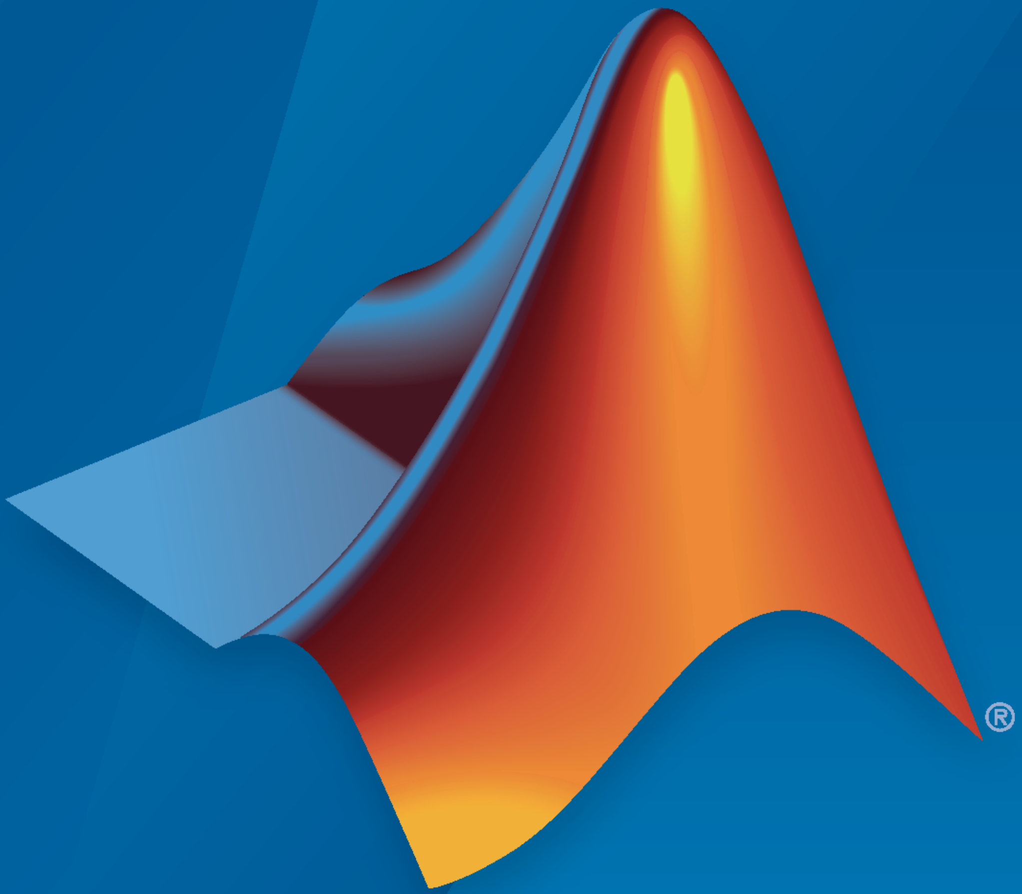
Vehicle Dynamics Blockset™

Reference



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Vehicle Dynamics Blockset™ Reference

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Revision History

March 2018	Online only	New for Version 1.0 (Release 2018a)
September 2018	Online only	Revised for Version 1.1 (Release 2018b)
March 2019	Online only	Revised for Version 1.2 (Release 2019a)
September 2019	Online only	Revised for Version 1.3 (Release 2019b)
March 2020	Online only	Revised for Version 1.4 (Release 2020a)
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March 2021	Online only	Revised for Version 1.6 (Release 2021a)
September 2021	Online only	Revised for Version 1.7 (Release 2021b)
March 2022	Online only	Revised for Version 1.8 (Release 2022a)
September 2022	Online only	Revised for Version 1.9 (Release 2022b)

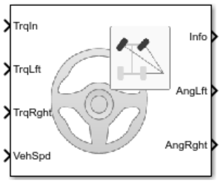
1

Steering and Suspension Blocks

Dynamic Steering

Dynamic steering for Ackerman, rack-and-pinion, and parallel steering mechanisms

Library: Vehicle Dynamics Blockset / Steering



Description

The Dynamic Steering block implements dynamic steering to calculate the wheel angles for Ackerman, rack-and-pinion, and parallel steering mechanisms. The block uses the steering wheel input torque, right wheel torque, and left wheel torque to calculate the wheel angles. The block uses the vehicle coordinate system.

If you select **Power assist**, you can specify a torque assist lookup table that is a function of the vehicle speed and steering wheel input torque. The block uses the steering wheel input torque and torque assist to calculate the steering dynamics.

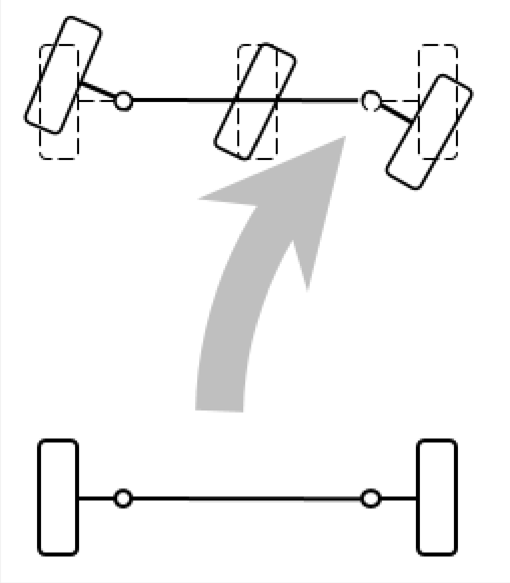
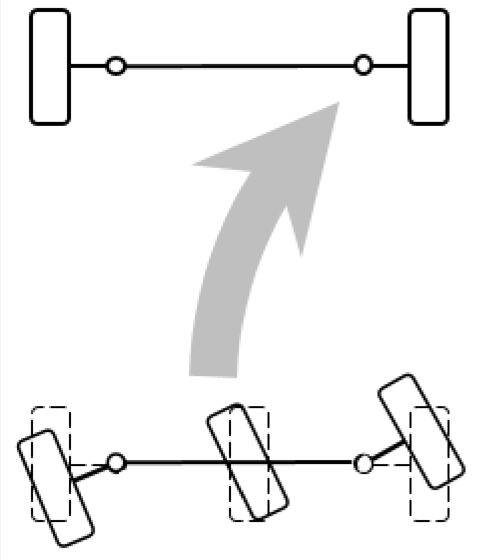
To specify the steering type, use the **Type** parameter.

Setting	Block Implementation
`Ackerman`	Ideal Ackerman steering. Wheel angles have a common turning circle center.
`Rack and pinion`	Ideal rack-and-pinion steering. Gears convert the steering rotation into linear motion.
`Parallel`	Parallel steering. Wheel angles are equal.

To specify the type of data for the steering mechanism, use the **Parametrized by** parameter.

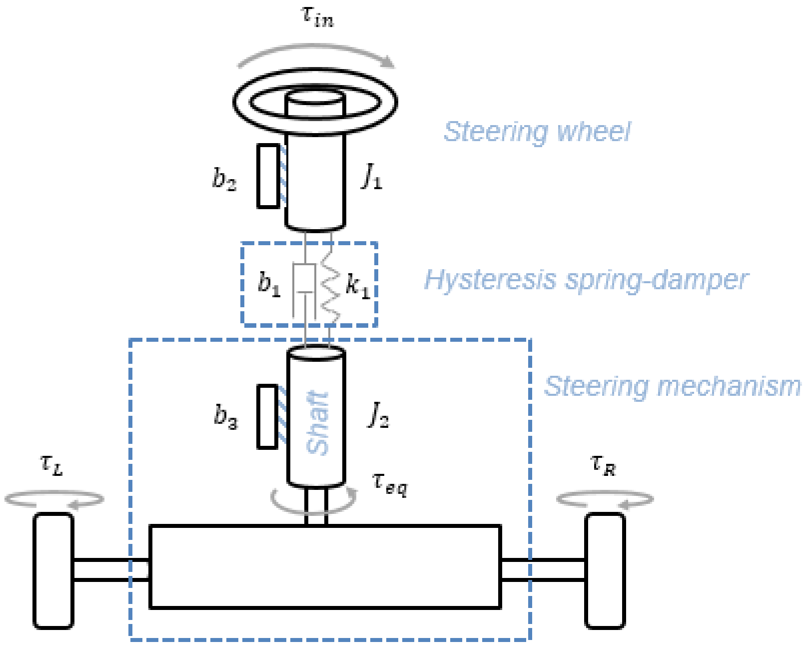
Setting	Block Implementation
`Constant`	Steering mechanism uses constant parameter data.
`Lookup table`	Steering mechanism implements tables for parameter data.

Use the **Location** parameter to specify front or rear steering.

Setting	Implementation
Front	Front steering 
Rear	Rear steering 

Dynamics

To calculate the steering dynamics, the Dynamic Steering block models the steering wheel, shaft, steering mechanism, hysteresis, and, optionally, power assist.



Calculation	Equations
Steering column and steering shaft dynamics	$J_1\ddot{\theta}_1 = \tau_{in} - b_2\dot{\theta}_1 - \tau_{hys}$ $J_2\ddot{\theta}_2 = \tau_{eq} - b_3\dot{\theta}_2 + \tau_{hys} - \tau_{fric}$
Hysteresis spring damper	$\delta = \theta_1 - \theta_2$ $\Delta\delta = \delta_{current} - \delta_{previous}$ $\tau_{hys} = \left(b_1\dot{\delta} - k_1\delta\right)\left(1 + \exp\left(-\frac{\lvert\Delta\delta\rvert}{\beta}\right)\right)$ $\beta = \begin{cases} \beta_u & \text{when } \delta > 0 \\ \beta_l & \text{when } \delta \le 0 \end{cases}$
Optional power assist	$\tau_{ast} = f_{trq}(v, \tau_{in})$ $J_1\ddot{\theta}_1 = \tau_{in} + \tau_{ast} - b_2\dot{\theta}_1 - \tau_{hys}$ $J_2\ddot{\theta}_2 = \tau_{eq} + \tau_{ast} - b_3\dot{\theta}_2 + \tau_{hys} - \tau_{fric}$

The illustration and equations use these variables.

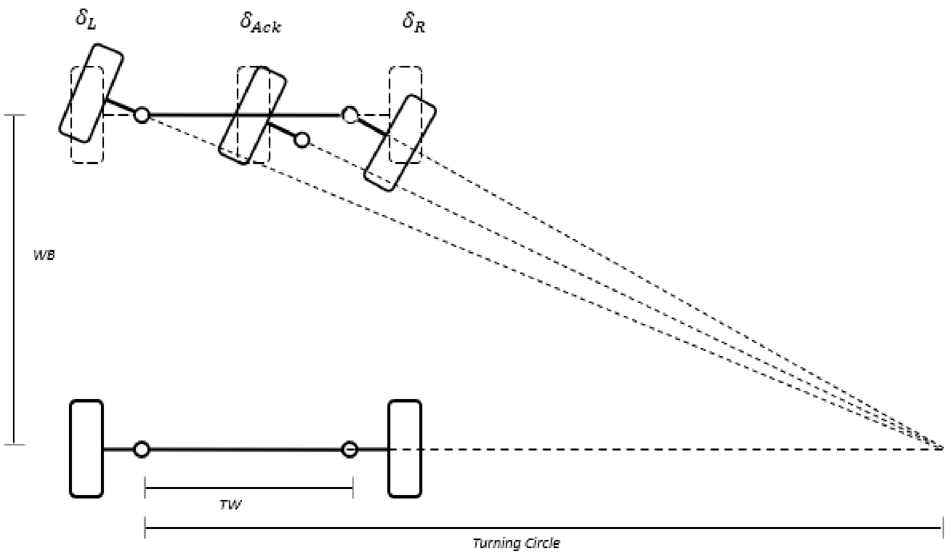
J_1	Steering wheel inertia
J_2	Steering mechanism inertia
$\theta_1, \dot{\theta}_1, \ddot{\theta}_1$	Steering wheel angle, angular velocity, and angular acceleration, respectively
$\theta_2, \dot{\theta}_2, \ddot{\theta}_2$	Shaft angle, angular velocity, and angular acceleration, respectively
b_1, k_1	Hysteresis spring and viscous damping coefficients, respectively

b_2	Steering wheel viscous damping coefficient
b_3	Steering mechanism damping coefficient
τ_{hys}	Hysteresis spring damping torque
τ_{fric}	Steering mechanism friction torque
τ_{eq}	Wheel equivalent torque
τ_{ast}	Torque assist
β_u , β_l	Upper and lower hysteresis modifiers, respectively
v	Vehicle speed
f_{trq}	Torque assist lookup table

Steering Types

Ackerman

For ideal Ackerman steering, the wheel angles have a common turning circle.



To calculate the steering angles, the block uses these equations.

$$\cot(\delta_L) - \cot(\delta_R) = \frac{TW}{WB}$$

$$\delta_{Ack} = \frac{\delta_{in}}{\gamma}$$

$$\delta_L = \tan^{-1}\left(\frac{WB\tan(\delta_{Ack})}{WB + 0.5TW\tan(\delta_{Ack})}\right)$$

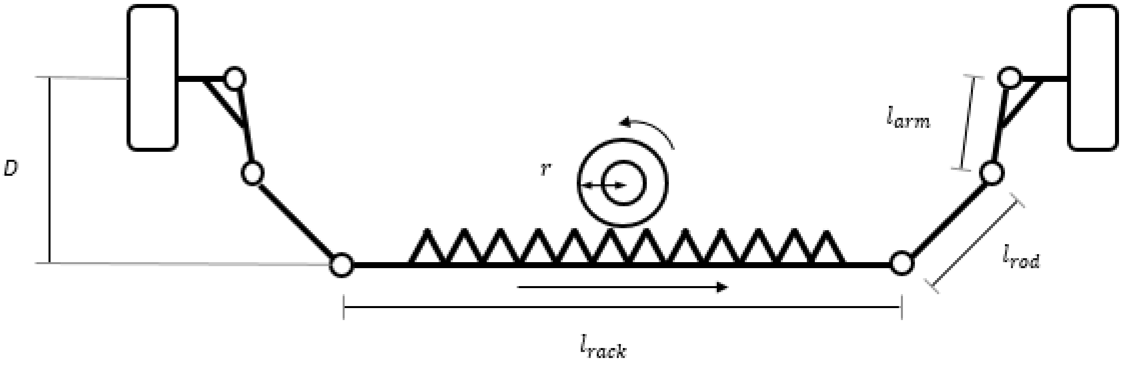
$$\delta_R = \tan^{-1}\left(\frac{WB\tan(\delta_{Ack})}{WB - 0.5TW\tan(\delta_{Ack})}\right)$$

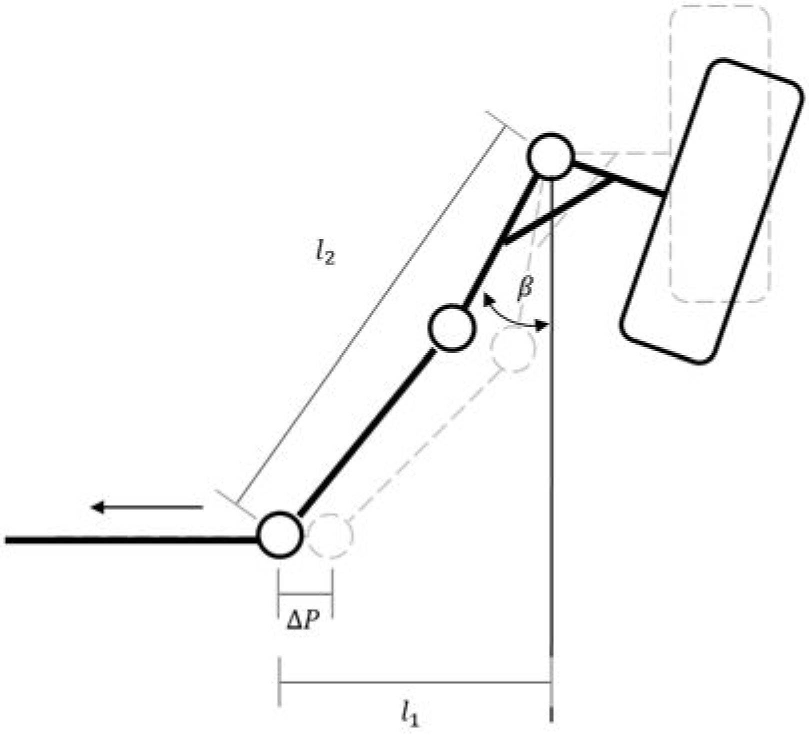
The illustration and equations use these variables.

δ_{in}	Steering angle
δ_L	Left wheel angle
δ_R	Right wheel angle
δ_{vir}	Virtual wheel angle
TW	Track width
WB	Wheel base
γ	Steering ratio

Rack-and-Pinion

For ideal rack-and-pinion steering, the gears convert the steering rotation into linear motion.





To calculate the steering angles, the block uses these equations.

$$l_1 = \frac{TW - l_{rack}}{2} - \Delta P$$

$$l_2{}^2 = l_1{}^2 + D^2$$

$$\Delta P = r\delta_{in}$$

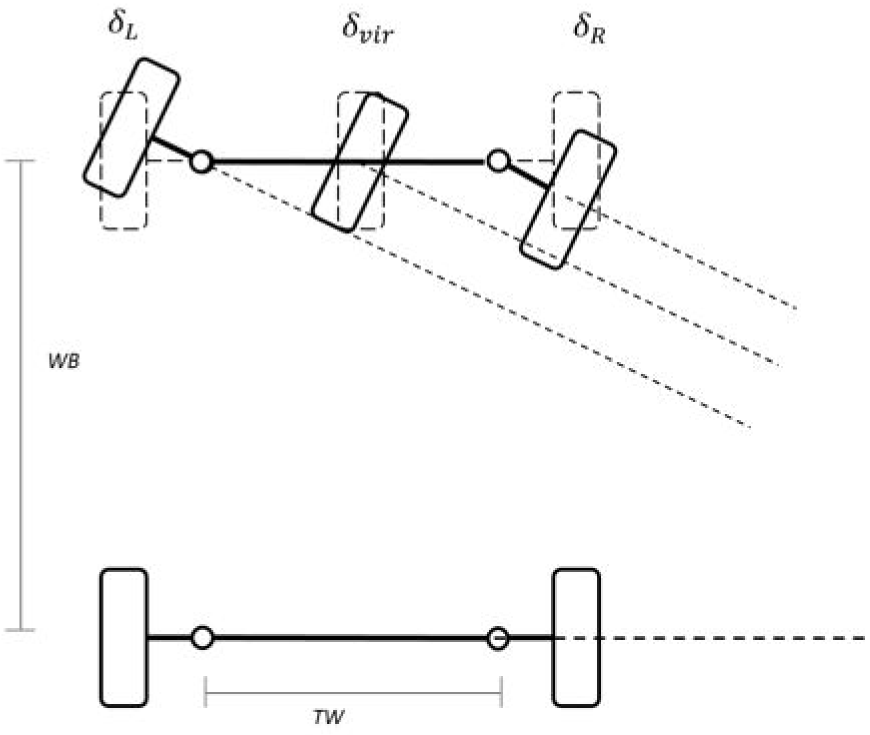
$$\beta = \frac{\pi}{2} - \tan^{-1}\left[\frac{D}{l_1}\right] - \cos^{-1}\left[\frac{l_{arm}{}^2 + l_2{}^2 - l_{rod}{}^2}{2l_{arm}l_2}\right]$$

The illustration and equations use these variables.

δ_{in}	Steering wheel angle
δ_L	Left wheel angle
δ_R	Right wheel angle
TW	Track width
r	Pinion radius
ΔP	Linear change in rack position
D	Distance between front axis and rack
l_{rack}	Rack casing length
l_{arm}	Steering arm length
l_{rod}	Tie rod length

Parallel

For parallel steering, the wheel angles are equal.



To calculate the steering angles, the block uses this equation.

$$\delta_R = \delta_L = \frac{\delta_{in}}{\gamma}$$

The illustration and equations use these variables.

δ_{in}	Steering wheel angle
δ_L	Left wheel angle
δ_R	Right wheel angle
γ	Steering ratio

Ports

Input

`TrqIn` — Torque
`scalar`

Torque, τ_{in}, in N·m.

`TrqLft` — Left wheel torque
`scalar`

Left wheel torque, τ_L, in N·m.

`TrqRght` — Right wheel torque
`scalar`

Right wheel torque, τ_R, in N·m.

`VehSpd` — Vehicle speed
`scalar`

Vehicle speed, v, in m/s.

Dependencies

To create `VehSpd`, select **Power assist**.

Output

`Info` — Bus signal
bus

Bus signal contains these block calculations.

Signal	Description	Unit
`StrgWhlAng`	Steering wheel angle	rad
`StrgWhlSpd`	Steering wheel angular velocity	rad/s
`ShftAng`	Shaft angle	rad
`ShftSpd`	Shaft angular velocity	rad/s
`AngLft`	Left wheel angle	rad
`SpdLft`	Left wheel angular velocity	rad/s
`AngRght`	Right wheel angle	rad
`SpdRght`	Right wheel angular velocity	rad/s
`TrqAst`	Torque assist	N·m
`PwrAst`	Power assist	W
`PwrLoss`	Power loss	W
`InstStrgRatio`	Instantaneous steering ratio	NA

`AngLft` — Left wheel angle
`scalar`

Left wheel angle, δ_L, in rad.

`AngRght` — Right wheel angle
`scalar`

Right wheel angle, δ_R, in rad.

Parameters

Type — Select steering type
`Rack and pinion` (default) | `Ackerman` | `Parallel`

To specify the steering type, use the **Type** parameter.

Setting	Block Implementation
`Ackerman`	Ideal Ackerman steering. Wheel angles have a common turning circle center.
`Rack and pinion`	Ideal rack-and-pinion steering. Gears convert the steering rotation into linear motion.
`Parallel`	Parallel steering. Wheel angles are equal.

Dependencies

This table summarizes the **Type** and **Parametrized by** parameter dependencies.

Type	Parameterized By	Creates Parameters
`Ackerman`	`Constant`	**Track width, TrckWdth** **Wheel base, WhlBase** **Steering range, StrgRng** **Steering ratio, StrgRatio**
	`Lookup table`	**Track width, TrckWdth** **Wheel base, WhlBase** **Steering range, StrgRng** **Steering angle breakpoints, StrgAngBpts** **Steering ratio table, StrgRatioTbl**
`Rack and pinion`	`Constant`	**Track width, TrckWdth** **Steering range, StrgRng** **Steering arm length, StrgArmLngth** **Rack casing length, RckCsLngth** **Tie rod length, TieRodLngth** **Distance between front axis and rack, D** **Pinion radius, PnnRadius**

Type	Parameterized By	Creates Parameters
	`Lookup table`	**Track width, TrckWdth** **Steering range, StrgRng** **Steering angle breakpoints, StrgAngBpts** **Steering arm length, StrgArmLngth** **Rack casing length, RckCsLngth** **Tie rod length, TieRodLngth** **Distance between front axis and rack, D** **Pinion radius, PnnRadiusTbl**
`Parallel`	`Constant`	**Steering range, StrgRng** **Steering ratio, StrgRatio**
	`Lookup table`	**Steering range, StrgRng** **Steering angle breakpoints, StrgAngBpts** **Steering ratio table, StrgRatioTbl**

`Parametrized by` — Select parameterization

`Lookup table` (default) | `Constant`

To specify the type of data for the steering mechanism, use the **Parametrized by** parameter.

Setting	Block Implementation
`Constant`	Steering mechanism uses constant parameter data.
`Lookup table`	Steering mechanism implements tables for parameter data.

Dependencies

This table summarizes the **Type** and **Parametrized by** parameter dependencies.

Type	Parameterized By	Creates Parameters
`Ackerman`	`Constant`	**Track width, TrckWdth** **Wheel base, WhlBase** **Steering range, StrgRng** **Steering ratio, StrgRatio**

Type	Parameterized By	Creates Parameters
	`Lookup table`	**Track width, TrckWdth** **Wheel base, WhlBase** **Steering range, StrgRng** **Steering angle breakpoints, StrgAngBpts** **Steering ratio table, StrgRatioTbl**
`Rack and pinion`	`Constant`	**Track width, TrckWdth** **Steering range, StrgRng** **Steering arm length, StrgArmLngth** **Rack casing length, RckCsLngth** **Tie rod length, TieRodLngth** **Distance between front axis and rack, D** **Pinion radius, PnnRadius**
	`Lookup table`	**Track width, TrckWdth** **Steering range, StrgRng** **Steering angle breakpoints, StrgAngBpts** **Steering arm length, StrgArmLngth** **Rack casing length, RckCsLngth** **Tie rod length, TieRodLngth** **Distance between front axis and rack, D** **Pinion radius, PnnRadiusTbl**
`Parallel`	`Constant`	**Steering range, StrgRng** **Steering ratio, StrgRatio**
	`Lookup table`	**Steering range, StrgRng** **Steering angle breakpoints, StrgAngBpts** **Steering ratio table, StrgRatioTbl**

`Power assist` — Specify power assist
on (default) | `off`

If you select **Power assist**, you can specify a torque assist lookup table, f_{trq}, that is a function of the vehicle speed, v, and steering wheel input torque, τ_{in}.

$$\tau_{ast} = f_{trq}(v, \tau_{in})$$

The block uses the steering wheel input torque and torque assist to calculate the steering dynamics.

Dependencies

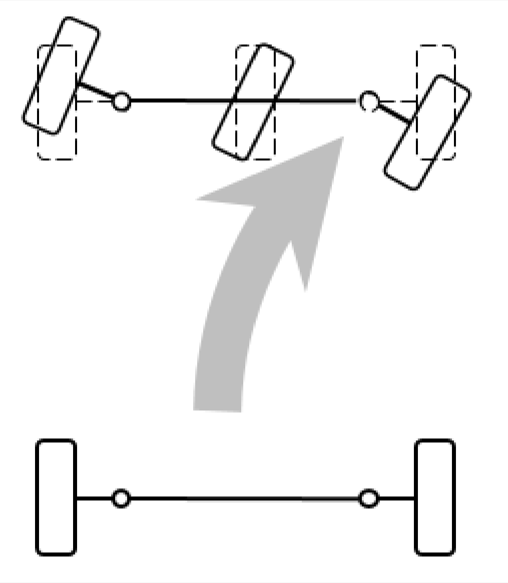
Selecting **Power assist** creates the `VehSpd` input port and these parameters.

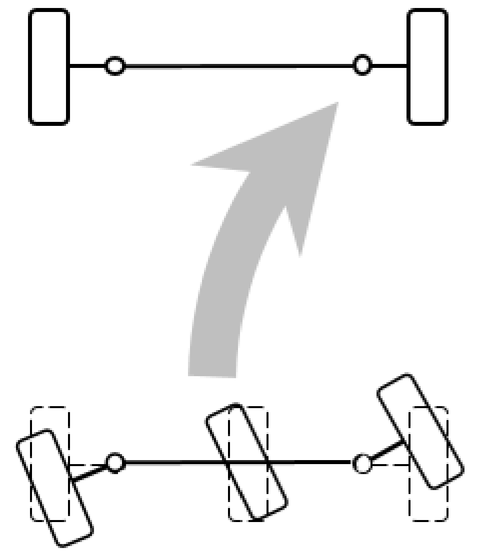
Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

`Location` — Select location

Front (default) | **Rear**

Use the **Location** parameter to specify front or rear steering.

Setting	Implementation
Front	Front steering 

Setting	Implementation
Rear	Rear steering 

General

`Track width, TrckWdth` — Width

`1` | `scalar`

Track width, *TW*, in m.

Dependencies

To create this parameter, set **Type** to `Ackerman` or `Rack and pinion`.

`Wheel base, WhlBase` — Base

`1.524` (default) | `scalar`

Wheel base, *WB*, in m.

Dependencies

To create this parameter, set **Type** to `Ackerman`.

`Steering range, StrgRng` — Range

`1.25*pi` (default) | `scalar`

Steering range, in rad. The block limits the wheel angles to remain within the steering range.

`Steering ratio, StrgRatio` — Ratio

`13.5` (default) | `scalar`

Steering ratio, γ, dimensionless.

Dependencies

To create this parameter:

- Set **Type** to `Ackerman` or `Parallel`.
- Set **Parametrized by** to `Constant`.

`Steering angle breakpoints, StrgAngBpts` — Breakpoints

`[-6.2832 -5.0265 -3.7699 -2.5133 -1.2566 0 1.2566 2.5133 3.7699 5.0265 6.2832]` (default) | `vector`

Steering angle breakpoints, in rad.

Dependencies

To create this parameter, set **Parametrized by** to `Lookup table`.

`Steering ratio table, StrgRatioTbl` — Table

`[13.5000 13.3750 13.2500 13.1250 13.0000 13.0000 13.0000 13.1250 13.2500 13.3750 13.5000]` (default) | `vector`

Steering ratio table, γ, dimensionless.

Dependencies

To create this parameter:

- Set **Type** to `Ackerman` or `Parallel`.
- Set **Parametrized by** to `Lookup table`.

Rack-and-Pinion

`Steering arm length, StrgArmLngth` — Length

`0.1` (default) | `scalar`

Steering arm length, l_{arm}, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Rack casing length, RckCsLngth` — Length

`0.5` (default) | `scalar`

Rack casing length, l_{rack}, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Tie rod length, TieRodLngth` — Length

`0.248` (default) | `scalar`

Tie rod length, l_{rod}, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Distance between front axis and rack, D` — Distance

`0.2` (default) | `scalar`

Distance between front axis and rack, *D*, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Pinion radius, PnnRadius` — Radius

`0.0057` (default) | `scalar`

Pinion radius, *r*, in m.

Dependencies

To create this parameter:

- Set **Type** to `Rack and pinion`.
- Set **Parametrized by** to `Constant`.

`Pinion radius table, PnnRadiusTbl` — Table

`[0.0055 0.0055 0.0056 0.0057 0.0057 0.0057 0.0058 0.0057 0.0056 0.0055 0.0055]` (default) | `vector`

Pinion radius table, *r*, in m.

Dependencies

To create this parameter:

- Set **Type** to `Rack and pinion`.
- Set **Parametrized by** to `Lookup table`.

Dynamics

`Steering wheel inertia, J1` — Inertia

`0.1` (default) | `scalar`

Steering wheel inertia, J_1, in kg*m^2.

`Steering mechanism inertia, J2` — Inertia

`0.01` (default) | `scalar`

Steering mechanism inertia, J_2, in kg*m^2.

`Upper hysteresis modifier, beta_u` — Upper hysteresis modifier

`0.1` (default) | `scalar`

Upper hysteresis modifier, β_u, dimensionless.

`Lower hysteresis modifier, beta_l` — Lower hysteresis modifier

`0.1` (default) | `scalar`

Lower hysteresis modifier, β_l, dimensionless.

`Hysteresis viscous damping, b1` — Damping

`0.001` (default) | `scalar`

Hysteresis damping, b_1, in N·m·s/rad.

`Hysteresis stiffness, k1` — Stiffness

`30` (default) | `scalar`

Hysteresis stiffness, k_1,in N·m/rad.

`Steering wheel damping, b2` — Damping

`1` (default) | `scalar`

Steering wheel damping, b_2, in N·m·s/rad.

`Steering mechanism damping, b3` — Damping

`0.001` (default) | `scalar`

Steering mechanism damping, b_3, in N·m·s/rad.

`Initial steering angle, theta_o` — Angle

`0` (default) | `scalar`

Initial steering angle, θ_0, in rad.

`Initial steering angular velocity, omega_o` — Angular velocity

`0` (default) | `scalar`

Initial steering angular velocity, ω_o, in rad/s.

`Friction torque, FricTrq` — Torque

`0` (default) | `scalar`

Friction torque, τ_{fric}, in N·m.

Power Assist

`Steering wheel torque breakpoints, TrqBpts` — Breakpoints

`[-100 0 100]` (default) | 1-by-`M` vector

Steering wheel torque breakpoints, in N·m.

Dependencies

Selecting **Power assist** creates the `VehSpd` input port and these parameters.

Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

`Vehicle speed breakpoints, VehSpdBpts` — Breakpoints

`[0 20]` (default) | 1-by-N vector

Vehicle speed breakpoints, in m/s.

Dependencies

Selecting **Power assist** creates the `VehSpd` input port and these parameters.

Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

`Assisting torque table, TrqTbl` — 2D torque table

`[0 -100;0 0;0 100]` (default) | M-by-N matrix

Assisting torque table, f_{trq}, in N·m.

The torque assist lookup table is a function of the vehicle speed, v, and steering wheel input torque, τ_{in}.

$$\tau_{ast} = f_{trq}(v, \tau_{in})$$

The block uses the steering wheel input torque and torque assist to calculate the steering dynamics.

Dependencies

Selecting **Power assist** creates the `VehSpd` input port and these parameters.

Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

`Assisting torque limit, TrqLmt` — Torque limit

`100` (default) | `scalar`

Assisting torque limit, in N·m.

Dependencies

Selecting **Power assist** creates the `VehSpd` input port and these parameters.

Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

`Assisting power limit, PwrLmt` — Power limit

`1000` (default) | `scalar`

Assisting power limit, in N·m/s.

Dependencies

Selecting **Power assist** creates the `VehSpd` input port and these parameters.

Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

`Assisting torque efficiency, Eta` — Efficiency

`1` (default) | `scalar`

Assisting torque efficiency, dimensionless.

Dependencies

Selecting **Power assist** creates the `VehSpd` input port and these parameters.

Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

`Cutoff frequency, omega_c` — Cutoff frequency
`200` (default) | `scalar`

Cutoff frequency, in rad/s.

Dependencies

Selecting **Power assist** creates the `VehSpd` input port and these parameters.

Power Assist	Parameters
`on`	**Steering wheel torque breakpoints, TrqBpts** **Vehicle speed breakpoints, VehSpdBpts** **Assisting torque table, TrqTbl** **Assisting torque limit, TrqLmt** **Assisting power limit, PwrLmt** **Assisting torque efficiency, Eta** **Cutoff frequency, omega_c**

Version History

Introduced in R2018a

References

[1] Crolla, David, David Foster, et al. *Encyclopedia of Automotive Engineering*. Volume 4, Part 5 *(Chassis Systems)* and Part 6 *(Electrical and Electronic Systems)*. Chichester, West Sussex, United Kingdom: John Wiley & Sons Ltd, 2015.

[2] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[3] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

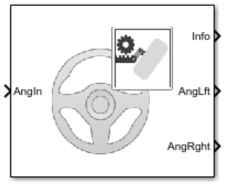
See Also

Kinematic Steering | Mapped Steering

Topics
“Coordinate Systems in Vehicle Dynamics Blockset”

Kinematic Steering

Kinematic steering for Ackerman, rack-and-pinion, and parallel steering mechanisms
Library: Vehicle Dynamics Blockset / Steering



Description

The Kinematic Steering block implements a steering model to determine the left and right wheel angles for Ackerman, rack-and-pinion, and parallel steering mechanisms. The block uses the vehicle coordinate system.

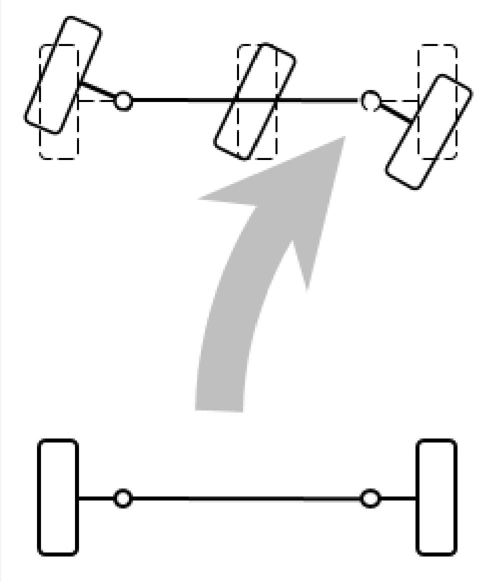
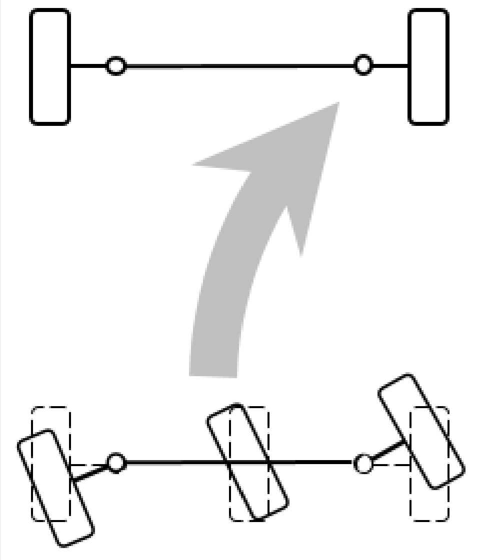
To specify the steering type, use the **Type** parameter.

Setting	Block Implementation
`Ackerman`	Ideal Ackerman steering, adjusted by percentage Ackerman. Wheel angles have a common turning circle center.
`Rack and pinion`	Ideal rack-and-pinion steering. Gears convert the steering rotation into linear motion.
`Parallel`	Parallel steering. Wheel angles are equal.

To specify the type of data for the steering mechanism, use the **Parametrized by** parameter.

Setting	Block Implementation
`Constant`	Steering mechanism uses constant parameter data.
`Lookup table`	Steering mechanism implements tables for parameter data.

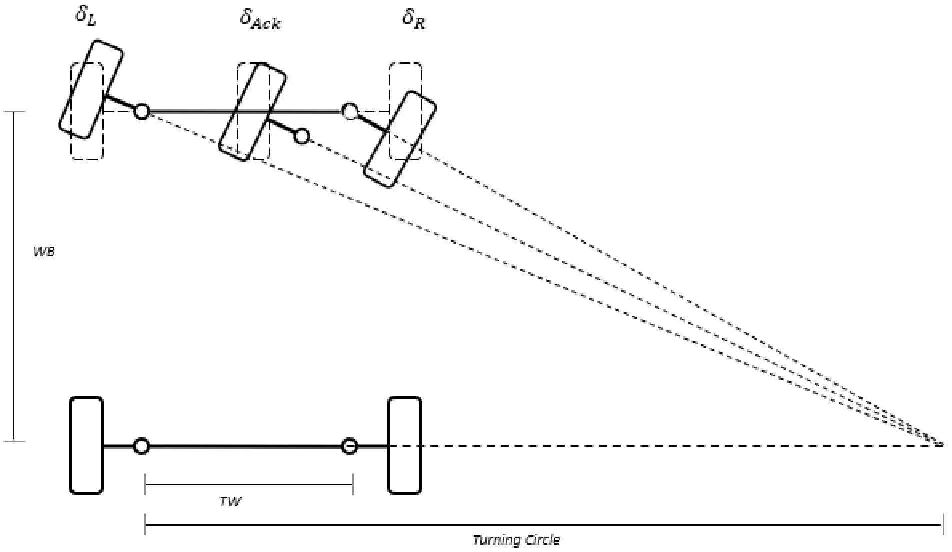
Use the **Location** parameter to specify front or rear steering.

Setting	Implementation
Front	Front steering 
Rear	Rear steering 

Steering Types

Ackerman

For ideal Ackerman steering, the wheel angles have a common turning circle.



To calculate the ideal wheel angles, the block uses these equations.

$$\cot(\delta_L) - \cot(\delta_R) = \frac{TW}{WB}$$

$$\delta_{Ack} = \frac{\delta_{in}}{\gamma}$$

$$\delta_L = \tan^{-1}\left(\frac{WB\tan(\delta_{Ack})}{WB + 0.5TW\tan(\delta_{Ack})}\right)$$

$$\delta_R = \tan^{-1}\left(\frac{WB\tan(\delta_{Ack})}{WB - 0.5TW\tan(\delta_{Ack})}\right)$$

After the block calculates the ideal wheel angles, it uses the Ackerman percentage to adjust the outside wheel angle.

$$\delta_o = \delta_i - p_{Ack}(\delta_i - \delta_{Ack})$$

The outside wheel angle depends on the turn direction.

- Right turn
  - Outside angle, δ_o, is left wheel angle, δ_L
  - Inside angle, δ_i, is right wheel angle, δ_R
- Left turn
  - Outside angle, δ_o, is right wheel angle, δ_R
  - Inside angle, δ_i, is left wheel angle, δ_L

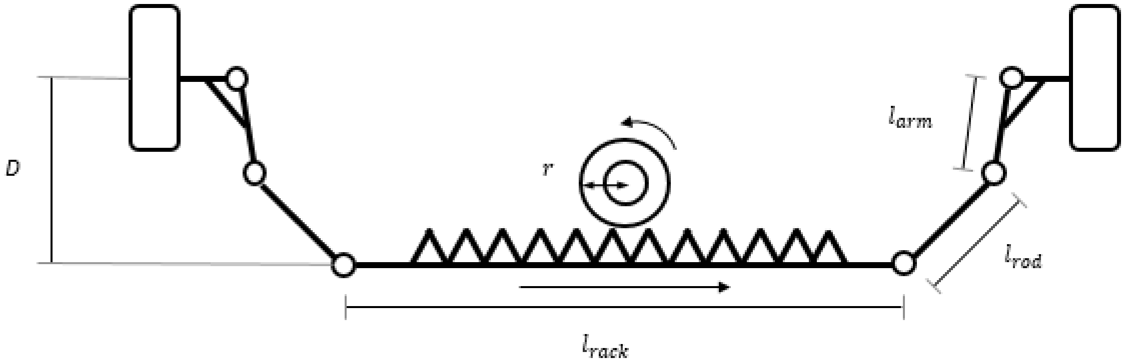
The illustration and equations use these variables.

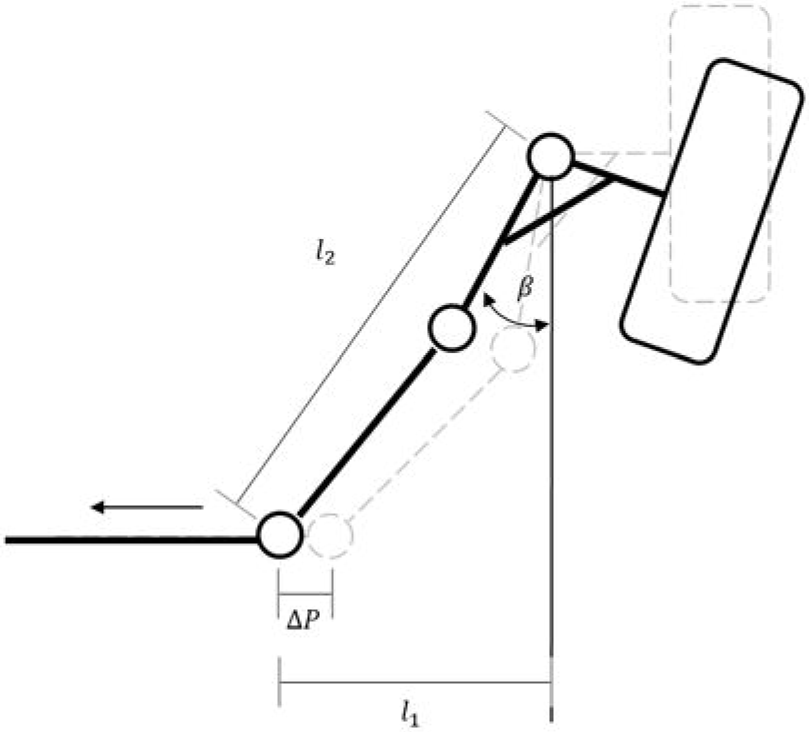
δ_{in}	Steering angle
δ_L	Left wheel angle

δ_R	Right wheel angle
δ_o	Outside wheel angle
δ_i	Inside wheel angle
p_{Ack}	Ackerman percentage
TW	Track width
WB	Wheel base
γ	Steering ratio

Rack-and-Pinion

For ideal rack-and-pinion steering, the gears convert the steering rotation into linear motion.





To calculate the steering angles, the block uses these equations.

$$l_1 = \frac{TW - l_{rack}}{2} - \Delta P$$

$$l_2{}^2 = l_1{}^2 + D^2$$

$$\Delta P = r\delta_{in}$$

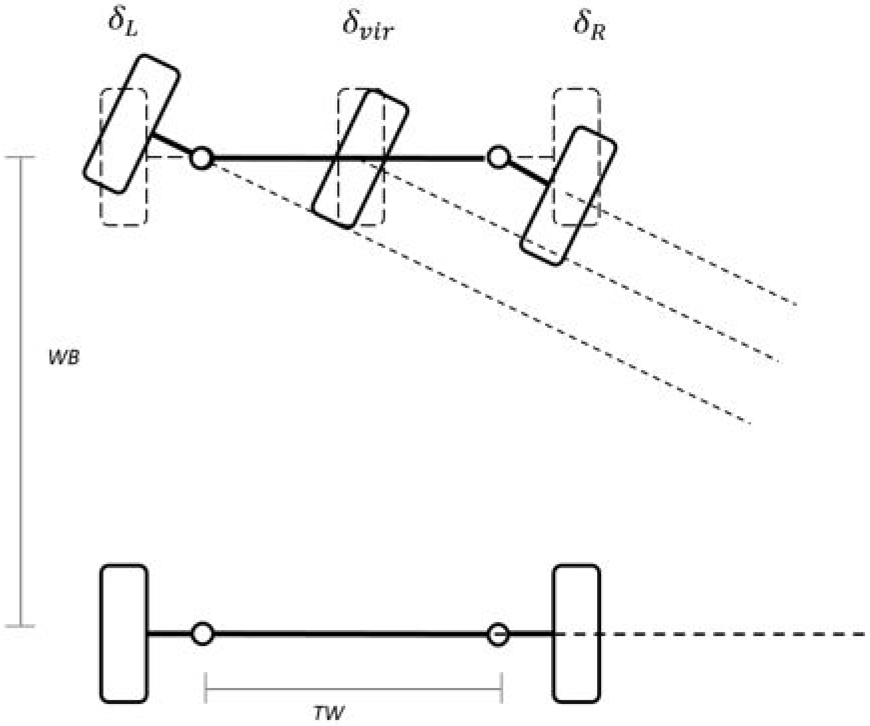
$$\beta = \frac{\pi}{2} - \tan^{-1}\left[\frac{D}{l_1}\right] - \cos^{-1}\left[\frac{l_{arm}{}^2 + l_2{}^2 - l_{rod}{}^2}{2l_{arm}l_2}\right]$$

The illustration and equations use these variables.

δ_{in}	Steering wheel angle
δ_L	Left wheel angle
δ_R	Right wheel angle
TW	Track width
r	Pinion radius
ΔP	Linear change in rack position
D	Distance between front axis and rack
l_{rack}	Rack casing length
l_{arm}	Steering arm length
l_{rod}	Tie rod length

Parallel

For parallel steering, the wheel angles are equal.



To calculate the steering angles, the block uses this equation.

$$\delta_R = \delta_L = \frac{\delta_{in}}{\gamma}$$

The illustration and equations use these variables.

δ_{in}	Steering wheel angle
δ_L	Left wheel angle
δ_R	Right wheel angle
γ	Steering ratio

Ports

Input

`AngIn` — Steering angle
`scalar`

Steering angle, δ_{in}, in rad.

Use the **Steering range, StrgRng** parameter to specify a steering angle range. By default, the value is set to 1.25*pi, which limits the steering angle to a range of -1.25*pi to 1.25*pi.

`PctAckIn` — Ackerman percentage
`scalar`

Ackerman percentage, δ_{in}, in percent.

Dependencies

To create this input port:

- Set **Type** to `Ackerman`.
- On the **Ackerman Steering** pane, select **Input percent Ackerman**.

Output

`Info` — Bus signal

bus

Bus signal contains this block calculation.

Signal	Description	Variable	Unit
`InstStrgRatio`	Instantaneous steering ratio	γ	NA

`AngLft` — Left wheel angle

`scalar`

Left wheel angle, δ_L, in rad.

`AngRght` — Right wheel angle

`scalar`

Right wheel angle, δ_R, in rad.

Parameters

Type — Select steering type

`Ackerman` (default) | `Rack and pinion` | `Parallel`

To specify the steering type, use the **Type** parameter.

Setting	Block Implementation
`Ackerman`	Ideal Ackerman steering. Wheel angles have a common turning circle center.
`Rack and pinion`	Ideal rack-and-pinion steering. Gears convert the steering rotation into linear motion.
`Parallel`	Parallel steering. Wheel angles are equal.

