2
```

Dhe measured velocity and acceleration is independent on the flange the sensor is connected to. The position depends on the flange (flange_a or flange_b) and the length L of the component. Plot PositionSensor1.s, PositionSensor2.s and SlidingMass1.s to see the difference.

Modelica.Mechanics.Translational.Examples.Friction

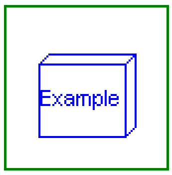


Use of model Stop

Information

1. Simulate and then plot Stop1.f as a function of Stop1.v This gives the Stribeck curve.
2. This model gives an example for a hard stop. However there can arise some problems with the used modeling approach (use of Reinit, convergence problems). In this case use the ElastoGap to model a stop (see example Preload).

Modelica.Mechanics.Translational.Examples.PreLoad

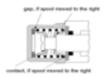


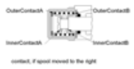
Preload of a spool using ElastoGap models.

Information

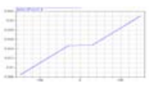
When designing hydraulic valves it is often necessary to hold the spool in a certain position as long as an external force is below a threshold value. If this force exceeds the treshold value a linear relation between force and position is desired. There are designs that need only one spring to accomplish this task. Using the ElastoGap elements this design can be modelled easily. Drawing of spool.

<

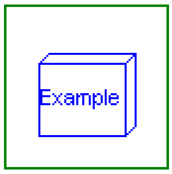




Spool position s as a function of working force f.



Modelica.Mechanics.Translational.Examples.ElastoGap



Demonstrate usgae of ElastoGap

Information

This model demonstrates the effect of ElastoGaps on eigenfrequency:
Plot mass1.s and mass2.s as well as mass1.v and mass2.v

mass1 is moved by both spring forces all the time.
Since elastoGap1 lifts off at s > -0.5 m and elastoGap2 lifts off s < +0.5 m, mass2 moves freely as long as -0.5 m < s < +0.5 m.

Parameters

Type	Name	Default	Description
TranslationalDampingConstant	d	1.5	damping constant [N.s/m]

Modelica.Mechanics.Translational.Components

Components for 1D translational mechanical drive trains

Information

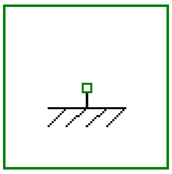
This package contains basic components 1D mechanical translational drive trains.

Package Content

Name	Description
Fixed	Fixed flange
Mass	Sliding mass with inertia
Rod	Rod without inertia

Spring	Linear 1D translational spring
Damper	Linear 1D translational damper
SpringDamper	Linear 1D translational spring and damper in parallel
ElastoGap	1D translational spring damper combination with gap
SupportFriction	Coulomb friction in support
Brake	Brake basend on Coulomb friction
IdealGearR2T	Gearbox transforming rotational into translational motion"
IdealRollingWheel	Simple 1-dim. model of an ideal rolling wheel without inertia
InitializeFlange	Initializes a flange with pre-defined position, speed and acceleration (usually, this is reference data from a control bus)
MassWithStopAndFriction	Sliding mass with hard stop and Stribeck friction
RelativeStates	Definition of relative state variables

Modelica.Mechanics.Translational.Components.Fixed



Fixed flange

Information

The *flange* of a 1D translational mechanical system *fixed* at an position s0 in the *housing*. May be used:

- to connect a compliant element, such as a spring or a damper, between a sliding mass and the housing.
- to fix a rigid element, such as a sliding mass, at a specific position.

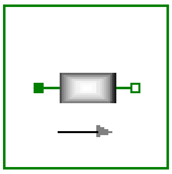
Parameters

Type	Name	Default	Description
Position	s0	0	fixed offset position of housing [m]

Connectors

Type	Name	Description
Flange_b	flange	

Modelica.Mechanics.Translational.Components.Mass



Sliding mass with inertia

Information

Sliding mass with *inertia, without friction* and two rigidly connected flanges.

The sliding mass has the length L, the position coordinate s is in the middle. Sign convention: A positive force at flange flange_a moves the sliding mass in the positive direction. A negative force at flange flange_a moves the sliding mass to the negative direction.

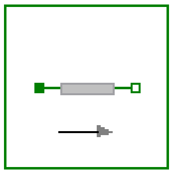
Parameters

Type	Name	Default	Description
Mass	m		mass of the sliding mass [kg]
Length	L	0	Length of component, from left flange to right flange (= flange_b.s - flange_a.s) [m]
Advanced			
StateSelect	stateSelect	StateSelect.default	Priority to use s and v as states

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of translational component
Flange_b	flange_b	Right flange of translational component

Modelica.Mechanics.Translational.Components.Rod



Rod without inertia

Information

Rod *without inertia* and two rigidly connected flanges.

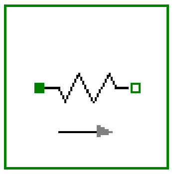
Parameters

Type	Name	Default	Description
Length	L		Length of component, from left flange to right flange (= flange_b.s - flange_a.s) [m]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of translational component
Flange_b	flange_b	Right flange of translational component

Modelica.Mechanics.Translational.Components.Spring



Linear 1D translational spring

Information

A *linear 1D translational spring*. The component can be connected either between two sliding masses, or between a sliding mass and the housing (model Fixed), to describe a coupling of the sliding mass with the housing via a spring.

Parameters

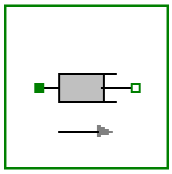
Type	Name	Default	Description
TranslationalSpringConstant	c		spring constant [N/m]
Distance	s_rel0	0	unstretched spring length [m]
Initialization			

Distance	s_rel.start	0	relative distance (= flange_b.s - flange_a.s) [m]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. translational component
Flange_b	flange_b	Right flange of compliant 1-dim. translational component

Modelica.Mechanics.Translational.Components.Damper



Linear 1D translational damper

Information

Linear, velocity dependent damper element. It can be either connected between a sliding mass and the housing (model Fixed), or between two sliding masses.

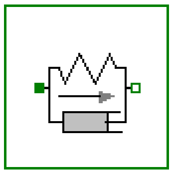
Parameters

Type	Name	Default	Description
TranslationalDampingConstant	d		damping constant [N.s/m]
Initialization			
Distance	s_rel.start	0	Relative distance (= flange_b.s - flange_a.s) [m]
Velocity	v_rel.start	0	Relative velocity (= der(s_rel)) [m/s]
Advanced			
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states
Distance	s_nominal	1e-4	Nominal value of s_rel (used for scaling) [m]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. translational component
Flange_b	flange_b	Right flange of compliant 1-dim. transational component

Modelica.Mechanics.Translational.Components.SpringDamper



Linear 1D translational spring and damper in parallel

Information

A *spring and damper element connected in parallel*. The component can be connected either between two sliding masses to describe the elasticity and damping, or between a sliding mass and the housing (model Fixed), to describe a coupling of the sliding mass with the housing via a spring/damper.