`Parametrized by` — Select parameterization

`Constant` (default) | `Lookup table`

To specify the type of data for the steering mechanism, use the **Parametrized by** parameter.

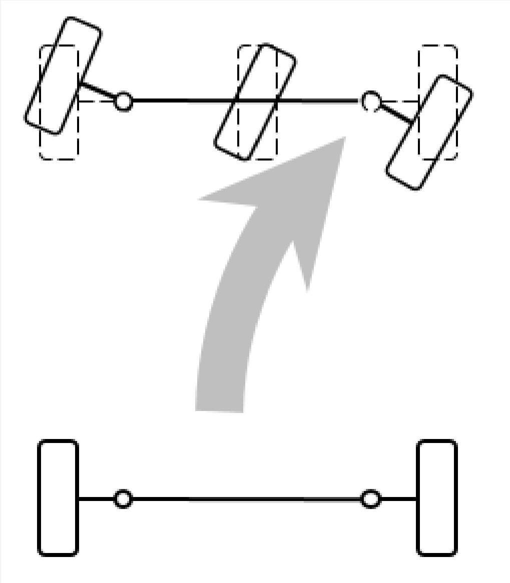
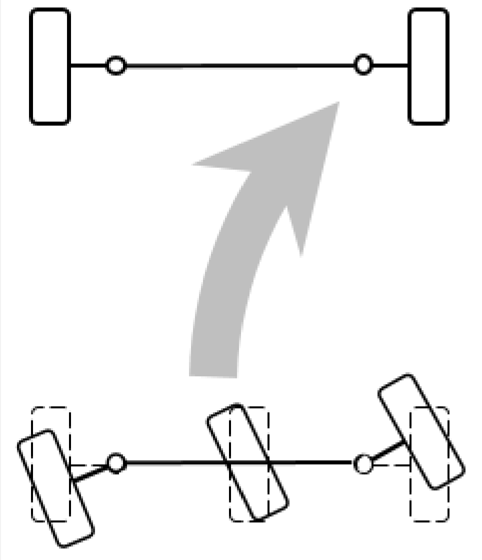
Setting	Block Implementation
`Constant`	Steering mechanism uses constant parameter data.

Setting	Block Implementation
`Lookup table`	Steering mechanism implements tables for parameter data.

`Location` — Select location

Front (default) | **Rear**

Use the **Location** parameter to specify front or rear steering.

Setting	Implementation
Front	Front steering 
Rear	Rear steering 

`Normalization factor, NrmFctr` — Adjust the steering angle

`scalar`

Factor, Nrm_{Fctr}, that the block uses to adjust the steering ratio, γ or pinion radius, r. The block can only normalize if you have **Parametrized by** set to `Constant`.

To adjust the steering ratio or pinion radius, click **Normalize**.

Steering Type	Normalization
`Ackerman` `Parallel`	Block updates the **Steering ratio, StrgRatio** parameter to the normalized value, γ_{nrm}, specified by this equation. $\gamma_{nrm} = \frac{1}{Nrm_{Fctr}}$
`Rack and pinion`	Block updates the **Pinion radius, PnnRadius** parameter to using the normalization factor, Nrm_{Fctr}.

General

`Track width, TrckWdth` — Width

`1` (default) | `scalar`

Track width, TW, in m.

Dependencies

To create this parameter, set **Type** to `Ackerman` or `Rack and pinion`.

`Wheel base, WhlBase` — Base

`1.524` (default) | `scalar`

Wheel base, WB, in m.

Dependencies

To create this parameter, set **Type** to `Ackerman`.

`Deadband, Db` — Deadband

`0` (default) | `scalar`

Deadband steering angle before pinion engages the gear, in rad.

`Steering range, StrgRng` — Steering wheel angle input range

`1.25*pi` (default) | `scalar`

Steering wheel angle input range, in rad. The block limits the steering wheel input angles to remain within the steering range.

`Steering ratio, StrgRatio` — Ratio

`100` (default) | `scalar`

Steering ratio, γ, dimensionless.

Dependencies

To create this parameter:

- Set **Type** to `Ackerman` or `Parallel`.
- Set **Parametrized by** to `Constant`.

`Steering angle breakpoints, StrgAngBpts` — Breakpoints

`[-6.2832 -5.0265 -3.7699 -2.5133 -1.2566 0 1.2566 2.5133 3.7699 5.0265 6.2832]` (default) | `vector`

Steering angle breakpoints, in rad.

Dependencies

To create this parameter, set **Parametrized by** to `Lookup table`.

`Steering ratio table, StrgRatioTbl` — Table

`[13.5000 13.3750 13.2500 13.1250 13.0000 13.0000 13.0000 13.1250 13.2500 13.3750 13.5000]` (default) | `vector`

Steering ratio table, γ, dimensionless.

Dependencies

To create this parameter:

- Set **Type** to `Ackerman` or `Parallel`.
- Set **Parametrized by** to `Lookup table`.

Rack-and-Pinion

`Steering arm length, StrgArmLngth` — Length

`0.1` (default) | `scalar`

Steering arm length, l_{arm}, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Rack casing length, RckCsLngth` — Length

`0.5` (default) | `scalar`

Rack casing length, l_{rack}, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Tie rod length, TieRodLngth` — Length

`0.248` (default) | `scalar`

Tie rod length, l_{rod}, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Distance between front axis and rack, D` — Distance

`0.2` (default) | `scalar`

Distance between front axis and rack, *D*, in m.

Dependencies

To create this parameter, set **Type** to `Rack and pinion`.

`Pinion radius, PnnRadius` — Radius

`0.0057` (default) | `scalar`

Pinion radius, *r*, in m.

Dependencies

To create this parameter:

- Set **Type** to `Rack and pinion`.
- Set **Parametrized by** to `Constant`.

`Pinion radius table, PnnRadiusTbl` — Table

`[0.0055 0.0055 0.0056 0.0057 0.0057 0.0057 0.0058 0.0057 0.0056 0.0055 0.0055]` (default) | `vector`

Pinion radius table, *r*, in m.

Dependencies

To create this parameter:

- Set **Type** to `Rack and pinion`.
- Set **Parametrized by** to `Lookup table`.

Ackerman Steering

`Input Percent Ackerman` — Create `PctAckIn` input port

`off` (default) | `on`

Select to create `PctAckIn` input port.

Dependencies

To enable this parameter, set **Type** to `Ackerman`.

`Percent Ackerman, PctAck` — Percent Ackerman constant

`100` (default) | `scalar`

Constant value of percent Ackerman, in percent.

Dependencies

To enable this parameter:

- Set **Type** to `Ackerman`
- Set **Parametrized by** to `Constant`

- Clear **Input Percent Ackerman**

`Percent Ackerman table, PctAckTbl` — Percent Ackerman table

`ones(1,11)*100` (default) | `vector`

Table of percent Ackerman values as a function of the steering angle, δ_{in}, in percent.

Dependencies

To enable this parameter:

- Set **Type** to `Ackerman`
- Set **Parametrized by** to `Constant`
- Clear **Input Percent Ackerman**

Version History

Introduced in R2018a

References

[1] Crolla, David, David Foster, et al. *Encyclopedia of Automotive Engineering*. Volume 4, Part 5 *(Chassis Systems)* and Part 6 *(Electrical and Electronic Systems)*. Chichester, West Sussex, United Kingdom: John Wiley & Sons Ltd, 2015.

[2] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[3] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Dynamic Steering | Mapped Steering

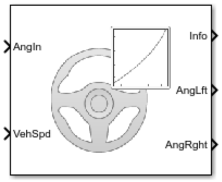
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Mapped Steering

Mapped steering with speed-dependent option

Library: Vehicle Dynamics Blockset / Steering



Description

The Mapped Steering block implements lookup tables to calculate the right and left wheel angles. Use the **Speed dependent** parameter to implement a speed-dependent table for the steering angle calculations. The block uses the vehicle coordinate system.

Steering Wheel Angle

If you set **Steering type** to `Steering wheel angle`, the block implements these tables.

Speed Dependent	Implementation	Calculations
`on` (default)	Block uses three tables: • f_s — Function of vehicle speed • f_L — Function of superimposed steering wheel angle • f_R — Function of superimposed steering wheel angle	$\delta_{SpdF} = f_s(v)$ $\delta_{SuprImp} = \delta_{SpdF} \cdot \delta_{in}$ $\delta_L = f_L(\delta_{SuprImp})$ $\delta_R = f_R(\delta_{SuprImp})$
`off`	Block uses two tables: • f_L — Function of steering wheel angle • f_R — Function of steering wheel angle	$\delta_L = f_L(\delta_{in})$ $\delta_R = f_R(\delta_{in})$

Rack Travel Displacement

If you set **Steering type** to `Rack travel displacement`, the block implements these tables.

Speed Dependent	Implementation	Calculations
`on` (default)	Block uses three tables: • f_s — Function of vehicle speed • f_L — Function of rack displacement • f_R — Function of rack displacement	$\delta_{SpdF} = f_s(v)$ $\delta_{SuprImp} = \delta_{SpdF} \cdot \delta_{in}$ $\Delta_{Rack} = \delta_{SuprImp} \cdot Gr$ $\delta_L = f_L(\Delta_{Rack})$ $\delta_R = f_R(\Delta_{Rack})$
`off`	Block uses two tables: • f_L — Function of rack displacement • f_R — Function of rack displacement	$\Delta_{Rack} = \delta_{in} \cdot Gr$ $\delta_L = f_L(\Delta_{Rack})$ $\delta_R = f_R(\Delta_{Rack})$

The block uses a gear ratio to adjust the rack displacement. To use a

- Constant gear ratio, set **Gear ratio parameterized by** to `Constant`.
- Gear ratio as a function of steering angle, set **Gear ratio parameterized by** to `Lookup table`.

The equations use these variables.

δ_{in}	Steering wheel angle
δ_{SpdF}	Steering wheel angle speed factor
$\delta_{SuprImp}$	Superimposed steering wheel angle
δ_L, δ_R	Left and right wheel angles, respectively
Δ_{Rack}	Rack displacement
Gr	Gear ratio

Ports

Input

`AngIn` — Steering angle

`scalar`

Steering angle, δ_{in}, in rad.

Use the **Steering angle breakpoints, StrgAngBpts** parameter to specify a steering angle range. By default, the value is set to 1.25*pi, which limits the steering angle to a range of -1.25*pi to 1.25*pi.

`VehSpd` — Vehicle speed

`scalar`

Vehicle speed, Veh_{spd}, in m/s.

Dependencies

To create this port, select **Speed dependent**.

Output

`Info` — Bus signal
bus

Bus signal containing these block calculations.

Signal	Description	Variable	Unit
`AngLft`	Left wheel angle	δ_L	rad
`AngRght`	Left wheel angle	δ_R	rad

`AngLft` — Left wheel angle
`scalar`

Left wheel angle, δ_L, in rad.

`AngRght` — Right wheel angle
`scalar`

Right wheel angle, δ_R, in rad.

Parameters

Options

`Speed dependent` — Use speed-dependent tables
on (default) | off

Select to use speed-dependent tables.

Dependencies

Selecting this parameter creates input port `VehSpd`.

`Steering type` — Use speed-dependent tables
`Steering wheel angle` (default) | `Rack travel displacement`

If you set **Steering type** to `Steering wheel angle`, the block implements these tables.

Speed Dependent	Implementation
`on` (default)	Block uses three tables: • f_s — Function of vehicle speed • f_L — Function of superimposed steering wheel angle • f_R — Function of superimposed steering wheel angle
`off`	Block uses two tables: • f_L — Function of steering wheel angle • f_R — Function of steering wheel angle

If you set **Steering type** to `Rack travel displacement`, the block implements these tables.

Speed Dependent	Implementation
`on` (default)	Block uses three tables: • f_s — Function of vehicle speed • f_L — Function of rack displacement • f_R — Function of rack displacement
`off`	Block uses two tables: • f_L — Function of rack displacement • f_R — Function of rack displacement

`Steering angle breakpoints, StrgAngBpts` — Steering angle breakpoints

`[-1.5*pi 1.5*pi]` (default) | `vector`

Steering angle breakpoints, in rad.

Dependencies

If you set **Steering type** to `Rack travel displacement`, to enable this parameter, set **Gear ratio parameterized by** to `Lookup table`.

`Rack displacement breakpoints, RackDispBpts` — Rack displacement breakpoints

`[-40 -19.2 -4.53 4.53 19.2 40]` (default) | `vector`

Rack displacement breakpoints, in mm.

Dependencies

To enable this parameter, set **Steering type** to `Rack travel displacement` and **Gear ratio parameterized by** to `Lookup table`.

`Gear ratio table, GrTbl` — Gear ratio table

`[9.87 9.87 7.16 7.16 9.87 9.87]*2*pi` (default) | `vector`

Gear ratio table as a function of rack displacement, in mm/rev.

Dependencies

To enable this parameter, set **Steering type** to `Rack travel displacement` and **Gear ratio parameterized by** to `Lookup table`.

`Gear ratio constant, Gr` — Gear ratio constant

`8.28*2*pi` (default) | `scalar`

Gear ratio constant, in mm/rev.

Dependencies

To enable this parameter, set **Steering type** to `Rack travel displacement` and **Gear ratio parameterized by** to `Constant`.

`Left wheel angle table, WhlLftTbl` — Left wheel angle table

`[-1.5*pi 1.5*pi]/13.5]` (default) | `vector`

Left wheel angle table, δ_L, in rad.

`Right wheel angle table, WhlRghtTbl` — Right wheel angle table
`[-1.5*pi 1.5*pi]/13.5` (default) | `vector`

Right wheel angle table, δ_R, in rad.

`Vehicle speed breakpoints, VehSpdBpts` — Vehicle speed breakpoints
`[-1 1]` (default) | `vector`

Vehicle speed breakpoints, in m/s.

Dependencies

To create this parameter, select **Speed dependent**.

`Superimposed speed factor table, SpdFctTbl` — Speed factor
`[1 1]` (default) | `vector`

Superimposed speed factor table, f_s, dimensionless. The table is a factor of vehicle speed, v.

Dependencies

To create this parameter, select **Speed dependent**.

Version History

Introduced in R2018a

References

[1] Crolla, David, David Foster, et al. *Encyclopedia of Automotive Engineering*. Volume 4, Part 5 *(Chassis Systems)* and Part 6 *(Electrical and Electronic Systems)*. Chichester, West Sussex, United Kingdom: John Wiley & Sons Ltd, 2015.

[2] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[3] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Dynamic Steering | Kinematic Steering

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Steering System

Steering system for Ackerman, rack-and-pinion, and parallel steering mechanisms
Library: Vehicle Dynamics Blockset / Steering

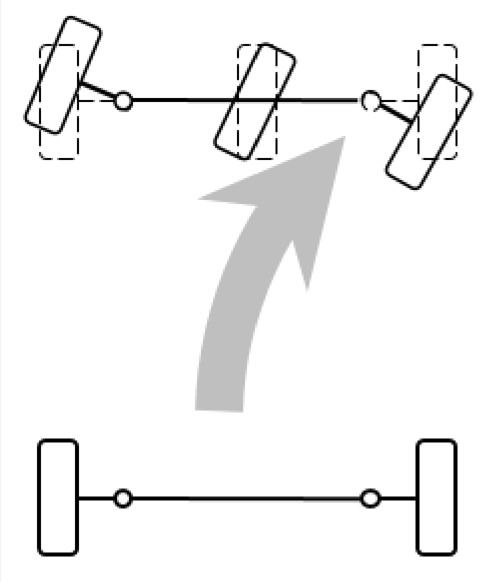
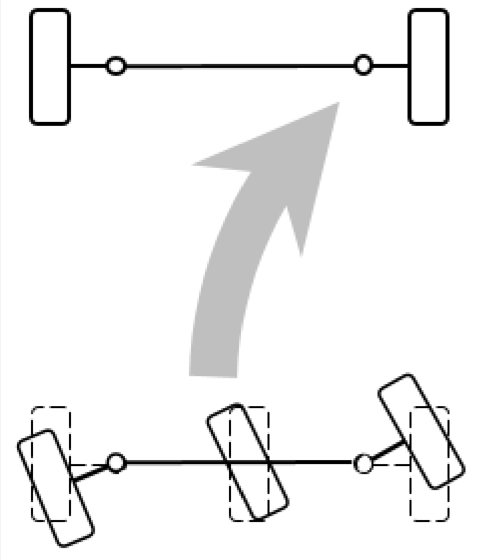
Description

The Steering System block implements dynamic steering to calculate the wheel angles for rack-and-pinion mechanisms with friction, compliance, and Ackerman steering features. The block uses the steering wheel input angle or torque, vehicle speed, caster angle, and right and left wheel feedbacks to calculate the wheel angles. The block uses the vehicle coordinate system.

If you select the **Power assist** parameter, you can specify a torque assist lookup table that is a function of the vehicle speed and steering wheel input torque. The block uses the steering wheel input torque and torque assist to calculate the steering dynamics. If you select the **Ackerman steering** parameter, you can specify a lookup table of percent Ackerman values to calculate the Ackerman steering effects. Otherwise, the block calculates the wheel angles based on a perfect 100 percent Ackerman.

If you select the **Power assist**, **Ackerman steering**, or **Kingpin moment** parameters in the **Input signals** section, you can specify additional inputs for the external power assist torques, percent Ackerman values, or kingpin moments.

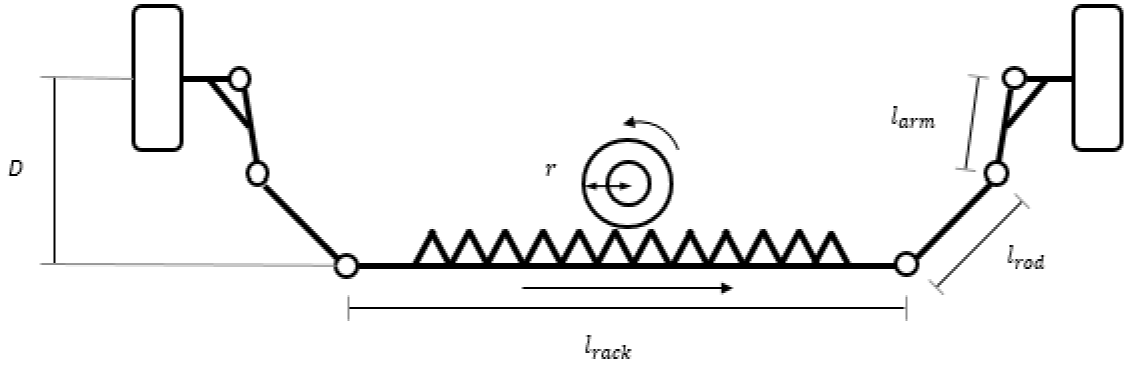
Use the **Location** parameter to specify front or rear steering.

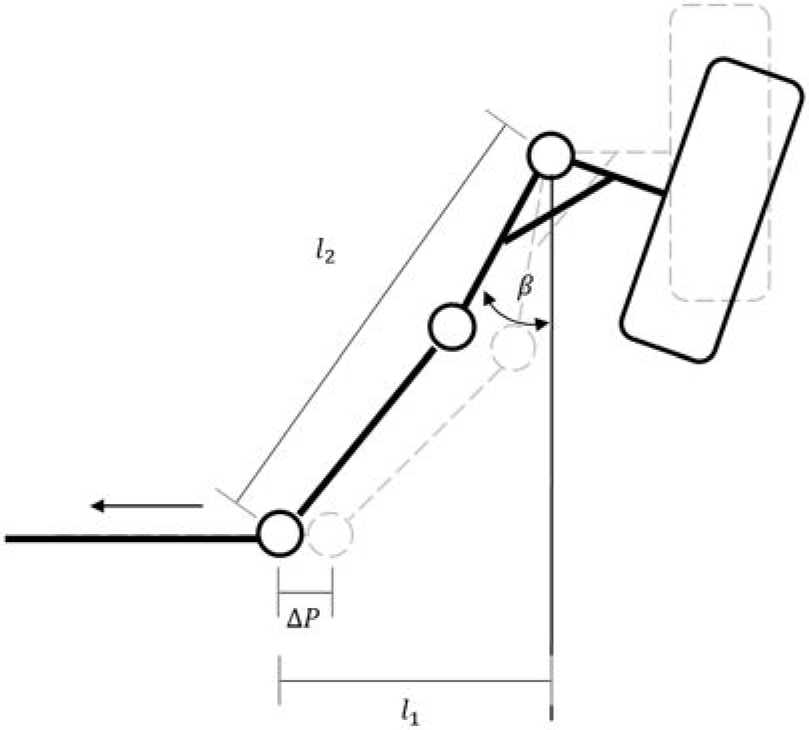
Setting	Implementation
Front	Front steering 
Rear	Rear steering 

Steering

Rack-and-Pinion

For ideal rack-and-pinion steering, the gears convert the steering rotation into linear motion.





To calculate the steering angles, the block uses these equations.

$$l_1 = \frac{TW - l_{rack}}{2} - \Delta P$$

$$l_2^2 = l_1^2 + D^2$$

$$\Delta P = r\delta_{in}$$

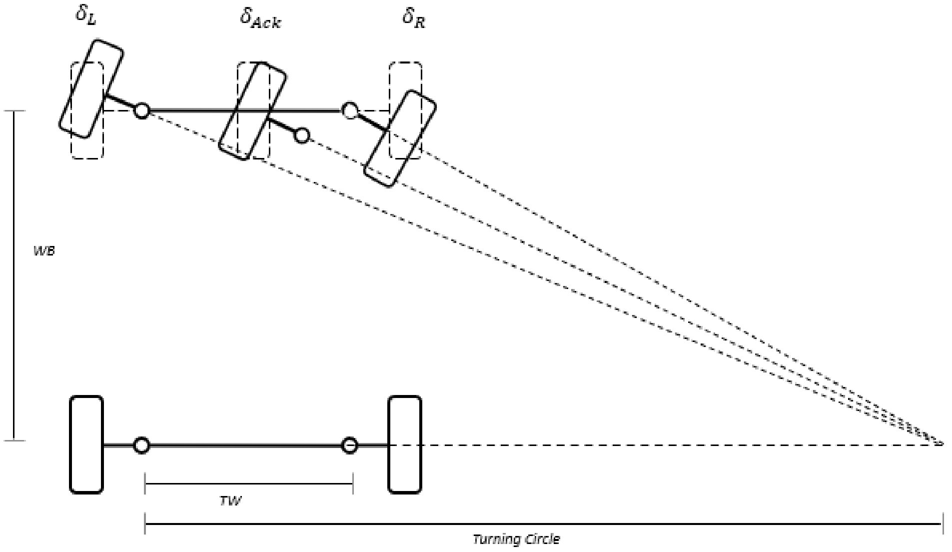
$$\beta = \frac{\pi}{2} - \tan^{-1}\left[\frac{D}{l_1}\right] - \cos^{-1}\left[\frac{l_{arm}^2 + l_2^2 - l_{rod}^2}{2l_{arm}l_2}\right]$$

The illustration and equations use these variables.

δ_{in}	Steering wheel angle
δ_L	Left wheel angle
δ_R	Right wheel angle
TW	Track width
r	Pinion radius
ΔP	Linear change in rack position
D	Distance between front axis and rack
l_{rack}	Rack casing length
l_{arm}	Steering arm length
l_{rod}	Tie rod length

Ackerman

For ideal Ackerman steering, the wheel angles have a common turning circle.



To calculate the steering angles, the block uses these equations.

$$\cot(\delta_L) - \cot(\delta_R) = \frac{TW}{WB}$$

$$\delta_{Ack} = \frac{\delta_{in}}{\gamma}$$

$$\delta_L = \tan^{-1}\left(\frac{WB\tan(\delta_{Ack})}{WB + 0.5TW\tan(\delta_{Ack})}\right)$$

$$\delta_R = \tan^{-1}\left(\frac{WB\tan(\delta_{Ack})}{WB - 0.5TW\tan(\delta_{Ack})}\right)$$

The illustration and equations use these variables.

δ_{in}	Steering angle

δ_L	Left wheel angle
δ_R	Right wheel angle
δ_{vir}	Virtual wheel angle
TW	Track width
WB	Wheel base
γ	Steering ratio

Ports

Input

`VehSpd` — Vehicle speed
`scalar`

Vehicle speed, v, in m/s, specified as a scalar.

`CstrAng` — Wheel caster angle
`1-by-2 vector`

Wheel caster angle, τ_L, in radians, specified as a 1-by-2 vector. The first element represents the angle of the left wheel and the second element represents the angle of the right wheel.

Dependencies

To enable this port, clear **Input signals** > **Kingpin moment**.

`WhelAngFdk` — Wheel angle feedback
`1-by-2 vector`

Wheel angle feedback, in radians, specified as a 1-by-2 vector. The first element represents the angle feedback for the left wheel and the second element represents the angle feedback for the right wheel.

Dependencies

To enable this port, clear **Input signals** > **Kingpin moment**.

`StrWhlAng` — Steering angle input
`scalar`

Steering angle input, in radians, specified as a scalar.

Dependencies

To enable this port, select **Steer inputs** > **Angle**.

`StrWhlTrq` — Steering torque input
`scalar`

Steering torque input, in N*m, specified as a scalar.

Dependencies

To enable this port, select **Steer inputs** > **Torque**.

`PwrAstTrq` — External power assistant torque

scalar

External power assistant torque, in N*m, specified as a scalar.

Dependencies

To enable this port, select **Input signals** > **Power assist**.

`PctAck` — External percent Ackerman value

scalar

External percent Ackerman value, in N*m, specified as a scalar.

Dependencies

To enable this port, select **Input signals** > **Ackerman steering**.

`TireFdk` — Tire forces and moments feedback

1-by-6 vector

Tire forces and moments feedback, specified as a 1-by-6 vector that contains the following values, in order:

Description	Unit
x-directional Force	N
y-directional Force	N
z-directional Force	N
x-directional Moment	N*m
y-directional Moment	N*m
z-directional Moment	N*m

Dependencies

To enable this port, clear **Input signals** > **Kingpin moment**.

`LftKpM` — Left kingpin moment

scalar

Left kingpin moment, in N*m, specified as a scalar.

Dependencies

To enable this port, select **Input signals** > **Kingpin moment**.

`RghtKpM` — Right kingpin moment

scalar

Right kingpin moment, in N*m, specified as a scalar.

Dependencies

To enable this port, select **Input signals** > **Kingpin moment**.

Output

`Info` — Vehicle dynamics information
bus

Vehicle dynamics information, returned as a bus signal that contains:

Signal	Description	Unit
`StrgWhlAng`	Steering wheel angle	rad
`StrgWhlSpd`	Steering wheel angular velocity	rad/s
`ShftAng`	Shaft angle	rad
`ShftSpd`	Shaft angular velocity	rad/s
`AngLft`	Left wheel angle	rad
`SpdLft`	Left wheel angular velocity	rad/s
`AngRght`	Right wheel angle	rad
`SpdRght`	Right wheel angular velocity	rad/s
`TrqAst`	Torque assist	N·m
`PwrAst`	Power assist	W
`PwrLoss`	Power loss	W
`InstStrgRatio`	Instantaneous steering ratio	NA

`LftWhlAng` — Left wheel angle
`scalar`

Left wheel angle, δ_L, in radians, returned as a scalar.

`RghtWhlAng` — Right wheel angle
`scalar`

Right wheel angle, δ_R, in radians, returned as a scalar.

Parameters

Block Options

Type — Steering type
`Rack and pinion` (default)

Steering type for the steering system.

`Intermediate shaft type` — Intermediate shaft type
`Single Cardan joint` (default) | `Double Cardan joints`

Whether to model the intermediate shaft type using single or double cardan joints.

`Power assist` — Whether to model power assist
on (default) | `off`

Select to model power assist in the steering system.

Dependencies

To enable this parameter, in the **Input signals** section, clear **Power assist**.

`Ackerman steering` — Whether to use Ackerman steering

`on` (default) | `off`

Select to use Ackerman steering in the steering system.

Dependencies

To enable this parameter, in the **Input signals** section, clear **Ackerman steering**.

Input Signals

`Power assist` — Specify external power assistance torque

`off` (default) | `on`

Select this parameter to enable the **PwrAstTrq** port.

`Ackerman steering` — Specify external percent Ackerman value

`off` (default) | `on`

Select this parameter to enable the **PctAct** port.

`Kingpin moment` — Specify right and left wheel angles

`off` (default) | `on`

Select this parameter to enable the **LftKpM** and **RghtKpM** ports.

`Location` — Location of steering system

Front (default) | **Rear**

Select the front or rear axle as the location of the steering system.

`Steer inputs` — Wheel angle or torque

Angle (default) | **Torque**

Specify wheel angle or wheel torque steering input.

General

`Track width, TrckWdth` — Track width

`1` (default) | `scalar`

Track width, *TW*, in m, specified as a scalar.

`Steering range, StrgRng` — Steering range

`1.25*pi` (default) | `scalar`

Steering range, in rad, specified as a scalar. The block limits the wheel angles to remain within the steering range.

`Steering wheel inertia, StrWhlInert` — Steering wheel inertia

`0.1` (default) | `scalar`

Steering wheel inertia, in kg*m^2, specified as a scalar.

`Steering column inertia, StrColInert` — Steering column inertia
`0.01` (default) | `scalar`

Steering column inertia, in kg*m^2, specified as a scalar.

`Kingpin offset, KngpnOfst` — Kingpin offset
`0.075` (default) | `scalar`

Kingpin offset, in m, specified as a scalar.

`Kingpin inclination angle, Lambda` — Kingpin inclination angle
`0.20943951023932` (default) | `scalar`

Kingpin inclination angle, in rad, specified as a scalar.

`Hub lead, HbLead` — Hub lead
`4.00E-05` (default) | `scalar`

Hub lead, in m, specified as a scalar.

`Static loaded radius, StcLdRadius` — Static loaded radius
`0.4` (default) | `scalar`

Static loaded radius, in m, specified as a scalar.

`Overall steer ratio, OvrlStrRatio` — Overall steer ratio
`17.42` (default) | `scalar`

Overall steer ratio, specified as a scalar.

`Steering angle breakpoints, StrgAngBpts` — Steering angle breakpoints
`[-6.2832 -5.0265 -3.7699 -2.5133 -1.2566 0 1.2566 2.5133 3.7699 5.0265 6.2832]` (default)

Steering angle breakpoints, in rad, specified as a `1`-by-`11` vector.

Dependencies

To enable this parameter, set one of these parameters to `Lookup table`:

- **Rack and pinion > Rack gain parameterized by**
- **Ackerman steering > Percent Ackerman parameterized by**

`Caster angle, CstrAng` — Caster angle
`0` (default) | `scalar`

Caster angle, in rad, specified as a scalar.

Dependencies

To enable this parameter, select **Input signals > Kingpin moment**.

Rack and Pinion

`Rack gain parametrized by` — Rack gain parametrization
`Constant` (default) | `Lookup table`

Whether to parametrize the rack gain as a constant value or by using a lookup table.

`Rack gain, RckGn` — Rack gain
`0.062` (default) | `scalar`

Rack gain, in m/rev, specified as a scalar.

Dependencies

To enable this parameter, set **Rack gain parametrized by** to `Constant`.

`Rack gain table, RckGnTbl` — Rack gain table
`ones(1,11)*0.0057*2*pi` (default) | `1-by-11 vector`

Rack gain table, in m/rev, specified as a 1-by-11 vector.

Dependencies

To enable this parameter, set **Rack gain parametrized by** to `Lookup table`.

`Steering arm length, StrgArmLngth` — Steering arm length
`0.1` (default) | `scalar`

Steering arm length, in m, specified as a scalar.

`Rack casing length, RckCsLngth` — Rack casing length
`0.5` (default) | `scalar`

Rack casing length, in m, specified as a scalar.

`Tie rod length, TieRodLngth` — Tie rod length
`0.248` (default) | `scalar`

Tie rod length, l_{rod}, in m, specified as a scalar.

`Distance between axis and rack, Dst` — Distance between front axis and rack
`0.2` (default) | `scalar`

Distance between the front axis and rack, D, in m, specified as a scalar.

`Efficiency of gears, Epsilon` — Efficiency of gears
`0.9` (default) | `scalar`

Efficiency of the gears, ε, specified as a scalar.

`Pinion inertia, PnInert` — Pinion inertia
`0.1` (default) | `scalar`

Pinion inertia, in kg*m^2, specified as a scalar.

Single Cardan Joint

`Spatial angle for the single Cardan joint, SptlAng` — Spatial angle for single cardan joint
`2.6178` (default) | `scalar`

Spatial angle for the single cardan joint, in rad, specified as a scalar.

Dependencies

To enable this parameter, set **Intermediate shaft type** to `Single Cardan joint`.

Double Cardan Joints

`Spatial angle for the upper Cardan joint, Alpha_b` — Spatial angle for upper cardan joint

`2.6178` (default) | `scalar`

Spatial angle for the upper cardan joint, in rad, specified as a scalar.

Dependencies

To enable this parameter, set **Intermediate shaft type** to `Double Cardan joints`.

`Spatial angle for the lower Cardan joints, Alpha_c` — Spatial angle for lower cardan joints

`2.7051` (default) | `scalar`

Spatial angle for the lower cardan joints, in rad, specified as a scalar.

Dependencies

To enable this parameter, set **Intermediate shaft type** to `Double Cardan joints`.

`Edge view angle between the planes of the two joints, Sigma_bc` — Edge view angle between planes of the two joints

`0.2618` (default) | `scalar`

Edge view angle between the planes of the two joints, in rad, specified as a scalar.

Dependencies

To enable this parameter, set **Intermediate shaft type** to `Double Cardan joints`.

`Phase angle, Gamma` — Phase angle

`0.2618` (default) | `scalar`

Phase angle, in rad, specified as a scalar.

Dependencies

To enable this parameter, set **Intermediate shaft type** to `Double Cardan joints`.

Power Assist

`Steering wheel torque breakpoints, TrqBpts` — Steering wheel torque breakpoints

`[-100 0 100]` (default) | 1-by-*M* vector

Steering wheel torque breakpoints, in N·m, specified as a 1-by-*M* vector.

Dependencies

To enable this parameter, select **Power assist**.

`Vehicle speed breakpoints, VehSpdBpts` — Vehicle speed breakpoints

`[0 20]` (default) | 1-by-*N* vector

Vehicle speed breakpoints, in m/s, specified as a 1-by-*N* vector.

Dependencies

To enable this parameter, select **Power assist**.

`Assisting torque table, TrqTbl` — Assisting torque table

`[0 -100;0 0;0 100]` (default) | *M*-by-*N* matrix

Assisting torque table, f_{trq}, in N·m, specified as an *M*-by-*N* matrix.

The torque assist lookup table is a function of the vehicle speed, v, and steering wheel input torque, τ_{in}:

$\tau_{ast} = f_{trq}(v, \tau_{in})$.

The block uses the steering wheel input torque and torque assist to calculate the steering dynamics.

Dependencies

To enable this parameter, select **Power assist**.

`Assisting torque limit, TrqLmt` — Assisting torque limit

`100` (default) | `scalar`

Assisting torque limit, in N·m, specified as a scalar.

Dependencies

To enable this parameter, select **Power assist**.

`Assisting power limit, PwrLmt` — Assisting power limit

`1000` (default) | `scalar`

Assisting power limit, in N·m/s, specified as a scalar.

Dependencies

To enable this parameter, select **Power assist**.

`Assisting torque efficiency, Eta` — Assisting torque efficiency

`1` (default) | `scalar`

Assisting torque efficiency, specified as a scalar.

Dependencies

To enable this parameter, select **Power assist**.

`Cutoff frequency, CutOmege [rad/s]` — Cutoff frequency

`200` (default) | `scalar`

Cutoff frequency, in rad/s, specified as a scalar.

Dependencies

To enable this parameter, select **Power assist**.

Ackerman Steering

`Percent Ackerman parametrized by` — Ackerman parametrization

`Constant` (default) | `Lookup table`

Whether to parametrize the Ackerman values as a constant value or by using a lookup table.

Dependencies

To enable this parameter, select **Ackerman steering**.

`Percent Ackerman, PctAck` — Percent Ackerman

`100` (default) | `scalar`

Percent Ackerman, specified as a scalar.

Dependencies

To enable this parameter, select **Ackerman steering** and set **Percent Ackerman parametrized by** to `Constant`.

`Percent Ackerman table, PctAckTbl` — Percent Ackerman table

`ones(1,11)*100` (default)

Percent Ackerman table, specified as a 1-by-11 vector.

Dependencies

To enable this parameter, select **Ackerman steering** and set **Percent Ackerman parametrized by** to `Lookup table`.

Friction and Compliance

`Sealing stiffness, SlgStf` — Sealing stiffness

`1.5e4` (default) | `scalar`

Sealing stiffness, in N*m/rad, specified as a scalar.

`Upper boundary friction, UpprFric` — Upper boundary friction

`1` (default) | `scalar`

Upper boundary friction, in N, specified as a scalar.

`Pressure change due to friction boundary increase, PrsFric` — Pressure change due to friction boundary increase

`1e-5` (default) | `scalar`

Pressure change due to friction boundary increase, in N/bar, specified as a scalar.

`Maxwell element stiffness, MaxStf` — Maxwell element stiffness

`10000` (default) | `scalar`

Maxwell element stiffness, in Nm/rad, specified as a scalar.

`Maxwell element upper boundary friction, MaxUpprFric` — Maxwell element upper boundary friction

`0.2` (default) | `scalar`

Maxwell element upper boundary friction, in N, specified as a scalar.

`Maxwell linear damping coefficient, MaxDamp` — Maxwell linear damping coefficient
`1` (default) | `scalar`

Maxwell linear damping coefficient, specified as a scalar.

`Torsion bar stiffness coefficient, TorStf` — Torsion bar stiffness coefficient
`30` (default) | `scalar`

Torsion bar stiffness coefficient, in N*m/rad, specified as a scalar.

`Torsion bar damping coefficient, TorDamp` — Torsion bar damping coefficient
`1` (default) | `scalar`

Torsion bar damping coefficient, in N*m*s/rad, specified as a scalar.

Version History

Introduced in R2022b

References

[1] Crolla, David, David Foster, et al. *Encyclopedia of Automotive Engineering*. Volume 4, Part 5 *(Chassis Systems)* and Part 6 *(Electrical and Electronic Systems)*. Chichester, West Sussex, United Kingdom: John Wiley & Sons Ltd, 2015.

[2] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[3] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

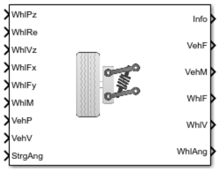
Kinematic Steering | Mapped Steering

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Independent Suspension - Double Wishbone

Double wishbone independent suspension
Library: Vehicle Dynamics Blockset / Suspension



Description

The Independent Suspension - Double Wishbone block implements an independent double wishbone suspension for multiple axles with multiple wheels per axle.

The block models the suspension compliance, damping, and geometric effects as functions of the relative positions and velocities of the vehicle and wheel carrier with axle-specific compliance and damping parameters. Using the suspension compliance and damping, the block calculates the suspension force on the vehicle and wheel. The block uses the Z-down coordinate system (defined in SAE J670).

For Each	You Can Specify
Axle	• Multiple wheels • An anti-sway bar for axles with two wheels • Suspension parameters
Wheel	• Steering angles

The block contains energy-storing spring elements and energy-dissipating damper elements. It does not contain energy-storing mass elements. The block assumes that the vehicle (sprung) and wheel (unsprung) blocks connected to the block store the mass-related suspension energy.

This table summarizes the block parameter settings for a vehicle with:

- Two axles
- Two wheels per axle
- Steering angle input for both wheels on the front axle
- An anti-sway bar on the front axle

Parameter	Setting
Number of axles, NumAxl	2
Number of wheels by axle, NumWhlsByAxl	`[2 2]`
Steered axle enable by axle, StrgEnByAxl	`[1 0]`
Anti-sway axle enable by axle, AntiSwayEnByAxl	`[1 0]`

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Suspension Compliance and Damping

The block uses a linear spring and damper to model the vertical dynamic effects of the suspension system. Using the relative positions and velocities of the vehicle and wheel carrier, the block calculates the vertical suspension forces on the wheel and vehicle. The block uses a linear equation that relates the vertical damping and compliance to the suspension height, suspension height rate of change, and absolute value of the steering angles.

The block implements this equation.

$$F_{wz_{a,t}} = F_{z0_a} + k_{z_a}(z_{v_{a,t}} - z_{w_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|) + c(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}) + F_{zhstop_{a,t}} + F_{zaswy_{a,t}}$$

The damping coefficient, c, depends on the **Enable active damping** parameter setting.

Enable active damping Setting	Damping
`off`	Constant, $c = c_{z_a}$
`on`	Lookup table that is a function of active damper duty cycle and actuator velocity $$c = f\left(duty, (\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}})\right)$$

The block assumes that the suspension elements have no mass. Therefore, the suspension forces and moments applied to the vehicle are equal to the suspension forces and moments applied to the wheel.

$$F_{vx_{a,t}} = F_{wx_{a,t}}$$
$$F_{vy_{a,t}} = F_{wy_{a,t}}$$
$$F_{vz_{a,t}} = -F_{wz_{a,t}}$$

$$M_{vx_{a,t}} = M_{wx_{a,t}} + F_{wy_{a,t}}(Re_{wy_{a,t}} + H_{a,t})$$
$$M_{vy_{a,t}} = M_{wy_{a,t}} + F_{wx_{a,t}}\left(Re_{wx_{a,t}} + H_{a,t}\right)$$
$$M_{vz_{a,t}} = M_{wz_{a,t}}$$

The block sets the wheel positions and velocities equal to the vehicle lateral and longitudinal positions and velocities.

$$x_{w_{a,t}} = x_{v_{a,t}}$$

$$y_{w_{a,t}} = y_{v_{a,t}}$$

$$\dot{x}_{w_{a,t}} = \dot{x}_{v_{a,t}}$$

$$\dot{y}_{w_{a,t}} = \dot{y}_{v_{a,t}}$$

The equations use these variables.

$F_{wz_{a,t}}$, $M_{wz_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{wx_{a,t}}$, $M_{wx_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{wy_{a,t}}$, $M_{wy_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *y*-axis
$F_{vz_{a,t}}$, $M_{vz_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{vx_{a,t}}$, $M_{vx_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{vy_{a,t}}$, $M_{vy_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *y*-axis
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
k_{z_a}	Vertical spring constant applied to wheels on axle `a`
kwa_z	Wheel and axle interface compliance constant
m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
c_{z_a}	Vertical damping constant applied to wheels on axle `a`
cwa_z	Wheel and axle interface damping constant
$Re_{w_{a,t}}$	Effective wheel radius for axle `a`, wheel `t`
$F_{zhstop_{a,t}}$	Vertical hardstop force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$F_{zaswy_{a,t}}$	Vertical anti-sway force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
Fwa_{z0}	Wheel and axle interface compliance constant
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{v_{a,t}}$, $\dot{x}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{w_{a,t}}$, $\dot{x}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$y_{v_{a,t}}$, $\dot{y}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis

$y_{w_{a,t}}$, $\dot{y}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$H_{a,t}$	Suspension height at axle `a`, wheel `t`
$Re_{w_{a,t}}$	Effective wheel radius at axle `a`, wheel `t`

Hardstop Forces

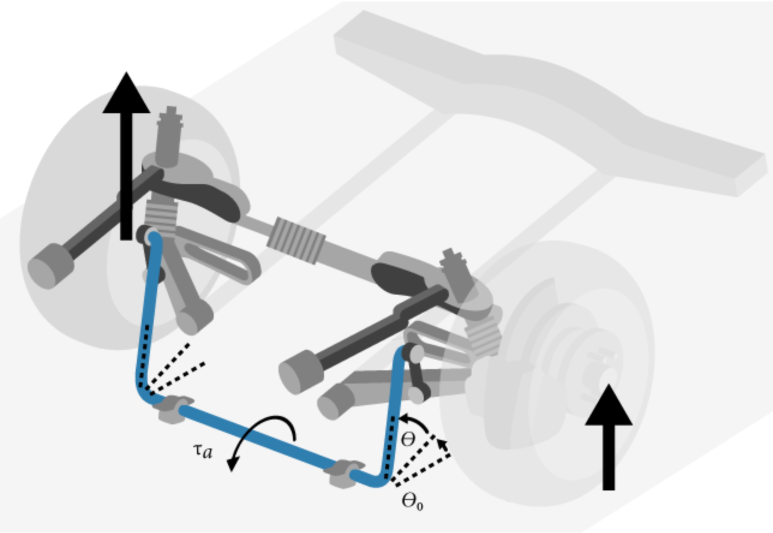
The hardstop feedback force, $F_{zhstop_{a,t}}$, that the block applies depends on whether the suspension is compressing or extending. The block applies the force:

- In compression, when the suspension is compressed more than the maximum distance specified by the **Suspension maximum height, Hmax** parameter.
- In extension, when the suspension extension is greater than maximum extension specified by the **Suspension maximum height, Hmax** parameter.

To calculate the force, the block uses a stiffness based on a hyperbolic tangent and exponential scaling.

Anti-Sway Bar

Optionally, use the **Anti-sway axle enable by axle, AntiSwayEnByAxl** parameter to implement an anti-sway bar force, $F_{zaswy_{a,t}}$, for axles that have two wheels. This figure shows how the anti-sway bar transmits torque between two independent suspension wheels on a shared axle. Each independent suspension applies a torque to the anti-sway bar via a radius arm that extends from the anti-sway bar back to the independent suspension connection point.



To calculate the sway bar force, the block implements these equations.

Calculation	Equation
Anti-sway bar angular deflection for a given axle and wheel, $\Delta\Theta_{a,t}$	$\theta_{0a} = \tan^{-1}\left(\frac{z_0}{r}\right)$ $\Delta\theta_{a,t} = \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,t}} + z_{v_{a,t}}}{r}\right)$

Calculation	**Equation**
Anti-sway bar twist angle, Θ_a	$\theta_a = -\tan^{-1}\left(\frac{\mathrm{rtan}\theta_{0a} - z_{w_{a,1}} + z_{v_{a,1}}}{r}\right)$ $-\tan^{-1}\left(\frac{r\mathrm{tan}\theta_{0a} - z_{w_{a,2}} + z_{v_{a,2}}}{r}\right)$
Anti-sway bar torque, τ_a	$\tau_a = k_a\theta_a$
Anti-sway bar forces applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis	$F_{zaswy_{a,1}} = \left(\frac{\tau_a}{r}\right)\cos\left(\theta_{0a} - \tan^{-1}\left(\frac{\mathrm{rtan}\theta_{0a} - z_{w_{a,1}} + z_{v_{a,1}}}{r}\right)\right)$ $F_{zaswy_{a,2}} = \left(\frac{\tau_a}{r}\right)\cos\left(\theta_{0a} - \tan^{-1}\left(\frac{\mathrm{rtan}\theta_{0a} - z_{w_{a,2}} + z_{v_{a,2}}}{r}\right)\right)$

The equations and figure use these variables.

τ_a	Anti-sway bar torque
θ	Anti-sway bar twist angle
θ_{0a}	Initial anti-sway bar twist angle
$\Delta\Theta_{a,t}$	Anti-sway bar angular deflection at axle `a`, wheel `t`
r	Anti-sway bar arm radius
z_0	Vertical distance from anti-sway bar connection point to anti-sway bar centerline
$F_{zsway_{a,t}}$	Anti-sway bar force applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Camber, Caster, and Toe Angles

To calculate the camber, caster, and toe angles, block uses linear functions of the suspension height and steering angle.

$$\xi_{a,t} = \xi_{0a} + m_{hcamber_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{cambersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\eta_{a,t} = \eta_{0a} + m_{hcaster_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{castersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\zeta_{a,t} = \zeta_{0a} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equations use these variables.

$\xi_{a,t}$	Camber angle of wheel on axle `a`, wheel `t`
$\eta_{a,t}$	Caster angle of wheel on axle `a`, wheel `t`
$\zeta_{a,t}$	Toe angle of wheel on axle `a`, wheel `t`
ξ_{0a}, η_{0a}, ζ_{0a}	Nominal suspension axle a camber, caster, and toe angles, respectively, at zero steering angle
$m_{hcamber_a}$, $m_{hcaster_a}$, m_{htoe_a}	Camber, caster, and toe angles, respectively, versus suspension height slope for axle `a`

$m_{camberstee r_a}$, $m_{castersteer_a}$, $m_{toesteer_a}$	Camber, caster, and toe angles, respectively, versus steering angle slope for axle `a`
m_{hsteer_a}	Steering angle versus vertical force slope for axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Steering Angles

Optionally, use the **Steered axle enable by axle, StrgEnByAxl** parameter to input steering angles for the wheels. To calculate the steering angles for the wheels, the block offsets the input steering angles with a linear function of the suspension height.

$$\delta_{whlsteer_{a,t}} = \delta_{steer_{a,t}} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equation uses these variables.

$m_{toesteer_a}$	Axle `a` toe angle versus steering angle slope
m_{hsteer_a}	Axle `a` steering angle versus vertical force slope
m_{htoe_a}	Axle `a` toe angle versus suspension height slope
$\delta_{whlsteer_{a,t}}$	Wheel steering angle for axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Power and Energy

The block calculates these suspension characteristics for each axle, `a`, wheel, `t`.

Calculation	Equation
Dissipated power, $P_{susp_{a,t}}$	$P_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Absorbed energy, $E_{susp_{a,t}}$	$E_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Suspension height, $H_{a,t}$	$H_{a,t} = -\left(z_{v_{a,t}} - z_{w_{a,t}} + \dfrac{F_{z0_a}}{k_{z_a}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right)$
Distance from wheel carrier center to tire/road interface	$z_{wtr_{a,t}} = Re_{w_{a,t}} + H_{a,t}$

The equations use these variables.

m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$Re_{w_{a,t}}$	Axle `a`, wheel `t` effective wheel radius from wheel carrier center to tire/road interface
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`

$z_{wtr_{a,t}}$	Distance from wheel carrier center to tire/road interface, along the vehicle-fixed *z*-axis
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Ports

Input

`WhlPz` — Wheel z-axis displacement
`array`

Wheel displacement, z_w, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlPz} = z_w = \left[z_{w_{1,1}} \; z_{w_{1,2}} \; z_{w_{2,1}} \; z_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius
`array`

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlRe} = Re_w = \left[Re_{w_{1,1}} \; Re_{w_{1,2}} \; Re_{w_{2,1}} \; Re_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel z-axis velocity
`array`

Wheel velocity, $\dot{z}_w$, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}}\ \dot{z}_{w_{1,2}}\ \dot{z}_{w_{2,1}}\ \dot{z}_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

array

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed x-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

array

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed y-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

`array`

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed *x*-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed *y*-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\mathrm{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement

`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed x-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed y-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed z-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\mathrm{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(1,1)`	1	1	Vehicle-fixed x-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed y-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity
`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\mathrm{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Axis
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}} \;\; \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Wheel	**Array Element**	**Axle**	**Wheel Number**
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2

- 3D array signal (3-by-4)

Wheel	**Array Element**	**Axle**	**Wheel Number**
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2
Front left	`(2,1)`	1	1
Front right	`(2,2)`	1	2
Rear left	`(2,3)`	2	1
Rear right	`(2,4)`	2	2
Front left	`(3,1)`	1	1
Front right	`(3,2)`	1	2
Rear left	`(3,3)`	2	1
Rear right	`(3,4)`	2	2

Signal	**Description**	**Array Signal**	**Variable**	**Units**
`Camber`	Wheel angles according to the axle and wheel location.	1D	$\mathrm{WhlAng}[1,\ldots] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\mathrm{WhlAng}[2,\ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\mathrm{WhlAng}[3,\ldots] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J

Signal	Description	Array Signal	Variable	Units
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N

Signal	Description	Array Signal	Variable	Units
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} = \begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix}$ $= \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle
`array`

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle
`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\mathrm{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity
`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\text{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles
`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.

- Signal contains angles according to the axle and wheel locations.

$$\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

`Enable active damping` — Include damping

`off` (default) | `off`

Include damping

Dependencies

Selecting this parameter creates:

- **Damping coefficient map, f_act_susp_cz**
- **Damping actuator duty cycle breakpoints, f_act_susp_duty_bpt**

- **Damping actuator velocity breakpoints, f_act_susp_zdot_bpt**

`Number of axles, NumAxl` — Number of axles

`2` (default) | `scalar`

Number of axles, N_a, dimensionless.

`Number of wheels by axle, NumWhlsByAxl` — Number of wheels per axle

`[2 2]` (default) | `vector`

Number of wheels per axle, Nt_a, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example, `[1,2]` represents one wheel on axle one and two wheels on axle two.

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering

`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]` — For a two-axle vehicle, enables axle 1 steering and disables axle 2 steering
- `[1 1]` — For a two-axle vehicle, enables axle 1 and axle 2 steering

Dependencies

Setting any element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1 creates:

- Input port `StrgAng`.
- Parameters:
  - **Toe angle vs steering angle slope, ToeStrgSlp**
  - **Caster angle vs steering angle slope, CasterStrgSlp**
  - **Camber angle vs steering angle slope, CamberStrgSlp**
  - **Suspension height vs steering angle slope, StrgHgtSlp**

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

`Anti-sway axle enable by axle, AntiSwayEnByAxl` — Boolean vector to enable axle anti-sway

`[0 0]` (default) | `vector`

Boolean vector that enables axle anti-sway for axle a, dimensionless. For example, `[1 0]` enables axle 1 anti-sway and disables axle 2 anti-sway. Vector is `1` by the number of vehicle axles, N_a.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

Suspension

Compliance and Damping - Passive

`Suspension spring constant, Kz` — Suspension spring constant
`64370` (default) | `scalar` | `vector`

Linear vertical spring constant for independent suspension wheels on axle a, k_{z_a}, in N/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension spring preload, F0z` — Suspension spring preload
`9810` (default) | `scalar` | `vector`

Vertical preload spring force applied to the wheels on the axle at wheel carrier reference coordinates, F_{z0_a}, in N. Positive preload forces:

- Cause the vehicle to lift.
- Point along the negative vehicle-fixed z-axis.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension shock damping constant, Cz` — Suspension shock damping constant
`10000` (default) | `scalar` | `vector`

Linear vertical damping constant for independent suspension wheels on axle a, c_{z_a}, in Ns/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create this parameter, clear **Enable active damping**.

`Suspension maximum height, Hmax` — Height
`0.5` (default) | `scalar` | `vector`

Maximum suspension extension or minimum suspension compression height, H_{max}, for axle `a` before the suspension reaches a hardstop, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Compliance and Damping - Active

`Damping coefficient map, f_act_susp_cz` — Lookup table

`[10000 10000;10000 10000]` (default) | `M`-by-`N` array

Damping coefficient table as a function of active duty cycle and actuator compression velocity, in N·s/m. Each value specifies the damping for a specific combination of actuator duty cycle and velocity. The array dimensions must match the duty cycle, `M`, and actuator velocity, `N`, breakpoint vector dimensions.

Dependencies

To create this parameter, clear **Enable active damping**.

`Damping actuator duty cycle breakpoints, f_act_susp_duty_bpt` — Duty cycle breakpoints

`[0 1]` (default) | 1-by-`M` vector

Damping actuator duty cycle breakpoints, dimensionless.

Dependencies

To create this parameter, clear **Enable active damping**.

`Damping actuator velocity breakpoints, f_act_susp_zdot_bpt` — Velocity breakpoints

`[-1 1]` (default) | 1-by-`N` vector

Damping actuator velocity breakpoints, in m/s.

Dependencies

To create this parameter, clear **Enable active damping**.

Geometry

`Toe angle at steering center, Toe` — Toe angle

`0.0349` (default) | `scalar`

Nominal suspension toe angle at zero steering angle, ζ_{0a}, in rad.

`Roll steer vs suspension height slope, RollStrgSlp` — Steer angle suspension slope

`-0.2269` (default) | `scalar` | `vector`

Roll steer angle versus suspension height, m_{htoe_a}, in rad/m.

Vector is 1 by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Toe angle vs steering angle slope, ToeStrgSlp` — Toe angle steering slope

`0.01` (default) | `scalar` | `vector`

Toe angle versus steering angle slope, $m_{toesteer_a}$, dimensionless.

Vector is 1 by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Caster angle at steering center, Caster` — Caster angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension caster angle at zero steering angle, η_{0a}, in rad.

`Caster angle vs suspension height slope, CasterHslp` — Caster angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Caster angle versus suspension height, $m_{hcaster_a}$, in rad/m.

Vector is 1 by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Caster angle vs steering angle slope, CasterStrgSlp` — Caster angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Caster angle versus steering angle slope, $m_{castersteer_a}$, dimensionless.

Vector is 1 by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Camber angle at steering center, Camber` — Camber angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension camber angle at zero steering angle, ξ_{0a}, in rad.

`Camber angle vs suspension height slope, CamberHslp` — Camber angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Camber angle versus suspension height, $m_{hcamber_a}$, in rad/m.

Vector is 1 by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Camber angle vs steering angle slope, CamberStrgSlp` — Camber angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Camber angle versus steering angle slope, $m_{cambersteer_a}$, dimensionless.

Vector is 1 by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Suspension height vs steering angle slope, StrgHgtSlp` — Suspension height versus steering angle slope

`0.1432` (default) | `scalar` | `vector`

Steering angle to vertical force slope applied at suspension wheel carrier reference point, m_{hsteer_a}, in m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Anti-Sway

`Anti-sway arm radius, AntiSwayR` — Anti-sway arm radius

`0.2` (default) | `scalar` | `vector`

Anti-sway arm radius, r, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

`Anti-sway arm neutral angle, AntiSwayNtrlAng` — Anti-sway arm neutral angle

`0.5236` (default) | `scalar` | `vector`

Anti-sway arm neutral angle, θ_{0a}, at nominal suspension height, in rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

`Anti-sway torsion spring constant, AntiSwayTrsK` — Anti-sway torsion spring constant

`5.7296e+03` (default) | `scalar` | `vector`

Anti-sway bar torsion spring constant, k_a, in N·m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

Version History

Introduced in R2018a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

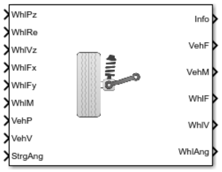
See Also

Independent Suspension - MacPherson | Independent Suspension - Mapped | Independent Suspension - K and C

Independent Suspension - MacPherson

MacPherson independent suspension

Library: Vehicle Dynamics Blockset / Suspension



Description

The Independent Suspension - MacPherson block implements an independent MacPherson suspension for multiple axles with multiple wheels per axle.

The block models the suspension compliance, damping, and geometric effects as functions of the relative positions and velocities of the vehicle and wheel carrier with axle-specific compliance and damping parameters. Using the suspension compliance and damping, the block calculates the suspension force on the vehicle and wheel. The block uses the Z-down coordinate system (defined in SAE J670).

For Each	You Can Specify
Axle	• Multiple wheels • An anti-sway bar for axles with two wheels • Suspension parameters
Wheel	• Steering angles

The block contains energy-storing spring elements and energy-dissipating damper elements. It does not contain energy-storing mass elements. The block assumes that the vehicle (sprung) and wheel (unsprung) blocks connected to the block store the mass-related suspension energy.

This table summarizes the block parameter settings for a vehicle with:

- Two axles
- Two wheels per axle
- Steering angle input for both wheels on the front axle
- An anti-sway bar on the front axle

Parameter	Setting
Number of axles, NumAxl	2
Number of wheels by axle, NumWhlsByAxl	`[2 2]`
Steered axle enable by axle, StrgEnByAxl	`[1 0]`
Anti-sway axle enable by axle, AntiSwayEnByAxl	`[1 0]`

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Suspension Compliance and Damping

The block uses a linear spring and damper to model the vertical dynamic effects of the suspension system. Using the relative positions and velocities of the vehicle and wheel carrier, the block calculates the vertical suspension forces on the wheel and vehicle. The block uses a linear equation that relates the vertical damping and compliance to the suspension height, suspension height rate of change, and absolute value of the steering angles.

The block implements this equation.

$$F_{wz_{a,t}} = F_{z0_a} + k_{z_a}(z_{v_{a,t}} - z_{w_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|) + c(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}) + F_{zhstop_{a,t}} + F_{zaswy_{a,t}}$$

The damping coefficient, c, depends on the **Enable active damping** parameter setting.

Enable active damping Setting	Damping
`off`	Constant, $c = c_{z_a}$
`on`	Lookup table that is a function of active damper duty cycle and actuator velocity $c = f\left(duty, (\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}})\right)$

The block assumes that the suspension elements have no mass. Therefore, the suspension forces and moments applied to the vehicle are equal to the suspension forces and moments applied to the wheel.

$$F_{vx_{a,t}} = F_{wx_{a,t}}$$

$$F_{vy_{a,t}} = F_{wy_{a,t}}$$

$$F_{vz_{a,t}} = -F_{wz_{a,t}}$$

$$M_{vx_{a,t}} = M_{wx_{a,t}} + F_{wy_{a,t}}(Re_{wy_{a,t}} + H_{a,t})$$

$$M_{vy_{a,t}} = M_{wy_{a,t}} + F_{wx_{a,t}}\left(Re_{wx_{a,t}} + H_{a,t}\right)$$

$$M_{vz_{a,t}} = M_{wz_{a,t}}$$

The block sets the wheel positions and velocities equal to the vehicle lateral and longitudinal positions and velocities.

$$x_{w_{a,t}} = x_{v_{a,t}}$$

$$y_{w_{a,t}} = y_{v_{a,t}}$$

$$\dot{x}_{w_{a,t}} = \dot{x}_{v_{a,t}}$$

$$\dot{y}_{w_{a,t}} = \dot{y}_{v_{a,t}}$$

The equations use these variables.

$F_{wz_{a,t}}$, $M_{wz_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{wx_{a,t}}$, $M_{wx_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{wy_{a,t}}$, $M_{wy_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *y*-axis
$F_{vz_{a,t}}$, $M_{vz_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{vx_{a,t}}$, $M_{vx_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{vy_{a,t}}$, $M_{vy_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *y*-axis
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
k_{z_a}	Vertical spring constant applied to wheels on axle `a`
kwa_z	Wheel and axle interface compliance constant
m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
c_{z_a}	Vertical damping constant applied to wheels on axle `a`
cwa_z	Wheel and axle interface damping constant
$Re_{w_{a,t}}$	Effective wheel radius for axle `a`, wheel `t`
$F_{zhstop_{a,t}}$	Vertical hardstop force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$F_{zaswy_{a,t}}$	Vertical anti-sway force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
Fwa_{z0}	Wheel and axle interface compliance constant
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{v_{a,t}}$, $\dot{x}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{w_{a,t}}$, $\dot{x}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$y_{v_{a,t}}$, $\dot{y}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis

$y_{w_{a,t}}$, $\dot{y}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$H_{a,t}$	Suspension height at axle `a`, wheel `t`
$Re_{w_{a,t}}$	Effective wheel radius at axle `a`, wheel `t`

Hardstop Forces

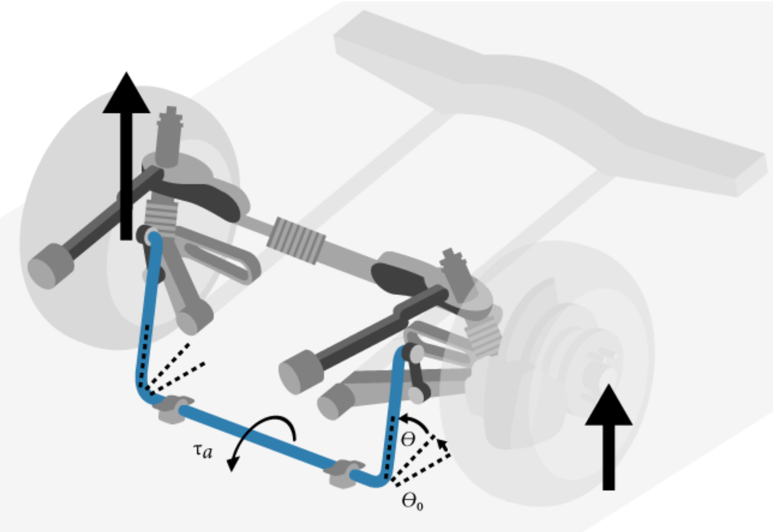
The hardstop feedback force, $F_{zhstop_{a,t}}$, that the block applies depends on whether the suspension is compressing or extending. The block applies the force:

- In compression, when the suspension is compressed more than the maximum distance specified by the **Suspension maximum height, Hmax** parameter.
- In extension, when the suspension extension is greater than maximum extension specified by the **Suspension maximum height, Hmax** parameter.

To calculate the force, the block uses a stiffness based on a hyperbolic tangent and exponential scaling.

Anti-Sway Bar

Optionally, use the **Anti-sway axle enable by axle, AntiSwayEnByAxl** parameter to implement an anti-sway bar force, $F_{zaswy_{a,t}}$, for axles that have two wheels. This figure shows how the anti-sway bar transmits torque between two independent suspension wheels on a shared axle. Each independent suspension applies a torque to the anti-sway bar via a radius arm that extends from the anti-sway bar back to the independent suspension connection point.



To calculate the sway bar force, the block implements these equations.

Calculation	Equation
Anti-sway bar angular deflection for a given axle and wheel, $\Delta\Theta_{a,t}$	$\theta_{0a} = \tan^{-1}\left(\frac{z_0}{r}\right)$ $\Delta\theta_{a,t} = \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,t}} + z_{v_{a,t}}}{r}\right)$

Calculation	**Equation**
Anti-sway bar twist angle, Θ_a	$\theta_a = -\tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,1}} + z_{v_{a,1}}}{r}\right) - \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,2}} + z_{v_{a,2}}}{r}\right)$
Anti-sway bar torque, τ_a	$\tau_a = k_a\theta_a$
Anti-sway bar forces applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis	$F_{zaswy_{a,1}} = \left(\frac{\tau_a}{r}\right)\cos\left(\theta_{0a} - \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,1}} + z_{v_{a,1}}}{r}\right)\right)$ $F_{zaswy_{a,2}} = \left(\frac{\tau_a}{r}\right)\cos\left(\theta_{0a} - \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,2}} + z_{v_{a,2}}}{r}\right)\right)$

The equations and figure use these variables.

τ_a	Anti-sway bar torque
θ	Anti-sway bar twist angle
θ_{0a}	Initial anti-sway bar twist angle
$\Delta\Theta_{a,t}$	Anti-sway bar angular deflection at axle `a`, wheel `t`
r	Anti-sway bar arm radius
z_0	Vertical distance from anti-sway bar connection point to anti-sway bar centerline
$F_{zsway_{a,t}}$	Anti-sway bar force applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Camber, Caster, and Toe Angles

To calculate the camber, caster, and toe angles, block uses linear functions of the suspension height and steering angle.

$$\xi_{a,t} = \xi_{0a} + m_{hcamber_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{craftersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\eta_{a,t} = \eta_{0a} + m_{hcaster_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{castersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\zeta_{a,t} = \zeta_{0a} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equations use these variables.

$\xi_{a,t}$	Camber angle of wheel on axle `a`, wheel `t`
$\eta_{a,t}$	Caster angle of wheel on axle `a`, wheel `t`
$\zeta_{a,t}$	Toe angle of wheel on axle `a`, wheel `t`
ξ_{0a}, η_{0a}, ζ_{0a}	Nominal suspension axle a camber, caster, and toe angles, respectively, at zero steering angle
$m_{hcamber_a}$, $m_{hcaster_a}$, m_{htoe_a}	Camber, caster, and toe angles, respectively, versus suspension height slope for axle `a`

$m_{cambersteer_a}$, $m_{castersteer_a}$, $m_{toesteer_a}$	Camber, caster, and toe angles, respectively, versus steering angle slope for axle `a`
m_{hsteer_a}	Steering angle versus vertical force slope for axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Steering Angles

Optionally, use the **Steered axle enable by axle, StrgEnByAxl** parameter to input steering angles for the wheels. To calculate the steering angles for the wheels, the block offsets the input steering angles with a linear function of the suspension height.

$$\delta_{whlsteer_{a,t}} = \delta_{steer_{a,t}} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equation uses these variables.

$m_{toesteer_a}$	Axle `a` toe angle versus steering angle slope
m_{hsteer_a}	Axle `a` steering angle versus vertical force slope
m_{htoe_a}	Axle `a` toe angle versus suspension height slope
$\delta_{whlsteer_{a,t}}$	Wheel steering angle for axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Power and Energy

The block calculates these suspension characteristics for each axle, `a`, wheel, `t`.

Calculation	Equation
Dissipated power, $P_{susp_{a,t}}$	$P_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Absorbed energy, $E_{susp_{a,t}}$	$E_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Suspension height, $H_{a,t}$	$H_{a,t} = -\left(z_{v_{a,t}} - z_{w_{a,t}} + \frac{F_{z0_a}}{k_{z_a}} + m_{hsteer_a}\left\|\delta_{steer_{a,t}}\right\|\right)$
Distance from wheel carrier center to tire/road interface	$z_{wtr_{a,t}} = Re_{w_{a,t}} + H_{a,t}$

The equations use these variables.

m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$Re_{w_{a,t}}$	Axle `a`, wheel `t` effective wheel radius from wheel carrier center to tire/road interface
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`

$z_{wtr_{a,t}}$	Distance from wheel carrier center to tire/road interface, along the vehicle-fixed *z*-axis
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Ports

Input

`WhlPz` — Wheel z-axis displacement
`array`

Wheel displacement, z_w, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlPz} = z_w = \left[z_{w_{1,1}}\ z_{w_{1,2}}\ z_{w_{2,1}}\ z_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius
`array`

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlRe} = Re_w = \left[Re_{w_{1,1}}\ Re_{w_{1,2}}\ Re_{w_{2,1}}\ Re_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel z-axis velocity
`array`

Wheel velocity, $\dot{z}_w$, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}}\ \dot{z}_{w_{1,2}}\ \dot{z}_{w_{2,1}}\ \dot{z}_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

`array`

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed *x*-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

`array`

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed *y*-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

`array`

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed *x*-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed *y*-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\mathrm{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement
`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\mathrm{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity

`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\mathrm{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Axis
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\mathrm{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}} \ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Wheel	**Array Element**	**Axle**	**Wheel Number**
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2

- 3D array signal (3-by-4)

Wheel	**Array Element**	**Axle**	**Wheel Number**
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2
Front left	`(2,1)`	1	1
Front right	`(2,2)`	1	2
Rear left	`(2,3)`	2	1
Rear right	`(2,4)`	2	2
Front left	`(3,1)`	1	1
Front right	`(3,2)`	1	2
Rear left	`(3,3)`	2	1
Rear right	`(3,4)`	2	2

Signal	**Description**	**Array Signal**	**Variable**	**Units**
`Camber`	Wheel angles according to the axle and wheel location.	1D	$\mathrm{WhlAng}[1,\ldots] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\mathrm{WhlAng}[2,\ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\mathrm{WhlAng}[3,\ldots] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J

Signal	Description	Array Signal	Variable	Units
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N

Signal	Description	Array Signal	Variable	Units
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} = \begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{wy_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix}$ $= \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle
`array`

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle
`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\text{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles

`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.

- Signal contains angles according to the axle and wheel locations.

$$\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

`Enable active damping` — Include damping

`off` (default) | `off`

Include damping

Dependencies

Selecting this parameter creates:

- **Damping coefficient map, f_act_susp_cz**
- **Damping actuator duty cycle breakpoints, f_act_susp_duty_bpt**

- **Damping actuator velocity breakpoints, f_act_susp_zdot_bpt**

`Number of axles, NumAxl` — Number of axles

`2` (default) | `scalar`

Number of axles, N_a, dimensionless.

`Number of wheels by axle, NumWhlsByAxl` — Number of wheels per axle

`[2 2]` (default) | `vector`

Number of wheels per axle, Nt_a, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example, `[1,2]` represents one wheel on axle one and two wheels on axle two.

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering

`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]` — For a two-axle vehicle, enables axle 1 steering and disables axle 2 steering
- `[1 1]` — For a two-axle vehicle, enables axle 1 and axle 2 steering

Dependencies

Setting any element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1 creates:

- Input port `StrgAng`.
- Parameters:
  - **Toe angle vs steering angle slope, ToeStrgSlp**
  - **Caster angle vs steering angle slope, CasterStrgSlp**
  - **Camber angle vs steering angle slope, CamberStrgSlp**
  - **Suspension height vs steering angle slope, StrgHgtSlp**

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

`Anti-sway axle enable by axle, AntiSwayEnByAxl` — Boolean vector to enable axle anti-sway

`[0 0]` (default) | `vector`

Boolean vector that enables axle anti-sway for axle a, dimensionless. For example, `[1 0]` enables axle 1 anti-sway and disables axle 2 anti-sway. Vector is `1` by the number of vehicle axles, N_a.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

Suspension

Compliance and Damping - Passive

`Suspension spring constant, Kz` — Suspension spring constant

`64370` (default) | `scalar` | `vector`

Linear vertical spring constant for independent suspension wheels on axle a, k_{z_a}, in N/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension spring preload, F0z` — Suspension spring preload

`9810` (default) | `scalar` | `vector`

Vertical preload spring force applied to the wheels on the axle at wheel carrier reference coordinates, F_{z0_a}, in N. Positive preload forces:

- Cause the vehicle to lift.
- Point along the negative vehicle-fixed *z*-axis.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension shock damping constant, Cz` — Suspension shock damping constant

`10000` (default) | `scalar` | `vector`

Linear vertical damping constant for independent suspension wheels on axle a, c_{z_a}, in Ns/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create this parameter, clear **Enable active damping**.

`Suspension maximum height, Hmax` — Height

`0.5` (default) | `scalar` | `vector`

Maximum suspension extension or minimum suspension compression height, H_{max}, for axle `a` before the suspension reaches a hardstop, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Compliance and Damping - Active

`Damping coefficient map, f_act_susp_cz` — Lookup table

`[10000 10000;10000 10000]` (default) | `M`-by-`N` array

Damping coefficient table as a function of active duty cycle and actuator compression velocity, in N·s/m. Each value specifies the damping for a specific combination of actuator duty cycle and velocity. The array dimensions must match the duty cycle, `M`, and actuator velocity, `N`, breakpoint vector dimensions.

Dependencies

To create this parameter, clear **Enable active damping**.

`Damping actuator duty cycle breakpoints, f_act_susp_duty_bpt` — Duty cycle breakpoints

`[0 1]` (default) | 1-by-`M` vector

Damping actuator duty cycle breakpoints, dimensionless.

Dependencies

To create this parameter, clear **Enable active damping**.

`Damping actuator velocity breakpoints, f_act_susp_zdot_bpt` — Velocity breakpoints

`[-1 1]` (default) | 1-by-`N` vector

Damping actuator velocity breakpoints, in m/s.

Dependencies

To create this parameter, clear **Enable active damping**.

Geometry

`Toe angle at steering center, Toe` — Toe angle

`0.0349` (default) | `scalar`

Nominal suspension toe angle at zero steering angle, ζ_{0a}, in rad.

`Roll steer vs suspension height slope, RollStrgSlp` — Steer angle suspension slope

`-0.2269` (default) | `scalar` | `vector`

Roll steer angle versus suspension height, m_{htoe_a}, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Toe angle vs steering angle slope, ToeStrgSlp` — Toe angle steering slope

`0.01` (default) | `scalar` | `vector`

Toe angle versus steering angle slope, $m_{toesteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Caster angle at steering center, Caster` — Caster angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension caster angle at zero steering angle, η_{0a}, in rad.

`Caster angle vs suspension height slope, CasterHslp` — Caster angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Caster angle versus suspension height, $m_{hcaster_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Caster angle vs steering angle slope, CasterStrgSlp` — Caster angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Caster angle versus steering angle slope, $m_{castersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Camber angle at steering center, Camber` — Camber angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension camber angle at zero steering angle, ξ_{0a}, in rad.

`Camber angle vs suspension height slope, CamberHslp` — Camber angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Camber angle versus suspension height, $m_{hcamber_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Camber angle vs steering angle slope, CamberStrgSlp` — Camber angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Camber angle versus steering angle slope, $m_{cambersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Suspension height vs steering angle slope, StrgHgtSlp` — Suspension height versus steering angle slope

`0.1432` (default) | `scalar` | `vector`

Steering angle to vertical force slope applied at suspension wheel carrier reference point, m_{hsteer_a}, in m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Anti-Sway

`Anti-sway arm radius, AntiSwayR` — Anti-sway arm radius

`0.2` (default) | `scalar` | `vector`

Anti-sway arm radius, r, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

`Anti-sway arm neutral angle, AntiSwayNtrlAng` — Anti-sway arm neutral angle

`0.5236` (default) | `scalar` | `vector`

Anti-sway arm neutral angle, θ_{0a}, at nominal suspension height, in rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

`Anti-sway torsion spring constant, AntiSwayTrsK` — Anti-sway torsion spring constant

`5.7296e+03` (default) | `scalar` | `vector`

Anti-sway bar torsion spring constant, k_a, in N·m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

Version History

Introduced in R2018a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

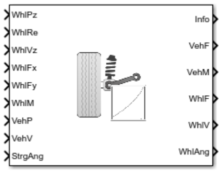
See Also

Independent Suspension - Double Wishbone | Independent Suspension - Mapped | Independent Suspension - K and C

Independent Suspension - Mapped

Mapped independent suspension

Library: Vehicle Dynamics Blockset / Suspension



Description

The Independent Suspension - Mapped block implements a mapped independent suspension for multiple axles with multiple wheels per axle. You can use the block to model suspension geometry, compliance, and damping effects from measured or simulated suspension response data.

The block models the suspension compliance, damping, and geometric effects as functions of the relative positions and velocities of the vehicle and wheel carrier with axle-specific compliance and damping parameters. Using the suspension compliance and damping, the block calculates the suspension force on the vehicle and wheel. The block uses the Z-down coordinate system (defined in SAE J670).

For Each	You Can Specify
Axle	• Multiple wheels • An anti-sway bar for axles with two wheels • Suspension parameters
Wheel	• Steering angles

The block contains energy-storing spring elements and energy-dissipating damper elements. It does not contain energy-storing mass elements. The block assumes that the vehicle (sprung) and wheel (unsprung) blocks connected to the block store the mass-related suspension energy.

This table summarizes the block parameter settings for a vehicle with:

- Two axles
- Two wheels per axle
- Steering angle input for both wheels on the front axle
- An anti-sway bar on the front axle

Parameter	Setting
Number of axles, NumAxl	`2`
Number of wheels by axle, NumWhlsByAxl	`[2 2]`
Steered axle enable by axle, StrgEnByAxl	`[1 0]`
Anti-sway axle enable by axle, AntiSwayEnByAxl	`[1 0]`

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Suspension Compliance and Damping

The block uses a lookup table that relates the vertical damping and compliance to the suspension height, suspension height rate of change, and steering angle. You can calibrate the wheel force lookup table so that steering angle changes from the nominal center position generate a force that increases the vehicle height.

The block implements these equations.

$$F_{wzlookup_a} = f(z_{v_{a,t}} - z_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}})$$

$$F_{wz_{a,t}} = F_{wzlookup_a} + F_{zaswy_{a,t}}$$

The block assumes that the suspension elements have no mass. Therefore, the suspension forces and moments applied to the vehicle are equal to the suspension forces and moments applied to the wheel.

$$F_{vx_{a,t}} = F_{wx_{a,t}}$$

$$F_{vy_{a,t}} = F_{wy_{a,t}}$$

$$F_{vz_{a,t}} = -F_{wz_{a,t}}$$

$$M_{vx_{a,t}} = M_{wx_{a,t}} + F_{wy_{a,t}}(Re_{wy_{a,t}} + H_{a,t})$$

$$M_{vy_{a,t}} = M_{wy_{a,t}} + F_{wx_{a,t}}\left(Re_{wx_{a,t}} + H_{a,t}\right)$$

$$M_{vz_{a,t}} = M_{wz_{a,t}}$$

The block sets the wheel positions and velocities equal to the vehicle lateral and longitudinal positions and velocities.

$$x_{w_{a,t}} = x_{v_{a,t}}$$

$$y_{w_{a,t}} = y_{v_{a,t}}$$

$$\dot{x}_{w_{a,t}} = \dot{x}_{v_{a,t}}$$

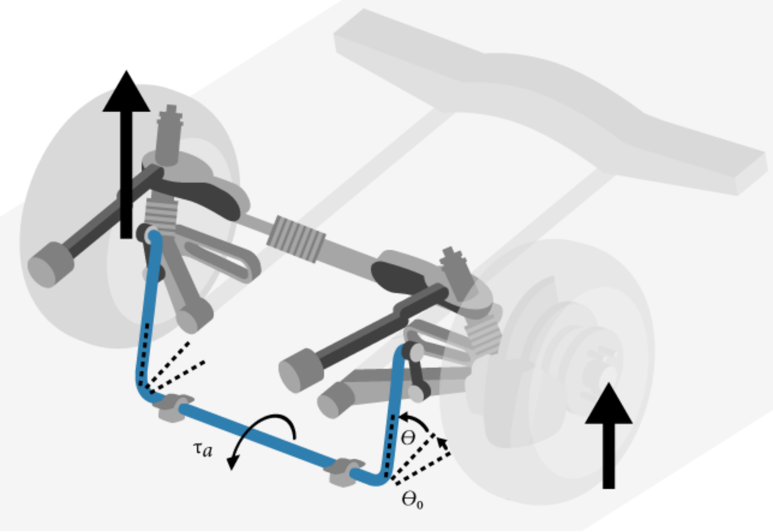
$$\dot{y}_{w_{a,t}} = \dot{y}_{v_{a,t}}$$

The equations use these variables.

$F_{wz_{a,t}}$, $M_{wz_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{wx_{a,t}}$, $M_{wx_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{wy_{a,t}}$, $M_{wy_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *y*-axis
$F_{vz_{a,t}}$, $M_{vz_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{vx_{a,t}}$, $M_{vx_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{vy_{a,t}}$, $M_{vy_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *y*-axis
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
k_{z_a}	Vertical spring constant applied to wheels on axle `a`
kwa_z	Wheel and axle interface compliance constant
m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
c_{z_a}	Vertical damping constant applied to wheels on axle `a`
cwa_z	Wheel and axle interface damping constant
$Re_{w_{a,t}}$	Effective wheel radius for axle `a`, wheel `t`
$F_{zhstop_{a,t}}$	Vertical hardstop force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$F_{zaswy_{a,t}}$	Vertical anti-sway force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
Fwa_{z0}	Wheel and axle interface compliance constant
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{v_{a,t}}$, $\dot{x}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{w_{a,t}}$, $\dot{x}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$y_{v_{a,t}}$, $\dot{y}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$y_{w_{a,t}}$, $\dot{y}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$H_{a,t}$	Suspension height at axle `a`, wheel `t`
$Re_{w_{a,t}}$	Effective wheel radius at axle `a`, wheel `t`

Anti-Sway Bar

Optionally, use the **Anti-sway axle enable by axle, AntiSwayEnByAxl** parameter to implement an anti-sway bar force, $F_{zaswy_{a,t}}$, for axles that have two wheels. This figure shows how the anti-sway bar transmits torque between two independent suspension wheels on a shared axle. Each independent suspension applies a torque to the anti-sway bar via a radius arm that extends from the anti-sway bar back to the independent suspension connection point.



To calculate the sway bar force, the block implements these equations.

Calculation	Equation
Anti-sway bar angular deflection for a given axle and wheel, $\Delta\Theta_{a,t}$	$\theta_{0a} = \tan^{-1}\left(\frac{z_0}{r}\right)$ $\Delta\theta_{a,t} = \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,t}} + z_{v_{a,t}}}{r}\right)$
Anti-sway bar twist angle, Θ_a	$\theta_a = -\tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,1}} + z_{v_{a,1}}}{r}\right)$ $-\tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,2}} + z_{v_{a,2}}}{r}\right)$
Anti-sway bar torque, τ_a	$\tau_a = k_a\theta_a$
Anti-sway bar forces applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis	$F_{zaswy_{a,1}} = \left(\frac{\tau_a}{r}\right)\cos\left(\theta_{0a} - \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,1}} + z_{v_{a,1}}}{r}\right)\right)$ $F_{zaswy_{a,2}} = \left(\frac{\tau_a}{r}\right)\cos\left(\theta_{0a} - \tan^{-1}\left(\frac{r\tan\theta_{0a} - z_{w_{a,2}} + z_{v_{a,2}}}{r}\right)\right)$

The equations and figure use these variables.

τ_a	Anti-sway bar torque
θ	Anti-sway bar twist angle
θ_{0a}	Initial anti-sway bar twist angle
$\Delta\Theta_{a,t}$	Anti-sway bar angular deflection at axle `a`, wheel `t`
r	Anti-sway bar arm radius
z_0	Vertical distance from anti-sway bar connection point to anti-sway bar centerline

$F_{zsway_{a,t}}$	Anti-sway bar force applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Camber, Caster, and Toe Angles

To calculate the camber, caster, and toe angles, the block uses a lookup table, $G_{alookup}$, that is a function of the suspension height and steering angle.

$$[\xi_{a,t}\ \eta_{a,t}\ \zeta_{a,t}] = G_{alookup}f(z_{w_{a,t}} - z_{v_{a,t}}, \delta_{steer_{a,t}})$$

The equations use these variables.

$\xi_{a,t}$	Camber angle of wheel on axle `a`, wheel `t`
$\eta_{a,t}$	Caster angle of wheel on axle `a`, wheel `t`
$\zeta_{a,t}$	Toe angle of wheel on axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along vehicle-fixed *z*-axis

Steering Angles

Optionally, you can input steering angles for the wheels. To calculate the steering angles for the wheels, the block offsets the input steering angles as a function of the suspension height. For the calculation, the block uses a lookup table, $G_{alookup}$, that is a function of the suspension position and steering angle.

$$\delta_{whlsteer_{a,t}} = \delta_{steer_{a,t}} + G_{alookup}f\left(z_{w_{a,t}} - z_{v_{a,t}}, \delta_{steer_{a,t}}\right)$$

The equation uses these variables.

$\delta_{whlsteer_{a,t}}$	Wheel steering angle for axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Power and Energy

The block calculates these suspension characteristics for each axle, `a`, wheel, `t`.

Calculation	Equation
Dissipated power, $P_{susp_{a,t}}$	$P_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Absorbed energy, $E_{susp_{a,t}}$	$E_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Suspension height, $H_{a,t}$	$H_{a,t} = -\left(z_{v_{a,t}} - z_{w_{a,t}} - \text{median}(f\_susp\_dz\_bp)\right)$

Calculation	Equation
Distance from wheel carrier center to tire/road interface	$z_{wtr_{a,t}} = Re_{w_{a,t}} + H_{a,t}$

The equations use these variables.

m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$Re_{w_{a,t}}$	Axle `a`, wheel `t` effective wheel radius from wheel carrier center to tire/road interface
$f\_susp\_dz\_bp$	Vertical axis suspension height breakpoints
$z_{wtr_{a,t}}$	Distance from wheel carrier center to tire/road interface, along the vehicle-fixed z-axis
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed z-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed z-axis

Ports

Input

`WhlPz` — Wheel z-axis displacement

`array`

Wheel displacement, z_w, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlPz} = z_w = \left[z_{w_{1,1}}\ z_{w_{1,2}}\ z_{w_{2,1}}\ z_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius

`array`

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlRe} = Re_w = \left[Re_{w_{1,1}}\ Re_{w_{1,2}}\ Re_{w_{2,1}}\ Re_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel z-axis velocity

`array`

Wheel velocity, $\dot{z}_w$, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}}\ \dot{z}_{w_{1,2}}\ \dot{z}_{w_{2,1}}\ \dot{z}_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

`array`

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed x-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

`array`

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed y-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

`array`

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed *x*-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed *y*-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\text{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement
`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\mathrm{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	

Wheel	Array Element	Axle	Wheel Number	Axis
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity

`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\text{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis

Wheel	Array Element	Axle	Wheel Number	Axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\mathrm{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Wheel	Array Element	Axle	Wheel Number
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2

- 3D array signal (3-by-4)

Wheel	Array Element	Axle	Wheel Number
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2
Front left	`(2,1)`	1	1
Front right	`(2,2)`	1	2
Rear left	`(2,3)`	2	1
Rear right	`(2,4)`	2	2
Front left	`(3,1)`	1	1
Front right	`(3,2)`	1	2
Rear left	`(3,3)`	2	1
Rear right	`(3,4)`	2	2

Signal	Description	Array Signal	Variable	Units
`Camber`	Wheel angles according to the axle and wheel location.	1D	$\mathrm{WhlAng}[1,\ldots] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\mathrm{WhlAng}[2,\ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\mathrm{WhlAng}[3,\ldots] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m

Signal	Description	Array Signal	Variable	Units
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m

Signal	Description	Array Signal	Variable	Units
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} =$ $\begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s

Signal	Description	Array Signal	Variable	Units
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle

array

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\text{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle
`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\mathrm{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	

Array Element	**Axle**	**Wheel Number**	**Moment Axis**
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Force Axis**
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles
`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.
- Signal contains angles according to the axle and wheel locations.

$$\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Angle
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

Axles

`Number of axles, NumAxl` — Number of axles

2 (default) | `scalar`

Number of axles, N_a, dimensionless.

`Number of wheels by axle, NumWhlsByAxl` — Number of wheels per axle

`[2 2]` (default) | `vector`

Number of wheels per axle, Nt_a, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example, `[1,2]` represents one wheel on axle one and two wheels on axle two.

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering

`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]` — For a two-axle vehicle, enables axle 1 steering and disables axle 2 steering
- `[1 1]` — For a two-axle vehicle, enables axle 1 and axle 2 steering

Dependencies

Setting any element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1 creates:

- Input port `StrgAng`.
- Parameters:
  - **Toe angle vs steering angle slope, ToeStrgSlp**
  - **Caster angle vs steering angle slope, CasterStrgSlp**
  - **Camber angle vs steering angle slope, CamberStrgSlp**
  - **Suspension height vs steering angle slope, StrgHgtSlp**

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

`Anti-sway axle enable by axle, AntiSwayEnByAxl` — Boolean vector to enable axle anti-sway

`[0 0]` (default) | `vector`

Boolean vector that enables axle anti-sway for axle *a*, dimensionless. For example, `[1 0]` enables axle 1 anti-sway and disables axle 2 anti-sway. Vector is `1` by the number of vehicle axles, N_a.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

Suspension

Mapped

`Axle breakpoints, f_susp_axl_bp` — Breakpoints

`[1 2]` (default) | 1-by-P array

Axle breakpoints, dimensionless.

`Vertical axis suspension height breakpoints, f_susp_dz_bp` — Breakpoints

1-by-M array

Vertical axis suspension height breakpoints, in m.

`Vertical axis suspension height velocity breakpoints, f_susp_dzdot_bp` — Breakpoints
1-by-N array

Vertical axis suspension height velocity breakpoints, in m/s.

`Vertical axis suspension force and moment responses, f_susp_fmz` — Output array
`zeros(31,31,61,2,4)` (default) | M-by-N-by-O-by-P-by-4 array

Array of output values as a function of:

- Vertical suspension height, *M*
- Vertical suspension height velocity, *N*
- Steering angle, *O*
- Axle, *P*
- 4 output types
  - 1 — Vertical force, in N
  - 2 — User-defined
  - 3 — Stored energy, in J
  - 4 — Absorbed power, in W

The array dimensions must match the breakpoint dimensions

`Suspension geometry responses, f_susp_geom` — Suspension geometry responses
`zeros(31,61,2,3)` (default) | M-by-O-by-P-by-3 array

Array of geometric suspension values as a function of:

- Vertical suspension height, *M*
- Steering angle, *O*
- Axle, *P*
- 3 output types
  - 1 — Camber angle, in rad
  - 2 — Caster angle, in rad
  - 3 — Toe angle, in rad

The array dimensions must match the breakpoint dimensions

`Steering angle breakpoints, f_susp_strgdelta_bp` — Steering angle breakpoints
1-by-O array

Steering angle breakpoints, in rad.

Anti-Sway

`Anti-sway arm radius, AntiSwayR` — Anti-sway arm radius
`0.2` (default) | `scalar` | `vector`

Anti-sway arm radius, *r*, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

`Anti-sway arm neutral angle, AntiSwayNtrlAng` — Anti-sway arm neutral angle

`0.5236` (default) | `scalar` | `vector`

Anti-sway arm neutral angle, θ_{0a}, at nominal suspension height, in rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

`Anti-sway torsion spring constant, AntiSwayTrsK` — Anti-sway torsion spring constant

`5.7296e+03` (default) | `scalar` | `vector`

Anti-sway bar torsion spring constant, k_a, in N·m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

Setting an element of the **Anti-sway axle enable by axle, AntiSwayEnByAxl** vector to 1 creates these anti-sway parameters:

- **Anti-sway arm radius, AntiSwayR**
- **Anti-sway arm neutral angle, AntiSwayNtrlAng**
- **Anti-sway torsion spring constant, AntiSwayTrsK**

Version History

Introduced in R2018a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

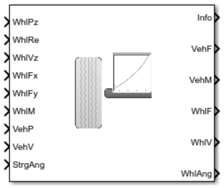
See Also

Independent Suspension - Double Wishbone | Independent Suspension - MacPherson | Independent Suspension - K and C

Solid Axle Suspension - Mapped

Mapped solid axle suspension

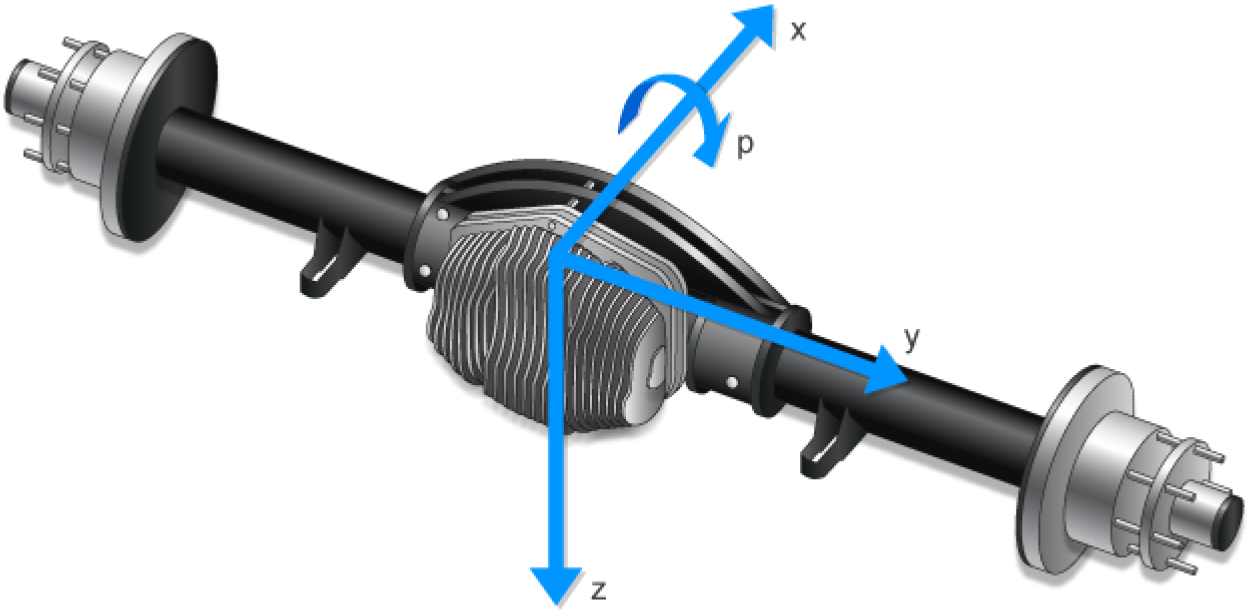
Library: Vehicle Dynamics Blockset / Suspension



Description

The Solid Axle Suspension - Mapped block implements a mapped solid axle suspension for multiple axles with multiple wheels per axle.

The block models the suspension compliance, damping, and geometric effects as functions of the wheel positions and velocities, with axle-specific compliance and damping parameters. Using the wheel position and velocity, the block calculates the vertical wheel position and suspension forces on the vehicle and wheel. The block uses the Z-down (defined in SAE J670) and a solid axle coordinate system. The solid axle coordinate system, shown here, is aligned with the Z-down vehicle coordinate system, with the *x*-axis in the direction of forward vehicle motion.



For Each	You Can Specify
Axle	• Multiple wheels • Suspension parameters
Wheel	• Steering angles

The block contains energy-storing spring elements and energy-dissipating damper elements. The block also stores energy via the axle roll angular acceleration and axle center of mass vertical and lateral acceleration.