Parameters

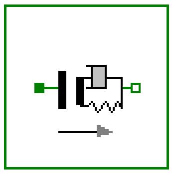
Type	Name	Default	Description
TranslationalSpringConstant	c		spring constant [N/m]
TranslationalDampingConstant	d		damping constant [N.s/m]

Position	s_rel0	0	unstretched spring length [m]
Initialization			
Distance	s_rel.start	0	Relative distance (= flange_b.s - flange_a.s) [m]
Velocity	v_rel.start	0	Relative velocity (= der(s_rel)) [m/s]
Advanced			
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states
Distance	s_nominal	1e-4	Nominal value of s_rel (used for scaling) [m]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. translational component
Flange_b	flange_b	Right flange of compliant 1-dim. transational component

Modelica.Mechanics.Translational.Components.ElastoGap



1D translational spring damper combination with gap

Information

A linear spring damper combination that can lift off. The component can be connected between a sliding mass and the housing (model Fixed), to describe the contact of a sliding mass with the housing.

As long as s_rel > s_rel0, no force is exerted (s_rel = flange_b.s - flange_a.s). If s_rel ≤ s_rel0, the contact force is basically computed with a linear spring/damper characteristic:

desiredContactForce = c*(s_rel - s_rel0) + d***der**(s_rel)

This force law leads to the following difficulties:

1. If the damper force becomes larger as the spring force and with opposite sign, the contact force would be "pulling/sticking" which is unphysical, since during contact only pushing forces can occur.
2. When contact occurs with a non-zero relative speed (which is the usual situation), the damping force has a non-zero value and therefore the contact force changes discontinuously at s_rel = s_rel0. Again, this is not physical because the force can only change continuously. (Note, this component is not an idealized model where a steep characteristic is approximated by a discontinuity, but it shall model the steep characteristic.)

In the literature there are several proposals to fix problem (2). However, there seems to be no proposal to avoid sticking. For this reason, the most simple approach is used in the ElastoGap model, to fix both problems by slight changes to the linear spring/damper characteristic:

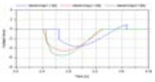
```
if s_rel > s_rel0 then
   f_c = 0;          // spring force
   f_d = 0;          // damper force
   flange_b.f = 0;
else
   f_c = c*(s_rel - s_rel0);     // spring force
   f_d = d*der(s_rel);           // damper force
   flange_b.f = if f_c + f_d ≥ 0 then 0 else f_c + max( f_c, f_d );
end if;
```

Note, when sticking would occur (f_c + f_d ≥ 0), then the contact force is explicitly set to zero. The "max(f_c, f_d)" part in the if-expression, limits the damping force when it is pushing. This means that at the start of the contact (s_rel = s_rel0), the damping force is zero and is continuous. The effect of both modifications is that the absolute value of the damping force is always limited by the absolute value of the spring force: |f_d| ≤ |

f_c|.

In the next figure, a typical simulation with the ElastoGap model is shown (Examples.ElastoGap) where the different effects are visualized:

1. Curve 1 (elastoGap1.f) is the unmodified contact force, i.e., the linear spring/damper characteristic. A pulling/sticking force is present at the end of the contact.
2. Curve 2 (elastoGap2.f) is the contact force, where the force is explicitly set to zero when pulling/sticking occurs. The contact force is discontinuous at being of the contact.
3. Curve 3 (elastoGap3.f) is the ElastoGap model of this library. No discontinuity and no pulling/sticking occurs.



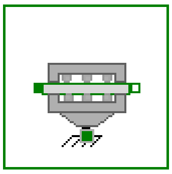
Parameters

Type	Name	Default	Description
TranslationalSpringConstant	c		Spring constant [N/m]
TranslationalDampingConstant	d		Damping constant [N.s/m]
Position	s_rel0	0	Unstretched spring length [m]
Initialization			
Distance	s_rel.start	0	Relative distance (= flange_b.s - flange_a.s) [m]
Velocity	v_rel.start	0	Relative velocity (= der(s_rel)) [m/s]
Advanced			
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states
Distance	s_nominal	1e-4	Nominal value of s_rel (used for scaling) [m]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. translational component
Flange_b	flange_b	Right flange of compliant 1-dim. transational component

Modelica.Mechanics.Translational.Components.SupportFriction



Coulomb friction in support

Information

This element describes **Coulomb friction** in **support**, i.e., a frictional force acting between a flange and the housing. The positive sliding friction force "f" has to be defined by table "f_pos" as function of the absolute velocity "v". E.g.

```
  v |   f
 ---+-----
  0 |   0
  1 |   2
  2 |   5
  3 |   8
```

gives the following table:

```
f_pos = [0, 0; 1, 2; 2, 5; 3, 8];
```

Currently, only linear interpolation in the table is supported. Outside of the table, extrapolation through the last two table entries is used. It is assumed that the negative sliding friction force has the same characteristic with negative values. Friction is modelled in the following way:

When the absolute velocity "v" is not zero, the friction force is a function of v and of a constant normal force. This dependency is defined via table f_pos and can be determined by measurements, e.g. by driving the gear with constant velocity and measuring the needed driving force (= friction force).

When the absolute velocity becomes zero, the elements connected by the friction element become stuck, i.e., the absolute position remains constant. In this phase the friction force is calculated from a force balance due to the requirement, that the absolute acceleration shall be zero. The elements begin to slide when the friction force exceeds a threshold value, called the maximum static friction force, computed via:

```
maximum_static_friction = peak * sliding_friction(v=0)   (peak >= 1)
```

This procedure is implemented in a "clean" way by state events and leads to continuous/discrete systems of equations if friction elements are dynamically coupled which have to be solved by appropriate numerical methods. The method is described in:

Otter M., Elmqvist H., and Mattsson S.E. (1999):
Hybrid Modeling in Modelica based on the Synchronous Data Flow Principle. CACSD'99, Aug. 22.-26, Hawaii.

More precise friction models take into account the elasticity of the material when the two elements are "stuck", as well as other effects, like hysteresis. This has the advantage that the friction element can be completely described by a differential equation without events. The drawback is that the system becomes stiff (about 10-20 times slower simulation) and that more material constants have to be supplied which requires more sophisticated identification. For more details, see the following references, especially (Armstrong and Canudas de Witt 1996):

Armstrong B. (1991):
Control of Machines with Friction. Kluwer Academic Press, Boston MA.

Armstrong B., and Canudas de Wit C. (1996):
Friction Modeling and Compensation. The Control Handbook, edited by W.S.Levine, CRC Press, pp. 1369-1382.

Canudas de Wit C., Olsson H., Astroem K.J., and Lischinsky P. (1995):
A new model for control of systems with friction. IEEE Transactions on Automatic Control, Vol. 40, No. 3, pp. 419-425.