This table summarizes the block parameter settings for a vehicle with:

- Two axles
- Two wheels per axle
- Steering angle input for both wheels on the front axle

Parameter	Setting
Number of axles, NumAxl	`2`
Number of wheels by axle, NumWhlsByAxl	`[2 2]`
Steered axle enable by axle, StrgEnByAxl	`[1 0]`

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Suspension Compliance and Damping

The block uses a lookup table that relates the vertical damping and compliance to the suspension height, suspension height rate of change, and steering angle. You can calibrate the wheel force lookup table so that steering angle changes from the nominal center position generate a force that increases the vehicle height. Specifically, the block:

Uses	To Calculate
• Longitudinal and lateral displacement and velocity of the vehicle. • Longitudinal and lateral displacement and velocity of the wheel. • Vertical wheel forces applied to the vehicle.	• Suspension forces applied to the axle center. • Vertical displacements and velocities of the vehicle and wheel. • Longitudinal, lateral, and vertical suspension forces and moments applied to the vehicle. • Longitudinal, lateral, and vertical suspension forces and moments applied to the wheel.

To calculate the dynamics of the axle, the block implements these equations. The block neglects the effects of:

- Lateral and longitudinal translational velocity.
- Angular velocity about the vertical and lateral axes.

$$\begin{bmatrix}\ddot{x}_a\\ \ddot{y}_a\\ \ddot{z}_a\end{bmatrix} = \frac{1}{M_a}\begin{bmatrix}F_{xa}\\ F_{ya}\\ F_{za}\end{bmatrix} + \begin{bmatrix}\dot{x}_a\\ \dot{y}_a\\ \dot{z}_a\end{bmatrix} \times \begin{bmatrix}p\\ q\\ r\end{bmatrix} = \frac{1}{M_a}\begin{bmatrix}0\\ 0\\ F_{za}\end{bmatrix} + \begin{bmatrix}0\\ 0\\ \dot{z}_a\end{bmatrix} \times \begin{bmatrix}p\\ 0\\ 0\end{bmatrix} + \begin{bmatrix}0\\ 0\\ g\end{bmatrix} = \begin{bmatrix}0\\ p\dot{z}_a\\ \frac{F_{za}}{M_a} + g\end{bmatrix}$$

$$\begin{bmatrix}\dot{p}\\ \dot{q}\\ \dot{r}\end{bmatrix} = \left[\begin{bmatrix}M_x\\ M_y\\ M_z\end{bmatrix} - \begin{bmatrix}p\\ q\\ r\end{bmatrix} \times \begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}\begin{bmatrix}p\\ q\\ r\end{bmatrix}\right]\begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}^{-1}$$

$$= \left[\begin{bmatrix}M_x\\ 0\\ 0\end{bmatrix} - \begin{bmatrix}p\\ q\\ 0\end{bmatrix} \times \begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}\begin{bmatrix}p\\ 0\\ 0\end{bmatrix}\right]\begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}^{-1} = \begin{bmatrix}\frac{M_x}{I_{xx}}\\ 0\\ 0\end{bmatrix}$$

For the forces and moments, the block uses lookup tables.

$$F_{wz_{a,t}} = f(z_{v_{a,t}} - z_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}})$$

$$M_{vz_{a,t}} = f(z_{v_{a,t}} - z_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}})$$

The suspension forces and moments applied to the vehicle are equal to the suspension forces and moments applied to the wheel.

$$F_{vx_{a,t}} = F_{wx_{a,t}}$$

$$F_{vy_{a,t}} = F_{wy_{a,t}}$$

$$F_{vz_{a,t}} = -F_{wz_{a,t}}$$

$$M_{vx_{a,t}} = M_{wx_{a,t}} + F_{wy_{a,t}}(Re_{wy_{a,t}} + H_{a,t})$$

$$M_{vy_{a,t}} = M_{wy_{a,t}} + F_{wx_{a,t}}\left(Re_{wx_{a,t}} + H_{a,t}\right)$$

$$M_{vz_{a,t}} = M_{wz_{a,t}}$$

The equations use these variables.

$F_{wz_{a,t}}$, $M_{wz_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{wx_{a,t}}$, $M_{wx_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{wy_{a,t}}$, $M_{wy_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *y*-axis
$F_{vz_{a,t}}$, $M_{vz_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{vx_{a,t}}$, $M_{vx_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{vy_{a,t}}$, $M_{vy_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *y*-axis
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`

k_{z_a}	Vertical spring constant applied to wheels on axle `a`
kwa_z	Wheel and axle interface compliance constant
m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
c_{z_a}	Vertical damping constant applied to wheels on axle `a`
cwa_z	Wheel and axle interface damping constant
$Re_{w_{a,t}}$	Effective wheel radius for axle `a`, wheel `t`
$F_{zhstop_{a,t}}$	Vertical hardstop force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$F_{zaswy_{a,t}}$	Vertical anti-sway force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
Fwa_{z0}	Wheel and axle interface compliance constant
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{v_{a,t}}$, $\dot{x}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{w_{a,t}}$, $\dot{x}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$y_{v_{a,t}}$, $\dot{y}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$y_{w_{a,t}}$, $\dot{y}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$H_{a,t}$	Suspension height at axle `a`, wheel `t`
$Re_{w_{a,t}}$	Effective wheel radius at axle `a`, wheel `t`

Camber, Caster, and Toe Angles

To calculate the camber, caster, and toe angles, the block uses a lookup table, $G_{alookup}$, that is a function of the suspension height and steering angle.

$$[\xi_{a,t}\ \eta_{a,t}\ \zeta_{a,t}] = G_{alookup}f(z_{w_{a,t}} - z_{v_{a,t}}, \delta_{steer_{a,t}})$$

The equations use these variables.

$\xi_{a,t}$	Camber angle of wheel on axle `a`, wheel `t`
$\eta_{a,t}$	Caster angle of wheel on axle `a`, wheel `t`
$\zeta_{a,t}$	Toe angle of wheel on axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along vehicle-fixed *z*-axis

Steering Angles

Optionally, you can input steering angles for the wheels. To calculate the steering angles for the wheels, the block offsets the input steering angles as a function of the suspension height. For the calculation, the block uses a lookup table, $G_{alookup}$, that is a function of the suspension position and steering angle.

$$\delta_{whlsteer_{a,t}} = \delta_{steer_{a,t}} + G_{alookup} f\left(z_{w_{a,t}} - z_{v_{a,t}}, \delta_{steer_{a,t}}\right)$$

The equation uses these variables.

$\delta_{whlsteer_{a,t}}$	Wheel steering angle for axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed z-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed z-axis

Power and Energy

The block calculates these suspension characteristics for each axle, `a`, wheel, `t`.

Calculation	Equation
Dissipated power, $P_{susp_{a,t}}$	$P_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Absorbed energy, $E_{susp_{a,t}}$	$E_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Suspension height, $H_{a,t}$	$H_{a,t} = -\left(z_{v_{a,t}} - z_{w_{a,t}} - \text{median}(f\_susp\_dz\_bp)\right)$
Distance from wheel carrier center to tire/road interface	$z_{wtr_{a,t}} = Re_{w_{a,t}} + H_{a,t}$

The equations use these variables.

m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$Re_{w_{a,t}}$	Axle `a`, wheel `t` effective wheel radius from wheel carrier center to tire/road interface
$f\_susp\_dz\_bp$	Vertical axis suspension height breakpoints
$z_{wtr_{a,t}}$	Distance from wheel carrier center to tire/road interface, along the vehicle-fixed z-axis
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed z-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed z-axis

Ports

Input

`WhlPz` — Wheel z-axis displacement

array

Wheel displacement, z_w, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlPz} = z_w = \left[z_{w_{1,1}} \; z_{w_{1,2}} \; z_{w_{2,1}} \; z_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius

`array`

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlRe} = Re_w = \left[Re_{w_{1,1}} \; Re_{w_{1,2}} \; Re_{w_{2,1}} \; Re_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel z-axis velocity

`array`

Wheel velocity, $\dot{z}_w$, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}} \; \dot{z}_{w_{1,2}} \; \dot{z}_{w_{2,1}} \; \dot{z}_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

`array`

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed x-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

`array`

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed y-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

`array`

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed x-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed y-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed z-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\text{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement

`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\text{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity
`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\text{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Axis**
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

array

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \begin{bmatrix} \delta_{steer_{1,1}} & \delta_{steer_{1,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2

- 3D array signal (3-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2
`(2,1)`	1	1
`(2,2)`	1	2
`(2,3)`	2	1
`(2,4)`	2	2
`(3,1)`	1	1
`(3,2)`	1	2
`(3,3)`	2	1
`(3,4)`	2	2

Signal	Description	Array Signal	Variable	Units
`Camber`	Wheel angles according to the axle.	1D	$\mathrm{WhlAng}[1,\ldots] = \xi = [\xi_{a,t}]$	rad

Signal	Description	Array Signal	Variable	Units
`Caster`			$\text{WhlAng}[2, \ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\text{WhlAng}[3, \ldots] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m

Signal	**Description**	**Array Signal**	**Variable**	**Units**
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} =$ $\begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{wy_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s

Signal	Description	Array Signal	Variable	Units
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle

array

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\text{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle

`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\mathrm{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	

Array Element	Axle	Wheel Number	Moment Axis
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel
`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles
`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.
- Signal contains angles according to the axle and wheel locations.

$$\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Angle
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

Axles

`Number of axles, NumAxl` — Number of axles
2 (default) | `scalar`

Number of axles, N_a, dimensionless.

`Number of wheels by axle, NumWhlsByAxl` — Number of wheels per axle
`[2 2]` (default) | `vector`

Number of wheels per axle, Nt_a, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example, `[1,2]` represents one wheel on axle one and two wheels on axle two.

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering
`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]`—For a two-axle vehicle, enables axle one steering and disables axle two steering
- `[1 1]`—For a two-axle vehicle, enables axle one and axle two steering

Dependencies

Setting an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1:

- Creates input port `StrgAng`.
- Creates these parameters
  - **Toe angle vs steering angle slope, ToeStrgSlp**
  - **Caster angle vs steering angle slope, CasterStrgSlp**
  - **Camber angle vs steering angle slope, CamberStrgSlp**
  - **Suspension height vs steering angle slope, StrgHgtSlp**

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Axle and wheels lumped principal moments of inertia about longitudinal axis, AxlIxx — Inertia

`300` (default) | `vector`

Axle and wheels lumped principal moments of inertia about longitudinal axis, AxleIxx *a*, in kg*m^2.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Axle and wheels lumped mass, AxlM — Mass

`[2 2]` (default) | `vector`

Axle and wheels lumped mass, *a*, in kg.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Track hardpoint coordinates relative to axle center, TrackCoords — Point

`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Track hardpoint coordinates, Tc_t, along the solid axle *x*, *y*, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `TrackCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and wheel locations.

$$Tc_t = \begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{w_{1,1}} & z_{w_{1,2}} & z_{w_{2,1}} & z_{w_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Axis
`TrackCoords(1, 1)`	1	1	Solid axle *x*-axis
`TrackCoords(1, 2)`	1	2	
`TrackCoords(1, 3)`	2	1	
`TrackCoords(1, 4)`	2	2	
`TrackCoords(2, 1)`	1	1	Solid axle *y*-axis
`TrackCoords(2, 2)`	1	2	
`TrackCoords(2, 3)`	2	1	
`TrackCoords(2, 4)`	2	2	
`TrackCoords(3, 1)`	1	1	Solid axle *z*-axis
`TrackCoords(3, 2)`	1	2	
`TrackCoords(3, 3)`	2	1	
`TrackCoords(3, 4)`	2	2	

Suspension hardpoint coordinates relative to axle center, `SuspCoords` — Point
`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Suspension hardpoint coordinates, Sc_t, along the solid axle *x*-, *y*-, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `SuspCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and track locations.

$$Sc_t = \begin{bmatrix} x_{s_{1,1}} & x_{s_{1,2}} & x_{s_{2,1}} & x_{s_{2,2}} \\ y_{s_{1,1}} & y_{s_{1,2}} & y_{s_{2,1}} & y_{s_{2,2}} \\ z_{s_{1,1}} & z_{s_{1,2}} & z_{s_{2,1}} & z_{s_{2,2}} \end{bmatrix}$$

Array Element	Axle	Track	Axis
`SuspCoords(1,1)`	1	1	Solid axle *x*-axis
`SuspCoords(1,2)`	1	2	
`SuspCoords(1,3)`	2	1	
`SuspCoords(1,4)`	2	2	
`SuspCoords(2,1)`	1	1	Solid axle *y*-axis
`SuspCoords(2,2)`	1	2	
`SuspCoords(2,3)`	2	1	
`SuspCoords(2,4)`	2	2	
`SuspCoords(3,1)`	1	1	Solid axle *z*-axis
`SuspCoords(3,2)`	1	2	
`SuspCoords(3,3)`	2	1	
`SuspCoords(3,4)`	2	2	

`Wheel and axle interface compliance constant, KzWhlAxl` — Spring rate
`6437000` (default) | `scalar`

Wheel and axle interface compliance constant, kwa_z, in N/m.

`Wheel and axle interface compliance preload, F0zWhlAxl` — Spring rate
`9810` (default) | `scalar`

Wheel and axle interface compliance preload, Fwa_{z0}, in N.

`Wheel and axle interface damping constant, CzWhlAxl` — Damping
`10000` (default) | `scalar`

Wheel and axle interface damping constant, cwa_z, in m.

Suspension

Mapped

`Axle breakpoints, f_susp_axl_bp` — Breakpoints
`[1 2]` (default) | 1-by-P array

Axle breakpoints, dimensionless.

`Vertical axis suspension height breakpoints, f_susp_dz_bp` — Breakpoints

1-by-M array

Vertical axis suspension height breakpoints, in m.

`Vertical axis suspension height velocity breakpoints, f_susp_dzdot_bp` — Breakpoints

1-by-N array

Vertical axis suspension height velocity breakpoints, in m/s.

`Vertical axis suspension force and moment responses, f_susp_fmz` — Output array

`zeros(31,31,61,2,4)` (default) | M-by-N-by-O-by-P-by-4 array

Array of output values as a function of:

- Vertical suspension height, *M*
- Vertical suspension height velocity, *N*
- Steering angle, *O*
- Axle, *P*
- 4 output types
  - 1 — Vertical force, in N
  - 2 — User-defined
  - 3 — Stored energy, in J
  - 4 — Absorbed power, in W

The array dimensions must match the breakpoint dimensions

`Suspension geometry responses, f_susp_geom` — Suspension geometry responses

`zeros(31,61,2,3)` (default) | M-by-O-by-P-by-3 array

Array of geometric suspension values as a function of:

- Vertical suspension height, *M*
- Steering angle, *O*
- Axle, *P*
- 3 output types
  - 1 — Camber angle, in rad
  - 2 — Caster angle, in rad
  - 3 — Toe angle, in rad

The array dimensions must match the breakpoint dimensions

`Steering angle breakpoints, f_susp_strgdelta_bp` — Steering angle breakpoints

1-by-O array

Steering angle breakpoints, in rad.

Version History

Introduced in R2018a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

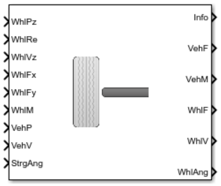
See Also

Solid Axle Suspension | Solid Axle Suspension - Coil Spring | Solid Axle Suspension - Leaf Spring

Solid Axle Suspension

Solid axle suspension for multiple axles

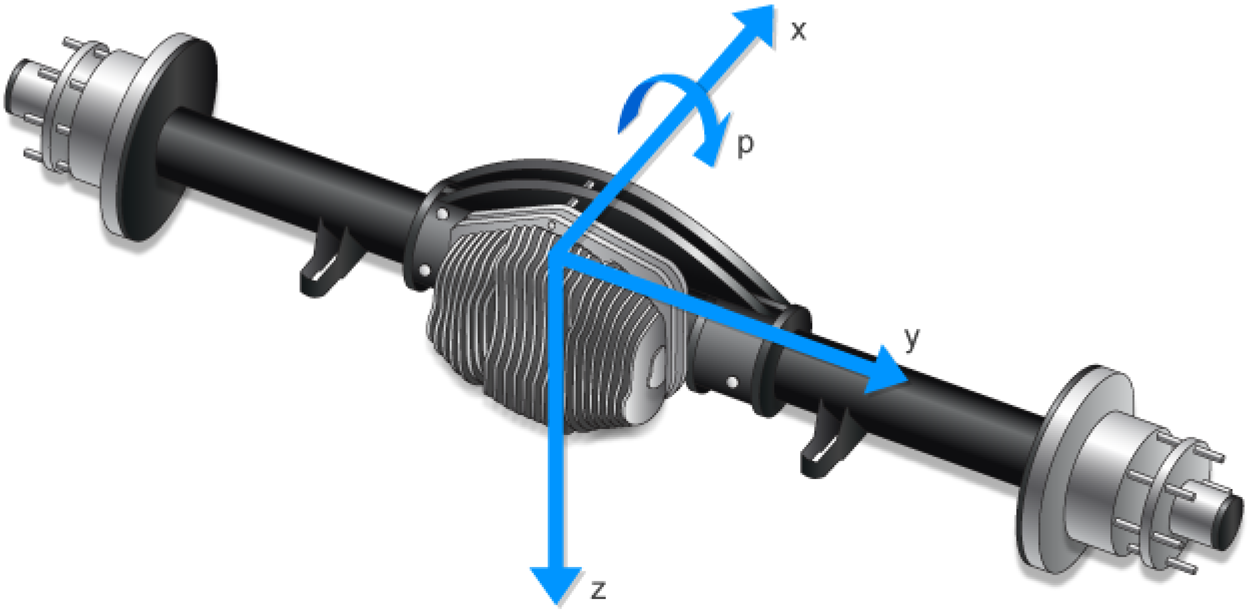
Library: Vehicle Dynamics Blockset / Suspension



Description

The Solid Axle Suspension block implements a solid axle suspension for multiple axles with multiple wheels per axle.

The block models the suspension compliance, damping, and geometric effects as functions of the wheel positions and velocities, with axle-specific compliance and damping parameters. Using the wheel position and velocity, the block calculates the vertical wheel position and suspension forces on the vehicle and wheel. The block uses the Z-down (defined in SAE J670) and a solid axle coordinate system. The solid axle coordinate system, shown here, is aligned with the Z-down vehicle coordinate system, with the *x*-axis in the direction of forward vehicle motion.



For Each	You Can Specify
Axle	• Multiple wheels • Suspension parameters
Wheel	• Steering angles

The block contains energy-storing spring elements and energy-dissipating damper elements. The block also stores energy via the axle roll angular acceleration and axle center of mass vertical and lateral acceleration.

This table summarizes the block parameter settings for a vehicle with:

- Two axles
- Two wheels per axle
- Steering angle input for both wheels on the front axle

Parameter	Setting
Number of axles, NumAxl	2
Number of wheels by axle, NumWhlsByAxl	`[2 2]`
Steered axle enable by axle, StrgEnByAxl	`[1 0]`

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Suspension Compliance and Damping

The block uses a linear spring and damper to model the vertical dynamic effects of the suspension system on the vehicle and wheel. Specifically, the block:

Uses	To Calculate
• Longitudinal and lateral displacement and velocity of the vehicle. • Longitudinal and lateral displacement and velocity of the wheel. • Vertical wheel forces applied to the vehicle.	• Suspension forces applied to the axle center. • Vertical displacements and velocities of the vehicle and wheel. • Longitudinal, lateral and vertical suspension forces and moments applied to the vehicle. • Longitudinal, lateral and vertical suspension forces and moments applied to the wheel.

To calculate the dynamics of the axle, the block implements these equations. The block neglects the effects of:

- Lateral and longitudinal translational velocity.
- Angular velocity about the vertical and lateral axes.

$$\begin{bmatrix}\ddot{x}_a\\ \ddot{y}_a\\ \ddot{z}_a\end{bmatrix} = \frac{1}{M_a}\begin{bmatrix}F_{xa}\\ F_{ya}\\ F_{za}\end{bmatrix} + \begin{bmatrix}\dot{x}_a\\ \dot{y}_a\\ \dot{z}_a\end{bmatrix} \times \begin{bmatrix}p\\ q\\ r\end{bmatrix} = \frac{1}{M_a}\begin{bmatrix}0\\ 0\\ F_{za}\end{bmatrix} + \begin{bmatrix}0\\ 0\\ \dot{z}_a\end{bmatrix} \times \begin{bmatrix}p\\ 0\\ 0\end{bmatrix} + \begin{bmatrix}0\\ 0\\ g\end{bmatrix} = \begin{bmatrix}0\\ p\dot{z}_a\\ \frac{F_{za}}{M_a} + g\end{bmatrix}$$

$$\begin{bmatrix}\dot{p}\\ \dot{q}\\ \dot{r}\end{bmatrix} = \left[\begin{bmatrix}M_x\\ M_y\\ M_z\end{bmatrix} - \begin{bmatrix}p\\ q\\ r\end{bmatrix} \times \begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}\begin{bmatrix}p\\ q\\ r\end{bmatrix}\right]\begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}^{-1}$$

$$= \left[\begin{bmatrix}M_x\\ 0\\ 0\end{bmatrix} - \begin{bmatrix}p\\ q\\ 0\end{bmatrix} \times \begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}\begin{bmatrix}p\\ 0\\ 0\end{bmatrix}\right]\begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}^{-1} = \begin{bmatrix}\frac{M_x}{I_{xx}}\\ 0\\ 0\end{bmatrix}$$

The net vertical force on the axle center of mass is the sum of the wheel and suspension forces acting on the axle.

$$F_{za} = \sum_{t=1}^{Nta}\left(F_{wz_{a,t}} + F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right)\right)$$

The net moment about the roll axis of the solid axle suspension accounts for the hardpoint coordinates of the suspension and wheels.

$$M_x = \sum_{t=1}^{Nta}\Bigg(F_{wz_{a,t}}y_{w_t} + \left(F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right)\right)y_{s_t}$$
$$+ M_{wx_{a,t}}\frac{I_{xx}}{I_{xx} + M_a y_{w_t}}\Bigg)$$

Block parameters provide the track and suspension hardpoints coordinates.

$$Tc_t = \begin{bmatrix}x_{w_1} & x_{w_2} & \cdots\\ y_{w_1} & y_{w_2} & \cdots\\ z_{w_1} & z_{w_2} & \cdots\end{bmatrix}$$

$$Sc_t = \begin{bmatrix}x_{s_1} & x_{s_2} & \cdots\\ y_{s_1} & y_{s_2} & \cdots\\ z_{s_1} & z_{s_2} & \cdots\end{bmatrix}$$

The block uses Euler angles to transform the track and suspension displacements, velocities, and accelerations to the vehicle coordinate system.

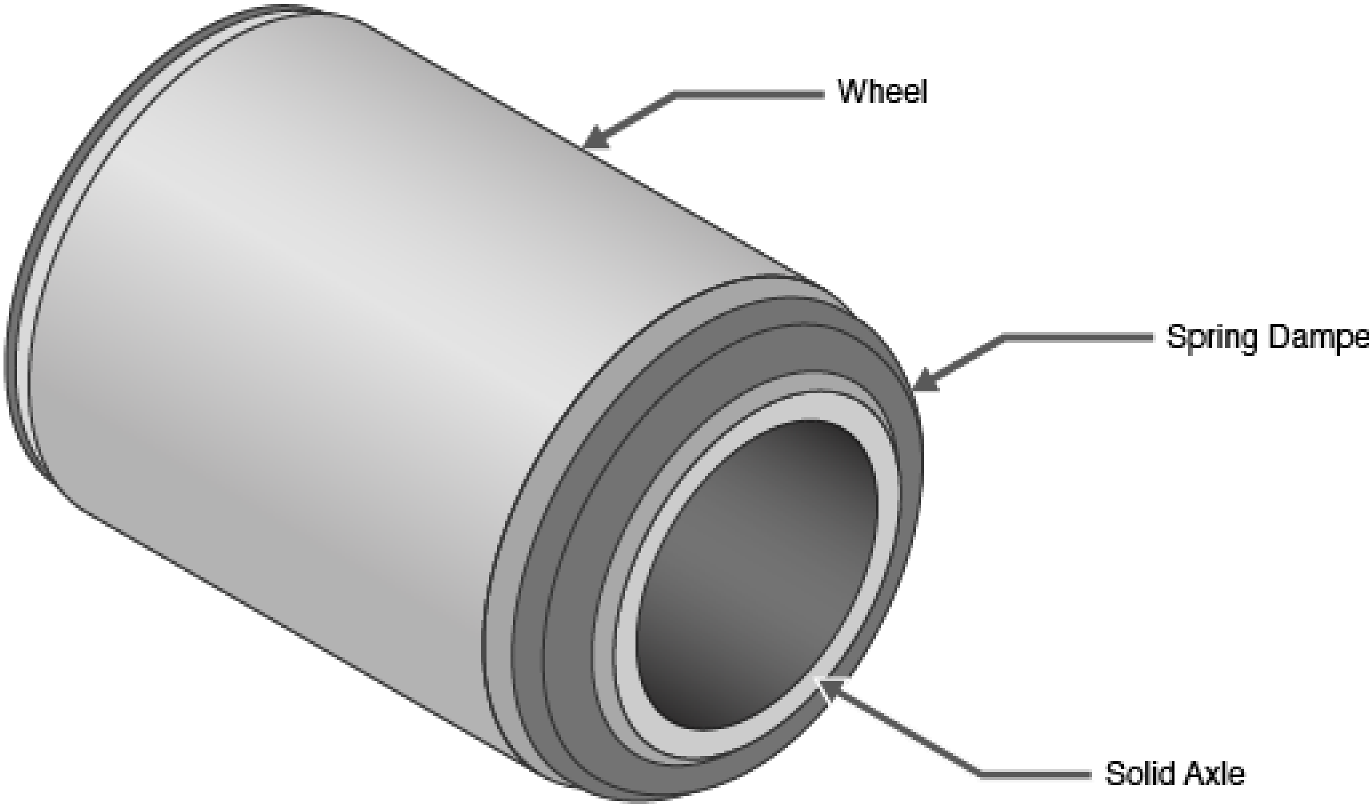
To calculate the suspension forces applied to the vehicle, the block implements this equation.

$$F_{vz_{a,t}} = -\left(F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right) + F_{zhstop_{a,t}}\right)$$

The suspension forces and moments applied to the vehicle are equal to the suspension forces and moments applied to the wheel.

$$F_{vx_{a,t}} = F_{wx_{a,t}}$$
$$F_{vy_{a,t}} = F_{wy_{a,t}}$$
$$F_{vz_{a,t}} = -F_{wz_{a,t}}$$
$$M_{vx_{a,t}} = M_{wx_{a,t}} + F_{wy_{a,t}}(Re_{wy_{a,t}} + H_{a,t})$$
$$M_{vy_{a,t}} = M_{wy_{a,t}} + F_{wx_{a,t}}\left(Re_{wx_{a,t}} + H_{a,t}\right)$$
$$M_{vz_{a,t}} = M_{wz_{a,t}}$$

To calculate the vertical force applied to the suspension at the wheel location, the block implements a stiff spring-damper, shown here.



The block uses this equation.

$$F_{wz_{a,t}} = -Fwa_{z0} - kwa_z\left(z_{w_{a,t}} - z_{s_{a,t}}\right) - cwa_z\left(\dot{z}_{w_{a,t}} - \dot{z}_{s_{a,t}}\right)$$

The equations use these variables.

$F_{wz_{a,t}}$, $M_{wz_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{wx_{a,t}}$, $M_{wx_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *x*-axis

$F_{wy_{a,t}}$, $M_{wy_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *y*-axis
$F_{vz_{a,t}}$, $M_{vz_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{vx_{a,t}}$, $M_{vx_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{vy_{a,t}}$, $M_{vy_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *y*-axis
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
k_{z_a}	Vertical spring constant applied to wheels on axle `a`
kwa_z	Wheel and axle interface compliance constant
m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
c_{z_a}	Vertical damping constant applied to wheels on axle `a`
cwa_z	Wheel and axle interface damping constant
$Re_{w_{a,t}}$	Effective wheel radius for axle `a`, wheel `t`
$F_{zhstop_{a,t}}$	Vertical hardstop force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$F_{zaswy_{a,t}}$	Vertical anti-sway force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
Fwa_{z0}	Wheel and axle interface compliance constant
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{v_{a,t}}$, $\dot{x}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{w_{a,t}}$, $\dot{x}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$y_{v_{a,t}}$, $\dot{y}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$y_{w_{a,t}}$, $\dot{y}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$H_{a,t}$	Suspension height at axle `a`, wheel `t`
$Re_{w_{a,t}}$	Effective wheel radius at axle `a`, wheel `t`

Hardstop Forces

The hardstop feedback force, $F_{zhstop_{a,t}}$, that the block applies depends on whether the suspension is compressing or extending. The block applies the force:

- In compression, when the suspension is compressed more than the maximum distance specified by the **Suspension maximum height, Hmax** parameter.
- In extension, when the suspension extension is greater than maximum extension specified by the **Suspension maximum height, Hmax** parameter.

To calculate the force, the block uses a stiffness based on a hyperbolic tangent and exponential scaling.

Camber, Caster, and Toe Angles

To calculate the camber, caster, and toe angles, block uses linear functions of the suspension height and steering angle.

$$\xi_{a,t} = \xi_{0a} + m_{hcamber_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{cambersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\eta_{a,t} = \eta_{0a} + m_{hcaster_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{castersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\zeta_{a,t} = \zeta_{0a} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equations use these variables.

$\xi_{a,t}$	Camber angle of wheel on axle `a`, wheel `t`
$\eta_{a,t}$	Caster angle of wheel on axle `a`, wheel `t`
$\zeta_{a,t}$	Toe angle of wheel on axle `a`, wheel `t`
ξ_{0a}, η_{0a}, ζ_{0a}	Nominal suspension axle a camber, caster, and toe angles, respectively, at zero steering angle
$m_{hcamber_a}$, $m_{hcaster_a}$, m_{htoe_a}	Camber, caster, and toe angles, respectively, versus suspension height slope for axle `a`
$m_{cambersteer_a}$, $m_{castersteer_a}$, $m_{toesteer_a}$	Camber, caster, and toe angles, respectively, versus steering angle slope for axle `a`
m_{hsteer_a}	Steering angle versus vertical force slope for axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Steering Angles

Optionally, use the **Steered axle enable by axle, StrgEnByAxl** parameter to input steering angles for the wheels. To calculate the steering angles for the wheels, the block offsets the input steering angles with a linear function of the suspension height.

$$\delta_{whlsteer_{a,t}} = \delta_{steer_{a,t}} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equation uses these variables.

$m_{toesteer_a}$	Axle `a` toe angle versus steering angle slope
m_{hsteer_a}	Axle `a` steering angle versus vertical force slope
m_{htoe_a}	Axle `a` toe angle versus suspension height slope
$\delta_{whlsteer_{a,t}}$	Wheel steering angle for axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Power and Energy

The block calculates these suspension characteristics for each axle, `a`, wheel, `t`.

Calculation	Equation
Dissipated power, $P_{susp_{a,t}}$	$P_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Absorbed energy, $E_{susp_{a,t}}$	$E_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Suspension height, $H_{a,t}$	$H_{a,t} = -\left(z_{v_{a,t}} - z_{w_{a,t}} + \frac{F_{z0_a}}{k_{z_a}} + m_{hsteer_a}\left\lvert\delta_{steer_{a,t}}\right\rvert\right)$
Distance from wheel carrier center to tire/road interface	$z_{wtr_{a,t}} = Re_{w_{a,t}} + H_{a,t}$

The equations use these variables.

m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$Re_{w_{a,t}}$	Axle `a`, wheel `t` effective wheel radius from wheel carrier center to tire/road interface
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
$z_{wtr_{a,t}}$	Distance from wheel carrier center to tire/road interface, along the vehicle-fixed *z*-axis
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Ports

Input

`WhlPz` — Wheel z-axis displacement
`array`

Wheel displacement, z_w, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

  $$\text{WhlPz} = z_w = \left[z_{w_{1,1}}\ z_{w_{1,2}}\ z_{w_{2,1}}\ z_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2

Wheel	Array Element	Axle	Wheel Number
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius

array

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlRe} = Re_w = \left[Re_{w_{1,1}}\ Re_{w_{1,2}}\ Re_{w_{2,1}}\ Re_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel z-axis velocity

array

Wheel velocity, $\dot{z}_w$, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}}\ \dot{z}_{w_{1,2}}\ \dot{z}_{w_{2,1}}\ \dot{z}_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

array

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed x-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

`array`

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed *y*-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

`array`

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed *x*-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed *y*-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\text{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement

`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\text{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity

`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\mathrm{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\mathrm{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2

- 3D array signal (3-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2
`(2,1)`	1	1
`(2,2)`	1	2
`(2,3)`	2	1
`(2,4)`	2	2
`(3,1)`	1	1
`(3,2)`	1	2
`(3,3)`	2	1
`(3,4)`	2	2

Signal	Description	Array Signal	Variable	Units
`Camber`	Wheel angles according to the axle.	1D	$\mathrm{WhlAng}[1,\ldots] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\mathrm{WhlAng}[2,\ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\mathrm{WhlAng}[3,\ldots] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m

Signal	Description	Array Signal	Variable	Units
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m

Signal	Description	Array Signal	Variable	Units
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} =$ $\begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{wy_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s

Signal	Description	Array Signal	Variable	Units
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle

`array`

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle

`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\mathrm{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	

Array Element	Axle	Wheel Number	Moment Axis
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles

`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.
- Signal contains angles according to the axle and wheel locations.

$$\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Angle
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

Axles

`Number of axles, NumAxl` — Number of axles
`2` (default) | `scalar`

Number of axles, N_a, dimensionless.

`Number of wheels by axle, NumWhlsByAxl` — Number of wheels per axle
`[2 2]` (default) | `vector`

Number of wheels per axle, Nt_a, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example, `[1,2]` represents one wheel on axle one and two wheels on axle two.

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering
`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]`—For a two-axle vehicle, enables axle one steering and disables axle two steering
- `[1 1]`—For a two-axle vehicle, enables axle one and axle two steering

Dependencies

Setting an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1:

- Creates input port `StrgAng`.
- Creates these parameters
  - **Toe angle vs steering angle slope, ToeStrgSlp**
  - **Caster angle vs steering angle slope, CasterStrgSlp**
  - **Camber angle vs steering angle slope, CamberStrgSlp**
  - **Suspension height vs steering angle slope, StrgHgtSlp**

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\mathrm{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Axle and wheels lumped principal moments of inertia about longitudinal axis, AxlIxx — Inertia

`300` (default) | `vector`

Axle and wheels lumped principal moments of inertia about longitudinal axis, AxleIxx *a*, in kg*m^2.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Axle and wheels lumped mass, AxlM — Mass

`[2 2]` (default) | `vector`

Axle and wheels lumped mass, *a*, in kg.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Track hardpoint coordinates relative to axle center, TrackCoords — Point

`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Track hardpoint coordinates, Tc_t, along the solid axle *x*, *y*, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `TrackCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and wheel locations.

$$Tc_t = \begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{w_{1,1}} & z_{w_{1,2}} & z_{w_{2,1}} & z_{w_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Axis
`TrackCoords(1, 1)`	1	1	Solid axle *x*-axis
`TrackCoords(1, 2)`	1	2	
`TrackCoords(1, 3)`	2	1	
`TrackCoords(1, 4)`	2	2	
`TrackCoords(2, 1)`	1	1	Solid axle *y*-axis
`TrackCoords(2, 2)`	1	2	
`TrackCoords(2, 3)`	2	1	
`TrackCoords(2, 4)`	2	2	
`TrackCoords(3, 1)`	1	1	Solid axle *z*-axis
`TrackCoords(3, 2)`	1	2	
`TrackCoords(3, 3)`	2	1	
`TrackCoords(3, 4)`	2	2	

`Suspension hardpoint coordinates relative to axle center, SuspCoords` — Point
`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Suspension hardpoint coordinates, Sc_t, along the solid axle *x*-, *y*-, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `SuspCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and track locations.

$$Sc_t = \begin{bmatrix} x_{s_{1,1}} & x_{s_{1,2}} & x_{s_{2,1}} & x_{s_{2,2}} \\ y_{s_{1,1}} & y_{s_{1,2}} & y_{s_{2,1}} & y_{s_{2,2}} \\ z_{s_{1,1}} & z_{s_{1,2}} & z_{s_{2,1}} & z_{s_{2,2}} \end{bmatrix}$$

Array Element	Axle	Track	Axis
`SuspCoords(1,1)`	1	1	Solid axle *x*-axis
`SuspCoords(1,2)`	1	2	
`SuspCoords(1,3)`	2	1	
`SuspCoords(1,4)`	2	2	
`SuspCoords(2,1)`	1	1	Solid axle *y*-axis
`SuspCoords(2,2)`	1	2	
`SuspCoords(2,3)`	2	1	
`SuspCoords(2,4)`	2	2	
`SuspCoords(3,1)`	1	1	Solid axle *z*-axis
`SuspCoords(3,2)`	1	2	
`SuspCoords(3,3)`	2	1	
`SuspCoords(3,4)`	2	2	

`Wheel and axle interface compliance constant, KzWhlAxl` — Spring rate

`6437000` (default) | `scalar`

Wheel and axle interface compliance constant, kwa_z, in N/m.

`Wheel and axle interface compliance preload, F0zWhlAxl` — Spring rate

`9810` (default) | `scalar`

Wheel and axle interface compliance preload, Fwa_{z0}, in N.

`Wheel and axle interface damping constant, CzWhlAxl` — Damping

`10000` (default) | `scalar`

Wheel and axle interface damping constant, cwa_z, in m.

Suspension

Compliance and Damping - Passive

`Suspension spring constant, Kz` — Suspension spring constant

`64370` (default) | `scalar` | `vector`

Linear vertical spring constant for independent suspension wheels on axle a, k_{z_a}, in N/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension spring preload, F0z` — Suspension spring preload

`9810` (default) | `scalar` | `vector`

Vertical preload spring force applied to the wheels on the axle at wheel carrier reference coordinates, F_{z0_a}, in N. Positive preload forces:

- Cause the vehicle to lift.
- Point along the negative vehicle-fixed z-axis.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension shock damping constant, Cz` — Suspension shock damping constant

`10000` (default) | `scalar` | `vector`

Linear vertical damping constant for independent suspension wheels on axle a, c_{z_a}, in Ns/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create this parameter, clear **Enable active damping**.

`Suspension maximum height, Hmax` — Height

`0.5` (default) | `scalar` | `vector`

Maximum suspension extension or minimum suspension compression height, H_{max}, for axle `a` before the suspension reaches a hardstop, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Geometry

`Toe angle at steering center, Toe` — Toe angle

`0.0349` (default) | `scalar`

Nominal suspension toe angle at zero steering angle, ζ_{0a}, in rad.

`Roll steer vs suspension height slope, RollStrgSlp` — Steer angle suspension slope

`-0.2269` (default) | `scalar` | `vector`

Roll steer angle versus suspension height, m_{htoe_a}, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Toe angle vs steering angle slope, ToeStrgSlp` — Toe angle steering slope

`0.01` (default) | `scalar` | `vector`

Toe angle versus steering angle slope, $m_{toesteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Caster angle at steering center, Caster` — Caster angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension caster angle at zero steering angle, η_{0a}, in rad.

`Caster angle vs suspension height slope, CasterHslp` — Caster angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Caster angle versus suspension height, $m_{hcaster_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Caster angle vs steering angle slope, CasterStrgSlp` — Caster angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Caster angle versus steering angle slope, $m_{castersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Camber angle at steering center, Camber` — Camber angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension camber angle at zero steering angle, ξ_{0a}, in rad.

`Camber angle vs suspension height slope, CamberHslp` — Camber angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Camber angle versus suspension height, $m_{hcamber_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Camber angle vs steering angle slope, CamberStrgSlp` — Camber angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Camber angle versus steering angle slope, $m_{cambersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Suspension height vs steering angle slope, StrgHgtSlp` — Suspension height versus steering angle slope

`0.1432` (default) | `scalar` | `vector`

Steering angle to vertical force slope applied at suspension wheel carrier reference point, m_{hsteer_a}, in m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Version History

Introduced in R2018a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

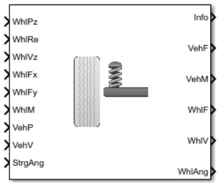
See Also

Solid Axle Suspension - Coil Spring | Solid Axle Suspension - Leaf Spring | Solid Axle Suspension - Mapped

Solid Axle Suspension - Coil Spring

Solid axle suspension with coil spring

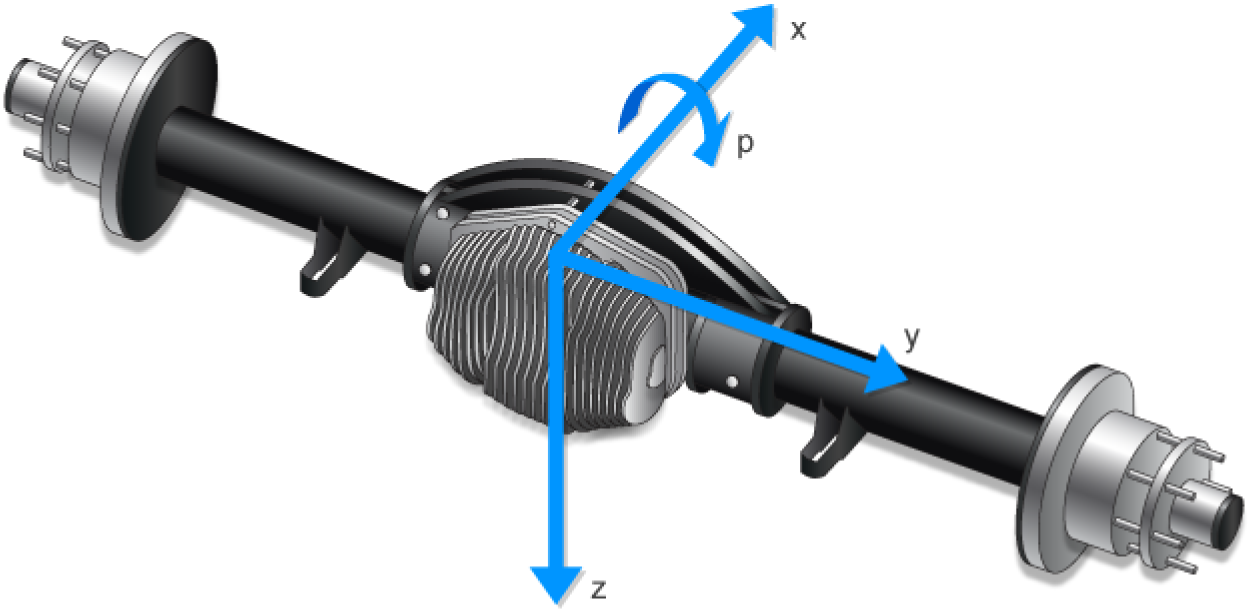
Library: Vehicle Dynamics Blockset / Suspension



Description

The Solid Axle Suspension - Coil Spring block implements a solid axle suspension with a coil spring for multiple axles with multiple wheels per axle.

The block models the suspension compliance, damping, and geometric effects as functions of the wheel positions and velocities, with axle-specific compliance and damping parameters. Using the wheel position and velocity, the block calculates the vertical wheel position and suspension forces on the vehicle and wheel. The block uses the Z-down (defined in SAE J670) and a solid axle coordinate system. The solid axle coordinate system, shown here, is aligned with the Z-down vehicle coordinate system, with the *x*-axis in the direction of forward vehicle motion.



For Each	You Can Specify
Axle	• Multiple wheels • Suspension parameters
Wheel	• Steering angles

The block contains energy-storing spring elements and energy-dissipating damper elements. The block also stores energy via the axle roll angular acceleration and axle center of mass vertical and lateral acceleration.

This table summarizes the block parameter settings for a vehicle with:

- Two axles
- Two wheels per axle
- Steering angle input for both wheels on the front axle

Parameter	Setting
Number of axles, NumAxl	2
Number of wheels by axle, NumWhlsByAxl	`[2 2]`
Steered axle enable by axle, StrgEnByAxl	`[1 0]`

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Suspension Compliance and Damping

The block uses a linear spring and damper to model the vertical dynamic effects of the suspension system on the vehicle and wheel. Specifically, the block:

Uses	To Calculate
• Longitudinal and lateral displacement and velocity of the vehicle. • Longitudinal and lateral displacement and velocity of the wheel. • Vertical wheel forces applied to the vehicle.	• Suspension forces applied to the axle center. • Vertical displacements and velocities of the vehicle and wheel. • Longitudinal, lateral and vertical suspension forces and moments applied to the vehicle. • Longitudinal, lateral and vertical suspension forces and moments applied to the wheel.

To calculate the dynamics of the axle, the block implements these equations. The block neglects the effects of:

- Lateral and longitudinal translational velocity.
- Angular velocity about the vertical and lateral axes.

$$\begin{bmatrix} \ddot{x}_a \\ \ddot{y}_a \\ \ddot{z}_a \end{bmatrix} = \frac{1}{M_a}\begin{bmatrix} F_{xa} \\ F_{ya} \\ F_{za} \end{bmatrix} + \begin{bmatrix} \dot{x}_a \\ \dot{y}_a \\ \dot{z}_a \end{bmatrix} \times \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \frac{1}{M_a}\begin{bmatrix} 0 \\ 0 \\ F_{za} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \dot{z}_a \end{bmatrix} \times \begin{bmatrix} p \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ g \end{bmatrix} = \begin{bmatrix} 0 \\ p\dot{z}_a \\ \frac{F_{za}}{M_a} + g \end{bmatrix}$$

$$\begin{bmatrix} \dot{p} \\ \dot{q} \\ \dot{r} \end{bmatrix} = \left[\begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} - \begin{bmatrix} p \\ q \\ r \end{bmatrix} \times \begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}\begin{bmatrix} p \\ q \\ r \end{bmatrix}\right]\begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}^{-1}$$

$$= \left[\begin{bmatrix} M_x \\ 0 \\ 0 \end{bmatrix} - \begin{bmatrix} p \\ q \\ 0 \end{bmatrix} \times \begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}\begin{bmatrix} p \\ 0 \\ 0 \end{bmatrix}\right]\begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}^{-1} = \begin{bmatrix} \frac{M_x}{I_{xx}} \\ 0 \\ 0 \end{bmatrix}$$

The net vertical force on the axle center of mass is the sum of the wheel and suspension forces acting on the axle.

$$F_{za} = \sum_{t=1}^{Nta}\left(F_{wz_{a,t}} + F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right)\right)$$

The net moment about the roll axis of the solid axle suspension accounts for the hardpoint coordinates of the suspension and wheels.

$$M_x = \sum_{t=1}^{Nta}\Bigg(F_{wz_{a,t}}y_{w_t} + \left(F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right)\right)y_{s_t}$$
$$+ M_{wx_{a,t}}\frac{I_{xx}}{I_{xx} + M_a y_{w_t}}\Bigg)$$

Block parameters provide the track and suspension hardpoints coordinates.

$$Tc_t = \begin{bmatrix} x_{w_1} & x_{w_2} & \cdots \\ y_{w_1} & y_{w_2} & \cdots \\ z_{w_1} & z_{w_2} & \cdots \end{bmatrix}$$
$$Sc_t = \begin{bmatrix} x_{s_1} & x_{s_2} & \cdots \\ y_{s_1} & y_{s_2} & \cdots \\ z_{s_1} & z_{s_2} & \cdots \end{bmatrix}$$

The block uses Euler angles to transform the track and suspension displacements, velocities, and accelerations to the vehicle coordinate system.

To calculate the suspension forces applied to the vehicle, the block implements this equation.