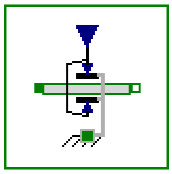
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Real	f_pos[:, 2]	[0, 1]	[v, f] Positive sliding friction characteristic (v>=0)
Real	peak	1	peak*f_pos[1,2] = Maximum friction force for v==0
Initialization			
Boolean	startForward.start	**false**	true, if v_rel=0 and start of forward sliding
Boolean	startBackward.start	**false**	true, if v_rel=0 and start of backward sliding
Boolean	locked.start	false	true, if v_rel=0 and not sliding
Advanced			
Velocity	v_small	1e-3	Relative velocity near to zero (see model info text) [m/s]

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Components.Brake



Brake basend on Coulomb friction

Information

This component models a **brake**, i.e., a component where a frictional force is acting between the housing and a flange and a controlled normal force presses the flange to the housing in order to increase friction. The normal force fn has to be provided as input signal f_normalized in a normalized form (0 ≤ f_normalized ≤ 1), fn = fn_max*f_normalized, where fn_max has to be provided as parameter. Friction in the brake is modelled in the following way:

When the absolute velocity "v" is not zero, the friction force is a function of the velocity dependent friction coefficient mue(v) , of the normal force "fn", and of a geometry constant "cgeo" which takes into account the geometry of the device and the assumptions on the friction distributions:

```
frictional_force = cgeo * mue(v) * fn
```

Typical values of coefficients of friction:

```
dry operation    :  mue = 0.2 .. 0.4
operating in oil:  mue = 0.05 .. 0.1
```

The positive part of the friction characteristic **mue**(v), v >= 0, is defined via table mue_pos (first column = v, second column = mue). Currently, only linear interpolation in the table is supported.

When the absolute velocity becomes zero, the elements connected by the friction element become stuck, i.e., the absolute position remains constant. In this phase the friction force is calculated from a force balance due to the requirement, that the absolute acceleration shall be zero. The elements begin to slide when the friction force exceeds a threshold value, called the maximum static friction force, computed via:

```
frictional_force = peak * cgeo * mue(w=0) * fn   (peak >= 1)
```

This procedure is implemented in a "clean" way by state events and leads to continuous/discrete systems of equations if friction elements are dynamically coupled. The method is described in:

Otter M., Elmqvist H., and Mattsson S.E. (1999):
Hybrid Modeling in Modelica based on the Synchronous Data Flow Principle. CACSD'99, Aug. 22.-26, Hawaii.

More precise friction models take into account the elasticity of the material when the two elements are "stuck", as well as other effects, like hysteresis. This has the advantage that the friction element can be completely described by a differential equation without events. The drawback is that the system becomes stiff (about 10-20 times slower simulation) and that more material constants have to be supplied which requires more sophisticated identification. For more details, see the following references, especially (Armstrong and Canudas de Witt 1996):

Armstrong B. (1991):
Control of Machines with Friction. Kluwer Academic Press, Boston MA.

Armstrong B., and Canudas de Wit C. (1996):

Friction Modeling and Compensation. The Control Handbook, edited by W.S.Levine, CRC Press, pp. 1369-1382.

Canudas de Wit C., Olsson H., Astroem K.J., and Lischinsky P. (1995):
A new model for control of systems with friction. IEEE Transactions on Automatic Control, Vol. 40, No. 3, pp. 419-425.

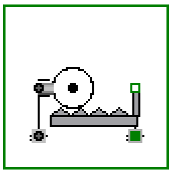
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Real	mue_pos[:, 2]	[0, 0.5]	[v, f] Positive sliding friction characteristic (v>=0)
Real	peak	1	peak*mue_pos[1,2] = Maximum friction force for v==0
Real	cgeo	1	Geometry constant containing friction distribution assumption
Force	fn_max		Maximum normal force [N]
Initialization			
Boolean	startForward.start	**false**	true, if v_rel=0 and start of forward sliding
Boolean	startBackward.start	**false**	true, if v_rel=0 and start of backward sliding
Boolean	locked.start	false	true, if v_rel=0 and not sliding
Advanced			
Velocity	v_small	1e-3	Relative velocity near to zero (see model info text) [m/s]

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component
input RealInput	f_normalized	Normalized force signal 0..1 (normal force = fn_max*f_normalized; brake is active if > 0)

Modelica.Mechanics.Translational.Components.IdealGearR2T



Gearbox transforming rotational into translational motion"

Parameters

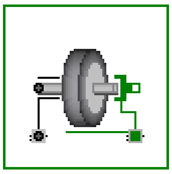
Type	Name	Default	Description
Boolean	useSupportR	false	= true, if rotational support flange enabled, otherwise implicitly grounded
Boolean	useSupportT	false	= true, if translational support flange enabled, otherwise implicitly grounded
Real	ratio		Transmission ratio (flange_a.phi/flange_b.s) [rad/m]

Connectors

Type	Name	Description
Flange_a	flangeR	Flange of rotational shaft
Flange_b	flangeT	Flange of translational rod

Support	supportR	Rotational support/housing of component
Support	supportT	Translational support/housing of component

Modelica.Mechanics.Translational.Components.IdealRollingWheel



Simple 1-dim. model of an ideal rolling wheel without inertia

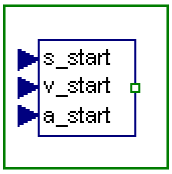
Parameters

Type	Name	Default	Description
Boolean	useSupportR	false	= true, if rotational support flange enabled, otherwise implicitly grounded
Boolean	useSupportT	false	= true, if translational support flange enabled, otherwise implicitly grounded
Distance	radius		Wheel radius [m]

Connectors

Type	Name	Description
Flange_a	flangeR	Flange of rotational shaft
Flange_b	flangeT	Flange of translational rod
Support	supportR	Rotational support/housing of component
Support	supportT	Translational support/housing of component

Modelica.Mechanics.Translational.Components.InitializeFlange



Initializes a flange with pre-defined position, speed and acceleration (usually, this is reference data from a control bus)

Information

This component is used to optionally initialize the position, speed, and/or acceleration of the flange to which this component is connected. Via parameters use_s_start, use_v_start, use_a_start the corresponding input signals s_start, v_start, a_start are conditionally activated. If an input is activated, the corresponding flange property is initialized with the input value at start time.

For example, if "use_s_start = true", then flange.s is initialized with the value of the input signal "s_start" at the start time.

Additionally, it is optionally possible to define the "StateSelect" attribute of the flange position and the flange speed via paramater "stateSelection".

This component is especially useful when the initial values of a flange shall be set according to reference signals of a controller that are provided via a signal bus.

Parameters

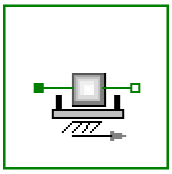
Type	Name	Default	Description
Boolean	use_s_start	true	= true, if initial position is defined by input s_start, otherwise not initialized
Boolean	use_v_start	true	= true, if initial speed is defined by input v_start, otherwise not initialized

Boolean	use_a_start	true	= true, if initial acceleration is defined by input a_start, otherwise not initialized
StateSelect	stateSelect	StateSelect.default	Priority to use flange angle and speed as states

Connectors

Type	Name	Description
input RealInput	s_start	Initial position of flange
input RealInput	v_start	Initial speed of flange
input RealInput	a_start	Initial angular acceleration of flange
Flange_b	flange	Flange that is initialized

Modelica.Mechanics.Translational.Components.MassWithStopAndFriction

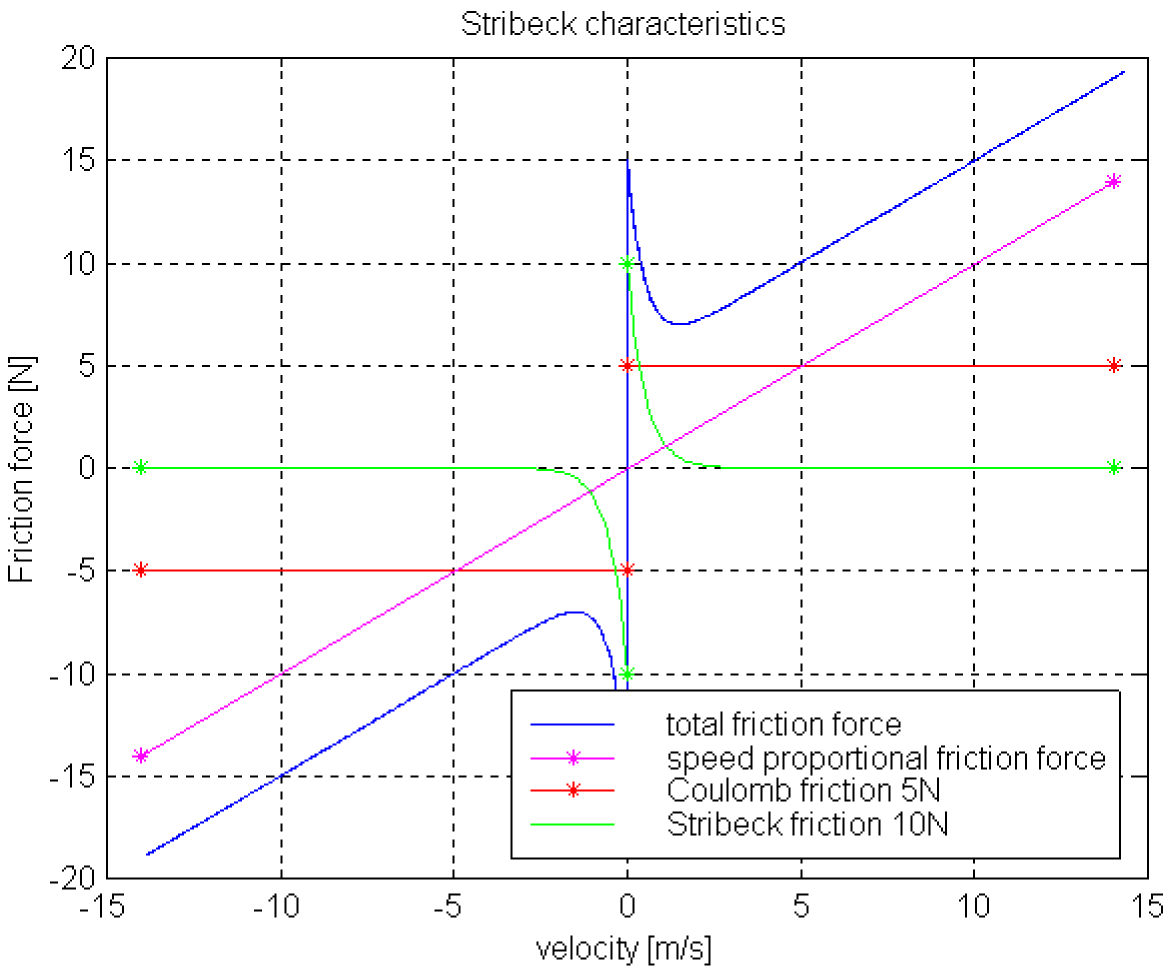


Sliding mass with hard stop and Stribeck friction

Information

This element describes the *Stribeck friction characteristics* of a sliding mass, i. e. the frictional force acting between the sliding mass and the support. Included is a *hard stop* for the position.
The surface is fixed and there is friction between sliding mass and surface. The frictional force f is given for positive velocity v by:

*f = F_Coulomb + F_prop * v + F_Stribeck * exp (-fexp * v)*



The distance between the left and the right connector is given by parameter L. The position of the center of gravity, coordinate s, is in the middle between the two flanges.

There are hard stops at smax and smin, i. e. if

> *flange_a.s >= smin*
> *and*
> *flange_b.s <= xmax*

the sliding mass can move freely.

When the absolute velocity becomes zero, the sliding mass becomes stuck, i.e., the absolute position remains constant. In this phase the friction force is calculated from a force balance due to the requirement that the absolute acceleration shall be zero. The elements begin to slide when the friction force exceeds a threshold value, called the maximum static friction force, computed via:

> *maximum_static_friction = F_Coulomb + F_Stribeck*

This requires the states Stop.s and Stop.v . If these states are eliminated during the index reduction the model will not work. To avoid this any inertias should be connected via springs to the Stop element, other sliding masses, dampers or hydraulic chambers must be avoided.

For more details of the used friction model see the following reference:

Beater P. (1999):

Entwurf hydraulischer Maschinen. Springer Verlag Berlin Heidelberg New York.

The friction model is implemented in a "clean" way by state events and leads to continuous/discrete systems of equations which have to be solved by appropriate numerical methods. The method is described in:

Otter M., Elmqvist H., and Mattsson S.E. (1999):

Hybrid Modeling in Modelica based on the Synchronous Data Flow Principle. CACSD'99, Aug. 22.-26, Hawaii.

More precise friction models take into account the elasticity of the material when the two elements are "stuck", as well as other effects, like hysteresis. This has the advantage that the friction element can be completely described by a differential equation without events. The drawback is that the system becomes stiff (about 10-20 times slower simulation) and that more material constants have to be supplied which requires more sophisticated identification. For more details, see the following references, especially (Armstrong and Canudas de Witt 1996):

Armstrong B. (1991):
Control of Machines with Friction. Kluwer Academic Press, Boston MA.
Armstrong B., and Canudas de Wit C. (1996):
Friction Modeling and Compensation. The Control Handbook, edited by W.S.Levine, CRC Press, pp. 1369-1382.
Canudas de Wit C., Olsson H., Astroem K.J., and Lischinsky P. (1995):
A *new model for control of systems with friction.* IEEE Transactions on Automatic Control, Vol. 40, No. 3, pp. 419-425.