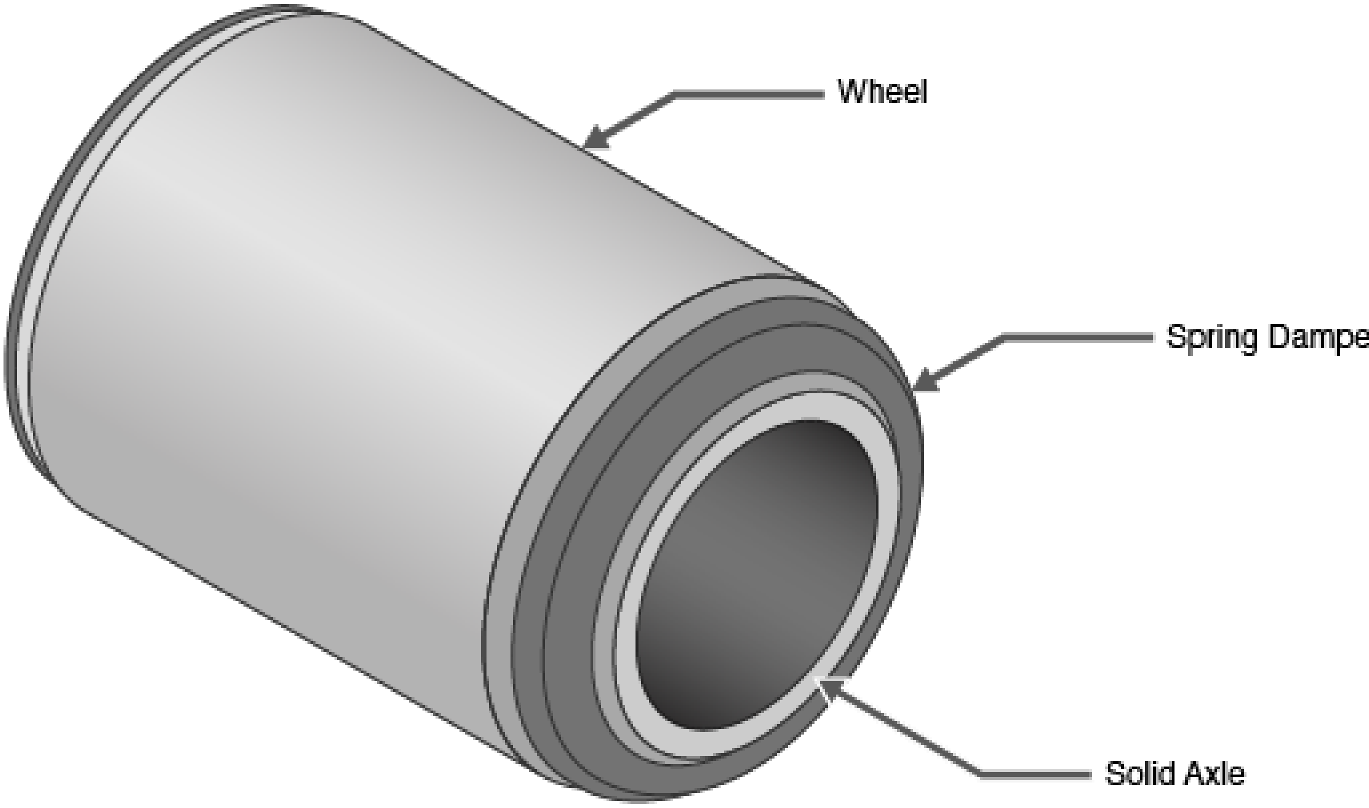
$$F_{vz_{a,t}} = -\left(F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right) + F_{zhstop_{a,t}}\right)$$

The suspension forces and moments applied to the vehicle are equal to the suspension forces and moments applied to the wheel.

$$
\begin{aligned}
&F_{vx_{a,t}} = F_{wx_{a,t}}\\
&F_{vy_{a,t}} = F_{wy_{a,t}}\\
&F_{vz_{a,t}} = -F_{wz_{a,t}}
\end{aligned}
$$

$$
\begin{aligned}
&M_{vx_{a,t}} = M_{wx_{a,t}} + F_{wy_{a,t}}(Re_{wy_{a,t}} + H_{a,t})\\
&M_{vy_{a,t}} = M_{wy_{a,t}} + F_{wx_{a,t}}\left(Re_{wx_{a,t}} + H_{a,t}\right)\\
&M_{vz_{a,t}} = M_{wz_{a,t}}
\end{aligned}
$$

To calculate the vertical force applied to the suspension at the wheel location, the block implements a stiff spring-damper, shown here.



The block uses this equation.

$$F_{wz_{a,t}} = -Fwa_{z0} - kwa_z\left(z_{w_{a,t}} - z_{s_{a,t}}\right) - cwa_z\left(\dot{z}_{w_{a,t}} - \dot{z}_{s_{a,t}}\right)$$

The equations use these variables.

$F_{wz_{a,t}}$, $M_{wz_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{wx_{a,t}}$, $M_{wx_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *x*-axis

$F_{wy_{a,t}}$, $M_{wy_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *y*-axis
$F_{vz_{a,t}}$, $M_{vz_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{vx_{a,t}}$, $M_{vx_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{vy_{a,t}}$, $M_{vy_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *y*-axis
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
k_{z_a}	Vertical spring constant applied to wheels on axle `a`
kwa_z	Wheel and axle interface compliance constant
m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
c_{z_a}	Vertical damping constant applied to wheels on axle `a`
cwa_z	Wheel and axle interface damping constant
$Re_{w_{a,t}}$	Effective wheel radius for axle `a`, wheel `t`
$F_{zhstop_{a,t}}$	Vertical hardstop force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$F_{zaswy_{a,t}}$	Vertical anti-sway force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
Fwa_{z0}	Wheel and axle interface compliance constant
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{v_{a,t}}$, $\dot{x}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{w_{a,t}}$, $\dot{x}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$y_{v_{a,t}}$, $\dot{y}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$y_{w_{a,t}}$, $\dot{y}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$H_{a,t}$	Suspension height at axle `a`, wheel `t`
$Re_{w_{a,t}}$	Effective wheel radius at axle `a`, wheel `t`

Hardstop Forces

The hardstop feedback force, $F_{zhstop_{a,t}}$, that the block applies depends on whether the suspension is compressing or extending. The block applies the force:

- In compression, when the suspension is compressed more than the maximum distance specified by the **Suspension maximum height, Hmax** parameter.
- In extension, when the suspension extension is greater than maximum extension specified by the **Suspension maximum height, Hmax** parameter.

To calculate the force, the block uses a stiffness based on a hyperbolic tangent and exponential scaling.

Camber, Caster, and Toe Angles

To calculate the camber, caster, and toe angles, block uses linear functions of the suspension height and steering angle.

$$\xi_{a,t} = \xi_{0a} + m_{hcamber_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{cambersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\eta_{a,t} = \eta_{0a} + m_{hcaster_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{castersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\zeta_{a,t} = \zeta_{0a} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equations use these variables.

$\xi_{a,t}$	Camber angle of wheel on axle `a`, wheel `t`
$\eta_{a,t}$	Caster angle of wheel on axle `a`, wheel `t`
$\zeta_{a,t}$	Toe angle of wheel on axle `a`, wheel `t`
ξ_{0a}, η_{0a}, ζ_{0a}	Nominal suspension axle a camber, caster, and toe angles, respectively, at zero steering angle
$m_{hcamber_a}$, $m_{hcaster_a}$, m_{htoe_a}	Camber, caster, and toe angles, respectively, versus suspension height slope for axle `a`
$m_{cambersteer_a}$, $m_{castersteer_a}$, $m_{toesteer_a}$	Camber, caster, and toe angles, respectively, versus steering angle slope for axle `a`
m_{hsteer_a}	Steering angle versus vertical force slope for axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Steering Angles

Optionally, use the **Steered axle enable by axle, StrgEnByAxl** parameter to input steering angles for the wheels. To calculate the steering angles for the wheels, the block offsets the input steering angles with a linear function of the suspension height.

$$\delta_{whlsteer_{a,t}} = \delta_{steer_{a,t}} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equation uses these variables.

$m_{toesteer_a}$	Axle `a` toe angle versus steering angle slope
m_{hsteer_a}	Axle `a` steering angle versus vertical force slope
m_{htoe_a}	Axle `a` toe angle versus suspension height slope
$\delta_{whlsteer_{a,t}}$	Wheel steering angle for axle `a`, wheel `t`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$z_{v_{a,t}}$	Vehicle displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Power and Energy

The block calculates these suspension characteristics for each axle, `a`, wheel, `t`.

Calculation	Equation
Dissipated power, $P_{susp_{a,t}}$	$P_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Absorbed energy, $E_{susp_{a,t}}$	$E_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Suspension height, $H_{a,t}$	$H_{a,t} = -\left(z_{v_{a,t}} - z_{w_{a,t}} + \frac{F_{z0_a}}{k_{z_a}} + m_{hsteer_a}\left\|\delta_{steer_{a,t}}\right\|\right)$
Distance from wheel carrier center to tire/road interface	$z_{wtr_{a,t}} = Re_{w_{a,t}} + H_{a,t}$

The equations use these variables.

m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$Re_{w_{a,t}}$	Axle `a`, wheel `t` effective wheel radius from wheel carrier center to tire/road interface
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
$z_{wtr_{a,t}}$	Distance from wheel carrier center to tire/road interface, along the vehicle-fixed *z*-axis
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Ports

Input

`WhlPz` — Wheel z-axis displacement

`array`

Wheel displacement, z_w, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

  $$\text{WhlPz} = z_w = \left[z_{w_{1,1}}\ z_{w_{1,2}}\ z_{w_{2,1}}\ z_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2

Wheel	Array Element	Axle	Wheel Number
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius

`array`

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

  $$\text{WhlRe} = Re_w = \left[Re_{w_{1,1}}\ Re_{w_{1,2}}\ Re_{w_{2,1}}\ Re_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel *z*-axis velocity

`array`

Wheel velocity, $\dot{z}_w$, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

  $$\text{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}}\ \dot{z}_{w_{1,2}}\ \dot{z}_{w_{2,1}}\ \dot{z}_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

`array`

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed *x*-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

`array`

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed *y*-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

`array`

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed *x*-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed *y*-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\text{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement
`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\mathrm{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity

`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\mathrm{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \begin{bmatrix}\delta_{steer_{1,1}} & \delta_{steer_{1,2}}\end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2

- 3D array signal (3-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2
`(2,1)`	1	1
`(2,2)`	1	2
`(2,3)`	2	1
`(2,4)`	2	2
`(3,1)`	1	1
`(3,2)`	1	2
`(3,3)`	2	1
`(3,4)`	2	2

Signal	Description	Array Signal	Variable	Units
`Camber`	Wheel angles according to the axle.	1D	$\text{WhlAng}[1,\ldots] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\text{WhlAng}[2,\ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\text{WhlAng}[3,\ldots] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m

Signal	Description	Array Signal	Variable	Units
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m

Signal	Description	Array Signal	Variable	Units
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} =$ $\begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{wy_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s

Signal	Description	Array Signal	Variable	Units
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle
array

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\text{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle

`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\mathrm{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	

Array Element	Axle	Wheel Number	Moment Axis
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles

`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.
- Signal contains angles according to the axle and wheel locations.

$$\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Angle**
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

Axles

`Number of axles, NumAxl` — Number of axles
2 (default) | `scalar`

Number of axles, N_a, dimensionless.

`Number of wheels by axle, NumWhlsByAxl` — Number of wheels per axle
`[2 2]` (default) | `vector`

Number of wheels per axle, Nt_a, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example, `[1,2]` represents one wheel on axle one and two wheels on axle two.

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering
`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]`—For a two-axle vehicle, enables axle one steering and disables axle two steering
- `[1 1]`—For a two-axle vehicle, enables axle one and axle two steering

Dependencies

Setting an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1:

- Creates input port `StrgAng`.
- Creates these parameters
  - **Toe angle vs steering angle slope, ToeStrgSlp**
  - **Caster angle vs steering angle slope, CasterStrgSlp**
  - **Camber angle vs steering angle slope, CamberStrgSlp**
  - **Suspension height vs steering angle slope, StrgHgtSlp**

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\mathrm{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

`Axle and wheels lumped principal moments of inertia about longitudinal axis, AxlIxx` — Inertia

`300` (default) | `vector`

Axle and wheels lumped principal moments of inertia about longitudinal axis, AxleIxx *a*, in kg*m^2.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Axle and wheels lumped mass, AxlM` — Mass

`[2 2]` (default) | `vector`

Axle and wheels lumped mass, *a*, in kg.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Track hardpoint coordinates relative to axle center, TrackCoords` — Point

`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Track hardpoint coordinates, Tc_t, along the solid axle *x*, *y*, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `TrackCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and wheel locations.

$$Tc_t = \begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{w_{1,1}} & z_{w_{1,2}} & z_{w_{2,1}} & z_{w_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Axis
`TrackCoords(1, 1)`	1	1	Solid axle *x*-axis
`TrackCoords(1, 2)`	1	2	
`TrackCoords(1, 3)`	2	1	
`TrackCoords(1, 4)`	2	2	
`TrackCoords(2, 1)`	1	1	Solid axle *y*-axis
`TrackCoords(2, 2)`	1	2	
`TrackCoords(2, 3)`	2	1	
`TrackCoords(2, 4)`	2	2	
`TrackCoords(3, 1)`	1	1	Solid axle *z*-axis
`TrackCoords(3, 2)`	1	2	
`TrackCoords(3, 3)`	2	1	
`TrackCoords(3, 4)`	2	2	

Suspension hardpoint coordinates relative to axle center, `SuspCoords` — Point
`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Suspension hardpoint coordinates, Sc_t, along the solid axle *x*-, *y*-, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `SuspCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and track locations.

$$Sc_t = \begin{bmatrix} x_{s_{1,1}} & x_{s_{1,2}} & x_{s_{2,1}} & x_{s_{2,2}} \\ y_{s_{1,1}} & y_{s_{1,2}} & y_{s_{2,1}} & y_{s_{2,2}} \\ z_{s_{1,1}} & z_{s_{1,2}} & z_{s_{2,1}} & z_{s_{2,2}} \end{bmatrix}$$

Array Element	Axle	Track	Axis
`SuspCoords(1,1)`	1	1	Solid axle *x*-axis
`SuspCoords(1,2)`	1	2	
`SuspCoords(1,3)`	2	1	
`SuspCoords(1,4)`	2	2	
`SuspCoords(2,1)`	1	1	Solid axle *y*-axis
`SuspCoords(2,2)`	1	2	
`SuspCoords(2,3)`	2	1	
`SuspCoords(2,4)`	2	2	
`SuspCoords(3,1)`	1	1	Solid axle *z*-axis
`SuspCoords(3,2)`	1	2	
`SuspCoords(3,3)`	2	1	
`SuspCoords(3,4)`	2	2	

`Wheel and axle interface compliance constant, KzWhlAxl` — Spring rate

`6437000` (default) | `scalar`

Wheel and axle interface compliance constant, kwa_z, in N/m.

`Wheel and axle interface compliance preload, F0zWhlAxl` — Spring rate

`9810` (default) | `scalar`

Wheel and axle interface compliance preload, Fwa_{z0}, in N.

`Wheel and axle interface damping constant, CzWhlAxl` — Damping

`10000` (default) | `scalar`

Wheel and axle interface damping constant, cwa_z, in m.

Suspension

Compliance and Damping - Passive

`Suspension spring constant, Kz` — Suspension spring constant

`64370` (default) | `scalar` | `vector`

Linear vertical spring constant for independent suspension wheels on axle a, k_{z_a}, in N/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension spring preload, F0z` — Suspension spring preload

`9810` (default) | `scalar` | `vector`

Vertical preload spring force applied to the wheels on the axle at wheel carrier reference coordinates, F_{z0_a}, in N. Positive preload forces:

- Cause the vehicle to lift.
- Point along the negative vehicle-fixed *z*-axis.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension shock damping constant, Cz` — Suspension shock damping constant

`10000` (default) | `scalar` | `vector`

Linear vertical damping constant for independent suspension wheels on axle a, c_{z_a}, in Ns/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create this parameter, clear **Enable active damping**.

`Suspension maximum height, Hmax` — Height

`0.5` (default) | `scalar` | `vector`

Maximum suspension extension or minimum suspension compression height, H_{max}, for axle `a` before the suspension reaches a hardstop, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Geometry

`Toe angle at steering center, Toe` — Toe angle

`0.0349` (default) | `scalar`

Nominal suspension toe angle at zero steering angle, ζ_{0a}, in rad.

`Roll steer vs suspension height slope, RollStrgSlp` — Steer angle suspension slope

`-0.2269` (default) | `scalar` | `vector`

Roll steer angle versus suspension height, m_{htoe_a}, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Toe angle vs steering angle slope, ToeStrgSlp` — Toe angle steering slope

`0.01` (default) | `scalar` | `vector`

Toe angle versus steering angle slope, $m_{toesteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Caster angle at steering center, Caster` — Caster angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension caster angle at zero steering angle, η_{0a}, in rad.

`Caster angle vs suspension height slope, CasterHslp` — Caster angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Caster angle versus suspension height, $m_{hcaster_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Caster angle vs steering angle slope, CasterStrgSlp` — Caster angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Caster angle versus steering angle slope, $m_{castersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Camber angle at steering center, Camber` — Camber angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension camber angle at zero steering angle, ξ_{0a}, in rad.

`Camber angle vs suspension height slope, CamberHslp` — Camber angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Camber angle versus suspension height, $m_{hcamber_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Camber angle vs steering angle slope, CamberStrgSlp` — Camber angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Camber angle versus steering angle slope, $m_{cambersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Suspension height vs steering angle slope, StrgHgtSlp` — Suspension height versus steering angle slope

`0.1432` (default) | `scalar` | `vector`

Steering angle to vertical force slope applied at suspension wheel carrier reference point, m_{hsteer_a}, in m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Version History

Introduced in R2018a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

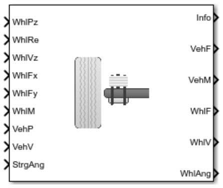
Generate C and C++ code using Simulink® Coder™.

See Also

Solid Axle Suspension | Solid Axle Suspension - Leaf Spring | Solid Axle Suspension - Mapped

Solid Axle Suspension - Leaf Spring

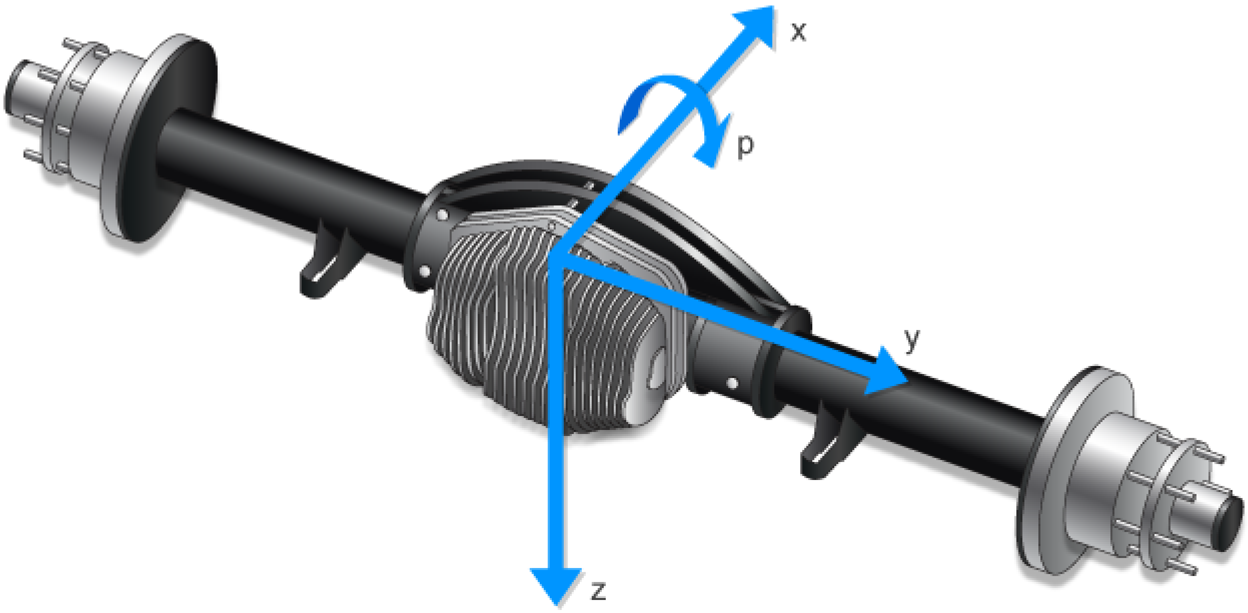
Solid axle suspension with leaf spring
Library: Vehicle Dynamics Blockset / Suspension



Description

The Solid Axle Suspension - Leaf Spring block implements a solid axle suspension with a leaf spring for multiple axles with multiple wheels per axle.

The block models the suspension compliance, damping, and geometric effects as functions of the wheel positions and velocities, with axle-specific compliance and damping parameters. Using the wheel position and velocity, the block calculates the vertical wheel position and suspension forces on the vehicle and wheel. The block uses the Z-down (defined in SAE J670) and a solid axle coordinate system. The solid axle coordinate system, shown here, is aligned with the Z-down vehicle coordinate system, with the *x*-axis in the direction of forward vehicle motion.



For Each	You Can Specify
Axle	• Multiple wheels • Suspension parameters
Wheel	• Steering angles

The block contains energy-storing spring elements and energy-dissipating damper elements. The block also stores energy via the axle roll angular acceleration and axle center of mass vertical and lateral acceleration.

This table summarizes the block parameter settings for a vehicle with:

- Two axles
- Two wheels per axle
- Steering angle input for both wheels on the front axle

Parameter	Setting
Number of axles, NumAxl	2
Number of wheels by axle, NumWhlsByAxl	`[2 2]`
Steered axle enable by axle, StrgEnByAxl	`[1 0]`

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Suspension Compliance and Damping

The block uses a linear spring and damper to model the vertical dynamic effects of the suspension system on the vehicle and wheel. Specifically, the block:

Uses	To Calculate
• Longitudinal and lateral displacement and velocity of the vehicle. • Longitudinal and lateral displacement and velocity of the wheel. • Vertical wheel forces applied to the vehicle.	• Suspension forces applied to the axle center. • Vertical displacements and velocities of the vehicle and wheel. • Longitudinal, lateral and vertical suspension forces and moments applied to the vehicle. • Longitudinal, lateral and vertical suspension forces and moments applied to the wheel.

To calculate the dynamics of the axle, the block implements these equations. The block neglects the effects of:

- Lateral and longitudinal translational velocity.
- Angular velocity about the vertical and lateral axes.

$$\begin{bmatrix}\ddot{x}_a\\ \ddot{y}_a\\ \ddot{z}_a\end{bmatrix} = \frac{1}{M_a}\begin{bmatrix}F_{xa}\\ F_{ya}\\ F_{za}\end{bmatrix} + \begin{bmatrix}\dot{x}_a\\ \dot{y}_a\\ \dot{z}_a\end{bmatrix} \times \begin{bmatrix}p\\ q\\ r\end{bmatrix} = \frac{1}{M_a}\begin{bmatrix}0\\ 0\\ F_{za}\end{bmatrix} + \begin{bmatrix}0\\ 0\\ \dot{z}_a\end{bmatrix} \times \begin{bmatrix}p\\ 0\\ 0\end{bmatrix} + \begin{bmatrix}0\\ 0\\ g\end{bmatrix} = \begin{bmatrix}0\\ p\dot{z}_a\\ \frac{F_{za}}{M_a} + g\end{bmatrix}$$

$$\begin{bmatrix}\dot{p}\\ \dot{q}\\ \dot{r}\end{bmatrix} = \left[\begin{bmatrix}M_x\\ M_y\\ M_z\end{bmatrix} - \begin{bmatrix}p\\ q\\ r\end{bmatrix} \times \begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}\begin{bmatrix}p\\ q\\ r\end{bmatrix}\right]\begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}^{-1}$$

$$= \left[\begin{bmatrix}M_x\\ 0\\ 0\end{bmatrix} - \begin{bmatrix}p\\ q\\ 0\end{bmatrix} \times \begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}\begin{bmatrix}p\\ 0\\ 0\end{bmatrix}\right]\begin{bmatrix}I_{xx} & 0 & 0\\ 0 & I_{yy} & 0\\ 0 & 0 & I_{zz}\end{bmatrix}^{-1} = \begin{bmatrix}\frac{M_x}{I_{xx}}\\ 0\\ 0\end{bmatrix}$$

The net vertical force on the axle center of mass is the sum of the wheel and suspension forces acting on the axle.

$$F_{za} = \sum_{t=1}^{Nta}\left(F_{wz_{a,t}} + F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right)\right)$$

The net moment about the roll axis of the solid axle suspension accounts for the hardpoint coordinates of the suspension and wheels.

$$M_x = \sum_{t=1}^{Nta}\left(F_{wz_{a,t}}y_{w_t} + \left(F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right)\right)y_{s_t}\right.$$
$$\left. + M_{wx_{a,t}}\frac{I_{xx}}{I_{xx} + M_a y_{w_t}}\right)$$

Block parameters provide the track and suspension hardpoints coordinates.

$$Tc_t = \begin{bmatrix}x_{w_1} & x_{w_2} & \cdots\\ y_{w_1} & y_{w_2} & \cdots\\ z_{w_1} & z_{w_2} & \cdots\end{bmatrix}$$

$$Sc_t = \begin{bmatrix}x_{s_1} & x_{s_2} & \cdots\\ y_{s_1} & y_{s_2} & \cdots\\ z_{s_1} & z_{s_2} & \cdots\end{bmatrix}$$

The block uses Euler angles to transform the track and suspension displacements, velocities, and accelerations to the vehicle coordinate system.

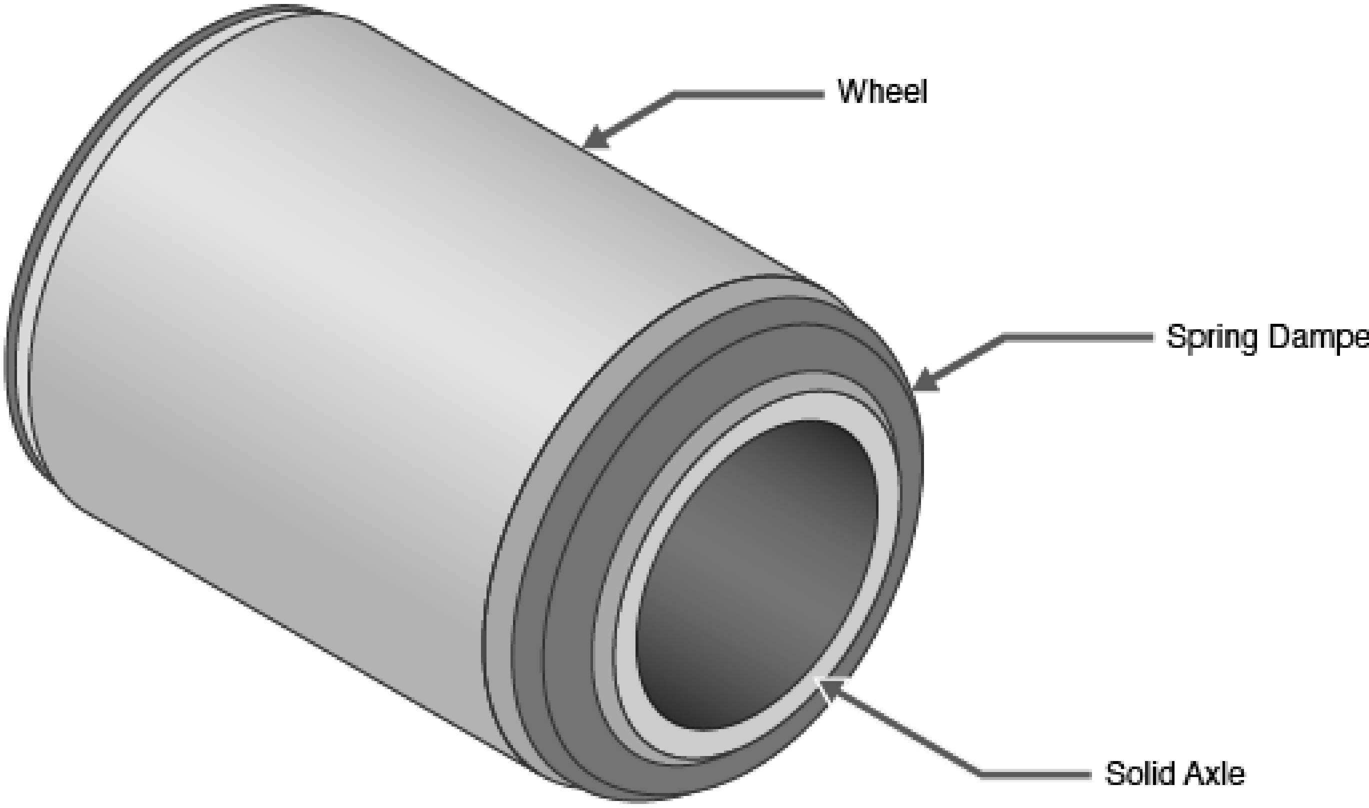
To calculate the suspension forces applied to the vehicle, the block implements this equation.

$$F_{vz_{a,t}} = -\left(F_{z0_a} + k_{z_a}\left(z_{v_{a,t}} - z_{s_{a,t}} + m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + c_{z_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{s_{a,t}}\right) + F_{zhstop_{a,t}}\right)$$

The suspension forces and moments applied to the vehicle are equal to the suspension forces and moments applied to the wheel.

$$F_{vx_{a,t}} = F_{wx_{a,t}}$$
$$F_{vy_{a,t}} = F_{wy_{a,t}}$$
$$F_{vz_{a,t}} = -F_{wz_{a,t}}$$
$$M_{vx_{a,t}} = M_{wx_{a,t}} + F_{wy_{a,t}}(Re_{wy_{a,t}} + H_{a,t})$$
$$M_{vy_{a,t}} = M_{wy_{a,t}} + F_{wx_{a,t}}\left(Re_{wx_{a,t}} + H_{a,t}\right)$$
$$M_{vz_{a,t}} = M_{wz_{a,t}}$$

To calculate the vertical force applied to the suspension at the wheel location, the block implements a stiff spring-damper, shown here.



The block uses this equation.

$$F_{wz_{a,t}} = -Fwa_{z0} - kwa_{z}\left(z_{w_{a,t}} - z_{s_{a,t}}\right) - cwa_{z}\left(\dot{z}_{w_{a,t}} - \dot{z}_{s_{a,t}}\right)$$

The equations use these variables.

$F_{wz_{a,t}}$, $M_{wz_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{wx_{a,t}}$, $M_{wx_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *x*-axis

$F_{wy_{a,t}}$, $M_{wy_{a,t}}$	Suspension force and moment applied to the wheel on axle `a`, wheel `t` along wheel-fixed *y*-axis
$F_{vz_{a,t}}$, $M_{vz_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *z*-axis
$F_{vx_{a,t}}$, $M_{vx_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *x*-axis
$F_{vy_{a,t}}$, $M_{vy_{a,t}}$	Suspension force and moment applied to the vehicle on axle `a`, wheel `t` along wheel-fixed *y*-axis
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
k_{z_a}	Vertical spring constant applied to wheels on axle `a`
kwa_z	Wheel and axle interface compliance constant
m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
c_{z_a}	Vertical damping constant applied to wheels on axle `a`
cwa_z	Wheel and axle interface damping constant
$Re_{w_{a,t}}$	Effective wheel radius for axle `a`, wheel `t`
$F_{zhstop_{a,t}}$	Vertical hardstop force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$F_{zaswy_{a,t}}$	Vertical anti-sway force at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
Fwa_{z0}	Wheel and axle interface compliance constant
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{v_{a,t}}$, $\dot{x}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$x_{w_{a,t}}$, $\dot{x}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$y_{v_{a,t}}$, $\dot{y}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$y_{w_{a,t}}$, $\dot{y}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *y*-axis
$H_{a,t}$	Suspension height at axle `a`, wheel `t`
$Re_{w_{a,t}}$	Effective wheel radius at axle `a`, wheel `t`

Hardstop Forces

The hardstop feedback force, $F_{zhstop_{a,t}}$, that the block applies depends on whether the suspension is compressing or extending. The block applies the force:

- In compression, when the suspension is compressed more than the maximum distance specified by the **Suspension maximum height, Hmax** parameter.
- In extension, when the suspension extension is greater than maximum extension specified by the **Suspension maximum height, Hmax** parameter.

To calculate the force, the block uses a stiffness based on a hyperbolic tangent and exponential scaling.

Camber, Caster, and Toe Angles

To calculate the camber, caster, and toe angles, block uses linear functions of the suspension height and steering angle.

$$\xi_{a,t} = \xi_{0a} + m_{hcamber_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{cambersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\eta_{a,t} = \eta_{0a} + m_{hcaster_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{castersteer_a}\left|\delta_{steer_{a,t}}\right|$$

$$\zeta_{a,t} = \zeta_{0a} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equations use these variables.

$\xi_{a,t}$	Camber angle of wheel on axle a, wheel t
$\eta_{a,t}$	Caster angle of wheel on axle a, wheel t
$\zeta_{a,t}$	Toe angle of wheel on axle a, wheel t
ξ_{0a}, η_{0a}, ζ_{0a}	Nominal suspension axle a camber, caster, and toe angles, respectively, at zero steering angle
$m_{hcamber_a}$, $m_{hcaster_a}$, m_{htoe_a}	Camber, caster, and toe angles, respectively, versus suspension height slope for axle a
$m_{cambersteer_a}$, $m_{castersteer_a}$, $m_{toesteer_a}$	Camber, caster, and toe angles, respectively, versus steering angle slope for axle a
m_{hsteer_a}	Steering angle versus vertical force slope for axle a
$\delta_{steer_{a,t}}$	Steering angle input for axle a, wheel t
$z_{v_{a,t}}$	Vehicle displacement at axle a, wheel t, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$	Wheel displacement at axle a, wheel t, along the vehicle-fixed *z*-axis

Steering Angles

Optionally, use the **Steered axle enable by axle, StrgEnByAxl** parameter to input steering angles for the wheels. To calculate the steering angles for the wheels, the block offsets the input steering angles with a linear function of the suspension height.

$$\delta_{whlsteer_{a,t}} = \delta_{steer_{a,t}} + m_{htoe_a}\left(z_{w_{a,t}} - z_{v_{a,t}} - m_{hsteer_a}\left|\delta_{steer_{a,t}}\right|\right) + m_{toesteer_a}\left|\delta_{steer_{a,t}}\right|$$

The equation uses these variables.

$m_{toesteer_a}$	Axle a toe angle versus steering angle slope
m_{hsteer_a}	Axle a steering angle versus vertical force slope
m_{htoe_a}	Axle a toe angle versus suspension height slope
$\delta_{whlsteer_{a,t}}$	Wheel steering angle for axle a, wheel t
$\delta_{steer_{a,t}}$	Steering angle input for axle a, wheel t
$z_{v_{a,t}}$	Vehicle displacement at axle a, wheel t, along the vehicle-fixed *z*-axis

$z_{w_{a,t}}$	Wheel displacement at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Power and Energy

The block calculates these suspension characteristics for each axle, `a`, wheel, `t`.

Calculation	Equation
Dissipated power, $P_{susp_{a,t}}$	$P_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Absorbed energy, $E_{susp_{a,t}}$	$E_{susp_{a,t}} = F_{wzlookup_a}\left(\dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \dot{z}_{v_{a,t}} - \dot{z}_{w_{a,t}}, \delta_{steer_{a,t}}\right)$
Suspension height, $H_{a,t}$	$H_{a,t} = -\left(z_{v_{a,t}} - z_{w_{a,t}} + \frac{F_{z0_a}}{k_{z_a}} + m_{hsteer_a}\left\|\delta_{steer_{a,t}}\right\|\right)$
Distance from wheel carrier center to tire/road interface	$z_{wtr_{a,t}} = Re_{w_{a,t}} + H_{a,t}$

The equations use these variables.

m_{hsteer_a}	Steering angle to vertical force slope applied at wheel carrier for wheels on axle `a`
$\delta_{steer_{a,t}}$	Steering angle input for axle `a`, wheel `t`
$Re_{w_{a,t}}$	Axle `a`, wheel `t` effective wheel radius from wheel carrier center to tire/road interface
F_{z0_a}	Vertical suspension spring preload force applied to the wheels on axle `a`
$z_{wtr_{a,t}}$	Distance from wheel carrier center to tire/road interface, along the vehicle-fixed *z*-axis
$z_{v_{a,t}}$, $\dot{z}_{v_{a,t}}$	Vehicle displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis
$z_{w_{a,t}}$, $\dot{z}_{w_{a,t}}$	Wheel displacement and velocity at axle `a`, wheel `t`, along the vehicle-fixed *z*-axis

Ports

Input

`WhlPz` — Wheel z-axis displacement

`array`

Wheel displacement, z_w, along wheel-fixed *z*-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

  $$\text{WhlPz} = z_w = \left[z_{w_{1,1}}\ z_{w_{1,2}}\ z_{w_{2,1}}\ z_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	`1`	`1`
Front right	`WhlPz(1,2)`	`1`	`2`

Wheel	Array Element	Axle	Wheel Number
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius

array

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlRe} = Re_w = \left[Re_{w_{1,1}}\ Re_{w_{1,2}}\ Re_{w_{2,1}}\ Re_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel *z*-axis velocity

array

Wheel velocity, $\dot{z}_w$, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}}\ \dot{z}_{w_{1,2}}\ \dot{z}_{w_{2,1}}\ \dot{z}_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

array

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed x-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

array

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed *y*-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

array

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed *x*-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed *y*-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\text{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement
`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\text{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Axis**
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity
`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\text{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\mathrm{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,\,1}} \;\; \delta_{steer_{1,\,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2

- 3D array signal (3-by-4)

Array Element	Axle	Wheel Number
`(1,1)`	1	1
`(1,2)`	1	2
`(1,3)`	2	1
`(1,4)`	2	2
`(2,1)`	1	1
`(2,2)`	1	2
`(2,3)`	2	1
`(2,4)`	2	2
`(3,1)`	1	1
`(3,2)`	1	2
`(3,3)`	2	1
`(3,4)`	2	2

Signal	Description	Array Signal	Variable	Units
`Camber`	Wheel angles according to the axle.	1D	$\text{WhlAng}[1, \ldots] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\text{WhlAng}[2, \ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\text{WhlAng}[3, \ldots] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m

Signal	Description	Array Signal	Variable	Units
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m

Signal	Description	Array Signal	Variable	Units
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} =$ $\begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{wy_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s

Signal	Description	Array Signal	Variable	Units
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle

array

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\text{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle

`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\mathrm{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	

Array Element	Axle	Wheel Number	Moment Axis
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles

`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.
- Signal contains angles according to the axle and wheel locations.

$$\mathrm{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Angle**
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

Axles

`Number of axles, NumAxl` — Number of axles
2 (default) | `scalar`

Number of axles, N_a, dimensionless.

`Number of wheels by axle, NumWhlsByAxl` — Number of wheels per axle
`[2 2]` (default) | `vector`

Number of wheels per axle, Nt_a, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example, `[1,2]` represents one wheel on axle one and two wheels on axle two.

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering
`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]`—For a two-axle vehicle, enables axle one steering and disables axle two steering
- `[1 1]`—For a two-axle vehicle, enables axle one and axle two steering

Dependencies

Setting an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1:

- Creates input port `StrgAng`.
- Creates these parameters
  - **Toe angle vs steering angle slope, ToeStrgSlp**
  - **Caster angle vs steering angle slope, CasterStrgSlp**
  - **Camber angle vs steering angle slope, CamberStrgSlp**
  - **Suspension height vs steering angle slope, StrgHgtSlp**

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

`Axle and wheels lumped principal moments of inertia about longitudinal axis, AxlIxx` — Inertia

`300` (default) | `vector`

Axle and wheels lumped principal moments of inertia about longitudinal axis, AxleIxx *a*, in kg*m^2.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Axle and wheels lumped mass, AxlM` — Mass

`[2 2]` (default) | `vector`

Axle and wheels lumped mass, *a*, in kg.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Track hardpoint coordinates relative to axle center, TrackCoords` — Point

`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Track hardpoint coordinates, Tc_t, along the solid axle *x*, *y*, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `TrackCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and wheel locations.

$$Tc_t = \begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{w_{1,1}} & z_{w_{1,2}} & z_{w_{2,1}} & z_{w_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Axis
`TrackCoords(1, 1)`	1	1	Solid axle *x*-axis
`TrackCoords(1, 2)`	1	2	
`TrackCoords(1, 3)`	2	1	
`TrackCoords(1, 4)`	2	2	
`TrackCoords(2, 1)`	1	1	Solid axle *y*-axis
`TrackCoords(2, 2)`	1	2	
`TrackCoords(2, 3)`	2	1	
`TrackCoords(2, 4)`	2	2	
`TrackCoords(3, 1)`	1	1	Solid axle *z*-axis
`TrackCoords(3, 2)`	1	2	
`TrackCoords(3, 3)`	2	1	
`TrackCoords(3, 4)`	2	2	

`Suspension hardpoint coordinates relative to axle center, SuspCoords` — Point
`[0 0 0 0;-1 1 -1 1;0 0 0 0]` (default) | `array`

Suspension hardpoint coordinates, Sc_t, along the solid axle *x*-, *y*-, and *z*-axes, in m.

For example, for a two-axle vehicle with two wheels per axle, the `SuspCoords` array:

- Dimensions are `[3x4]`.
- Contains four track hardpoint coordinates according to their axle and track locations.

$$Sc_t = \begin{bmatrix} x_{s_{1,1}} & x_{s_{1,2}} & x_{s_{2,1}} & x_{s_{2,2}} \\ y_{s_{1,1}} & y_{s_{1,2}} & y_{s_{2,1}} & y_{s_{2,2}} \\ z_{s_{1,1}} & z_{s_{1,2}} & z_{s_{2,1}} & z_{s_{2,2}} \end{bmatrix}$$

Array Element	Axle	Track	Axis
`SuspCoords(1,1)`	1	1	Solid axle *x*-axis
`SuspCoords(1,2)`	1	2	
`SuspCoords(1,3)`	2	1	
`SuspCoords(1,4)`	2	2	
`SuspCoords(2,1)`	1	1	Solid axle *y*-axis
`SuspCoords(2,2)`	1	2	
`SuspCoords(2,3)`	2	1	
`SuspCoords(2,4)`	2	2	
`SuspCoords(3,1)`	1	1	Solid axle *z*-axis
`SuspCoords(3,2)`	1	2	
`SuspCoords(3,3)`	2	1	
`SuspCoords(3,4)`	2	2	

`Wheel and axle interface compliance constant, KzWhlAxl` — Spring rate

`6437000` (default) | `scalar`

Wheel and axle interface compliance constant, kwa_z, in N/m.

`Wheel and axle interface compliance preload, F0zWhlAxl` — Spring rate

`9810` (default) | `scalar`

Wheel and axle interface compliance preload, Fwa_{z0}, in N.

`Wheel and axle interface damping constant, CzWhlAxl` — Damping

`10000` (default) | `scalar`

Wheel and axle interface damping constant, cwa_z, in m.

Suspension

Compliance and Damping - Passive

`Suspension spring constant, Kz` — Suspension spring constant

`64370` (default) | `scalar` | `vector`

Linear vertical spring constant for independent suspension wheels on axle a, k_{z_a}, in N/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension spring preload, F0z` — Suspension spring preload

`9810` (default) | `scalar` | `vector`

Vertical preload spring force applied to the wheels on the axle at wheel carrier reference coordinates, F_{z0_a}, in N. Positive preload forces:

- Cause the vehicle to lift.
- Point along the negative vehicle-fixed *z*-axis.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Suspension shock damping constant, Cz` — Suspension shock damping constant

`10000` (default) | `scalar` | `vector`

Linear vertical damping constant for independent suspension wheels on axle a, c_{z_a}, in Ns/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create this parameter, clear **Enable active damping**.

`Suspension maximum height, Hmax` — Height

`0.5` (default) | `scalar` | `vector`

Maximum suspension extension or minimum suspension compression height, H_{max}, for axle `a` before the suspension reaches a hardstop, in m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Geometry

`Toe angle at steering center, Toe` — Toe angle

`0.0349` (default) | `scalar`

Nominal suspension toe angle at zero steering angle, ζ_{0a}, in rad.

`Roll steer vs suspension height slope, RollStrgSlp` — Steer angle suspension slope

`-0.2269` (default) | `scalar` | `vector`

Roll steer angle versus suspension height, m_{htoe_a}, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Toe angle vs steering angle slope, ToeStrgSlp` — Toe angle steering slope

`0.01` (default) | `scalar` | `vector`

Toe angle versus steering angle slope, $m_{toesteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Caster angle at steering center, Caster` — Caster angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension caster angle at zero steering angle, η_{0a}, in rad.

`Caster angle vs suspension height slope, CasterHslp` — Caster angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Caster angle versus suspension height, $m_{hcaster_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Caster angle vs steering angle slope, CasterStrgSlp` — Caster angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Caster angle versus steering angle slope, $m_{castersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Camber angle at steering center, Camber` — Camber angle at steering center

`0.0698` (default) | `scalar`

Nominal suspension camber angle at zero steering angle, ξ_{0a}, in rad.

`Camber angle vs suspension height slope, CamberHslp` — Camber angle versus suspension height slope

`-0.2269` (default) | `scalar` | `vector`

Camber angle versus suspension height, $m_{hcamber_a}$, in rad/m.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

`Camber angle vs steering angle slope, CamberStrgSlp` — Camber angle versus steering angle slope

`0.01` (default) | `scalar` | `vector`

Camber angle versus steering angle slope, $m_{cambersteer_a}$, dimensionless.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Suspension height vs steering angle slope, StrgHgtSlp` — Suspension height versus steering angle slope

`0.1432` (default) | `scalar` | `vector`

Steering angle to vertical force slope applied at suspension wheel carrier reference point, m_{hsteer_a}, in m/rad.

Vector is `1` by the number of vehicle axles, N_a. If you provide a scalar value, the block uses that value for all axles.

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

Version History

Introduced in R2018a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

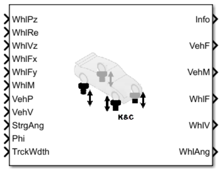
See Also

Solid Axle Suspension | Solid Axle Suspension - Coil Spring | Solid Axle Suspension - Mapped

Independent Suspension - K and C

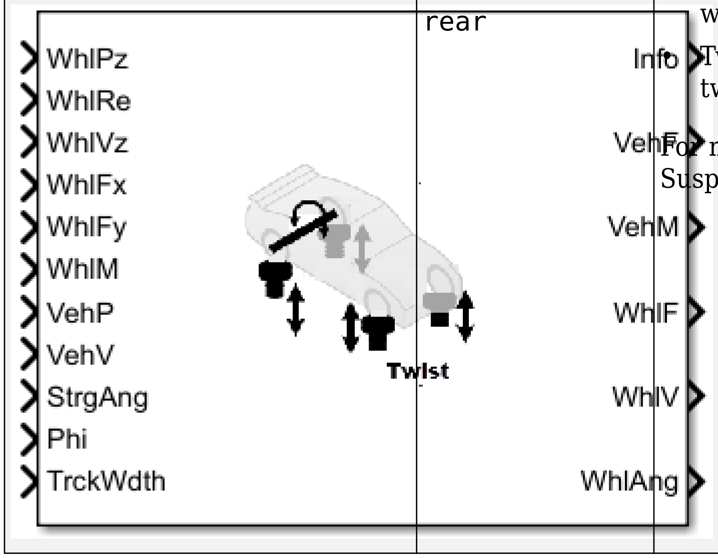
Independent kinematics and compliance test suspension

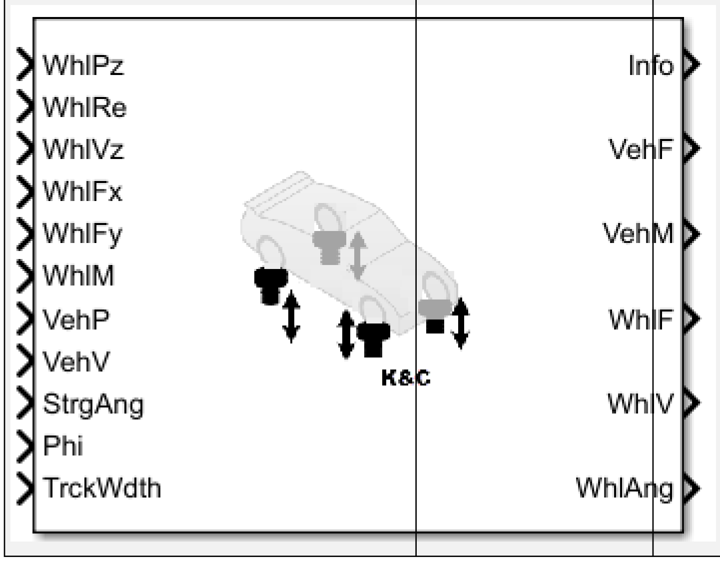
Library: Vehicle Dynamics Blockset / Suspension



Description

In the Vehicle Dynamics Blockset™ library, there are two types of suspension blocks that implement the kinematics and compliance (K and C) test suspension characteristics measured from simulated or actual laboratory suspension tests.