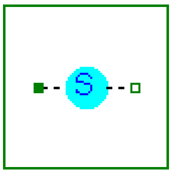
Parameters

Type	Name	Default	Description
Position	smax		Right stop for (right end of) sliding mass [m]
Position	smin		Left stop for (left end of) sliding mass [m]
Length	L		Length of component, from left flange to right flange (= flange_b.s - flange_a.s) [m]
Mass	m		mass [kg]
Real	F_prop		Velocity dependent friction [N.s/m]
Force	F_Coulomb		Constant friction: Coulomb force [N]
Force	F_Stribeck		Stribeck effect [N]
Real	fexp		Exponential decay [s/m]
Initialization			
Boolean	startForward.start	**false**	= true, if v_rel=0 and start of forward sliding or v_rel > v_small
Boolean	startBackward.start	**false**	= true, if v_rel=0 and start of backward sliding or v_rel < -v_small
Boolean	locked.start	false	true, if v_rel=0 and not sliding
Position	s.start	0	Absolute position of center of component (s = flange_a.s + L/2 = flange_b.s - L/2) [m]
Advanced			
Velocity	v_small	1e-3	Relative velocity near to zero (see model info text) [m/s]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of translational component
Flange_b	flange_b	Right flange of translational component

Modelica.Mechanics.Translational.Components.RelativeStates



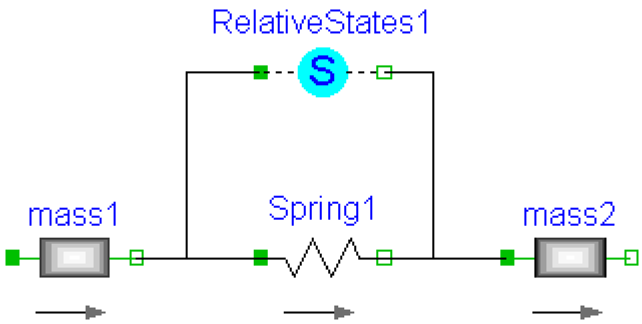
Definition of relative state variables

Information

Usually, the absolute position and the absolute velocity of Modelica.Mechanics.Translational.Inertia models are used as state variables. In some circumstances, relative quantities are better suited, e.g., because it may be easier to supply initial values. In such cases, model **RelativeStates** allows the definition of state variables in the following way:

- Connect an instance of this model between two flange connectors.
- The **relative position** and the **relative velocity** between the two connectors are used as **state variables**.

An example is given in the next figure



Here, the relative position and the relative velocity between the two masses are used as state variables. Additionally, the simulator selects either the absolute position and absolute velocity of model mass1 or of model mass2 as state variables.

Parameters

Type	Name	Default	Description
StateSelect	stateSelect	StateSelect.prefer	Priority to use the relative angle and relative speed as states

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)

Modelica.Mechanics.Translational.Sources

Sources to drive 1D translational mechanical components

Information

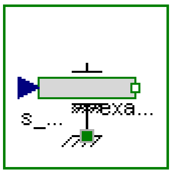
This package contains ideal sources to drive 1D mechanical translational drive trains.

Package Content

Name	Description

Position	Forced movement of a flange according to a reference position
Speed	Forced movement of a flange according to a reference speed
Accelerate	Forced movement of a flange according to an acceleration signal
Move	Forced movement of a flange according to a position, velocity and acceleration signal
Force	External force acting on a drive train element as input signal
Force2	Input signal acting as torque on two flanges
LinearSpeedDependentForce	Linear dependency of force versus speed
QuadraticSpeedDependentForce	Quadratic dependency of force versus speed
ConstantForce	Constant force, not dependent on speed
ConstantSpeed	Constant speed, not dependent on force
ForceStep	Constant force, not dependent on speed

Modelica.Mechanics.Translational.Sources.Position



Forced movement of a flange according to a reference position

Information

The input signal **s_ref** defines the **reference position** in [m]. Flange **flange_b** is **forced** to move relative to the support connector according to this reference motion. According to parameter **exact** (default = **false**), this is done in the following way:

1. **exact=true**
   The reference position is treated **exactly.** This is only possible, if the input signal is defined by an analytical function which can be differentiated at least twice. If this prerequisite is fulfilled, the Modelica translator will differentiate the input signal twice in order to compute the reference acceleration of the flange.
2. **exact=false**
   The reference position is **filtered** and the second derivative of the filtered curve is used to compute the reference acceleration of the flange. This second derivative is **not** computed by numerical differentiation but by an appropriate realization of the filter. For filtering, a second order Bessel filter is used. The critical frequency (also called cut-off frequency) of the filter is defined via parameter **f_crit** in [Hz]. This value should be selected in such a way that it is higher as the essential low frequencies in the signal.

The input signal can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Sources.

Parameters

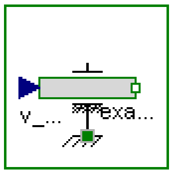
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Boolean	exact	false	true/false exact treatment/filtering the input signal
Frequency	f_crit	50	if exact=false, critical frequency of filter to filter input signal [Hz]

Connectors

Type	Name	Description

Flange_b	flange	Flange of component
Support	support	Support/housing of component
input RealInput	s_ref	reference position of flange as input signal

Modelica.Mechanics.Translational.Sources.Speed



Forced movement of a flange according to a reference speed

Information

The input signal **v_ref** defines the **reference speed** in [m/s]. Flange **flange_b** is **forced** to move relative to the support connector according to this reference motion. According to parameter **exact** (default = **false**), this is done in the following way:

1. **exact=true**
   The reference speed is treated **exactly**. This is only possible, if the input signal is defined by an analytical function which can be differentiated at least once. If this prerequisite is fulfilled, the Modelica translator will differentiate the input signal once in order to compute the reference acceleration of the flange.
2. **exact=false**
   The reference speed is **filtered** and the first derivative of the filtered curve is used to compute the reference acceleration of the flange. This first derivative is **not** computed by numerical differentiation but by an appropriate realization of the filter. For filtering, a first order filter is used. The critical frequency (also called cut-off frequency) of the filter is defined via parameter **f_crit** in [Hz]. This value should be selected in such a way that it is higher as the essential low frequencies in the signal.

The input signal can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Sources.

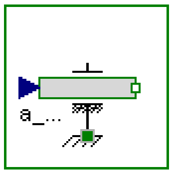
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Boolean	exact	false	true/false exact treatment/filtering the input signal
Frequency	f_crit	50	if exact=false, critical frequency of filter to filter input signal [Hz]

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component
input RealInput	v_ref	reference speed of flange as input signal

Modelica.Mechanics.Translational.Sources.Accelerate



Forced movement of a flange according to an acceleration signal

Information

The input signal **a** in [m/s2] moves the 1D translational flange connector flange_b with a predefined *acceleration*, i.e., the flange is *forced* to move relative to the support connector with this acceleration. The velocity and the position of the flange are also predefined and are determined by integration of the acceleration.

The acceleration "a(t)" can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Source.

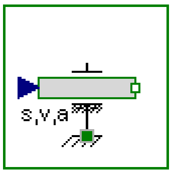
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component
input RealInput	a_ref	absolute acceleration of flange as input signal

Modelica.Mechanics.Translational.Sources.Move



Forced movement of a flange according to a position, velocity and acceleration signal

Information

Flange **flange_b** is **forced** to move relative to the support connector with a predefined motion according to the input signals:

```
u[1]: position of flange
u[2]: velocity of flange
u[3]: acceleration of flange
```

The user has to guarantee that the input signals are consistent to each other, i.e., that u[2] is the derivative of u[1] and that u[3] is the derivative of u. There are, however, also applications where by purpose these conditions do not hold. For example, if only the position dependent terms of a mechanical system shall be calculated, one may provide position = position(t) and set the velocity and the acceleration to zero.

The input signals can be provided from one of the signal generator blocks of the block library Modelica.Blocks.Sources.