Block	Suspension type Setting	Implementation
Twist-Beam Suspension - K and C  	`Independent front and twist-beam rear`	Kinematics and compliance effects of: • Independent suspension on a front axle with two wheels • Twist-beam suspension on a rear axle with two wheels For more information, see Twist-Beam Suspension - K and C.

Block	Suspension type Setting	Implementation
Independent Suspension - K and C  	`Independent front and rear`	Kinematics and compliance effects of four independent suspensions on a vehicle with two axles and two wheels per axle.

K and C Effects on Suspension

To determine the overall suspension forces and geometric effects on the vehicle and wheels, the block adds the individual effects from kinematic (bounce, roll, steering) and compliance (longitudinal and lateral forces, aligning moments) inputs. Specifically, the block multiplies the suspension geometry states by either gradient or table values to determine the K and C effects on wheel orientation and suspension forces.

Wheel orientation:

- Camber, caster, and steer angles
- Lateral wheel center displacement
- Longitudinal wheel center displacement

Vertical suspension forces:

- Anti-sway bar
- Shock force
- Wheel rate
- Contact patch swing arm (CPSA) force
- Longitudinal side view swing arm (SVSA) anti-effects

Camber, Caster, and Steer Angles

The block uses these parameters to account for the K and C effects on the camber, caster, and steer angles.

- **Bounce test**– Independent suspension

- **Roll test**– Independent suspension
- **Steer test**
- **Longitudinal compliance test**
- **Lateral compliance-opposed test**
- **Aligning torque compliance-opposed test**

Use the **Static alignment settings** parameters to set the initial state of the suspension.

Lateral Wheel Center Displacement

The block uses these parameters to account for the K and C effects the lateral wheel center displacement.

- **Bounce test**
- **Longitudinal compliance test**
- **Lateral compliance-opposed test**

Longitudinal Wheel Center Displacement

The block uses these parameters to account for the K and C effects on the longitudinal wheel center displacement.

- **Bounce test**
- **Longitudinal compliance test**

Shock Force

The block uses the **Shock force** parameters to calculate the shock force effect on the vertical suspension force. You can specify table-based or constant parameter values.

Wheel Rate

The block uses the **Bounce test** parameters to calculate the wheel rate effect on the vertical suspension force.

Contact Patch Swing Arm

The block uses these equations to calculate the effect of the contact patch swing arm (CPSA) forces on vertical suspension force.

$$\tan(\theta_{CPSA}) = f(Z_w)$$
$$F_{zCPSA} = F_y \tan(\theta_{CPSA})$$

The block also uses the **Static loaded radius of wheels** parameter in the CPSA force calculation.

The equations use these variables.

Θ_{CPSA}	Contact patch swing arm angle
F_y	Lateral suspension force
F_{zCPSA}	CPSA effect on vertical suspension force
z_w	Wheel displacement

Longitudinal Side View Swing Arm Anti-Effects

The block uses these equations to calculate the effect of the side view swing arm (SVSA) forces on vertical suspension force during acceleration and braking.

$$\tan(\theta_{SVSA}) = f(Z_w)$$

$$F_{zSVSA} = F_x \tan(\theta_{SVSA})$$

Use the **Drivetrain type** parameter to ensure that the block applies the acceleration anti-effects to the correct wheels.

The equations use these variables.

Θ_{SVSA}	Contact patch swing arm angle
F_x	Longitudinal wheel force
F_{zSVSA}	SVSA effect on vertical suspension force
z_w	Wheel displacement

Anti-Sway Bar

Optionally, use the **Anti-sway axle enable by axle, AntiSwayEnByAxl** parameter to implement anti-sway bar reaction forces by axle.

If you enable an anti-sway bar on the axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Suspension roll stiffness with anti-roll bar, RollStiffArb**, and the roll stiffness parameter measured with no anti-sway bar present **Suspension roll stiffness without anti-roll bar, RollStiffNoArb**.

If you do not enable an anti-sway bar, the roll stiffness is 0.

Ports

The block uses the wheel number, t, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	Axle	Wheel Number
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Input

`WhlPz` — Wheel z-axis displacement

array

Wheel displacement, z_w, along wheel-fixed z-axis, in m. Array dimensions are 1 by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlPz} = z_w = \left[z_{w_{1,1}} \ z_{w_{1,2}} \ z_{w_{2,1}} \ z_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius

`array`

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlRe} = Re_w = \left[Re_{w_{1,1}} \ Re_{w_{1,2}} \ Re_{w_{2,1}} \ Re_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel z-axis velocity

`array`

Wheel velocity, $\dot{z}_w$, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}} \ \dot{z}_{w_{1,2}} \ \dot{z}_{w_{2,1}} \ \dot{z}_{w_{2,2}} \right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

`array`

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed x-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

array

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed y-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\text{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

array

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed x-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed y-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed z-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\text{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Moment Axis**
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlM(3,2)`	1	2	
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement
`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\text{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Axis**
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	
Rear right	`VehP(2,4)`	2	2	
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity
`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains `4` velocities according to their axle and wheel locations.

$$\text{VehV} = \begin{bmatrix}\dot{x}_v \\ \dot{y}_v \\ \dot{z}_v\end{bmatrix} = \begin{bmatrix}\dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}}\end{bmatrix}$$

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Axis**
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehV(2,2)`	1	2	
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\text{StrgAng} = \delta_{steer} = \begin{bmatrix}\delta_{steer_{1,1}} & \delta_{steer_{1,2}}\end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Phi` — Vehicle pitch angle

`scalar`

Vehicle pitch angle about earth-fixed *Y*-axis, in rad.

`TrckWdth` — Track width

`array`

Distance between wheels on each axle. Input array dimensions are 1-by-2.

Array Element	Description
`TrckWdth(1,1)`	Distance between wheels on front axle
`TrckWdth(1,2)`	Distance between wheels on rear axle

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Wheel	Array Element	Axle	Wheel Number
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2

- 3D array signal (3-by-4)

Wheel	Array Element	Axle	Wheel Number
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2
Front left	`(2,1)`	1	1

Wheel	Array Element	Axle	Wheel Number
Front right	`(2,2)`	1	2
Rear left	`(2,3)`	2	1
Rear right	`(2,4)`	2	2
Front left	`(3,1)`	1	1
Front right	`(3,2)`	1	2
Rear left	`(3,3)`	2	1
Rear right	`(3,4)`	2	2

Signal	Description	Array Signal	Variable	Units
`Camber`	Wheel angles according to the axle and wheel location.	1D	$\mathrm{WhlAng}[1, ...] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\mathrm{WhlAng}[2, ...] = \eta = [\eta_{a,t}]$	
`Toe`			$\mathrm{WhlAng}[3, ...] = \zeta = [\zeta_{a,t}]$	
`Height`	Suspension height	1D	H	m
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N

Signal	Description	Array Signal	Variable	Units
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} =$ $\begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m

Signal	Description	Array Signal	Variable	Units
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\mathrm{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix}$ $= \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle

`array`

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle
`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\mathrm{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	Axle	Wheel Number	Moment Axis
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles
`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.
- Signal contains angles according to the axle and wheel locations.

$$\mathrm{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering

`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]` — For a two-axle vehicle, enables axle 1 steering and disables axle 2 steering
- `[1 1]` — For a two-axle vehicle, enables axle 1 and axle 2 steering

Dependencies

Setting any element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1 creates Input port `StrgAng`.

`Anti-sway axle enable by axle, AntiSwayEnByAxl` — Boolean vector to enable axle anti-sway

`[0 0]` (default) | `vector`

Boolean vector that enables axle anti-sway for axle *a*, dimensionless. For example, `[1 0]` enables axle 1 anti-sway and disables axle 2 anti-sway. Vector is `1` by the number of vehicle axles, N_a.

If you enable an anti-sway bar on the axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Suspension roll stiffness with anti-roll bar, RollStiffArb**, and the roll stiffness parameter measured with no anti-sway bar present **Suspension roll stiffness without anti-roll bar, RollStiffNoArb**.

If you do not enable an anti-sway bar, the stiffness is 0.

Suspension Parameters

`Suspension type` — Type of suspension

`Independent front and rear` | `Independent front and twist beam rear`

Select type of suspension.

`Drivetrain type` — Type of drivetrain

`FWD` (default) | `RWD` | `AWD`

Select type of drivetrain.

- `AWD` – All-wheel drive
- `FWD` – Front-wheel drive
- `RWD` – Rear-wheel drive

Directions

`+ Steer angle` — Positive steer angle

`Right` (default) | `Left`

Direction of positive steer angle during kinematics and compliance test.

`+ Fx used in compliance tests` — Positive longitudinal force

`Front` (default) | `Rear`

Direction of positive longitudinal force during kinematics and compliance test.

`+ Fy used in compliance tests` — Positive lateral force

`Right` (default) | `Left`

Direction of positive lateral force during kinematics and compliance test.

`+ Suspension Jounce` — Positive suspension jounce

`Up` (default) | `Down`

Direction of positive suspension jounce during kinematics and compliance test.

`+ WhlMz used in compliance tests` — Positive yaw moment

`Counter-clockwise` (default) | `Clockwise`

Direction of positive yaw moment during kinematics and compliance test.

Shock force

`Shock type` — Type of shock force
`Table-based` (default) | `Table-based individual``Constant`

Type of shock force.

If a table-based individual setting is chosen, table-based shock force is implemented together with constant motion ratios. If a table-based setting is chosen both shock force and motion ratios are calculated from lookup tables.

Setting	Implementation
`Table-based`	Table-based shock force and motion ratios.
`Table-based individual`	Table-based shock force and constant motion ratios.
`Constant`	Constant shock force and motion ratios.

`Shock force vs shock compression rate, ShckFrceVsCompRate` — Table
`struct('FL',[-100. -5000;0 0;100. 5000],'FR',[-100. -5000;0 0;100. 5000],'RL',[-100. -5000;0 0;100. 5000],'RR',[-100. -5000;0 0;100. 5000])` (default)

Shock force versus shock compression rate, specified as a structure, in N/mm per sec.

Dependencies

To create this parameter, set **Shock type** to `Table-based` or `Table-based individual`.

Data Types: `struct`

`Motion ratios by axle, MotRatios` — Table
`struct('FL',[-0.1 -0.1;0 0;0.1 0.1],'FR',[-0.1 -0.1;0 0;0.1 0.1],'RL',[-0.1 -0.1;0 0;0.1 0.1],'RR',[-0.1 -0.1;0 0;0.1 0.1])` (default)

Motion ratios by axle, specified as a structure.

Data Types: `struct`

Bounce test

`Bump steer, BumpSteer` — Table
`struct('FL',[-0.1 1.1459;0 0;0.1 -1.1459],'FR',[-0.1 1.1459;0 0;0.1 -1.1459],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.;0 0;0.1 0.])` (default)

Bump steer, specified as a structure, in deg/m.

Data Types: `struct`

`Bump camber, BumpCamber` — Table
`struct('FL',[-0.1 1.7189;0 0;0.1 -1.7189],'FR',[-0.1 1.7189;0 0;0.1 -1.7189],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.;0 0;0.1 0.])` (default)

Bump camber, specified as a structure, in deg/m.

Data Types: `struct`

`Bump caster, BumpCaster` — Table
`struct('FL',[-0.1 1.1459;0 0;0.1 -1.1459],'FR',[-0.1 1.1459;0 0;0.1 -1.1459],'RL',[-0.1 -11.4592;0 0;0.1 11.4592],'RR',[-0.1 -11.4592;0 0;0.1 11.4592])` (default)

Bump caster, specified as a structure, in deg/m.

Data Types: `struct`

`Lateral wheel center displacement, LatWhlCtrDisp` — Table
`struct('FL',[-0.1 0.02;0 0;0.1 -0.02],'FR',[-0.1 0.02;0 0;0.1 -0.02],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.;0 0;0.1 0.])` (default)

Lateral wheel center displacement, specified as a structure, in mm/mm.

Data Types: `struct`

`Longitudinal wheel center displacement, LngWhlCtrDisp` — Table
`struct('FL',[-0.1 -0.002;0 0;0.1 0.002],'FR',[-0.1 -0.002;0 0;0.1 0.002],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.02;0 0;0.1 0.01])` (default)

Longitudinal wheel center displacement, specified as a structure, in mm/mm.

Data Types: `struct`

`Normal wheel rates, NrmlWhlRates` — Table
`struct('FL',[-100. -5000;0 0;100. 5000],'FR',[-100. -5000;0 0;100. 5000],'RL',[-100. -5000;0 0;100. 5000],'RR',[-100. -5000;0 0;100. 5000])` (default) | vector

Normal wheel rates, specified as a structure, in N/mm.

Data Types: `struct`

`Normal wheel force offsets, NrmlWhlFrcOff` — Force offset
`[0 0 0 0]` (default)

Normal wheel force offsets, specified as a vector, in N.

Dependencies

To create this parameter, specify a **Normal wheel rates, NrmlWhlRates** vector.

Data Types: `struct`

Roll test

`Suspension roll stiffness with anti-roll bar, RollStiffArb` — Anti-sway bar enabled
`[800 700]` (default) | 1-by-2 vector

Suspension roll stiffness with anti-roll bar, specified as a 1-by-2 vector, in Nm/deg. The first element is the front axle roll stiffness. The second element is the rear axle roll stiffness.

If you enable an anti-sway bar on the axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Suspension roll stiffness with anti-roll bar, RollStiffArb**, and the roll stiffness parameter measured with no anti-sway bar present **Suspension roll stiffness without anti-roll bar, RollStiffNoArb**.

If you do not enable an anti-sway bar, the stiffness is 0.

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and rear`.

Data Types: `double`

`Suspension roll stiffness without anti-roll bar, RollStiffNoArb` — Anti-sway bar not enabled

`[0 0]` (default) | 1-by-2 vector

Suspension roll stiffness without anti-roll bar, specified as a 1-by-2 vector, in Nm/deg. The first element is the front axle roll stiffness. The second element is the rear axle roll stiffness.

If you enable an anti-sway bar on the axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Suspension roll stiffness with anti-roll bar, RollStiffArb**, and the roll stiffness parameter measured with no anti-sway bar present **Suspension roll stiffness without anti-roll bar, RollStiffNoArb**.

If you do not enable an anti-sway bar, the stiffness is 0.

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and rear`.

Data Types: `double`

Steer test

`Camber vs steer angle, CambVsSteerAng` — Table

`struct('FL',[-10. -1.;0 0;10. 1.],'FR',[-10. 1.;0 0;10. -1.],'RL',[-10. -1.;0 0;10. 1.],'RR',[-10. 1.;0 0;10. -1.])` (default)

Camber vs steer angle, specified as a structure, in deg/deg.

Data Types: `struct`

`Caster vs steer angle, CastVsSteerAng` — Table

`struct('FL',[-10. -1.;0 0;10. 1.],'FR',[-10. 1.;0 0;10. -1.],'RL',[-10. -1.;0 0;10. 1.],'RR',[-10. 1.;0 0;10. -1.])` (default)

Caster vs steer angle, specified as a structure, in deg/deg.

Data Types: `struct`

Longitudinal compliance test

`Longitudinal steer compliance, LngSteerCompl` — Table

`struct('NegFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]),'PosFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]))` (default)

Longitudinal steer compliance, specified as a structure, in deg/kN.

Data Types: `struct`

Longitudinal camber compliance, `LngCambCompl` — Table
`struct('NegFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]),'PosFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]))` (default)

Longitudinal camber compliance, specified as a structure, in deg/kN.

Data Types: `struct`

Longitudinal caster compliance, `LngCastCompl` — Table
`struct('NegFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]),'PosFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]))` (default)

Longitudinal caster compliance, specified as a structure, in deg/kN.

Data Types: `struct`

Longitudinal wheel center compliance, `LngWhlCtrCompl` — Table
`struct('NegFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]),'PosFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]))` (default)

Longitudinal wheel center compliance, specified as a structure, in mm/kN.

Data Types: `struct`

Lateral wheel center compliance from braking, `LatWhlCtrComplLngBrk` — Table
`struct('NegFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]),'PosFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]))` (default)

Lateral wheel center compliance from braking, specified as a structure, in mm/kN.

Data Types: `struct`

Lateral compliance-opposed test

Lateral steer compliance, `LatSteerCompl` — Table
`struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.])` (default)

Lateral steer compliance, specified as a structure, in deg/kN.

Data Types: `struct`

Lateral camber compliance, `LatCambCompl` — Table
`struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.])` (default)

Lateral camber compliance, specified as a structure, in deg/kN.

Data Types: `struct`

`Lateral wheel center compliance from lateral sources, LatWhlCtrComplLat` — Table
`struct('FL',[-2. -5.;0 0;2. 5.],'FR',[-2. 5.;0 0;2. -5.],'RL',[-2. -5.;0 0;2. 5.],'RR',[-2. 5.;0 0;2. -5.])` (default)

Lateral wheel center compliance from lateral sources, specified as a structure, in mm/kN.

Data Types: `struct`

Aligning torque compliance-opposed test

`Aligning torque steer compliance, AlgnTrqSteerCompl` — Table
`struct('FL',[-0.2 -1.;0 0;0.2 1.],'FR',[-0.2 1.;0 0;0.2 -1.],'RL',[-0.2 -1.;0 0;0.2 1.],'RR',[-0.2 1.;0 0;0.2 -1.])` (default)

Aligning torque steer compliance, specified as a structure, in deg/kNm.

Data Types: `struct`

`Aligning torque camber compliance, AlgnTrqCambCompl` — Table
`struct('FL',[-0.2 -1.;0 0;0.2 1.],'FR',[-0.2 1.;0 0;0.2 -1.],'RL',[-0.2 -1.;0 0;0.2 1.],'RR',[-0.2 1.;0 0;0.2 -1.])` (default)

Aligning torque camber compliance, specified as a structure, in deg/kNm.

Data Types: `struct`

Static alignment settings

`Toe, StatToe` — Wheel toe angle
`[0 0 0 0]` (default) | 1-by-4 vector

Static toe angle for each wheel, specified as a 1-by-4 vector, in deg.

Wheel	Array Element	Axle	Wheel Location
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear left	`(1,4)`	2	2

Data Types: `double`

`Camber, StatCamber` — Wheel camber angle
`[0 0 0 0]` (default) | 1-by-4 vector

Static camber angle for each wheel, specified as a 1-by-4 vector, in deg.

Wheel	Array Element	Axle
Front left	`(1,1)`	1
Front right	`(1,2)`	1
Rear left	`(1,3)`	2
Rear left	`(1,4)`	2

Data Types: `double`

`Caster, StatCaster` — Wheel caster angle

`[0 0 0 0]` (default) | 1-by-4 vector

Static caster angle for each wheel, specified as a 1-by-4 vector, in deg.

Wheel	Array Element	Axle
Front left	`(1,1)`	1
Front right	`(1,2)`	1
Rear left	`(1,3)`	2
Rear left	`(1,4)`	2

Data Types: `double`

Wheels

`Static loaded radius of wheels, StatLdWhlR` — Wheel radius

`[0.3 0.3 0.3 0.3]` (default) | 1-by-4 vector

Static loaded radius of wheels, specified as a 1-by-4 vector, in m.

Wheel	Array Element	Axle
Front left	`(1,1)`	1
Front right	`(1,2)`	1
Rear left	`(1,3)`	2
Rear left	`(1,4)`	2

Data Types: `double`

Version History

Introduced in R2022a

Parameter name change from `NumTracksByAxl` to `NumWhlsByAxl`

Behavior changed in R2022b

The **Number of tracks by axle, NumTracksByAxl** parameter is renamed to **Number of wheels by axle, NumWhlsByAxl**.

The block uses the number of wheels per axle to index the input and output block signals.

New Suspension type and Drivetrain type Parameters

Behavior changed in R2022b

Starting from R2022b, the Independent Suspension - K and C block includes **Suspension type** and **Drivetrain type** parameters that allow you specify a suspension and drivetrain. Previously, the block was configured for front wheel drive with independent front and rear suspensions.

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

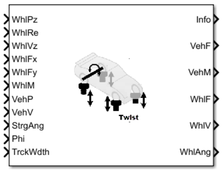
See Also

Independent Suspension - Double Wishbone | Independent Suspension - Mapped | Independent Suspension - MacPherson

Twist-Beam Suspension - K and C

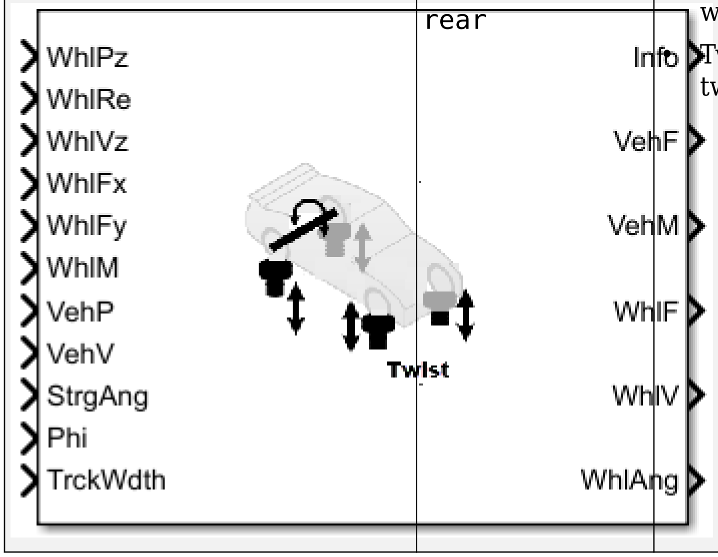
Twist-beam kinematics and compliance test suspension

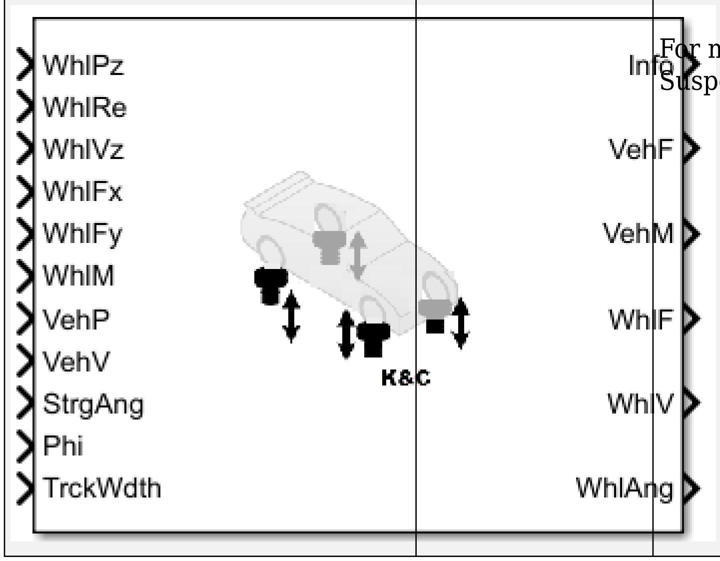
Library: Vehicle Dynamics Blockset / Suspension



Description

In the Vehicle Dynamics Blockset library, there are two types of suspension blocks that implement the kinematics and compliance (K and C) test suspension characteristics measured from simulated or actual laboratory suspension tests.

Block	Suspension type Setting	Implementation
Twist-Beam Suspension - K and C  	`Independent front and twist-beam rear`	Kinematics and compliance effects of: • Independent suspension on a front axle with two wheels • Twist-beam suspension on a rear axle with two wheels

Block	Suspension type Setting	Implementation
Independent Suspension - K and C  	`Independent front and rear`	Kinematics and compliance effects of four independent suspensions on a vehicle with two axles and two wheels per axle. For more information, see Independent Suspension - K and C.

K and C Effects on Suspension

To determine the overall suspension forces and geometric effects on the vehicle and wheels, the block adds the individual effects from kinematic (bounce, roll, steering) and compliance (longitudinal and lateral forces, aligning moments) inputs. Specifically, the block multiplies the suspension geometry states by either gradient or table values to determine the K and C effects on wheel orientation and suspension forces.

Wheel orientation:

- Camber, caster, and steer angles
- Lateral wheel center displacement
- Longitudinal wheel center displacement

Vertical suspension forces:

- Anti-sway bar
- Shock force
- Wheel rate
- Contact patch swing arm (CPSA) force
- Longitudinal side view swing arm (SVSA) anti-effects

Camber, Caster, and Steer Angles

The block uses these parameters to account for the K and C effects on the camber, caster, and steer angles.

- **Bounce test**– Independent suspension

- **Roll test**– Independent suspension
- **Steer test**
- **Longitudinal compliance test**
- **Lateral compliance-opposed test**
- **Aligning torque compliance-opposed test**

Use the **Static alignment settings** parameters to set the initial state of the suspension.

Lateral Wheel Center Displacement

The block uses these parameters to account for the K and C effects the lateral wheel center displacement.

- **Bounce test**
- **Longitudinal compliance test**
- **Lateral compliance-opposed test**

Longitudinal Wheel Center Displacement

The block uses these parameters to account for the K and C effects on the longitudinal wheel center displacement.

- **Bounce test**
- **Longitudinal compliance test**

Shock Force

The block uses the **Shock force** parameters to calculate the shock force effect on the vertical suspension force. You can specify table-based or constant parameter values.

Wheel Rate

The block uses the **Bounce test** parameters to calculate the wheel rate effect on the vertical suspension force.

Contact Patch Swing Arm

The block uses these equations to calculate the effect of the contact patch swing arm (CPSA) forces on vertical suspension force.

$$\tan(\theta_{CPSA}) = f(Z_w)$$
$$F_{zCPSA} = F_y \tan(\theta_{CPSA})$$

The block also uses the **Static loaded radius of wheels** parameter in the CPSA force calculation.

The equations use these variables.

Θ_{CPSA}	Contact patch swing arm angle
F_y	Lateral suspension force
F_{zCPSA}	CPSA effect on vertical suspension force
z_w	Wheel displacement

Longitudinal Side View Swing Arm Anti-Effects

The block uses these equations to calculate the effect of the side view swing arm (SVSA) forces on vertical suspension force during acceleration and braking.

$$\tan(\theta_{SVSA}) = f(Z_w)$$

$$F_{zSVSA} = F_x \tan(\theta_{SVSA})$$

Use the **Drivetrain type** parameter to ensure that the block applies the acceleration anti-effects to the correct wheels.

The equations use these variables.

Θ_{SVSA}	Contact patch swing arm angle
F_x	Longitudinal wheel force
F_{zSVSA}	SVSA effect on vertical suspension force
z_w	Wheel displacement

Anti-Sway Bar

Optionally, use the **Anti-sway axle enable by axle, AntiSwayEnByAxl** parameter to implement anti-sway bar reaction forces by axle.

If you do not enable an anti-sway bar, the axle roll stiffness is 0.

Front Axle

If you enable an anti-sway bar on the axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Front suspension roll stiffness with anti-roll bar, RollStiffArbFrnt**, and the roll stiffness parameter measured with no anti-sway bar present **Front suspension roll stiffness without anti-roll bar, RollStiffNoArbFrnt**.

Rear Axle

If you enable an anti-sway bar on the rear axle, the block uses this equation to calculate the twist-beam roll stiffness.

$$TB_{rs} = S_{rs} - \frac{\pi\left[\frac{1}{2}WR_{\nabla}TW^2\right]}{180}$$

The equation uses these variables.

TB_{rs}	Twist beam roll stiffness
S_{rs}	Suspension roll stiffness without twist beam, **RollStiffNoTwstRear** parameter
WR_{∇}	Normal wheel rate gradient, calculated from **NrmlWhlRates** parameter and suspension displacement
TW	Track width

Ports

The block uses the wheel number, *t*, to index the input and output signals. This table summarizes the wheel, axle, and corresponding wheel number for a vehicle with:

- Two axles
- Two wheels per axle

Wheel	**Axle**	**Wheel Number**
Front left	Front	1
Front right	Front	2
Rear left	Rear	1
Rear right	Rear	2

Input

`WhlPz` — Wheel z-axis displacement

`array`

Wheel displacement, z_w, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlPz`:

- Signal array dimensions are `[1x4]`.

  $$\text{WhlPz} = z_w = \left[z_{w_{1,1}}\ z_{w_{1,2}}\ z_{w_{2,1}}\ z_{w_{2,2}}\right]$$

Wheel	**Array Element**	**Axle**	**Wheel Number**
Front left	`WhlPz(1,1)`	1	1
Front right	`WhlPz(1,2)`	1	2
Rear left	`WhlPz(1,3)`	2	1
Rear right	`WhlPz(1,4)`	2	2

`WhlRe` — Wheel effective radius

`array`

Effective wheel radius, Re_w, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlRe`:

- Signal array dimensions are `[1x4]`.

  $$\text{WhlRe} = Re_w = \left[Re_{w_{1,1}}\ Re_{w_{1,2}}\ Re_{w_{2,1}}\ Re_{w_{2,2}}\right]$$

Wheel	**Array Element**	**Axle**	**Wheel Number**
Front left	`WhlRe(1,1)`	1	1
Front right	`WhlRe(1,2)`	1	2
Rear left	`WhlRe(1,3)`	2	1
Rear right	`WhlRe(1,4)`	2	2

`WhlVz` — Wheel z-axis velocity

`array`

Wheel velocity, $\dot{z}_w$, along wheel-fixed z-axis, in m. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlVz`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlVz} = \dot{z}_w = \left[\dot{z}_{w_{1,1}}\ \dot{z}_{w_{1,2}}\ \dot{z}_{w_{2,1}}\ \dot{z}_{w_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlVz(1,1)`	1	1
Front right	`WhlVz(1,2)`	1	2
Rear left	`WhlVz(1,3)`	2	1
Rear right	`WhlVz(1,4)`	2	2

`WhlFx` — Longitudinal wheel force on vehicle

`array`

Longitudinal wheel force applied to vehicle, F_{wx}, along the vehicle-fixed x-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFx`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlFx} = F_{wx} = \left[F_{wx_{1,1}}\ F_{wx_{1,2}}\ F_{wx_{2,1}}\ F_{wx_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFx(1,1)`	1	1
Front right	`WhlFx(1,2)`	1	2
Rear left	`WhlFx(1,3)`	2	1
Rear right	`WhlFx(1,4)`	2	2

`WhlFy` — Lateral wheel force on vehicle

`array`

Lateral wheel force applied to vehicle, F_{wy}, along the vehicle-fixed y-axis. Array dimensions are `1` by the total number of wheels on the vehicle.

For example, for a two-axle vehicle with two wheels per axle, the `WhlFy`:

- Signal array dimensions are `[1x4]`.

$$\mathrm{WhlFy} = F_{wy} = \left[F_{wy_{1,1}}\ F_{wy_{1,2}}\ F_{wy_{2,1}}\ F_{wy_{2,2}}\right]$$

Wheel	Array Element	Axle	Wheel Number
Front left	`WhlFy(1,1)`	1	1
Front right	`WhlFy(1,2)`	1	2
Rear left	`WhlFy(1.3)`	2	1

Wheel	Array Element	Axle	Wheel Number
Rear right	`WhlFy(1,4)`	2	2

`WhlM` — Suspension moment on wheel

`array`

Longitudinal, lateral, and vertical suspension moments at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N·m. Input array dimensions are `3` by the number of wheels on the vehicle.

- `WhlM(1,...)` — Suspension moment applied to the wheel about the vehicle-fixed *x*-axis (longitudinal)
- `WhlM(2,...)` — Suspension moment applied to the wheel about the vehicle-fixed *y*-axis (lateral)
- `WhlM(3,...)` — Suspension moment applied to the wheel about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to four wheels according to their axle and wheel locations.

$$\mathrm{WhlM} = M_w = \begin{bmatrix} M_{wx_{1,1}} & M_{wx_{1,2}} & M_{wx_{2,1}} & M_{wx_{2,2}} \\ M_{wy_{1,1}} & M_{wy_{1,2}} & M_{wy_{2,1}} & M_{wy_{2,2}} \\ M_{wz_{1,1}} & M_{wz_{1,2}} & M_{wz_{2,1}} & M_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front left	`WhlM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlM(1,2)`	1	2	
Rear left	`WhlM(1,3)`	2	1	
Rear right	`WhlM(1,4)`	2	2	
Front left	`WhlM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlM(2,2)`	1	2	
Rear left	`WhlM(2,3)`	2	1	
Rear right	`WhlM(2,4)`	2	2	
Front left	`WhlM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)

Wheel	Array Element	Axle	Wheel Number	Moment Axis
Front right	`WhlM(3,2)`	1	2	
Rear left	`WhlM(3,3)`	2	1	
Rear right	`WhlM(3,4)`	2	2	

VehP — Vehicle displacement
`array`

Vehicle displacement from axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are `3` the number of wheels on the vehicle.

- `VehP(1,...)` — Vehicle displacement from wheel, x_v, along the vehicle-fixed *x*-axis
- `VehP(2,...)` — Vehicle displacement from wheel, y_v, along the vehicle-fixed *y*-axis
- `VehP(3,...)` — Vehicle displacement from wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehP`:

- Signal dimensions are `[3x4]`.
- Signal contains four displacements according to their axle and wheel locations.

$$\mathrm{VehP} = \begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} x_{v_{1,1}} & x_{v_{1,2}} & x_{v_{2,1}} & x_{v_{2,2}} \\ y_{v_{1,1}} & y_{v_{1,2}} & y_{v_{2,1}} & y_{v_{2,2}} \\ z_{v_{1,1}} & z_{v_{1,2}} & z_{v_{2,1}} & z_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehP(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehP(1,2)`	1	2	
Rear left	`VehP(1,3)`	2	1	
Rear right	`VehP(1,4)`	2	2	
Front left	`VehP(2,1)`	1	1	Vehicle-fixed *y*-axis
Front right	`VehP(2,2)`	1	2	
Rear left	`VehP(2,3)`	2	1	

Wheel	Array Element	Axle	Wheel Number	Axis
Rear right	`VehP(2,4)`	2	2	
Front left	`VehP(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehP(3,2)`	1	2	
Rear left	`VehP(3,3)`	2	1	
Rear right	`VehP(3,4)`	2	2	

`VehV` — Vehicle velocity

`array`

Vehicle velocity at axle `a`, wheel `t` along vehicle-fixed coordinate system, in m. Input array dimensions are 3 by the number of wheels on the vehicle.

- `VehV(1,...)` — Vehicle velocity at wheel, x_v, along the vehicle-fixed *x*-axis
- `VehV(2,...)` — Vehicle velocity at wheel, y_v, along the vehicle-fixed *y*-axis
- `VehV(3,...)` — Vehicle velocity at wheel, z_v, along the vehicle-fixed *z*-axis

For example, for a two-axle vehicle with two wheels per axle, the `VehV`:

- Signal dimensions are `[3x4]`.
- Signal contains 4 velocities according to their axle and wheel locations.

$$\text{VehV} = \begin{bmatrix} \dot{x}_v \\ \dot{y}_v \\ \dot{z}_v \end{bmatrix} = \begin{bmatrix} \dot{x}_{v_{1,1}} & \dot{x}_{v_{1,2}} & \dot{x}_{v_{2,1}} & \dot{x}_{v_{2,2}} \\ \dot{y}_{v_{1,1}} & \dot{y}_{v_{1,2}} & \dot{y}_{v_{2,1}} & \dot{y}_{v_{2,2}} \\ \dot{z}_{v_{1,1}} & \dot{z}_{v_{1,2}} & \dot{z}_{v_{2,1}} & \dot{z}_{v_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Axis
Front left	`VehV(1,1)`	1	1	Vehicle-fixed *x*-axis
Front right	`VehV(1,2)`	1	2	
Rear left	`VehV(1,3)`	2	1	
Rear right	`VehV(1,4)`	2	2	
Front left	`VehV(2,1)`	1	1	Vehicle-fixed *y*-axis

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Axis**
Front right	`VehV(2,2)`	1	2	
Rear left	`VehV(2,3)`	2	1	
Rear right	`VehV(2,4)`	2	2	
Front left	`VehV(3,1)`	1	1	Vehicle-fixed *z*-axis
Front right	`VehV(3,2)`	1	2	
Rear left	`VehV(3,3)`	2	1	
Rear right	`VehV(3,4)`	2	2	

`StrgAng` — Steering angle, optional

`array`

Optional steering angle for each wheel, δ. Input array dimensions are `1` by the number of steered wheels.

For example, for a two-axle vehicle with two wheels per axle, you can input steering angles for both wheels on the first axle.

- To create the `StrgAng` port, set **Steered axle enable by axle, StrgEnByAxl** to `[1 0]`. The input signal array dimensions are `[1x2]`.
- The `StrgAng` signal contains two steering angles according to their axle and wheel locations.

$$\mathrm{StrgAng} = \delta_{steer} = \left[\delta_{steer_{1,1}}\ \delta_{steer_{1,2}}\right]$$

Wheel	**Array Element**	**Axle**	**Wheel Number**
Front left	`StrgAng(1,1)`	1	1
Front right	`StrgAng(1,2)`	1	2

Dependencies

To create input port `StrgAng`, set an element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1.

`Phi` — Vehicle pitch angle

`scalar`

Vehicle pitch angle about earth-fixed *Y*-axis, in rad.

`TrckWdth` — Track width

`array`

Distance between wheels on each axle. Input array dimensions are 1-by-2.

Array Element	Description
`TrckWdth(1,1)`	Distance between wheels on front axle
`TrckWdth(1,2)`	Distance between wheels on rear axle

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

For example, here are the indices for a two-axle, two-wheel vehicle. The total number of wheels is four.

- 1D array signal (1-by-4)

Wheel	Array Element	Axle	Wheel Number
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2

- 3D array signal (3-by-4)

Wheel	Array Element	Axle	Wheel Number
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear right	`(1,4)`	2	2
Front left	`(2,1)`	1	1
Front right	`(2,2)`	1	2
Rear left	`(2,3)`	2	1
Rear right	`(2,4)`	2	2
Front left	`(3,1)`	1	1
Front right	`(3,2)`	1	2
Rear left	`(3,3)`	2	1
Rear right	`(3,4)`	2	2

Signal	Description	Array Signal	Variable	Units
`Camber`	Wheel angles according to the axle and wheel location.	1D	$\text{WhlAng}[1,\ldots] = \xi = [\xi_{a,t}]$	rad
`Caster`			$\text{WhlAng}[2,\ldots] = \eta = [\eta_{a,t}]$	
`Toe`			$\text{WhlAng}[3,\ldots] = \zeta = [\zeta_{a,t}]$	

Signal	Description	Array Signal	Variable	Units
`Height`	Suspension height	1D	H	m
`Power`	Suspension power dissipation	1D	P_{susp}	W
`Energy`	Suspension absorbed energy	1D	E_{susp}	J
`VehF`	Suspension forces applied to the vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehF} = F_v =$ $\begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$	N
`VehM`	Suspension moments applied to vehicle	3D	For a two-axle, two wheels per axle vehicle: $\text{VehM} = M_v =$ $\begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$	N·m

Signal	Description	Array Signal	Variable	Units
`WhlF`	Suspension force applied to wheel	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlF} = F_w =$ $\begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$	N
`WhlP`	Wheel displacement	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlP} = \begin{bmatrix} x_w \\ y_w \\ z_w \end{bmatrix} =$ $\begin{bmatrix} x_{w_{1,1}} & x_{w_{1,2}} & x_{w_{2,1}} & x_{w_{2,2}} \\ y_{w_{1,1}} & y_{w_{1,2}} & y_{w_{2,1}} & y_{w_{2,2}} \\ z_{wtr_{1,1}} & z_{wtr_{1,2}} & z_{wtr_{2,1}} & z_{wtr_{2,2}} \end{bmatrix}$	m
`WhlV`	Wheel velocity	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix}$ $=$ $\begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$	m/s

Signal	Description	Array Signal	Variable	Units
`WhlAng`	Wheel camber, caster, toe angles	3D	For a two-axle, two wheels per axle vehicle: $\text{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$	rad

VehF — Suspension force on vehicle

array

Longitudinal, lateral, and vertical suspension force at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehF(1,...)` — Suspension force applied to vehicle along the vehicle-fixed *x*-axis (longitudinal)
- `VehF(2,...)` — Suspension force applied to vehicle along the vehicle-fixed *y*-axis (lateral)
- `VehF(3,...)` — Suspension force applied to vehicle along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehF`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension forces applied to the vehicle according to the axle and wheel locations.

$$\text{VehF} = F_v = \begin{bmatrix} F_{vx_{1,1}} & F_{vx_{1,2}} & F_{vx_{2,1}} & F_{vx_{2,2}} \\ F_{vy_{1,1}} & F_{vy_{1,2}} & F_{vy_{2,1}} & F_{vy_{2,2}} \\ F_{vz_{1,1}} & F_{vz_{1,2}} & F_{vz_{2,1}} & F_{vz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`VehF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`VehF(1,2)`	1	2	
Rear left	`VehF(1,3)`	2	1	
Rear right	`VehF(1,4)`	2	2	
Front left	`VehF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`VehF(2,2)`	1	2	

Wheel	**Array Element**	**Axle**	**Wheel Number**	**Force Axis**
Rear left	`VehF(2,3)`	2	1	
Rear right	`VehF(2,4)`	2	2	
Front left	`VehF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`VehF(3,2)`	1	2	
Rear left	`VehF(3,3)`	2	1	
Rear right	`VehF(3,4)`	2	2	

`VehM` — Suspension moment on vehicle

`array`

Longitudinal, lateral, and vertical suspension moment at axle `a`, wheel `t`, applied to the vehicle at the suspension connection point, in N·m. Array dimensions are `3` by the number of wheels on the vehicle.

- `VehM(1,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *x*-axis (longitudinal)
- `VehM(2,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *y*-axis (lateral)
- `VehM(3,...)` — Suspension moment applied to the vehicle about the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `VehM`:

- Signal dimensions are `[3x4]`.
- Signal contains suspension moments applied to vehicle according to the axle and wheel locations.

$$\text{VehM} = M_v = \begin{bmatrix} M_{vx_{1,1}} & M_{vx_{1,2}} & M_{vx_{2,1}} & M_{vx_{2,2}} \\ M_{vy_{1,1}} & M_{vy_{1,2}} & M_{vy_{2,1}} & M_{vy_{2,2}} \\ M_{vz_{1,1}} & M_{vz_{1,2}} & M_{vz_{2,1}} & M_{vz_{2,2}} \end{bmatrix}$$

Array Element	**Axle**	**Wheel Number**	**Moment Axis**
`VehM(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
`VehM(1,2)`	1	2	
`VehM(1,3)`	2	1	
`VehM(1,4)`	2	2	
`VehM(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
`VehM(2,2)`	1	2	

Array Element	Axle	Wheel Number	Moment Axis
`VehM(2,3)`	2	1	
`VehM(2,4)`	2	2	
`VehM(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
`VehM(3,2)`	1	2	
`VehM(3,3)`	2	1	
`VehM(3,4)`	2	2	

`WhlF` — Suspension force on wheel

`array`

Longitudinal, lateral, and vertical suspension forces at axle `a`, wheel `t`, applied to the wheel at the axle wheel carrier reference coordinate, in N. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlF(1,...)` — Suspension force on wheel along the vehicle-fixed *x*-axis (longitudinal)
- `WhlF(2,...)` — Suspension force on wheel along the vehicle-fixed *y*-axis (lateral)
- `WhlF(3,...)` — Suspension force on wheel along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlF`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlF} = F_w = \begin{bmatrix} F_{wx_{1,1}} & F_{wx_{1,2}} & F_{wx_{2,1}} & F_{wx_{2,2}} \\ F_{wy_{1,1}} & F_{wy_{1,2}} & F_{wy_{2,1}} & F_{wy_{2,2}} \\ F_{wz_{1,1}} & F_{wz_{1,2}} & F_{wz_{2,1}} & F_{wz_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlF(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlF(1,2)`	1	2	
Rear left	`WhlF(1,3)`	2	1	
Rear right	`WhlF(1,4)`	2	2	
Front left	`WhlF(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlF(2,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Rear left	`WhlF(2,3)`	2	1	
Rear right	`WhlF(2,4)`	2	2	
Front left	`WhlF(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

`WhlV` — Wheel velocity

`array`

Longitudinal, lateral, and vertical wheel velocity at axle `a`, wheel `t`, in m/s. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlV(1,...)` — Wheel velocity along the vehicle-fixed *x*-axis (longitudinal)
- `WhlV(2,...)` — Wheel velocity along the vehicle-fixed *y*-axis (lateral)
- `WhlV(3,...)` — Wheel velocity along the vehicle-fixed *z*-axis (vertical)

For example, for a two-axle vehicle with two wheels per axle, the `WhlV`:

- Signal dimensions are `[3x4]`.
- Signal contains wheel forces applied to the vehicle according to the axle and wheel locations.

$$\mathrm{WhlV} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{z}_w \end{bmatrix} = \begin{bmatrix} \dot{x}_{w_{1,1}} & \dot{x}_{w_{1,2}} & \dot{x}_{w_{2,1}} & \dot{x}_{w_{2,2}} \\ \dot{y}_{w_{1,1}} & \dot{y}_{w_{1,2}} & \dot{y}_{w_{2,1}} & \dot{y}_{w_{2,2}} \\ \dot{z}_{w_{1,1}} & \dot{z}_{w_{1,2}} & \dot{z}_{w_{2,1}} & \dot{z}_{w_{2,2}} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(1,1)`	1	1	Vehicle-fixed *x*-axis (longitudinal)
Front right	`WhlV(1,2)`	1	2	
Rear left	`WhlV(1,3)`	2	1	
Rear right	`WhlV(1,4)`	2	2	

Wheel	Array Element	Axle	Wheel Number	Force Axis
Front left	`WhlV(2,1)`	1	1	Vehicle-fixed *y*-axis (lateral)
Front right	`WhlV(2,2)`	1	2	
Rear left	`WhlV(2,3)`	2	1	
Rear right	`WhlV(2,4)`	2	2	
Front left	`WhlV(3,1)`	1	1	Vehicle-fixed *z*-axis (vertical)
Front right	`WhlV(3,2)`	1	2	
Rear left	`WhlV(3,3)`	2	1	
Rear right	`WhlV(3,4)`	2	2	

`WhlAng` — Wheel camber, caster, toe angles

`array`

Camber, caster, and toe angles at axle `a`, wheel `t`, in rad. Array dimensions are `3` by the number of wheels on the vehicle.

- `WhlAng(1,...)` — Camber angle
- `WhlAng(2,...)` — Caster angle
- `WhlAng(3,...)` — Toe angle

For example, for a two-axle vehicle with two wheels per axle, the `WhlAng`:

- Signal dimensions are `[3x4]`.
- Signal contains angles according to the axle and wheel locations.

$$\mathrm{WhlAng} = \begin{bmatrix} \xi \\ \eta \\ \zeta \end{bmatrix} = \begin{bmatrix} \xi_{1,1} & \xi_{1,2} & \xi_{2,1} & \xi_{2,2} \\ \eta_{1,1} & \eta_{1,2} & \eta_{2,1} & \eta_{2,2} \\ \zeta_{1,1} & \zeta_{1,2} & \zeta_{2,1} & \zeta_{2,2} \end{bmatrix}$$

Wheel	Array Element	Axle	Wheel Number	Angle
Front left	`WhlAng(1,1)`	1	1	Camber
Front right	`WhlAng(1,2)`	1	2	

Wheel	Array Element	Axle	Wheel Number	Angle
Rear left	`WhlAng(1,3)`	2	1	
Rear right	`WhlAng(1,4)`	2	2	
Front left	`WhlAng(2,1)`	1	1	Caster
Front right	`WhlAng(2,2)`	1	2	
Rear left	`WhlAng(2,3)`	2	1	
Rear right	`WhlAng(2,4)`	2	2	
Front left	`WhlAng(3,1)`	1	1	Toe
Front right	`WhlF(3,2)`	1	2	
Rear left	`WhlF(3,3)`	2	1	
Rear right	`WhlF(3,4)`	2	2	

Parameters

`Steered axle enable by axle, StrgEnByAxl` — Boolean vector to enable axle steering

`[1 0]` (default) | `vector`

Boolean vector that enables axle steering, En_{steer}, dimensionless. Vector is `1` by the number of vehicle axles, N_a. For example:

- `[1 0]` — For a two-axle vehicle, enables axle 1 steering and disables axle 2 steering
- `[1 1]` — For a two-axle vehicle, enables axle 1 and axle 2 steering

Dependencies

Setting any element of the **Steered axle enable by axle, StrgEnByAxl** vector to 1 creates Input port `StrgAng`.