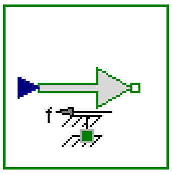
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component
input RealInput	u[3]	position, velocity and acceleration of flange as input signals

Modelica.Mechanics.Translational.Sources.Force



External force acting on a drive train element as input signal

Information

The input signal "f" in [N] characterizes an *external force* which acts (with positive sign) at a flange, i.e., the component connected to the flange is driven by force f.

Input signal f can be provided from one of the signal generator blocks of Modelica.Blocks.Source.

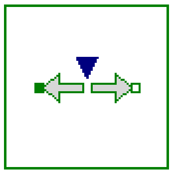
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component
input RealInput	f	driving force as input signal

Modelica.Mechanics.Translational.Sources.Force2



Input signal acting as torque on two flanges

Information

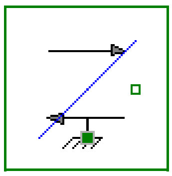
The input signal "f" in [N] characterizes an *external force* which acts (with positive sign) at both flanges, i.e., the components connected to these flanges are driven by force f.

Input signal s can be provided from one of the signal generator blocks of Modelica.Blocks.Source.

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)
input RealInput	f	driving force as input signal

Modelica.Mechanics.Translational.Sources.LinearSpeedDependentForce



Linear dependency of force versus speed

Information

Model of force, linearly dependent on velocity of flange.
Parameter ForceDirection chooses whether direction of force is the same in both directions of movement or not.

Parameters

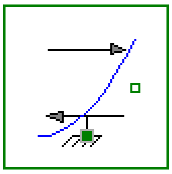
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Force	f_nominal		Nominal force (if negative, force is acting as load) [N]

Boolean	ForceDirection	true	Same direction of force in both directions of movement
Velocity	v_nominal		Nominal speed [m/s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Sources.QuadraticSpeedDependentForce



Quadratic dependency of force versus speed

Information

Model of force, quadratic dependent on velocity of flange.
Parameter ForceDirection chooses whether direction of force is the same in both directions of movement or not.

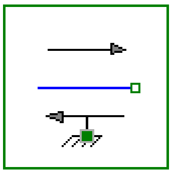
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Force	f_nominal		Nominal force (if negative, force is acting as load) [N]
Boolean	ForceDirection	true	Same direction of force in both directions of movement
Velocity	v_nominal		Nominal speed [m/s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Sources.ConstantForce



Constant force, not dependent on speed

Information

Model of constant force, not dependent on velocity of flange.
Positive force acts accelerating.

Parameters

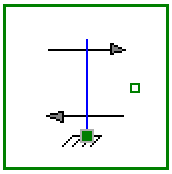
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Force	f_constant		Nominal force (if negative, force is acting as load) [N]

Connectors

Type	Name	Description

Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Sources.ConstantSpeed



Constant speed, not dependent on force

Information

Model of **fixed** verlocity of flange, not dependent on force.

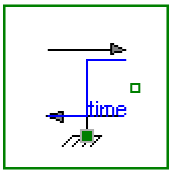
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Velocity	v_fixed		Fixed speed (if negative, force is acting as load) [m/s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Sources.ForceStep



Constant force, not dependent on speed

Information

Model of a force step at time .
Positive force acts accelerating.

Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded
Force	stepForce		Height of force step (if negative, force is acting as load) [N]
Force	offsetForce		Offset of force [N]
Time	startTime	0	Force = offset for time < startTime [s]

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Sensors

Sensors for 1-dim. translational mechanical quantities

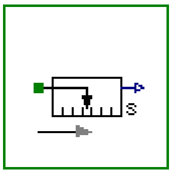
Information

This package contains ideal sensor components that provide the connector variables as signals for further processing with the Modelica.Blocks library.

Package Content

Name	Description
PositionSensor	Ideal sensor to measure the absolute position
SpeedSensor	Ideal sensor to measure the absolute velocity
AccSensor	Ideal sensor to measure the absolute acceleration
RelPositionSensor	Ideal sensor to measure the relative position
RelSpeedSensor	Ideal sensor to measure the relative speed
RelAccSensor	Ideal sensor to measure the relative acceleration
ForceSensor	Ideal sensor to measure the force between two flanges
PowerSensor	Ideal sensor to measure the power between two flanges (= flange_a.f*der(flange_a.s))

Modelica.Mechanics.Translational.Sensors.PositionSensor



Ideal sensor to measure the absolute position

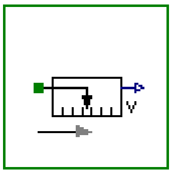
Information

Measures the *absolute position s* of a flange in an ideal way and provides the result as output signals (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange	flange to be measured (flange axis directed in to cut plane, e. g. from left to right)
output RealOutput	s	Absolute position of flange

Modelica.Mechanics.Translational.Sensors.SpeedSensor



Ideal sensor to measure the absolute velocity

Information

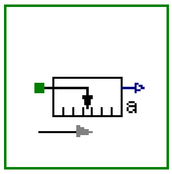
Measures the *absolute velocity v* of a flange in an ideal way and provides the result as output signals (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange	flange to be measured (flange axis directed in to cut plane, e. g. from left to right)
output RealOutput	v	Absolute velocity of flange as output signal

---

Modelica.Mechanics.Translational.Sensors.AccSensor



Ideal sensor to measure the absolute acceleration

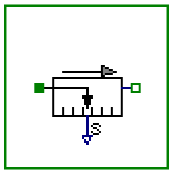
Information

Measures the *absolute acceleration a* of a flange in an ideal way and provides the result as output signals (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange	flange to be measured (flange axis directed in to cut plane, e. g. from left to right)
output RealOutput	a	Absolute acceleration of flange as output signal

Modelica.Mechanics.Translational.Sensors.RelPositionSensor



Ideal sensor to measure the relative position

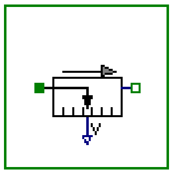
Information

Measures the *relative position s* of a flange in an ideal way and provides the result as output signals (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)
output RealOutput	s_rel	Distance between two flanges (= flange_b.s - flange_a.s)

Modelica.Mechanics.Translational.Sensors.RelSpeedSensor



Ideal sensor to measure the relative speed

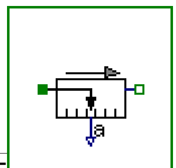
Information

Measures the *relative speed v* of a flange in an ideal way and provides the result as output signals (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)
output RealOutput	v_rel	Relative velocity between two flanges (= der(flange_b.s) - der(flange_a.s))

Modelica.Mechanics.Translational.Sensors.RelAccSensor



Ideal sensor to measure the relative acceleration

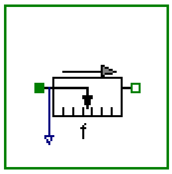
Information

Measures the *relative acceleration a* of a flange in an ideal way and provides the result as output signals (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)
output RealOutput	a_rel	Relative acceleration between two flanges (= der(v_rel))

Modelica.Mechanics.Translational.Sensors.ForceSensor



Ideal sensor to measure the force between two flanges

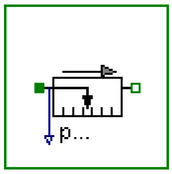
Information

Measures the *cut-force between two flanges* in an ideal way and provides the result as output signal (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)
output RealOutput	f	force in flange_a and flange_b (f = flange_a.f = -flange_b.f)

Modelica.Mechanics.Translational.Sensors.PowerSensor



Ideal sensor to measure the power between two flanges (= flange_a.f*der(flange_a.s))

Information

Measures the **power between two flanges** in an ideal way and provides the result as output signal **power** (to be further processed with blocks of the Modelica.Blocks library).