`Anti-sway axle enable by axle, AntiSwayEnByAxl` — Boolean vector to enable axle anti-sway

`[0 0]` (default) | `vector`

Boolean vector that enables axle anti-sway for axle a, dimensionless. For example, `[1 0]` enables a front axle anti-sway and disables a rear axle anti-sway. Vector is `1` by the number of vehicle axles, N_a.

If you enable an anti-sway bar on the front axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Suspension roll stiffness with anti-roll bar, RollStiffArb**, and the roll stiffness parameter measured with no anti-roll bar present **Suspension roll stiffness without anti-roll bar, RollStiffNoArb**.

If you enable an anti-sway bar on the rear axle, the block uses this equation to calculate the twist-beam roll stiffness.

$$TB_{rs} = S_{rs} - \frac{\pi\left[\frac{1}{2}WR_{\nabla}TW^{2}\right]}{180}$$

The equation uses these variables.

TB_{rs}	Twist beam roll stiffness
S_{rs}	Suspension roll stiffness without twist beam, **RollStiffNoTwstRear** parameter
WR_{∇}	Normal wheel rate gradient, calculated from **NrmlWhlRates** parameter and suspension displacement
TW	Track width

If you do not enable an anti-sway bar, the stiffness is 0.

Suspension Parameters

`Suspension type` — Type of suspension

`Independent front and rear` | `Independent front and twist beam rear`

Select type of suspension.

`Drivetrain type` — Type of drivetrain

`FWD` (default) | `RWD` | `AWD`

Select type of drivetrain.

- `AWD` – All-wheel drive
- `FWD` – Front-wheel drive
- `RWD` – Rear-wheel drive

Directions

`+ Steer angle` — Positive steer angle

`Right` (default) | `Left`

Direction of positive steer angle during kinematics and compliance test.

`+ Fx used in compliance tests` — Positive longitudinal force

`Front` (default) | `Rear`

Direction of positive longitudinal force during kinematics and compliance test.

`+ Fy used in compliance tests` — Positive lateral force

`Right` (default) | `Left`

Direction of positive lateral force during kinematics and compliance test.

`+ Suspension Jounce` — Positive suspension jounce

`Up` (default) | `Down`

Direction of positive suspension jounce during kinematics and compliance test.

`+ WhlMz used in compliance tests` — Positive yaw moment
`Counter-clockwise` (default) | `Clockwise`

Direction of positive yaw moment during kinematics and compliance test.

Shock force

`Shock type` — Type of shock force
`Table-based` (default) | `Table-based individualConstant`

Type of shock force.

If a table-based individual setting is chosen, table-based shock force is implemented together with constant motion ratios. If a table-based setting is chosen both shock force and motion ratios are calculated from lookup tables.

Setting	Implementation
`Table-based`	Table-based shock force and motion ratios.
`Table-based individual`	Table-based shock force and constant motion ratios.
`Constant`	Constant shock force and motion ratios.

`Shock force vs shock compression rate, ShckFrceVsCompRate` — Table
`struct('FL',[-100. -5000;0 0;100. 5000],'FR',[-100. -5000;0 0;100. 5000],'RL',[-100. -5000;0 0;100. 5000],'RR',[-100. -5000;0 0;100. 5000])` (default)

Shock force versus shock compression rate, specified as a structure, in N/mm per sec.

Dependencies

To create this parameter, set **Shock type** to `Table-based` or `Table-based individual`.

Data Types: `struct`

`Motion ratios by axle, MotRatios` — Table
`struct('FL',[-0.1 -0.1;0 0;0.1 0.1],'FR',[-0.1 -0.1;0 0;0.1 0.1],'RL',[-0.1 -0.1;0 0;0.1 0.1],'RR',[-0.1 -0.1;0 0;0.1 0.1])` (default)

Motion ratios by axle, specified as a structure.

Data Types: `struct`

Bounce test

`Bump steer, BumpSteer` — Table
`struct('FL',[-0.1 1.1459;0 0;0.1 -1.1459],'FR',[-0.1 1.1459;0 0;0.1 -1.1459],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.;0 0;0.1 0.])` (default)

Bump steer, specified as a structure, in deg/m.

Data Types: `struct`

Bump camber, `BumpCamber` — Table
`struct('FL',[-0.1 1.7189;0 0;0.1 -1.7189],'FR',[-0.1 1.7189;0 0;0.1 -1.7189],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.;0 0;0.1 0.])` (default)

Bump camber, specified as a structure, in deg/m.

Data Types: `struct`

Bump caster, `BumpCaster` — Table
`struct('FL',[-0.1 1.1459;0 0;0.1 -1.1459],'FR',[-0.1 1.1459;0 0;0.1 -1.1459],'RL',[-0.1 -11.4592;0 0;0.1 11.4592],'RR',[-0.1 -11.4592;0 0;0.1 11.4592])` (default)

Bump caster, specified as a structure, in deg/m.

Data Types: `struct`

Lateral wheel center displacement, `LatWhlCtrDisp` — Table
`struct('FL',[-0.1 0.02;0 0;0.1 -0.02],'FR',[-0.1 0.02;0 0;0.1 -0.02],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.;0 0;0.1 0.])` (default)

Lateral wheel center displacement, specified as a structure, in mm/mm.

Data Types: `struct`

Longitudinal wheel center displacement, `LngWhlCtrDisp` — Table
`struct('FL',[-0.1 -0.002;0 0;0.1 0.002],'FR',[-0.1 -0.002;0 0;0.1 0.002],'RL',[-0.1 0.;0 0;0.1 0.],'RR',[-0.1 0.02;0 0;0.1 0.01])` (default)

Longitudinal wheel center displacement, specified as a structure, in mm/mm.

Data Types: `struct`

Normal wheel rates, `NrmlWhlRates` — Table
`struct('FL',[-100. -5000;0 0;100. 5000],'FR',[-100. -5000;0 0;100. 5000],'RL',[-100. -5000;0 0;100. 5000],'RR',[-100. -5000;0 0;100. 5000])` (default) | vector

Normal wheel rates, specified as a structure, in N/mm.

Data Types: `struct`

Normal wheel force offsets, `NrmlWhlFrcOff` — Force offset
`[0 0 0 0]` (default)

Normal wheel force offsets, specified as a vector, in N.

Dependencies

To create this parameter, specify a **Normal wheel rates, NrmlWhlRates** vector.

Data Types: `struct`

Roll test

Roll steer, `RollSteer` — Table
`struct('RL',[-10. -1.;0 0;10. 1.],'RR',[-10. 1.;0 0;10. -1.])` (default)

Rear axle roll steer, specified as a structure, in deg/deg.

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and twist-beam rear`.

Data Types: `struct`

`Roll camber, RollCamber` — Table

`struct('RL',[-10. -1.;0 0;10. 1.],'RR',[-10. 1.;0 0;10. -1.])` (default)

Rear axle roll camber, specified as a structure, in deg/deg.

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and twist-beam rear`.

Data Types: `struct`

`Roll caster, RollCaster` — Table

`struct('RL',[-10. -1.;0 0;10. 1.],'RR',[-10. 1.;0 0;10. -1.])` (default)

Rear axle roll caster, specified as a structure, in deg/deg.

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and twist-beam rear`.

Data Types: `struct`

`Front suspension roll stiffness with anti-roll bar, RollStiffArbFrnt` — Anti-sway bar enabled

`800` (default) | scalar

Front axle suspension roll stiffness with anti-roll bar, specified as a scalar.

If you enable an anti-sway bar on the axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Front suspension roll stiffness with anti-roll bar, RollStiffArbFrnt**, and the roll stiffness parameter measured with no anti-sway bar present, **Front suspension roll stiffness without anti-roll bar, RollStiffNoArbFrnt**.

If you do not enable an anti-sway bar, the front axle roll stiffness is 0.

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and twist-beam rear`.

Data Types: `double`

`Front suspension roll stiffness without anti-roll bar, RollStiffNoArbFrnt` — Anti-sway bar not enabled

`0` (default) | scalar

Front suspension roll stiffness without an anti-roll bar, specified as a scalar, in Nm/deg.

If you enable an anti-sway bar on the axle, the anti-sway bar stiffness is the difference between the anti-sway bar torque parameter, **Front suspension roll stiffness with anti-roll bar, RollStiffArbFrnt**, and the roll stiffness parameter measured with no anti-sway bar present, **Front suspension roll stiffness without anti-roll bar, RollStiffNoArbFrnt**.

If you do not enable an anti-sway bar, the axle roll stiffness is 0.

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and twist-beam rear`.

Data Types: `double`

`Rear suspension roll stiffness without twist-beam, RollStiffNoTwstRear` — Anti-sway bar not enabled

`0` (default) | scalar

Rear suspension roll stiffness without an twist beam, specified as a scalar, in Nm/deg. T

If you do not enable an anti-sway bar, the rear axle roll stiffness is 0.

If you enable an anti-sway bar on the rear axle, the block uses this equation to calculate the twist-beam roll stiffness.

$$TB_{rs} = S_{rs} - \frac{\pi\left[\frac{1}{2}WR_{\nabla}TW^2\right]}{180}$$

The equation uses these variables.

TB_{rs}	Twist beam roll stiffness
S_{rs}	Suspension roll stiffness without twist beam, **RollStiffNoTwstRear** parameter
WR_{∇}	Normal wheel rate gradient, calculated from **NrmlWhlRates** parameter and suspension displacement
TW	Track width

Dependencies

To enable this parameter, set **Suspension type** to `Independent front and twist-beam rear`.

Data Types: `double`

Steer test

`Camber vs steer angle, CambVsSteerAng` — Table

`struct('FL',[-10. -1.;0 0;10. 1.],'FR',[-10. 1.;0 0;10. -1.],'RL',[-10. -1.;0 0;10. 1.],'RR',[-10. 1.;0 0;10. -1.])` (default)

Camber vs steer angle, specified as a structure, in deg/deg.

Data Types: `struct`

`Caster vs steer angle, CastVsSteerAng` — Table

`struct('FL',[-10. -1.;0 0;10. 1.],'FR',[-10. 1.;0 0;10. -1.],'RL',[-10. -1.;0 0;10. 1.],'RR',[-10. 1.;0 0;10. -1.])` (default)

Caster vs steer angle, specified as a structure, in deg/deg.

Data Types: `struct`

Longitudinal compliance test

`Longitudinal steer compliance, LngSteerCompl` — Table

`struct('NegFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]),'PosFx',struct('FL',[-2. -1.;0`

`0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]))` (default)

Longitudinal steer compliance, specified as a structure, in deg/kN.

Data Types: `struct`

`Longitudinal camber compliance, LngCambCompl` — Table
`struct('NegFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]),'PosFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]))` (default)

Longitudinal camber compliance, specified as a structure, in deg/kN.

Data Types: `struct`

`Longitudinal caster compliance, LngCastCompl` — Table
`struct('NegFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]),'PosFx',struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.]))` (default)

Longitudinal caster compliance, specified as a structure, in deg/kN.

Data Types: `struct`

`Longitudinal wheel center compliance, LngWhlCtrCompl` — Table
`struct('NegFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]),'PosFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]))` (default)

Longitudinal wheel center compliance, specified as a structure, in mm/kN.

Data Types: `struct`

`Lateral wheel center compliance from braking, LatWhlCtrComplLngBrk` — Table
`struct('NegFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]),'PosFx',struct('FL',[-2. -10.;0 0;2. 10.],'FR',[-2. 10.;0 0;2. -10.],'RL',[-2. -10.;0 0;2. 10.],'RR',[-2. 10.;0 0;2. -10.]))` (default)

Lateral wheel center compliance from braking, specified as a structure, in mm/kN.

Data Types: `struct`

Lateral compliance-opposed test

`Lateral steer compliance, LatSteerCompl` — Table
`struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.])` (default)

Lateral steer compliance, specified as a structure, in deg/kN.

Data Types: `struct`

`Lateral camber compliance, LatCambCompl` — Table
`struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.])` (default)

Lateral camber compliance, specified as a structure, in deg/kN.

Data Types: `struct`

`Lateral wheel center compliance from lateral sources, LatWhlCtrComplLat` — Table
`struct('FL',[-2. -5.;0 0;2. 5.],'FR',[-2. 5.;0 0;2. -5.],'RL',[-2. -5.;0 0;2. 5.],'RR',[-2. 5.;0 0;2. -5.])` (default)

Lateral wheel center compliance from lateral sources, specified as a structure, in mm/kN.

Data Types: `struct`

Aligning torque compliance-opposed test

`Aligning torque steer compliance, AlgnTrqSteerCompl` — Table
`struct('FL',[-0.2 -1.;0 0;0.2 1.],'FR',[-0.2 1.;0 0;0.2 -1.],'RL',[-0.2 -1.;0 0;0.2 1.],'RR',[-0.2 1.;0 0;0.2 -1.])` (default)

Aligning torque steer compliance, specified as a structure, in deg/kNm.

Data Types: `struct`

`Aligning torque camber compliance, AlgnTrqCambCompl` — Table
`struct('FL',[-0.2 -1.;0 0;0.2 1.],'FR',[-0.2 1.;0 0;0.2 -1.],'RL',[-0.2 -1.;0 0;0.2 1.],'RR',[-0.2 1.;0 0;0.2 -1.])` (default)

Aligning torque camber compliance, specified as a structure, in deg/kNm.

Data Types: `struct`

Parallel lateral force compliance test

`Lateral load transfer, LatLdTrnsfr` — Table
`struct('FL',[-2. -1.;0 0;2. 1.],'FR',[-2. 1.;0 0;2. -1.],'RL',[-2. -1.;0 0;2. 1.],'RR',[-2. 1.;0 0;2. -1.])` (default)

Lateral load transfer, specified as a structure, in N/kN.

Dependencies

To create this parameter, set **Suspension type** to `Independent front and twist-beam rear`.

Data Types: `struct`

Static alignment settings

`Toe, StatToe` — Wheel toe angle
`[0 0 0 0]` (default) | 1-by-4 vector

Static toe angle for each wheel, specified as a 1-by-4 vector, in deg.

Wheel	**Array Element**	**Axle**	**Wheel Location**
Front left	`(1,1)`	1	1
Front right	`(1,2)`	1	2
Rear left	`(1,3)`	2	1
Rear left	`(1,4)`	2	2

Data Types: `double`

`Camber, StatCamber` — Wheel camber angle

`[0 0 0 0]` (default) | 1-by-4 vector

Static camber angle for each wheel, specified as a 1-by-4 vector, in deg.

Wheel	**Array Element**	**Axle**
Front left	`(1,1)`	1
Front right	`(1,2)`	1
Rear left	`(1,3)`	2
Rear left	`(1,4)`	2

Data Types: `double`

`Caster, StatCaster` — Wheel caster angle

`[0 0 0 0]` (default) | 1-by-4 vector

Static caster angle for each wheel, specified as a 1-by-4 vector, in deg.

Wheel	**Array Element**	**Axle**
Front left	`(1,1)`	1
Front right	`(1,2)`	1
Rear left	`(1,3)`	2
Rear left	`(1,4)`	2

Data Types: `double`

Wheels

`Static loaded radius of wheels, StatLdWhlR` — Wheel radius

`[0.3 0.3 0.3 0.3]` (default) | 1-by-4 vector

Static loaded radius of wheels, specified as a 1-by-4 vector, in m.

Wheel	**Array Element**	**Axle**
Front left	`(1,1)`	1
Front right	`(1,2)`	1
Rear left	`(1,3)`	2
Rear left	`(1,4)`	2

Data Types: `double`

Version History

Introduced in R2022b

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

See Also

Independent Suspension - Double Wishbone | Independent Suspension - Mapped | Independent Suspension - MacPherson

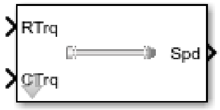
2

Drivetrain Blocks

Rotational Inertia

Ideal mechanical rotational inertia

Library:	Powertrain Blockset / Drivetrain / Couplings Vehicle Dynamics Blockset / Powertrain / Drivetrain / Couplings



Description

The Rotational Inertia block implements an ideal mechanical rotational inertia.

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Variable	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrR`	Mechanical power from base shaft	P_{TR}	$P_{TR} = T_R\omega$
		`PwrC`	Mechanical power from follower shaft	P_{TC}	$P_{TC} = T_C\omega$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrDampLoss`	Power loss due to damping	P_d	$P_d = -b\|\omega\|^2$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredShft`	Rate change of stored internal torsional energy	P_s	$P_s = \omega\dot{\omega}J$

The equations use these variables.

T_R	Input torque
T_C	Output torque
ω	Driveshaft angular velocity
J	Rotational inertia
b	Rotational viscous damping
P_d	Power loss due to damping
P_s	Rate change of stored internal torsional energy

Ports

Input

`RTrq` — Input torque
`scalar`

Applied input driveshaft torque, T_R, in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Simulink`.

`CTrq` — Output torque
`scalar`

Load driveshaft torque, T_C, in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Simulink`.

`R` — Angular velocity and torque
two-way connector port

Angular velocity in rad/s. Torque is in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Two-way connection`.

`Inertia` — Input
`scalar`

Rotational inertia, in kg·m^2.

Dependencies

To create the `Inertia` port, select **External inertia input**.

Output

`Info` — Bus signal
bus

Bus signal containing these block calculations.

Signal			Description	Variable	Units
Trq	`R`		Applied input driveshaft torque	T_R	N·m
	`C`		Output driveshaft torque	T_C	N·m
	`Damp`		Damping torque	$T_d=b\omega$	N·m
Spd			Angular driveshaft speed	ω	rad/s
PwrInfo	`PwrTrnsfrd`	`PwrR`	Mechanical power from base shaft	P_{TR}	W
		`PwrC`	Mechanical power from follower shaft	P_{TC}	W
	`PwrNotTrnsfrd`	`PwrDampLoss`	Power loss due to damping	P_d	W
	`PwrStored`	`PwrStoredShft`	Rate change of stored internal torsional energy	P_s	W

Dependencies

To enable this port, select **Output Info bus**.

Spd — Driveshaft speed

`scalar`

Angular driveshaft speed, ω, in rad/s.

Dependencies

To enable this port, for **Port Configuration**, select `Simulink`.

`C` — Angular velocity and torque

two-way connector port

Angular velocity in rad/s. Torque is in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Two-way connection`.

Parameters

Block Options

`Port Configuration` — Specify configuration

`Simulink` (default) | `Two-way connection`

Specify the port configuration.

Dependencies

Specifying `Simulink` creates these ports:

- `RTrq`
- `CTrq`
- `Spd`

Specifying `Two-way connection` creates these ports:

- `R`
- `C`

`Output Info bus` — Selection
`off` (default) | `on`

Select to create the `Info` output port.

`External inertia input` — Input rotational inertia
`off` (default) | `on`

Dependencies

To create the `Inertia` port, select **External inertia input**.

Parameters

`Rotational inertia, J` — Inertia
`.01` (default) | `scalar`

Rotational inertia, in kg·m^2.

Dependencies

To enable this parameter, clear **Input rotational inertia**.

`Torsional damping, b` — Damping
`.001` (default) | `scalar`

Torsional damping, in N·m· s/rad.

`Initial velocity, omega_o` — Angular
`0` (default) | `scalar`

Initial angular velocity, in rad/s.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

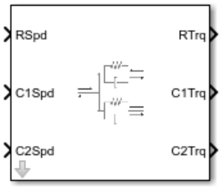
See Also

Split Torsional Compliance | Torsional Compliance

Split Torsional Compliance

Split torsional coupler

Library: Powertrain Blockset / Drivetrain / Couplings
Vehicle Dynamics Blockset / Powertrain / Drivetrain / Couplings



Description

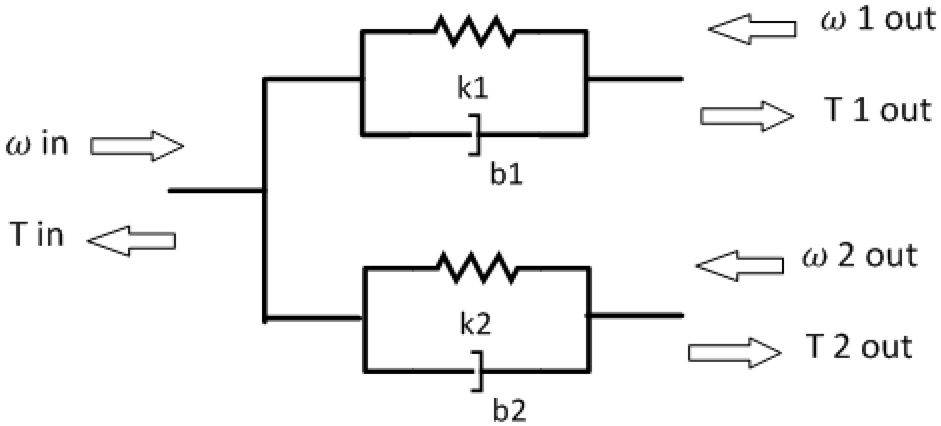
The Split Torsional Compliance block implements parallel spring-damper coupling between shafts. You can specify the type of coupling by selecting one of the **Coupling Configuration** parameters:

- `Shaft split` — Single input shaft coupled to two output shafts
- `Shaft merge` — Two input shafts coupled to a single output shaft

In fuel economy and emissions studies, you can use the Split Torsional Compliance block to model mechanical rotational compliance between common driveline elements such as motors, planetary gears, and clutches. For example, use the `Shaft split` configuration to couple a motor and two planetary gear sets. Use the `Shaft merge` configuration to couple a dual clutch transmission to an output shaft.

Shaft Split

For the `Shaft split` configuration, the block implements this schematic and equations.



$$T_{in} = -(\omega_{in} - \omega_{1out})b_1 - (\omega_{in} - \omega_{2out})b_2 - \theta_1 k_1 - \theta_2 k_2$$
$$T_{1out} = (\omega_{in} - \omega_{1out})b_1 + \theta_1 k_1$$
$$T_{2out} = (\omega_{in} - \omega_{2out})b_2 + \theta_2 k_2$$

$$\dot{\theta}_1 = (\omega_{in} - \omega_{1out})$$
$$\dot{\theta}_2 = (\omega_{in} - \omega_{2out})$$

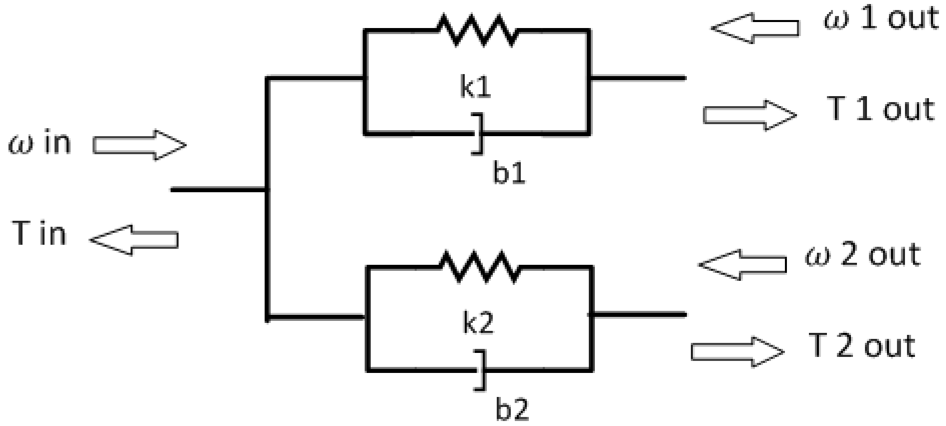
To account for frequency-dependent damping, both damping terms incorporate a low-pass filter.

The equations use these variables.

T_{in}	Resulting applied input reaction torque
ω_{in}	Input shaft rotational velocity
T_{1out}	Resulting applied torque to first output shaft
ω_{1out}	First output shaft rotational velocity
T_{2out}	Resulting applied torque to second output shaft
ω_{2out}	Second output shaft rotational velocity
θ_1, θ_2	First, second shaft rotation, respectively
b_1, b_2	First, second shaft viscous damping, respectively
k_1, k_2	First, second shaft torsional stiffness, respectively

Shaft Merge

For the `Shaft merge` configuration, the block implements this schematic and equations.



$$T_{out} = (-\omega_{out} + \omega_{1in})b_1 + (-\omega_{out} + \omega_{2in})b_2 + \theta_1 k_1 + \theta_2 k_2$$
$$T_{1out} = (\omega_{out} - \omega_{1in})b_1 - \theta_1 k_1$$
$$T_{2out} = (\omega_{out} - \omega_{2in})b_2 - \theta_2 k_2$$

$$\dot{\theta}_1 = (\omega_{1in} - \omega_{out})$$
$$\dot{\theta}_2 = (\omega_{2in} - \omega_{out})$$

To account for frequency-dependent damping, both damping terms incorporate a low-pass filter.

The equations use these variables.

T_{out}	Resulting applied output torque
ω_{out}	Output shaft rotational velocity
T_{1in}	Resulting reaction torque to first input shaft
ω_{1in}	First input shaft rotational velocity
T_{2in}	Resulting reaction torque to second input shaft
ω_{2in}	Second input shaft rotational velocity
θ_1, θ_2	First, second shaft rotation, respectively
b_1, b_2	First, second shaft viscous damping, respectively
k_1, k_2	First, second shaft torsional stiffness, respectively

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Variable	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrR`	For the `Shaft split` configuration, mechanical power from input shaft	P_{TR}	$P_{TR} = -T_R\omega_R$
		`PwrC1`	For the `Shaft split` configuration, mechanical power from first output shaft	P_{TC1}	$P_{TC1} = -T_{C1}\omega_{C1}$
		`PwrC2`	For the `Shaft split` configuration, mechanical power from second output shaft	P_{TC2}	$P_{TC2} = -T_{C2}\omega_{C2}$
		`PwrC`	For the `Shaft merge` configuration, mechanical power from output shaft	P_{TC}	$P_{TC} = T_C\omega_C$

Bus Signal			Description	Variable	Equations
		`PwrR1`	For the `Shaft merge` configuration, mechanical power from first input shaft	P_{TR1}	$P_{TR1} = T_{R1}\omega_{R1}$
		`PwrR2`	For the `Shaft merge` configuration, mechanical power from second input shaft	P_{TR2}	$P_{TR2} = T_{R2}\omega_{R2}$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrDampLoss`	Mechanical damping loss	P_d	$P_d = -\left(b_1\lvert\dot{\theta}_1\rvert^2 + b_2\lvert\dot{\theta}_2\rvert^2\right)$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredShft`	Rate change in spring energy	P_s	$P_s = \left(k_1\theta_1\dot{\theta}_1 + k_2\theta_2\dot{\theta}_2\right)$

The equations use these variables.

T_R	Shaft R torque
T_C	Shaft C torque
ω_R	Shaft R angular velocity
ω_C	Shaft C angular velocity
θ	Coupled shaft rotation
k	Shaft torsional stiffness
b	Rotational viscous damping
P_t	Total mechanical power
P_d	Power loss due to damping
P_s	Rate change of stored spring energy

Ports

Input

`RSpd` — Input shaft speed
`scalar`

Input shaft rotational velocity, ω_{in}, in rad/s.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft split`

`C1Spd` — First output shaft speed
`scalar`

First output shaft rotational velocity, ω_{1out}, in rad/s.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft split`

`C2Spd` — Second output shaft speed
`scalar`

Second output shaft rotational velocity, ω_{2out}, in rad/s.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft split`

`CSpd` — Input speed
`scalar`

Output shaft rotational velocity, ω_{out}, in rad/s.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft merge`

`R1Spd` — First input shaft speed
`scalar`

First input shaft rotational velocity, ω_{1in}, in rad/s.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft merge`

R2Spd — Second input shaft speed

`scalar`

Second input shaft rotational velocity, ω_{2in}, in rad/s.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft merge`

R — Input shaft angular velocity and torque

two-way connector port

Input shaft angular velocity, ω_{in}, in rad/s and torque, T_{in}, in N·m.

Dependencies

To enable this port, select:

- **Port Configuration**>`Two-way connection`
- **Coupling Configuration**>`Shaft split`

R1 — First input shaft angular velocity and torque

two-way connector port

First input shaft angular velocity, ω_{1in}, in rad/s and torque, T_{1in}, in N·m.

Dependencies

To enable this port, select:

- **Port Configuration**>`Two-way connection`
- **Coupling Configuration**>`Shaft merge`

R2 — Second input shaft angular velocity and torque

two-way connector port

Second input shaft angular velocity, ω_{2in}, in rad/s and torque, T_{2in}, in N·m.

Dependencies

To enable this port, select:

- **Port Configuration**>`Two-way connection`
- **Coupling Configuration**>`Shaft merge`

Output

`Info` — Bus signal
bus

If you set **Coupling Configuration** to `Shaft split`, the Info bus contains these signals.

Signal			Description	Variable	Units
Trq	`R`		Input shaft torque	T_{in}	N·m
	`C1`		First output shaft torque	T_{1out}	N·m
	`C2`		Second output shaft torque	T_{2out}	N·m
	`Damp`	`C1`	First output shaft damping torque	$b_1\omega_{1out}$	N·m
		`C2`	Second output shaft damping torque	$b_2\omega_{2out}$	N·m
	`Spring`	`C1`	First output shaft spring torque	$k_1\theta_1$	N·m
		`C2`	Second output shaft spring torque	$k_2\theta_2$	N·m
Spd	`R`		Input shaft angular velocity	ω_{in}	rad/s
	`C1`		First output shaft angular velocity	ω_{1out}	rad/s
	`C2`		Second output shaft angular velocity	ω_{2out}	rad/s
	`deltadot1`		Difference in input and first output shaft angular velocity	$\dot{\theta}_1$	rad/s
	`deltadot2`		Difference in input and second output shaft angular velocity	$\dot{\theta}_2$	rad/s
PwrInfo	`PwrTrnsfrd`	`PwrR`	Mechanical power from input shaft	P_{TR}	W
		`PwrC1`	Mechanical power from first output shaft	P_{TC1}	W
		`PwrC2`	Mechanical power from second output shaft	P_{TC2}	W
	`PwrNotTrnsfrd`	`PwrDampLoss`	Mechanical damping loss	P_d	W
	`PwrStored`	`PwrStoredShft`	Rate change of stored internal torsional energy	P_s	W

If you set **Coupling Configuration** to `Shaft merge`, the Info bus contains these signals.

Signal			Description	Variable	Units
Trq	`C`		Output shaft torque	T_{out}	N·m
	`R1`		First input shaft torque	T_{1in}	N·m
	`R2`		Second input shaft torque	T_{2in}	N·m

Signal			**Description**	**Variable**	**Units**
	`Damp`	`R1`	First input shaft damping torque	$b_1\omega_{1in}$	N·m
		`R2`	Second in shaft damping torque	$b_2\omega_{2in}$	N·m
	`Spring`	`R1`	First input shaft spring torque	$k_1\theta_1$	N·m
		`R2`	Second in shaft spring torque	$k_2\theta_2$	N·m
Spd	`C`		Output shaft angular velocity	ω_{out}	rad/s
	`R1`		First input shaft angular velocity	ω_{1in}	rad/s
	`R2`		Second input shaft angular velocity	ω_{2in}	rad/s
	`deltadot1`		Difference in first input and output shaft angular velocity	$\dot{\theta}_1$	rad/s
	`deltadot2`		Difference in second input and output shaft angular velocity	$\dot{\theta}_2$	rad/s
PwrInfo	`PwrTrnsfrd`	`PwrC`	Mechanical power from output shaft	P_{TC}	W
		`PwrR1`	Mechanical power from first input shaft	P_{TR1}	W
		`PwrR2`	Mechanical power from second input shaft	P_{TR2}	W
	`PwrNotTrnsfrd`	`PwrDampLoss`	Mechanical damping loss	P_d	W
	`PwrStored`	`PwrStoredShft`	Rate change of stored internal torsional energy	P_s	W

Dependencies

To enable this port, select **Output Info bus**.

`RTrq` — Input shaft torque

`scalar`

Input shaft torque, T_{in}, in N·m.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft split`

`C1Trq` — First output shaft torque

`scalar`

First output shaft torque, T_{1out}, in N·m.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft split`

`C2Trq` — Second output shaft torque

`scalar`

Second output shaft torque, T_{2out}, in N·m.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft split`

`CTrq` — Output shaft torque

`scalar`

Output shaft torque, T_{out}, in N·m.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft merge`

`R1Trq` — First input shaft torque

`scalar`

First input shaft torque, T_{1in}, in N·m.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft merge`

`R2Trq` — Second input shaft torque

`scalar`

Second input shaft torque, T_{2in}, in N·m.

Dependencies

To enable this port, set both of these parameters:

- **Port Configuration** to `Simulink`
- **Coupling Configuration** to `Shaft merge`

`C1` — First output shaft angular velocity and torque

two-way connector port

First output shaft angular velocity, ω_{1out}, in rad/s and torque, T_{1out}, in N·m.

Dependencies

To enable this port, select:

- **Port Configuration**>`Two-way connection`
- **Coupling Configuration**>`Shaft split`

`C2` — Second output shaft angular velocity and torque

two-way connector port

Second output shaft angular velocity, ω_{2out}, in rad/s and torque, T_{2out}, in N·m.

Dependencies

To enable this port, select:

- **Port Configuration**>`Two-way connection`
- **Coupling Configuration**>`Shaft split`

`C` — Output shaft angular velocity and torque

two-way connector port

Output shaft angular velocity, ω_{out}, in rad/s and torque, T_{out}, in N·m.

Dependencies

To enable this port, select:

- **Port Configuration**>`Two-way connection`
- **Coupling Configuration**>`Shaft merge`

Parameters

Block Options

`Port Configuration` — Specify configuration

`Simulink` (default) | `Two-way connection`

Specify the port configuration.

`Coupling Configuration` — Specify configuration

`Shaft split` (default) | `Shaft merge`

Specify the coupling type.

`Output Info bus` — Selection

`off` (default) | `on`

Select to create the `Info` output port.

Coupling 1

`Torsional stiffness, k1` — Stiffness

`5e4` (default) | `scalar`

Rotational inertia, k_1, in N·m/rad.

`Torsional damping, b1` — Damping
`1e2` (default) | `scalar`

Torsional damping, b_1, in N·m· s/rad.

`Damping cutoff frequency, omega1_c` — Frequency
`3000` (default) | `scalar`

Damping cutoff frequency, in rad/s.

Coupling 2

`Torsional stiffness, k2` — Stiffness
`5e4` (default) | `scalar`

Rotational inertia, k_2, in N·m/rad.

`Torsional damping, b2` — Damping
`1e2` (default) | `scalar`

Torsional damping, b_2, in N·m· s/rad.

`Damping cutoff frequency, omega2_c` — Frequency
`3000` (default) | `scalar`

Damping cutoff frequency, in rad/s.

Version History

Introduced in R2017b

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

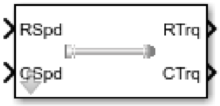
See Also

Rotational Inertia | Torsional Compliance

Torsional Compliance

Parallel spring-damper

Library:	Powertrain Blockset / Drivetrain / Couplings Vehicle Dynamics Blockset / Powertrain / Drivetrain / Couplings



Description

The Torsional Compliance block implements a parallel spring-damper to couple two rotating driveshafts. The block uses the driveshaft angular velocities, torsional stiffness, and torsional damping to determine the torques.

$$T_R = -(\omega_R - \omega_C)b - \theta k$$

$$T_C = (\omega_R - \omega_C)b + \theta k$$

$$\dot{\theta} = (\omega_R - \omega_C)$$

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Variable	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrR`	Mechanical power from driveshaft R	P_{TR}	$P_{TR} = T_R\omega_R$
		`PwrC`	Mechanical power from driveshaft C	P_{TC}	$P_{TC} = T_c\omega_c$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrDampLoss`	Mechanical damping loss	P_d	$P_d = -b\left\|\dot{\theta}\right\|^2$

Bus Signal			**Description**	**Variable**	**Equations**
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredShft`	Rate change in spring energy	P_S	$P_s = -\theta k\dot{\theta}$

The equations use these variables.

T_R	Driveshaft R torque
T_C	Driveshaft C torque
ω_R	Driveshaft R angular velocity
ω_C	Driveshaft C angular velocity
θ	Coupled driveshaft rotation
k	Driveshaft torsional stiffness
b	Rotational viscous damping
P_d	Power loss due to damping
P_s	Rate change of stored spring energy

Ports

Input

RSpd — Driveshaft R angular velocity
`scalar`

Input driveshaft angular velocity, in rad/s.

Dependencies

To enable this port, for **Port Configuration**, select `Simulink`.

CSpd — Driveshaft C angular velocity
`scalar`

Output driveshaft angular velocity, in rad/s.

Dependencies

To enable this port, for **Port Configuration**, select `Simulink`.

R — Angular velocity and torque
two-way connector port

Angular velocity in rad/s. Torque is in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Two-way connection`.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal			Description	Variable	Units
Trq	`R`		Input driveshaft torque	T_R	N·m
	`C`		Output driveshaft torque	T_C	N·m
	`Damp`		Damping torque	$T_s = b\dot{\theta}$	N·m
	`Spring`		Spring torque	$T_d = k\theta$	N·m
Spd	`R`		Input driveshaft angular velocity	ω_R	rad/s
	`C`		Output driveshaft angular velocity	ω_C	rad/s
	`deltadot`		Difference in input and output driveshaft angular velocity	$\dot{\theta}$	rad/s
PwrInfo	`PwrTrnsfrd`	`PwrR`	Mechanical power from driveshaft R	P_{TR}	W
		`PwrC`	Mechanical power from driveshaft C	P_{TC}	W
	`PwrNotTrnsfrd`	`PwrDampLoss`	Power loss due to damping	P_d	W
	`PwrStored`	`PwrStoredShft`	Rate change of stored internal kinetic energy	P_s	W

Dependencies

To enable this port, select **Output Info bus**.

`RTrq` — Driveshaft R torque

`scalar`

Input drive shaft torque, in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Simulink`.

`CTrq` — Driveshaft C torque

`scalar`

Applied output driveshaft torque, in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Simulink`.

`C` — Angular velocity and torque

two-way connector port

Angular velocity in rad/s. Torque is in N·m.

Dependencies

To enable this port, for **Port Configuration**, select `Two-way connection`.

Parameters

Block Options

`Port Configuration` — Specify configuration

`Simulink` (default) | `Two-way connection`

Specify the port configuration.

Dependencies

Specifying `Simulink` creates these ports:

- `RSpd`
- `CSpd`
- `RTrq`
- `CTrq`

Specifying `Two-way connection` creates these ports:

- `R`
- `C`

`Output Info bus` — Selection

`off` (default) | `on`

Select to create the `Info` output port.

`Torsional stiffness, k` — Inertia

`1e4` (default) | `scalar`

Torsional stiffness, in N·m/rad.

`Torsional damping, b` — Damping

`1e2` (default) | `scalar`

Torsional damping, in N·m· s/rad.

`Initial deflection, theta_o` — Angular

`0` (default) | `scalar`

Initial deflection, in rad.

`Initial velocity difference, domega_o` — Angular

`0` (default) | `scalar`

Initial velocity difference, in rad/s.

`Damping cut-off frequency, omega_c` — Frequency
`3000` (default) | `scalar`

Damping cut-off frequency, in rad/s.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

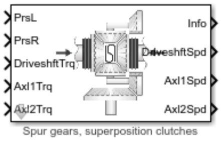
See Also

Rotational Inertia | Split Torsional Compliance

Active Differential

Spur or planetary active differential gear

Library: Vehicle Dynamics Blockset / Powertrain / Drivetrain / Final Drive Unit



Description

The Active Differential block implements an active differential to account for the power transfer from the transmission to the axles. The block models the active differential as an open differential coupled to either a spur or planetary differential gear set. The block uses external pressure signals to regulate the clutch pressure to either speed up or slow down each axle rotation.

Use the block in hardware-in-the-loop (HIL) and optimization workflows to dynamically couple the driveshaft to the wheel axles when you want to direct the transmission torque to a specific axle. For detailed front wheel driving studies, use the block to couple the driveshaft to universal joints. The block is suitable to use in system-level closed-loop control studies, for example, yaw stability and torque vectoring. All the parameters are tunable.

To specify the active differential, open the **Active Differential** parameters and specify **Active differential type**.

Setting	Block Implementation
`Spur gears, superposition clutches`	Clutches are in superposition through a three-gang gear system and a differential case
`Double planetary gears, stationary clutches`	Clutches are fixed to the carrier and axles through double planetary gear sets

Use the **Open Differential** parameter **Crown wheel (ring gear) located** to specify the open differential location, either to the left or right of the center-line.

Depending on the available data, to specify the method to couple the different torques applied to the axles, use the **Slip Coupling** parameter **Coupling type**.

Setting	Block Implementation
`Pre-loaded ideal clutch`	Torque modeled as a dry clutch with constant friction coefficients
`Slip speed dependent torque data`	Torque determined from a lookup table that is a function of slip-speed and clutch pressure

The Active Differential block does not include a controller or external clutch actuator dynamics. Use this information to control the input clutch pressure. The info bus contains the slip speeds at clutch 1, $\Delta\omega_{cl1}$, and clutch 2, $\Delta\omega_{cl2}$.

Input Axle Torque	**$\Delta\omega_{cl1}$**	**$\Delta\omega_{cl2}$**	**Input Clutch Pressure**
Positive axle 1 torque	`> 0`	N/A	Increase clutch 1 pressure
Positive axle 1 torque	`< 0`	N/A	Disengage clutch 1 and 2
Positive axle 2 torque	N/A	`> 0`	Increase clutch 1 pressure
Positive axle 2 torque	N/A	`< 0`	Disengage clutch 1 and 2

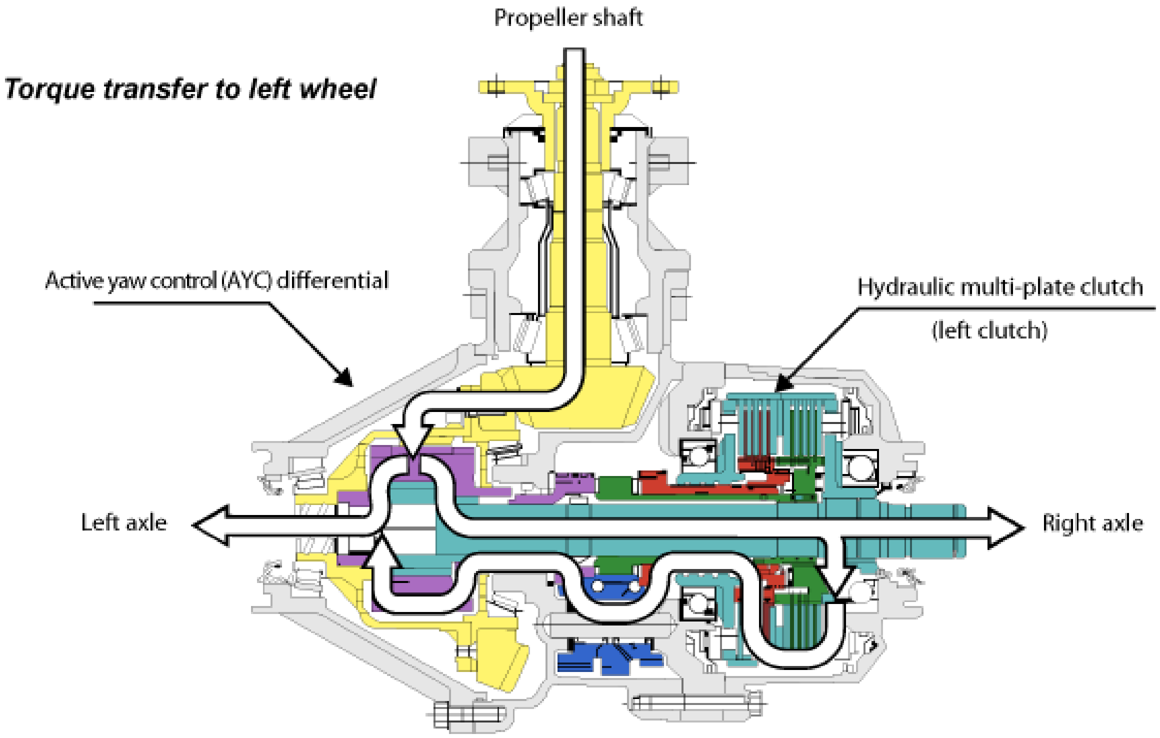
Differentials

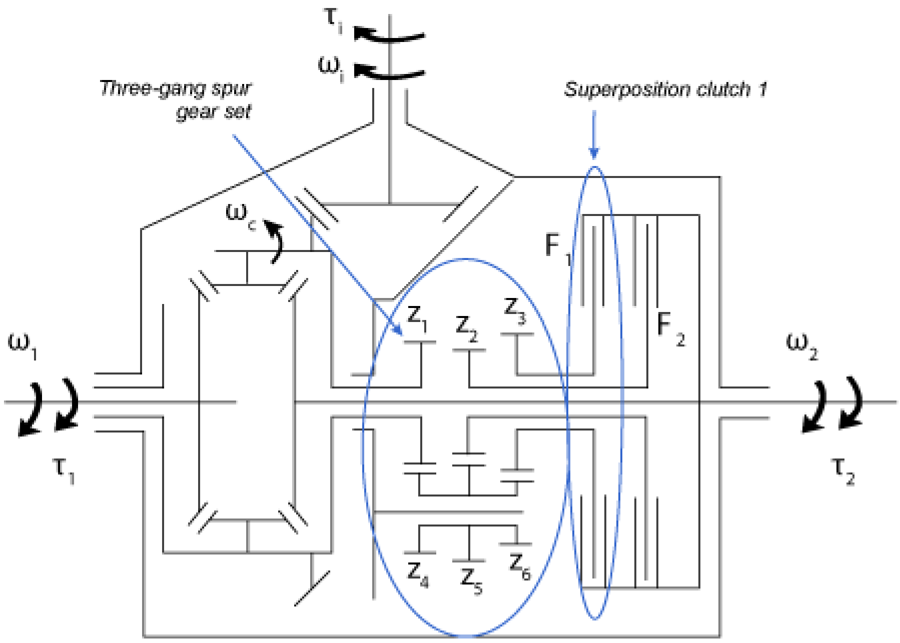
The Active Differential block implements these equations to represent the mechanical dynamic response for the superposition and stationary clutch configurations. To determine the gear ratios, the block uses the clutch speed and the number of teeth for each gear pair. The allowable wheel speed difference (AWSD) limits the wheel speed difference for positive torque.