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)
output RealOutput	power	Power in flange flange_a

Modelica.Mechanics.Translational.Interfaces

Interfaces for 1-dim. translational mechanical components

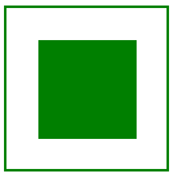
Information

This package contains connectors and partial models for 1-dim. translational mechanical components. The components of this package can only be used as basic building elements for models.

Package Content

Name	Description
Flange_a	(left) 1D translational flange (flange axis directed INTO cut plane, e. g. from left to right)
Flange_b	right 1D translational flange (flange axis directed OUT OF cut plane)
Support	Support/housing 1D translational flange
InternalSupport	Adapter model to utilize conditional support connector
PartialTwoFlanges	Component with two translational 1D flanges
PartialOneFlangeAndSupport	Partial model for a component with one translational 1-dim. shaft flange and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components
PartialTwoFlangesAndSupport	Partial model for a component with two translational 1-dim. shaft flanges and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components
PartialRigid	Rigid connection of two translational 1D flanges
PartialCompliant	Compliant connection of two translational 1D flanges
PartialCompliantWithRelativeStates	Base model for the compliant connection of two translational 1-dim. shaft flanges where the relative position and relative velocities are used as states
PartialElementaryOneFlangeAndSupport	Partial model for a component with one translational 1-dim. shaft flange and a support used for textual modeling, i.e., for elementary models
PartialElementaryTwoFlangesAndSupport	Partial model for a component with one translational 1-dim. shaft flange and a support used for textual modeling, i.e., for elementary models
PartialElementaryRotationalToTranslational	
PartialForce	Partial model of a force acting at the flange (accelerates the flange)
PartialAbsoluteSensor	Device to measure a single absolute flange variable
PartialRelativeSensor	Device to measure a single relative variable between two flanges
PartialFriction	Base model of Coulomb friction elements

Modelica.Mechanics.Translational.Interfaces.Flange_a



(left) 1D translational flange (flange axis directed INTO cut plane, e. g. from left to right)

Information

This is a flange for 1D translational mechanical systems. In the cut plane of the flange a unit vector n, called flange axis, is defined which is directed INTO the cut plane, i. e. from left to right. All vectors in the cut plane are resolved with respect to this unit vector. E.g. force f characterizes a vector which is directed in the direction of n with value equal to f. When this flange is connected to other 1D translational flanges, this means that the axes vectors of the connected flanges are identical.

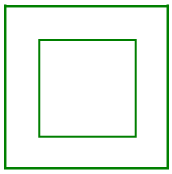
The following variables are transported through this connector:

```
s: Absolute position of the flange in [m]. A positive translation
   means that the flange is translated along the flange axis.
f: Cut-force in direction of the flange axis in [N].
```

Contents

Type	Name	Description
Position	s	absolute position of flange [m]
flow Force	f	cut force directed into flange [N]

Modelica.Mechanics.Translational.Interfaces.Flange_b



right 1D translational flange (flange axis directed OUT OF cut plane)

Information

This is a flange for 1D translational mechanical systems. In the cut plane of the flange a unit vector n, called flange axis, is defined which is directed OUT OF the cut plane. All vectors in the cut plane are resolved with respect to this unit vector. E.g. force f characterizes a vector which is directed in the direction of n with value equal to f. When this flange is connected to other 1D translational flanges, this means that the axes vectors of the connected flanges are identical.

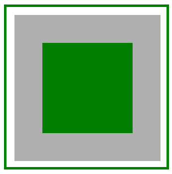
The following variables are transported through this connector:

```
s: Absolute position of the flange in [m]. A positive translation
   means that the flange is translated along the flange axis.
f: Cut-force in direction of the flange axis in [N].
```

Contents

Type	Name	Description
Position	s	absolute position of flange [m]
flow Force	f	cut force directed into flange [N]

Modelica.Mechanics.Translational.Interfaces.Support

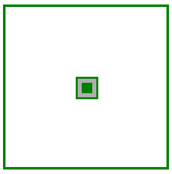


Support/housing 1D translational flange

Contents

Type	Name	Description
Position	s	absolute position of flange [m]
flow Force	f	cut force directed into flange [N]

Modelica.Mechanics.Translational.Interfaces.InternalSupport



Adapter model to utilize conditional support connector

Information

This is an adapter model to utilize a conditional support connector in an elementary component, i.e., where the component equations are defined textually:

- If *useSupport* = *true*, the flange has to be connected to the conditional support connector.
- If *useSupport* = *false*, the flange has to be connected to the conditional fixed model.

Variable **f** is defined as **input** and must be provided when using this component as a modifier (computed via a force balance in the model where InternalSupport is used). Usually, model InternalSupport is utilized via the partial models:

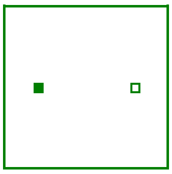
PartialElementaryOneFlangeAndSupport,
PartialElementaryTwoFlangesAndSupport,
PartialElementaryRotationalToTranslational.

Note, the support position can always be accessed as internalSupport.s, and the support force can always be accessed as internalSupport.f.

Connectors

Type	Name	Description
Flange_a	flange	Internal support flange (must be connected to the conditional support connector for useSupport=true and to conditional fixed model for useSupport=false)

Modelica.Mechanics.Translational.Interfaces.PartialTwoFlanges



Component with two translational 1D flanges

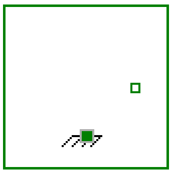
Information

This is a 1D translational component with two flanges. It is used e.g. to built up parts of a drive train consisting of several base components.

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)

Modelica.Mechanics.Translational.Interfaces.PartialOneFlangeAndSupport



Partial model for a component with one translational 1-dim. shaft flange and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components

Information

This is a 1-dim. translational component with one flange and a support/housing. It is used e.g. to build up parts of a drive train graphically consisting of several components.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

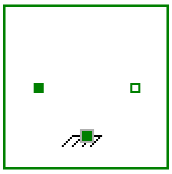
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Interfaces.PartialTwoFlangesAndSupport



Partial model for a component with two translational 1-dim. shaft flanges and a support used for graphical modeling, i.e., the model is build up by drag-and-drop from elementary components

Information

This is a 1-dim. translational component with two flanges and a support/housing. It is used e.g. to build up parts of a drive train graphically consisting of several components.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

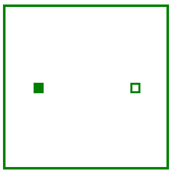
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left end
Flange_b	flange_b	Flange of right end
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Interfaces.PartialRigid



Rigid connection of two translational 1D flanges

Information

This is a 1-dim. translational component with two *rigidly* connected flanges. The fixed distance between the left and the right flange is defined by parameter "L". The forces at the right and left flange can be different. It is used e.g. to built up sliding masses.

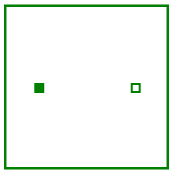
Parameters

Type	Name	Default	Description
Length	L		Length of component, from left flange to right flange (= flange_b.s - flange_a.s) [m]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of translational component
Flange_b	flange_b	Right flange of translational component

Modelica.Mechanics.Translational.Interfaces.PartialCompliant



Compliant connection of two translational 1D flanges

Information

This is a 1D translational component with a *compliant* connection of two translational 1D flanges where inertial effects between the two flanges are not included. The absolute value of the force at the left and the right flange is the same. It is used to built up springs, dampers etc.

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. translational component
Flange_b	flange_b	Right flange of compliant 1-dim. translational component

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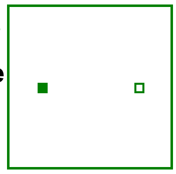
Modelica.Mechanics.Translational.Interfaces.PartialCompliantWithRelativeStates



Base model for the compliant connection of two translational 1-dim. shaft flanges where the relative position and relative velocities are used as states

Information

This is a 1-dim. translational component with a compliant connection of two translational 1-dim. flanges where inertial effects between the two flanges are neglected. The basic assumption is that the cut-forces of the two flanges sum-up to zero, i.e., they have the same absolute value but opposite sign: flange_a.f + flange_b.f = 0. This base class is used to built up force elements such as springs, dampers, friction.

The difference to base classe "PartialCompliant" is that the relative distance and the relative velocity are defined as preferred states. The reason is that for a large class of drive trains, the absolute position is quickly increasing during operation. Numerically, it is better to use relative distances between drive train components because they remain in a limited size. For this reason, StateSelect.prefer is set for the relative distance of this component.

In order to improve the numerics, a nominal value for the relative distance should be set, since drive train distances are in a small order and then step size control of the integrator is practically switched off for such a variable. A default nominal value of s_nominal = 1e-4 is defined. This nominal value might also be computed from other values, such as "s_nominal = f_nominal / c" for a spring, if f_nominal and c have more meaningful values for the user.

Parameters

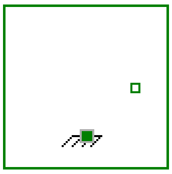
Type	Name	Default	Description

Advanced			
StateSelect	stateSelect	StateSelect.prefer	Priority to use phi_rel and w_rel as states
Distance	s_nominal	1e-4	Nominal value of s_rel (used for scaling) [m]

Connectors

Type	Name	Description
Flange_a	flange_a	Left flange of compliant 1-dim. translational component
Flange_b	flange_b	Right flange of compliant 1-dim. transational component

Modelica.Mechanics.Translational.Interfaces.PartialElementaryOneFlangeAndSupport



Partial model for a component with one translational 1-dim. shaft flange and a support used for textual modeling, i.e., for elementary models

Information

This is a 1-dim. translational component with one flange and a support/housing. It is used to build up elementary components of a drive train with equations in the text layer.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

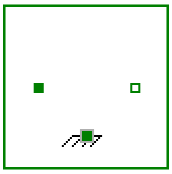
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Interfaces.PartialElementaryTwoFlangesAndSupport



Partial model for a component with one translational 1-dim. shaft flange and a support used for textual modeling, i.e., for elementary models

Information

This is a 1-dim. translational component with two flanges and an additional support. It is used e.g. to build up elementary ideal gear components. The component contains the force balance, i.e., the sum of the forces of the connectors is zero (therefore, components that are based on PartialGear cannot have a mass). The support connector needs to be connected to avoid the unphysical behavior that the support force is required to be zero (= the default value, if the connector is not connected).

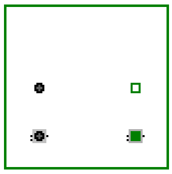
Parameters

Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_a	flange_a	Flange of left shaft
Flange_b	flange_b	Flange of right shaft
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Interfaces.PartialElementaryRotationalToTranslational



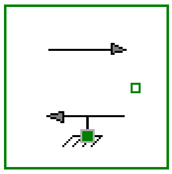
Parameters

Type	Name	Default	Description
Boolean	useSupportR	false	= true, if rotational support flange enabled, otherwise implicitly grounded
Boolean	useSupportT	false	= true, if translational support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description
Flange_a	flangeR	Flange of rotational shaft
Flange_b	flangeT	Flange of translational rod
Support	supportR	Rotational support/housing of component
Support	supportT	Translational support/housing of component

Modelica.Mechanics.Translational.Interfaces.PartialForce



Partial model of a force acting at the flange (accelerates the flange)

Information

Partial model of force that accelerates the flange.

If *useSupport=true*, the support connector is conditionally enabled and needs to be connected.
If *useSupport=false*, the support connector is conditionally disabled and instead the component is internally fixed to ground.

Parameters

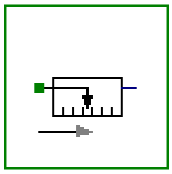
Type	Name	Default	Description
Boolean	useSupport	false	= true, if support flange enabled, otherwise implicitly grounded

Connectors

Type	Name	Description

Flange_b	flange	Flange of component
Support	support	Support/housing of component

Modelica.Mechanics.Translational.Interfaces.PartialAbsoluteSensor



Device to measure a single absolute flange variable

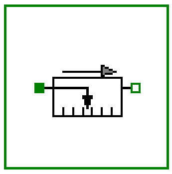
Information

This is the superclass of a 1D translational component with one flange and one output signal in order to measure an absolute kinematic quantity in the flange and to provide the measured signal as output signal for further processing with the Modelica.Blocks blocks.

Connectors

Type	Name	Description
Flange_a	flange	flange to be measured (flange axis directed in to cut plane, e. g. from left to right)

Modelica.Mechanics.Translational.Interfaces.PartialRelativeSensor



Device to measure a single relative variable between two flanges

Information

This is a superclass for 1D translational components with two rigidly connected flanges and one output signal in order to measure relative kinematic quantities between the two flanges or the cut-force in the flange and to provide the measured signal as output signal for further processing with the Modelica.Blocks blocks.

Connectors

Type	Name	Description
Flange_a	flange_a	(left) driving flange (flange axis directed in to cut plane, e. g. from left to right)
Flange_b	flange_b	(right) driven flange (flange axis directed out of cut plane)

Modelica.Mechanics.Translational.Interfaces.PartialFriction

Base model of Coulomb friction elements

Information

Basic model for Coulomb friction that models the stuck phase in a reliable way.

Parameters

Type	Name	Default	Description
Advanced			
Velocity	v_small	1e-3	Relative velocity near to zero (see model info text) [m/s]