Mechanical Dynamic Response	**Equations**	
	Superposition Clutches and Spur Gearing	**Stationary Clutches and Planetary Gearing**
Crown gear	$\dot{\omega}_d(J_d + J_{gs}) = T_d - \omega_d b_d - T_i$	$\dot{\omega}_d(\ J_d + J_{s1} + J_{s2}) = T_d - \omega_d b_d - T_i$
Axle 1	$\dot{\omega}_1 J_1 = \eta T_1 - \omega_1 b_1 - T_{i1}$	$\dot{\omega}_1(J_1 + J_{r1}) = T_1 - \omega_1 b_1 - T_{i1}$
Axle 2	$\dot{\omega}_2 J_2 = \eta T_2 - \omega_2 b_2 - T_{i2}$	$\dot{\omega}_2(J_{axle2} + J_{r1}) = T_2 - \omega_2 b_2 - T_{i2}$
Gear ratios	$\frac{\omega_{cl1}}{\omega_d} = N_{s1} = \frac{z_1 z_6}{z_4 z_3}$ $\frac{\omega_{cl2}}{\omega_d} = N_{s2} = \frac{z_1 z_5}{z_4 z_2}$	$\frac{\omega_{cl1}}{\omega_d} = N_{p1} = \frac{z_1 z_6}{z_4 z_3}$ $\frac{\omega_{cl2}}{\omega_d} = N_{p2} = \frac{z_1 z_5}{z_4 z_2}$
Rigid Coupling Constraints	$T_1 = \quad \frac{NT_i}{2} - \frac{N_{s2}}{2} T_{cl2} + \frac{N_{s1}}{2} T_{cl1}$ $T_2 = \quad \frac{NT_i}{2} + (1 - \frac{N_{s2}}{2}) T_{cl2} - (1 - \frac{N_{s1}}{2}) T_{cl1}$ $\omega_{d\,=} \ = \frac{N}{2}(\omega_1 + \omega_2)$	$T_1 = \quad \frac{NT_i}{2} - \frac{N_{p2}}{(N_{p2} - 1)2} T_{cl2} + \frac{(2 - N_{p1})}{(N_{p1} - 1)2} T_{cl1}$ $T_2 = \quad \frac{NT_i}{2} + \frac{(2 - N_{p2})}{(N_{p2} - 1)2} T_{cl2} - \frac{N_{p1}}{(N_{p1} - 1)2} T_{cl1}$ $\omega_{d\,=} \ = \frac{N}{2}(\omega_1 + \omega_2)$
Allowable wheel speed difference (AWSD)	$\overline{\Delta\omega}_{max} = (N_{s2} - N_{s1}) \cdot 100\%$	$\overline{\Delta\omega}_{max} = (N_{p1,\,2} - 1) \cdot 100\%$

Superposition Clutches and Spur Gearing

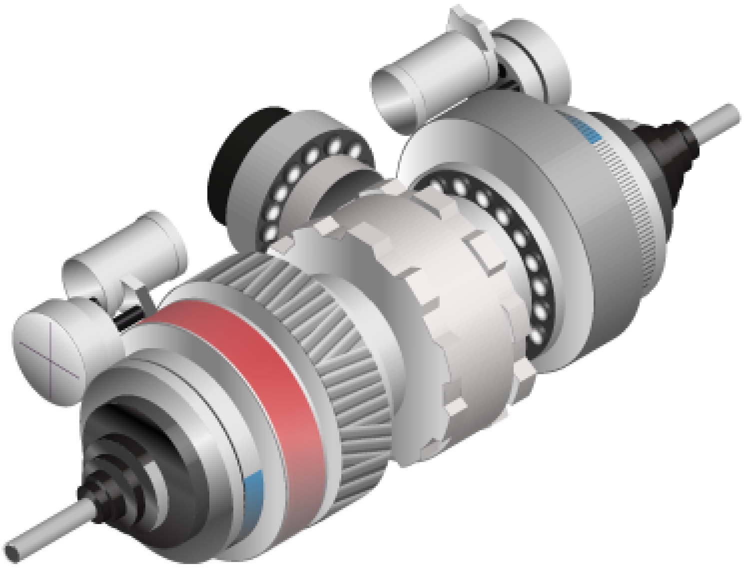
These superposition clutch illustrations show the clutch configuration and schematic for torque transfer to the left wheel.

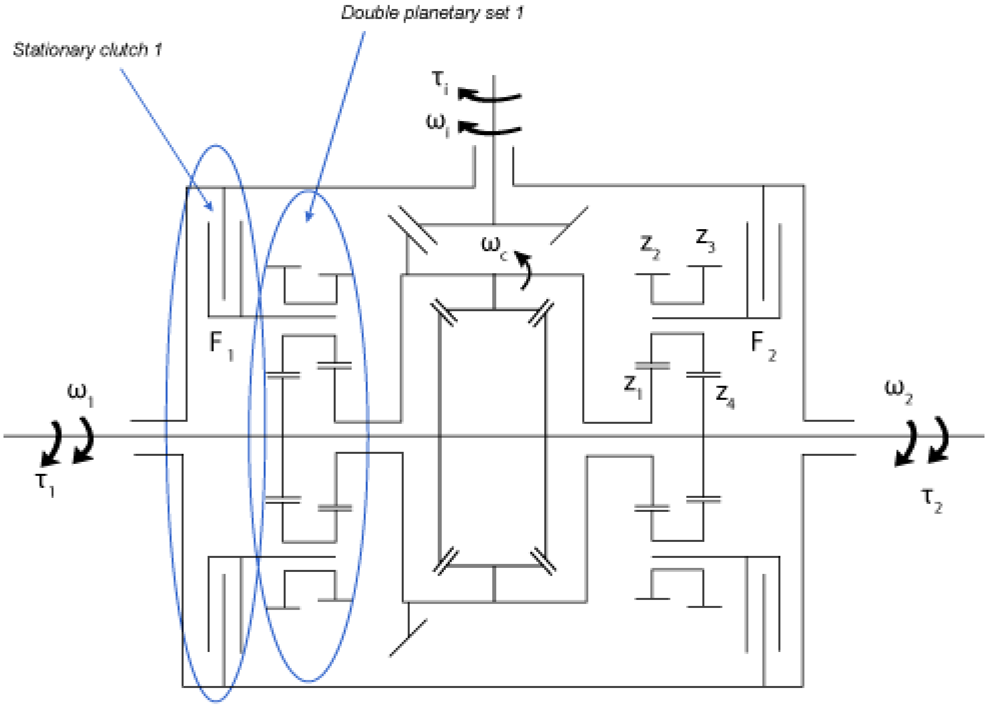

Torque transfer to left wheel
Propeller shaft
Active yaw control (AYC) differential
Hydraulic multi-plate clutch
(left clutch)
Left axle
Right axle


τi
ωi
Three-gang spur gear set
Superposition clutch 1
ωc
F1
F2
Z1
Z2
Z3
Z4
Z5
Z6
ω1
τ1
ω2
τ2

Stationary Clutches and Planetary Gearing

The illustrations show the stationary clutch configuration and schematic.





Slip Coupling

For both the ideal clutch and slip-speed configurations, the slip coupling is a function of the slip-speed and clutch pressure. The slip-speed depends on the slip velocity at each of the clutch interfaces.

$$\varpi = [\Delta\omega_{c1}, \Delta\omega_{c2}]$$

Ideal Clutch

The ideal clutch coupling model uses the axle slip speed, clutch pressure, and friction to calculate the clutch torque. The friction coefficient is a function of the slip speed.

$$T_C = F_T N_d \mu(|\bar{\varpi}|) R_{eff} \tanh(4\bar{\varpi})$$

To calculate the total clutch force, the block uses the effective radius, clutch pressure, and clutch preload force.

$$F_T = \quad F_C + P_{1,2}\mathrm{A}_{eff}, \quad F_T \geq 0$$

The disc radii determine the effective clutch radius over which the clutch force acts.

$$R_{eff} = \frac{2(R_o3 - R_i3)}{3(R_o2 - R_i2)}$$

Slip-Speed

To calculate the clutch torque, the slip speed coupling model uses torque data that is a function of slip speed and clutch pressure. The angular velocities of the axles determine the slip speed.

$$T_C = T_C(\varpi, \quad P_{1,2})$$

The equations use these variables.

A_{eff}	Effective clutch pressure area
b_d	Crown gear linear viscous damping
b_1, b_2	Axle 1 and 2 linear viscous damping, respectively
F_c, F_T	Clutch preload force and total force, respectively
J_d	Carrier rotational inertia
J_{gc}	Three-gang gear rotational inertia
J_{c1}, J_{c2}	Planetary carrier 1 and 2 rotational inertia, respectively
J_{r1}, J_{r2}	Planetary ring gear 1 and 2 rotational inertia, respectively
J_{s1}, J_{s2}	Planetary sun gear 1 and 2 rotational inertia, respectively
J_1, J_2	Axle 1 and 2 rotational inertia, respectively
N	Carrier-to-drive shaft gear ratio
N_d	Number of disks
N_{s1}, N_{s2}	Clutch 1 and 2 carrier-to-spur gear ratio, respectively
N_{p1}, N_{p2}	Planetary 1 and 2 carrier-to-axle gear ratio, respectively
P_1, P_2	Clutch 1 and 2 pressure, respectively

R_{eff}	Effective clutch radius
R_i, R_o	Annular disk inner and outer radius, respectively
T_c	Clutch torque
T_{cl1}, T_{cl2}	Clutch 1 and 2 coupling torque, respectively
T_d	Driveshaft torque
T_1, T_2	Axle 1 and 2 torque, respectively
T_i	Axle internal resistance torque
T_{i1}, T_{i2}	Axle 1 and 2 internal resistance torque
ω_d	Driveshaft angular velocity
ϖ	Slip speed
ω_1, ω_2	Axle 1 and 2 angular velocity, respectively
$\Delta\omega_{cl1}$, $\Delta\omega_{cl2}$	Clutch 1 and 2 slip speed at interface, respectively
ω_{cl1}, ω_{cl2}	Clutch 1 and 2 angular velocity, respectively
μ	Clutch coefficient of friction
z_i	Number of teeth on gear *i*

Ports

Inputs

`Prs1` — Clutch 1 pressure
`scalar`

Clutch 1 pressure, P_1, in Pa.

`Prs2` — Clutch 2 pressure
`scalar`

Clutch 2 pressure, P_2, in Pa.

`DriveshftTrq` — Driveshaft torque
`scalar`

Applied input torque, T_d, typically from the engine driveshaft, in N·m.

`Axl1Trq` — Torque
`scalar`

Axle 1 torque, T_1, in N·m.

`Axl2Trq` — Torque
`scalar`

Axle 2 torque, T_2, in N·m.

Output

`Info` — Bus signal
bus

Bus signal containing these block calculations.

Signal		Description	Units
`Driveshft`	`DriveshftTrq`	Drive shaft torque	N·m
	`DriveshftSpd`	Drive shaft angular velocity	rad/s
`Axl1`	`Axl1Trq`	Axle 1 torque	N·m
	`Axl1Spd`	Axle 1 angular velocity	rad/s
`Axl2`	`Axl2Trq`	Axle 2 torque	N·m
	`Axl2Spd`	Axle 2 angular velocity	rad/s
`Cplng`	`CplngTrq1`	Clutch 1 coupling torque	N·m
	`CplngTrq2`	Clutch 2 coupling torque	N·m
	`CplngSlipSpd1`	Clutch 1 slip speed	rad/s
	`CplngSlipSpd2`	Clutch 2 slip speed	rad/s
	`CplngPrs1`	Clutch 1 input pressure	Pa
	`CplngPrs2`	Clutch 2 input pressure	Pa

`DriveshftSpd` — Angular velocity
`scalar`

Driveshaft angular velocity, ω_d, in rad/s.

`Axl1Spd` — Angular velocity
`scalar`

Axle 1 angular velocity, ω_1, in rad/s.

`Axl2Spd` — Angular velocity
`scalar`

Axle 2 angular velocity, ω_2, in rad/s.

Parameters

Active Differential

`Active differential type` — Differential
`Spur gears, superposition clutches` (default) | `Double planetary gears, stationary clutches`

Specify the type of active differential.

Setting	Block Implementation
`Spur gears, superposition clutches`	Clutches are in superposition through a three-gang gear system and a differential case
`Double planetary gears, stationary clutches`	Clutches are fixed to the carrier and axles through double planetary gear sets

`Clutch 1 to differential case gear ratio, Ns1` — Clutch 1-spur gear ratio

`.875` (default) | `scalar`

Clutch 1-to-carrier spur gear ratio, N_{s1}, dimensionless.

Dependencies

To enable the spur gear parameters, select `Spur gears, superposition clutches` for the **Active differential type** parameter.

`Clutch 2 to differential case gear ratio, Ns2` — Clutch 2-spur gear ratio

`1.125` (default) | `scalar`

Clutch 2-to-carrier spur gear ratio, N_{s2}, dimensionless.

Dependencies

To enable the spur gear parameters, select `Spur gears, superposition clutches` for the **Active differential type** parameter.

`Three-gang gear inertia, Jgc` — Rotational inertia

`.003` (default) | `scalar`

Three-gang gear rotational inertia, J_{gc}, in kg·m^2.

Dependencies

To enable the spur gear parameters, select `Spur gears, superposition clutches` for the **Active differential type** parameter.

`Axle 1 planetary carrier to axle gear ratio, Np1` — Planetary 1 carrier gear ratio

`1.125` (default) | `scalar`

Planetary 1 carrier-to-axle gear ratio, N_{p1}, dimensionless.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

`Axle 1 sun gear inertia, Js1` — Planetary 1 sun gear inertia

`.001` (default) | `scalar`

Planetary 1 sun gear inertia, J_{s1}, in kg·m^2.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

`Axle 1 carrier inertia, Jc1` — Planetary 1 carrier inertia

`.001` (default) | `scalar`

Planetary 1 carrier inertia, J_{c1}, in kg·m^2.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

`Axle 1 ring inertia, Jr1` — Planetary 1 ring gear inertia

`.002` (default) | `scalar`

Planetary 1 ring gear inertia, J_{r1}, kg·m^2.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

`Axle 2 planetary carrier to axle gear ratio, Np2` — Planetary 2 carrier gear ratio

`1.125` (default) | `scalar`

Planetary 2 carrier-to-axle gear ratio, N_{p2}, dimensionless.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

`Axle 2 sun gear inertia, Js2` — Planetary 2 sun gear inertia

`.001` (default) | `scalar`

Planetary 2 sun gear inertia, J_{s2}, in kg·m^2.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

`Axle 2 carrier inertia, Jc2` — Planetary 2 carrier inertia

`.001` (default) | `scalar`

Planetary 2 carrier inertia, J_{c2}, in kg·m^2.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

`Axle 2 ring inertia, Jr2` — Planetary 2 ring gear inertia

`.002` (default) | `scalar`

Planetary 2 ring gear inertia, J_{r2}, in kg·m^2.

Dependencies

To enable the planetary gear parameters, select `Double planetary gears, stationary clutches` for the **Active differential type** parameter.

Open Differential

`Crown wheel (ring gear) located` — Specify crown wheel connection

`To the left of center-line` (default) | `To the right of center-line`

Specify the crown wheel connection to the drive shaft.

`Carrier to drive shaft ratio, NC/ND` — Ratio
`4` (default) | `scalar`

Carrier-to-drive shaft gear ratio, *N*.

`Carrier inertia, Jd` — Inertia
`.1` (default) | `scalar`

Rotational inertia of the crown gear assembly, J_d, in kg·m^2. You can include the drive shaft inertia.

`Carrier damping, bd` — Damping
`1e-3` (default) | `scalar`

Crown gear linear viscous damping, b_d, in N·m·s/rad.

`Axle 1 inertia, Jw1` — Inertia
`.1` (default) | `scalar`

Axle 1 rotational inertia, J_1, in kg·m^2.

`Axle 1 damping, bw1` — Damping
`1e-3` (default) | `scalar`

Axle 1 linear viscous damping, b_1, in N·m·s/rad.

`Axle 2 inertia, Jw2` — Inertia
`.1` (default) | `scalar`

Axle 2 rotational inertia, J_2, in kg·m^2.

`Axle 2 damping, bw2` — Damping
`1e-3` (default) | `scalar`

Axle 2 linear viscous damping, b_2, in N·m·s/rad.

`Axle 1 initial velocity, omegaw1o` — Angular velocity
`0` (default) | `scalar`

Axle 1 initial velocity, ω_{o1}, in rad/s.

`Axle 2 initial velocity, omegaw2o` — Angular velocity
`0` (default) | `scalar`

Axle 2 initial velocity, ω_{o2}, in rad/s.

Slip Coupling

`Coupling type` — Torque coupling
`Ideal pre-loaded clutch` (default) | `Slip speed dependent torque data` | `Input torque dependent torque data`

Specify the type of torque coupling.

Setting	Block Implementation
`Pre-loaded ideal clutch`	Torque modeled as a wet clutch with a constant velocity

Setting	Block Implementation
`Slip speed dependent torque data`	Torque determined from a lookup table that is a function of slip-speed and clutch pressure

`Effective applied pressure area` — Pressure area

`0.01` (default) | `scalar`

Effective applied pressure area, in N/m^2.

Dependencies

To enable the clutch parameters, select `Ideal pre-loaded clutch` for the **Coupling type** parameter.

`Number of disks, Ndisks` — Torque coupling

`4` (default) | `scalar`

Number of disks.

Dependencies

To enable the clutch parameters, select `Ideal pre-loaded clutch` for the **Coupling type** parameter.

`Effective radius, Reff` — Radius

`.20` (default) | `scalar`

The effective radius, R_{eff}, used with the applied clutch friction force to determine the friction force. The effective radius is defined as:

$$R_{eff} = \frac{2(R_o3 - R_i3)}{3(R_o2 - R_i2)}$$

The equation uses these variables.

R_o	Annular disk outer radius
R_i	Annular disk inner radius

Dependencies

To enable the clutch parameters, select `Ideal pre-loaded clutch` for the **Coupling type** parameter.

`Nominal preload force, Fc` — Force

`500` (default) | `scalar`

Nominal preload force, in N.

Dependencies

To enable the clutch parameters, select `Ideal pre-loaded clutch` for the **Coupling type** parameter.

`Friction coefficient vector, mu` — Friction

`[.16 0.13 0.115 0.11 0.105 0.1025 0.10125 .10125]` (default) | `vector`

Friction coefficient vector.

Dependencies

To enable the clutch parameters, select `Ideal pre-loaded clutch` for the **Coupling type** parameter.

`Slip speed vector, dw` — Angular velocity
`[0 10 20 40 60 80 100 500]` (default) | `vector`

Slip speed vector, in rad/s.

To enable the clutch parameters, select `Ideal pre-loaded clutch` for the **Coupling type** parameter.

`Torque - slip speed matrix, TdPdw` — Clutch torque
`[-1000,-500,-90,-50,-5,0,5,50,90,500,1000].*ones(11)` (default) | `matrix`

Torque matrix, T_c, in N·m.

Dependencies

To enable the slip speed parameters, select `Slip speed dependent torque data` for the **Coupling type** parameter.

`Clutch pressure vector, pT` — Clutch pressure breakpoints
`[0 1e3 5e3 7e3 1e4 2e4 5e4 1e5 5e5 1e6 5e6]` (default) | `vector`

Clutch pressure breakpoints vector, $P_{1,2}$, in Pa.

Dependencies

To enable the slip speed parameters, select `Slip speed dependent torque data` for the **Coupling type** parameter.

`Slip speed vector, dwT` — Slip speed breakpoints
`[-500 -200, -175, -100, - 50, 0, 50, 100, 175, 200, 500]` (default) | `vector`

Slip speed breakpoints vector, ω, in rad/s.

Dependencies

To enable the slip speed parameters, select `Slip speed dependent torque data` for the **Coupling type** parameter.

`Coupling time constant, tauC` — Constant
`.01` (default) | `scalar`

Coupling time constant, in s.

Version History

Introduced in R2018b

References

[1] Deur, J., Ivanović, V., Hancock, M., and Assadian, F. "Modeling of Active Differential Dynamics." In ASME proceedings. *Transportation Systems*. Vol. 17, pp: 427-436.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

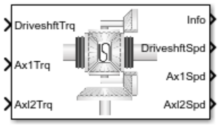
See Also

Open Differential | Limited Slip Differential

Limited Slip Differential

Limited differential as a planetary bevel gear

Library: Powertrain Blockset / Drivetrain / Final Drive Unit
Vehicle Dynamics Blockset / Powertrain / Drivetrain / Final Drive Unit



Description

The Limited Slip Differential block implements a differential as a planetary bevel gear train. The block matches the driveshaft bevel gear to the crown (ring) bevel gear. You can specify:

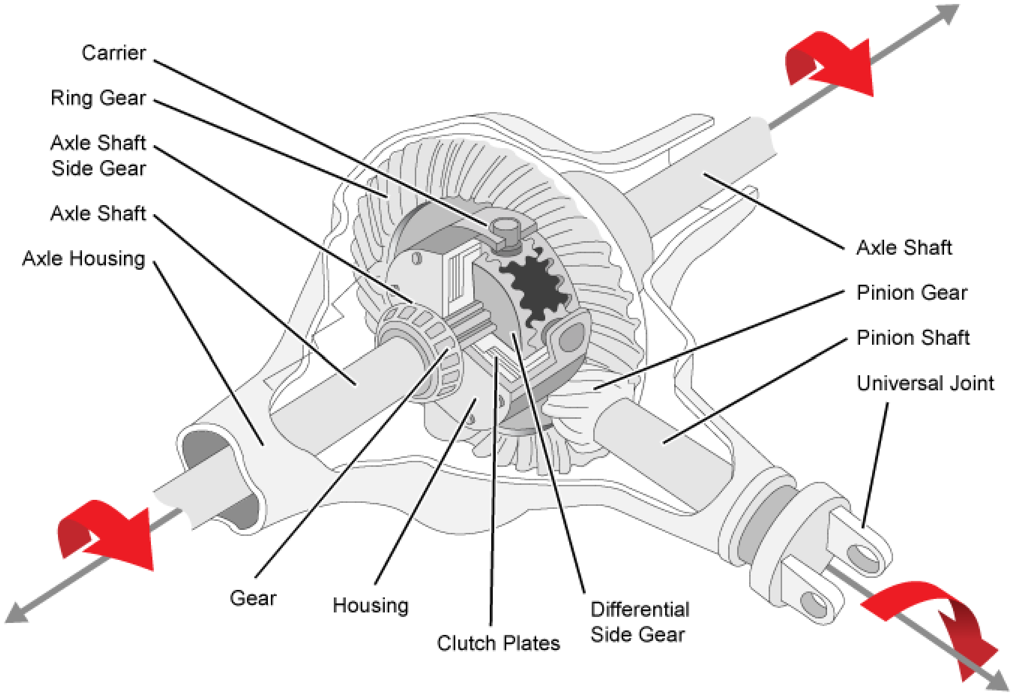
- Carrier-to-driveshaft ratio
- Crown wheel location
- Viscous and damping coefficients for the axles and carrier
- Type of slip coupling

Use the block in system-level driveline analysis to account for the power transfer from the transmission to the wheels. The block is suitable for use in hardware-in-the-loop (HIL) and optimization workflows. All the parameters are tunable.

In a limited slip differential, to prevent one of the wheels from slipping, the differential splits the torque applied to the left and right axles. With different torque applied to the axles, the wheels can move at different angular velocities, preventing slip. The block implements three methods for coupling the different torques applied to the axes:

- Pre-loaded ideal clutch
- Slip speed-dependent torque data
- Input torque dependent torque data

The block uses a coordinate system that produces positive tire and vehicle motion for standard engine, transmission, and differential configurations. The arrows indicate positive motion.



Efficiency

To account for the block efficiency, use the **Efficiency factors** parameter. This table summarizes the block implementation for each setting.

Setting	Implementation
`Constant`	Constant efficiency that you can set with the **Constant efficiency factor, eta** parameter.
`Driveshaft torque, temperature and speed`	Efficiency as a function of base gear input torque, air temperature, and driveshaft speed. Use these parameters to specify the lookup table and breakpoints: • **Efficiency lookup table, eta_tbl** • **Efficiency torque breakpoints, Trq_bpts** • **Efficiency speed breakpoints, omega_bpts** • **Efficiency temperature breakpoints, Temp_bpts** For the air temperature, you can either: • Select **Input temperature** to create an input port. • Set a **Ambient temperature, Tamb** parameter value. To select the interpolation method, use the **Interpolation method** parameter. For more information, see “Interpolation Methods”.

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrDriveshft`	Mechanical power from driveshaft	$\eta T_d \omega_d$
		`PwrAxl1`	Mechanical power from axle 1	$\eta T_1 \omega_1$
		`PwrAxl2`	Mechanical power from axle 2	$\eta T_2 \omega_2$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrMechLoss`	Total power loss	$\dot{W}_{loss} = -(P_t + P_d + P_c) + P_s$ $P_t = \eta(T_d \omega_d + T_1 \omega_1 + T_2 \omega_2)$
		`PwrDampLoss`	Power loss due to damping	$P_d = -(b_1 \lvert\omega_1\rvert + b_2 \lvert\omega_2\rvert + b_d \lvert\omega_d\rvert)$
		`PwrCplngLoss`	Power loss due to clutch	$P_c = T_c \lvert\bar{\omega}\rvert$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredShft`	Rate change of stored internal energy	$P_s = -(\omega_1 \dot{\omega}_1 J_1 + \omega_2 \dot{\omega}_2 J_2 + \omega_d \dot{\omega}_d J_d)$

Dynamics

The Limited Slip Differential block implements these differential equations to represent the mechanical dynamic response for the crown gear, left axle, and right axle.

Mechanical Dynamic Response	Differential Equation
Crown Gear	$\dot{\omega}_d J_d = \eta T_d - \omega_d b_d - T_i$
Left Axle	$\dot{\omega}_1 J_1 = \eta T_1 - \omega_1 b_1 - T_{i1}$
Right Axle	$\dot{\omega}_2 J_2 = \eta T_2 - \omega_2 b_2 - T_{i2}$

The block assumes rigid coupling between the crown gear and axles. These constraint equations apply.

$$\eta T_1 = \frac{N}{2} T_i - \frac{1}{2} T_c$$

$$\eta T_2 = \frac{N}{2} T_i + \frac{1}{2} T_c$$

$$\omega_d = \frac{N}{2}(\omega_1 + \omega_2)$$

The equations use these variables.

N	Carrier-to-driveshaft gear ratio
J_d	Rotational inertia of the crown gear assembly
b_d	Crown gear linear viscous damping
ω_d	Driveshaft angular speed
ϖ	Slip speed
J_1	Axle 1 rotational inertia
b_1	Axle 1 linear viscous damping
ω_1	Axle 1 speed
J_2	Axle 2 rotational inertia
b_2	Axle 2 linear viscous damping
ω_2	Axle 2 angular speed
η	Efficiency
T_d	Driveshaft torque
T_1	Axle 1 torque
T_2	Axle 2 torque
T_i	Axle internal resistance torque
T_{i1}	Axle 1 internal resistance torque
T_{i2}	Axle 2 internal resistance torque
μ	Coefficient of friction
R_{eff}	Effective clutch radius
R_o	Annular disk outer radius
R_i	Annular disk inner radius
F_c	Clutch force
T_c	Clutch torque
μ	Coefficient of friction

Table blocks in the Limited Slip Differential have these parameter settings:

- **Interpolation method** — `Linear`
- **Extrapolation method** — `Clip`

Ideal Clutch Coupling

The ideal clutch coupling model uses the axle slip speed and friction to calculate the clutch torque. The friction coefficient is a function of the slip speed.

$$T_c = F_c N \mu(|\varpi|) R_{eff} \tanh(4|\varpi|)$$

The disc radii determine the effective clutch radius over which the clutch force acts.

$$R_{eff} = \frac{2(R_o3 - R_i3)}{3(R_o2 - R_i2)}$$

The angular velocities of the axles determine the slip speed.

$$\varpi = \omega_1 - \omega_2$$

Slip Speed Coupling

To calculate the clutch torque, the slip speed coupling model uses torque data that is a function of slip speed. The angular velocities of the axles determine the slip speed.

$$\varpi = \omega_1 - \omega_2$$

Input Torque Coupling

To calculate the clutch torque, the input torque coupling model uses torque data that is a function of input torque.

The Open Differential block assumes rigid coupling between the crown gear and axles. These constraint equations apply.

$$\eta T_{i1} = \quad \eta T_{i2} = \frac{N}{2} T_i$$

$$\omega_d = \frac{N}{2}(\omega_1 + \omega_2)$$

Ports

Inputs

`DriveshftTrq` — Torque
`scalar`

Applied input torque, typically from the engine crankshaft, in N·m.

`Axl1Trq` — Torque
`scalar`

Axle 1 torque, T_1, in N·m.

`Axl2Trq` — Torque
`scalar`

Axle 2 torque, T_2, in N·m.

`Temp` — Temperature
`scalar`

Temperature, in K.

Dependencies

To enable this port:

- Set **Efficiency factors** to `Driveshaft torque, speed and temperature`.
- Select **Input temperature**.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal			Description	Units
`Driveshft`	`DriveshftTrq`		Driveshaft torque	N·m
	`DriveshftSpd`		Driveshaft speed	rad/s
`Axl1`	`Axl1Trq`		Axle 1 torque	N·m
	`Axl1Spd`		Axle 1 speed	rad/s
`Axl2`	`Axl2Trq`		Axle 2 torque	N·m
	`Axl2Spd`		Axle 2 speed	rad/s
`Cplng`	`CplngTrq`		Torque coupling	N·m
	`CplngSlipSpd`		Slip speed	rad/s
`PwrInfo`	`PwrTrnsfrd`	`PwrDriveshft`	Mechanical power from driveshaft	W
		`PwrAxl1`	Mechanical power from axle 1	W
		`PwrAxl2`	Mechanical power from axle 2	W
	`PwrNotTrnsfrd`	`PwrMechLoss`	Total power loss	W
		`PwrDampLoss`	Power loss due to damping	W
		`PwrCplngLoss`	Power loss due to clutch	W
	`PwrStoredShft`	`PwrStoredShft`	Rate change of stored internal energy	W

`DriveshftSpd` — Angular speed

`scalar`

Driveshaft angular speed, ω_d, in rad/s.

`Axl1Spd` — Angular speed

`scalar`

Axle 1 angular speed, ω_1, in rad/s.

`Axl2Spd` — Angular speed

`scalar`

Axle 2 angular speed, ω_2, in rad/s.

Parameters

Block Options

`Efficiency factors` — Specify configuration

`Constant` (default) | `Driveshaft torque, speed and temperature`

To account for the block efficiency, use the **Efficiency factors** parameter. This table summarizes the block implementation for each setting.

Setting	Implementation
`Constant`	Constant efficiency that you can set with the **Constant efficiency factor, eta** parameter.
`Driveshaft torque, temperature and speed`	Efficiency as a function of base gear input torque, air temperature, and driveshaft speed. Use these parameters to specify the lookup table and breakpoints: • **Efficiency lookup table, eta_tbl** • **Efficiency torque breakpoints, Trq_bpts** • **Efficiency speed breakpoints, omega_bpts** • **Efficiency temperature breakpoints, Temp_bpts** For the air temperature, you can either: • Select **Input temperature** to create an input port. • Set a **Ambient temperature, Tamb** parameter value. To select the interpolation method, use the **Interpolation method** parameter. For more information, see "Interpolation Methods".

`Interpolation method` — Method

`Flat` | `Nearest` | `Linear point-slope` | `Linear Lagrange` | `Cubic spline`

For more information, see "Interpolation Methods".

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Input temperature` — Create input port

`off` (default) | `on`

Select to create input port `Temp` for the temperature.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

Open Differential

`Crown wheel (ring gear) located` — Specify crown wheel connection

`To the left of center-line` (default) | `To the right of center-line`

Specify the crown wheel connection to the driveshaft.

`Carrier to drive shaft ratio, NC/ND` — Ratio
`4` (default) | `scalar`

Carrier-to-driveshaft gear ratio, *N*.

`Carrier inertia, Jd` — Inertia
`.1` (default) | `scalar`

Rotational inertia of the crown gear assembly, J_d, in kg·m^2. You can include the driveshaft inertia.

`Carrier damping, bd` — Damping
`1e-3` (default) | `scalar`

Crown gear linear viscous damping, b_d, in N·m·s/rad.

`Axle 1 inertia, Jw1` — Inertia
`.1` (default) | `scalar`

Axle 1 rotational inertia, J_1, in kg·m^2.

`Axle 1 damping, bw1` — Damping
`1e-3` (default) | `scalar`

Axle 1 linear viscous damping, b_1, in N·m·s/rad.

`Axle 2 inertia, Jw2` — Inertia
`.1` (default) | `scalar`

Axle 2 rotational inertia, J_2, in kg·m^2.

`Axle 2 damping, bw2` — Damping
`1e-3` (default) | `scalar`

Axle 2 linear viscous damping, b_2, in N·m·s/rad.

`Axle 1 initial velocity, omegaw1o` — Angular velocity
`0` (default) | `scalar`

Axle 1 initial velocity, ω_{o1}, in rad/s.

`Axle 2 initial velocity, omegaw2o` — Angular velocity
`0` (default) | `scalar`

Axle 2 initial velocity, ω_{o2}, in rad/s.

`Constant efficiency factor, eta` — Efficiency
`1` (default) | `scalar`

Constant efficiency, η.

Dependencies

To enable this parameter, set **Efficiency factors** to `Constant`.

`Efficiency lookup table, eta_tbl` — Lookup table

`M`-by-`N`-by-`L` array

Dimensionless array of values for efficiency as a function of:

- `M` input torques
- `N` input speed
- `L` air temperatures

Each value specifies the efficiency for a specific combination of torque, speed, and temperature. The array size must match the dimensions defined by the torque, speed, and temperature breakpoint vectors.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency torque breakpoints, Trq_bpts` — Torque breakpoints

`[25, 50, 75, 100, 150, 200, 250]` (default) | 1-by-`M` vector

Vector of input torque, breakpoints for efficiency, in N·m.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency speed breakpoints, omega_bpts` — Speed breakpoints

`[52.4 78.5 105 131 157 183 209 262 314 419 524]` (default) | 1-by-`N` vector

Vector of speed, breakpoints for efficiency, in rad/s.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency temperature breakpoints, Temp_bpts` — Temperature breakpoints

`[290 358]` (default) | 1-by-`L` vector

Vector of ambient temperature breakpoints for efficiency, in K.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Ambient temperature, Tamb` — Ambient temperature

`297.15` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter:

- Set **Efficiency factors** to `Driveshaft torque, speed and temperature`.
- Clear **Input temperature**.

Slip Coupling

`Coupling type` — Torque coupling

`Pre-loaded ideal clutch` (default) | `Slip speed dependent torque data` | `Input torque dependent torque data`

Specify the type of torque coupling.

`Number of disks, Ndisks` — Torque coupling

`4` (default) | `scalar`

Number of disks.

Dependencies

To enable the ideal clutch parameters, select `Pre-loaded ideal clutch` for the **Coupling type** parameter.

`Effective radius, Reff` — Radius

`.20` (default) | `scalar`

The effective radius, R_{eff}, used with the applied clutch friction force to determine the friction force. The effective radius is defined as:

$$R_{eff} = \frac{2(R_o 3 - R_i 3)}{3(R_o 2 - R_i 2)}$$

The equation uses these variables.

R_o	Annular disk outer radius
R_i	Annular disk inner radius

Dependencies

To enable the clutch parameters, select `Pre-loaded ideal clutch` for the **Coupling type** parameter.

`Nominal preload force, Fc` — Force

`500` (default) | `scalar`

Nominal preload force, in N.

Dependencies

To enable the clutch parameters, select `Pre-loaded ideal clutch` for the **Coupling type** parameter.

`Friction coefficient vector, muc` — Friction

`[.16 0.13 0.115 0.11 0.105 0.1025 0.10125]` (default) | `vector`

Friction coefficient vector.

Dependencies

To enable the clutch parameters, select `Pre-loaded ideal clutch` for the **Coupling type** parameter.

`Slip speed vector, dw` — Angular velocity

`[0 10 20 40 60 80 100]` (default) | `vector`

Slip speed vector, in rad/s.

Dependencies

To enable the clutch parameters, select `Pre-loaded ideal clutch` for the **Coupling type** parameter.

`Torque - slip speed vector, Tdw` — Torque

`[-100, -90, -50, -5, 0, 5, 50, 90, 100]` (default) | `vector`

Torque vector, in N·m.

Dependencies

To enable the slip speed parameters, select `Slip speed dependent torque data` for the **Coupling type** parameter.

`Slip speed vector, dwT` — Angular velocity

`[-200, -175, -100, - 50, 0, 50, 100, 175, 200]` (default) | `vector`

Slip speed vector, in rad/s.

Dependencies

To enable the slip speed parameters, select `Slip speed dependent torque data` for the **Coupling type** parameter.

`Torque - input torque vector, TTin` — Torque

`[-200 -175 -100 - 50 0 50 100 175 200]` (default) | `vector`

Torque vector, in N·m.

Dependencies

To enable the input torque parameters, select `Input torque dependent torque data` for the **Coupling type** parameter.

`Input torque vector, Tin` — Torque

`[-200 -175 -100 - 50 0 50 100 175 200]` (default) | `vector`

Torque vector, in N·m.

Dependencies

To enable the input torque parameters, select `Input torque dependent torque data` for the **Coupling type** parameter.

`Coupling time constant, tauC` — Constant

`.01` (default) | `scalar`

Coupling time constant, in s.

Version History

Introduced in R2017a

References

[1] Deur, J., Ivanović, V., Hancock, M., and Assadian, F. "Modeling of Active Differential Dynamics." In ASME proceedings. *Transportation Systems*. Vol. 17, pp: 427-436.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

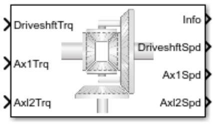
See Also

Open Differential

Open Differential

Differential as a planetary bevel gear

Library: Powertrain Blockset / Drivetrain / Final Drive Unit
Vehicle Dynamics Blockset / Powertrain / Drivetrain / Final Drive Unit



Description

The Open Differential block implements a differential as a planetary bevel gear train. The block matches the driveshaft bevel gear to the crown (ring) bevel gear. You can specify:

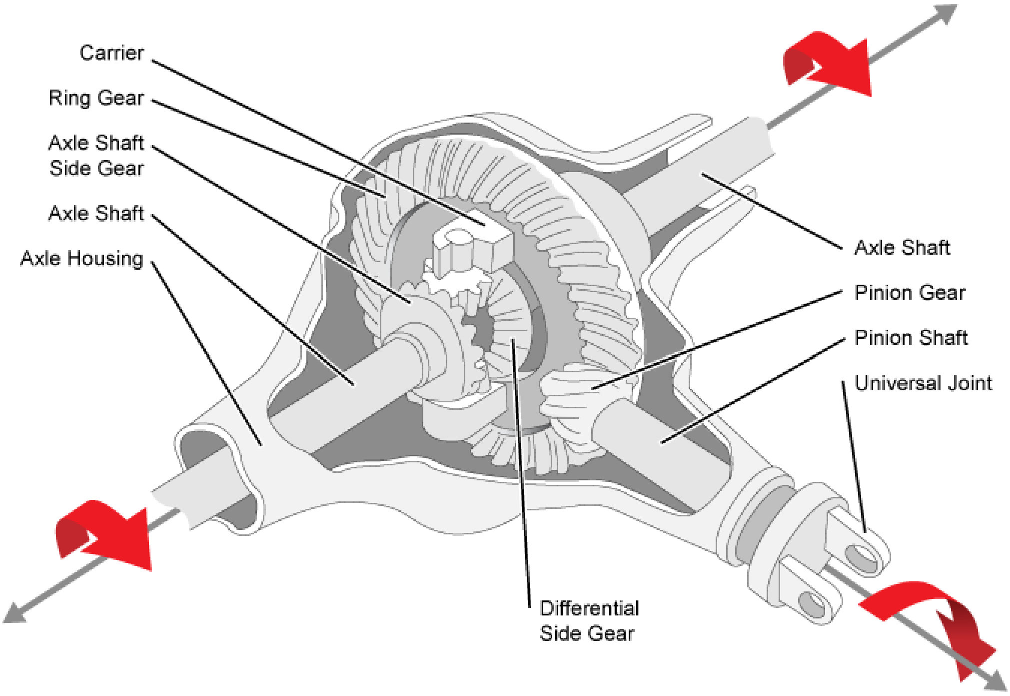
- Carrier-to-driveshaft ratio
- Crown wheel location
- Viscous and damping coefficients for the axles and carrier

Use the Open Differential block to:

- Dynamically couple the post-transmission driveshaft to the wheel axles or universal joints
- Model simplified or older drivetrains when optimal traction control does not require passive or active torque vectoring
- Model mechanical power splitting in generic gearbox and drive line scenarios

The block is suitable for use in hardware-in-the-loop (HIL) and optimization workflows. All the parameters are tunable.

The block uses a coordinate system that produces positive tire and vehicle motion for standard engine, transmission, and differential configurations. The arrows indicate positive motion.



Efficiency

To account for the block efficiency, use the **Efficiency factors** parameter. This table summarizes the block implementation for each setting.

Setting	Implementation
`Constant`	Constant efficiency that you can set with the **Constant efficiency factor, eta** parameter.
`Driveshaft torque, temperature and speed`	Efficiency as a function of base gear input torque, air temperature, and driveshaft speed. Use these parameters to specify the lookup table and breakpoints: • **Efficiency lookup table, eta_tbl** • **Efficiency torque breakpoints, Trq_bpts** • **Efficiency speed breakpoints, omega_bpts** • **Efficiency temperature breakpoints, Temp_bpts** For the air temperature, you can either: • Select **Input temperature** to create an input port. • Set a **Ambient temperature, Tamb** parameter value. To select the interpolation method, use the **Interpolation method** parameter. For more information, see “Interpolation Methods”.

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks - Positive signals indicate flow into block - Negative signals indicate flow out of block	`PwrDriveshft`	Mechanical power from driveshaft	$\eta T_d \omega_d$
		`PwrAxl1`	Mechanical power from axle 1	$\eta T_1 \omega_1$
		`PwrAxl2`	Mechanical power from axle 2	$\eta T_2 \omega_2$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred - Positive signals indicate an input - Negative signals indicate a loss	`PwrMechLoss`	Total power loss	$\dot{W}_{loss} = \quad -(P_t + P_d) + P_s$ $P_t = \eta T_d \omega_d + \eta T_1 \omega_1 + \eta T_2 \omega_2$
		`PwrDampLoss`	Power loss due to damping	$P_d = -(b_1 \lvert\omega_1\rvert + b_2 \lvert\omega_2\rvert + b_d \lvert\omega_d\rvert)$
	`PwrStored` — Stored energy rate of change - Positive signals indicate an increase - Negative signals indicate a decrease	`PwrStoredShft`	Rate change of stored internal energy	$P_s = -(\omega_1 \dot{\omega}_1 J_1 + \omega_2 \dot{\omega}_2 J_2 + \omega_d \dot{\omega}_d J_d)$

Dynamics

The Open Differential block implements these differential equations to represent the mechanical dynamic response for the crown gear, left axle, and right axle.

Mechanical Dynamic Response	Differential Equation
Crown Gear	$\dot{\omega}_d J_d = \eta T_d - \omega_d b_d - T_i$
Left Axle	$\dot{\omega}_1 J_1 = \eta T_1 - \omega_1 b_1 - T_{i1}$
Right Axle	$\dot{\omega}_2 J_2 = \eta T_2 - \omega_2 b_2 - T_{i2}$

The Open Differential block assumes rigid coupling between the crown gear and axles. These constraint equations apply.

$$\eta T_{i1} = \quad \eta T_{i2} = \frac{N}{2} T_i$$

$$\omega_d = \frac{N}{2}(\omega_1 + \omega_2)$$

The equations use these variables.

N	Carrier-to-driveshaft gear ratio
J_d	Rotational inertia of the crown gear assembly
b_d	Crown gear linear viscous damping
ω_d	Driveshaft angular speed
η	Differential efficiency
J_1	Axle 1 rotational inertia
b_1	Axle 1 linear viscous damping
ω_1	Axle 1 speed
J_2	Axle 2 rotational inertia
b_2	Axle 2 linear viscous damping
ω_2	Axle 2 angular speed
T_d	Driveshaft torque
T_1	Axle 1 torque
T_2	Axle 2 torque
T_i	Driveshaft internal resistance torque
T_{i1}	Axle 1 internal resistance torque
T_{i2}	Axle 2 internal resistance torque

Ports

Inputs

`DriveshftTrq` — Torque
`scalar`

Applied input torque, typically from the engine crankshaft, in N·m.

`Axl1Trq` — Torque
`scalar`

Axle 1 torque, T_1, in N·m.

`Axl2Trq` — Torque
`scalar`

Axle 2 torque, T_2, in N·m.

`Temp` — Temperature
`scalar`

Temperature, in K.

Dependencies

To enable this port:

- Set **Efficiency factors** to `Driveshaft torque, speed and temperature`.
- Select **Input temperature**.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal			Description	Units
`Driveshft`	`DriveshftTrq`		Driveshaft torque	N·m
	`DriveshftSpd`		Driveshaft speed	rad/s
`Axl1`	`Axl1Trq`		Axle 1 torque	N·m
	`Axl1Spd`		Axle 1 speed	rad/s
`Axl2`	`Axl2Trq`		Axle 2 torque	N·m
	`Axl2Spd`		Axle 2 speed	rad/s
`PwrInfo`	`PwrTrnsfrd`	`PwrDriveshft`	Mechanical power from driveshaft	W
		`PwrAxl1`	Mechanical power from axle 1	W
		`PwrAxl2`	Mechanical power from axle 2	W
	`PwrTrnsfrd`	`PwrMechLoss`	Total power loss	W
		`PwrDampLoss`	Power loss due to damping	W
	`PwrStored`	`PwrStoredShft`	Rate change of stored internal energy	W

`DriveshftSpd` — Angular speed

`scalar`

Driveshaft angular speed, ω_d, in rad/s.

`Axl1Spd` — Angular speed

`scalar`

Axle 1 angular speed, ω_1, in rad/s.

`Axl2Spd` — Angular speed

`scalar`

Axle 2 angular speed, ω_2, in rad/s.

Parameters

Block Options

`Efficiency factors` — Specify configuration

`Constant` (default) | `Driveshaft torque, speed and temperature`

To account for the block efficiency, use the **Efficiency factors** parameter. This table summarizes the block implementation for each setting.

Setting	Implementation
`Constant`	Constant efficiency that you can set with the **Constant efficiency factor, eta** parameter.
`Driveshaft torque, temperature and speed`	Efficiency as a function of base gear input torque, air temperature, and driveshaft speed. Use these parameters to specify the lookup table and breakpoints: • **Efficiency lookup table, eta_tbl** • **Efficiency torque breakpoints, Trq_bpts** • **Efficiency speed breakpoints, omega_bpts** • **Efficiency temperature breakpoints, Temp_bpts** For the air temperature, you can either: • Select **Input temperature** to create an input port. • Set a **Ambient temperature, Tamb** parameter value. To select the interpolation method, use the **Interpolation method** parameter. For more information, see “Interpolation Methods”.

`Interpolation method` — Method

`Flat` | `Nearest` | `Linear point-slope` | `Linear Lagrange` | `Cubic spline`

For more information, see “Interpolation Methods”.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Input temperature` — Create input port

`off` (default) | `on`

Select to create input port `Temp` for the temperature.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Crown wheel (ring gear) located` — Specify crown wheel connection

`To the left of center-line` (default) | `To the right of center-line`

Specify the crown wheel connection to the driveshaft.

`Carrier to drive shaft ratio, Ndiff` — Ratio

`4` (default) | `scalar`

Carrier-to-driveshaft gear ratio, *N*, dimensionless.

`Carrier inertia, Jd` — Inertia

`.1` (default) | `scalar`

Rotational inertia of the crown gear assembly, J_d, in kg·m^2. You can include the driveshaft inertia.

`Carrier damping, bd` — Damping

`1e-3` (default) | `scalar`

Crown gear linear viscous damping, b_d, in N·m·s/rad.

`Axle 1 inertia, Jw1` — Inertia

`.1` (default) | `scalar`

Axle 1 rotational inertia, J_1, in kg·m^2.

`Axle 1 damping, bw1` — Damping

`1e-3` (default) | `scalar`

Axle 1 linear viscous damping, b_1, in N·m·s/rad.

`Axle 2 inertia, Jw2` — Inertia

`.1` (default) | `scalar`

Axle 2 rotational inertia, J_2, in kg·m^2.

`Axle 2 damping, bw2` — Damping

`1e-3` (default) | `scalar`

Axle 2 linear viscous damping, b_2, in N·m·s/rad.

`Axle 1 initial velocity, omegaw1o` — Angular velocity

`0` (default) | `scalar`

Axle 1 initial velocity, ω_{o1}, in rad/s.

`Axle 2 initial velocity, omegaw2o` — Angular velocity

`0` (default) | `scalar`

Axle 2 initial velocity, ω_{o2}, in rad/s.

Efficiency

`Constant efficiency factor, eta` — Efficiency

`1` (default) | `scalar`

Constant efficiency, η.

Dependencies

To enable this parameter, set **Efficiency factors** to `Constant`.

`Efficiency lookup table, eta_tbl` — Lookup table

M-by-N-by-L array

Dimensionless array of values for efficiency as a function of:

- `M` input torques
- `N` input speed
- `L` air temperatures

Each value specifies the efficiency for a specific combination of torque, speed, and temperature. The array size must match the dimensions defined by the torque, speed, and temperature breakpoint vectors.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency torque breakpoints, Trq_bpts` — Torque breakpoints

`[25, 50, 75, 100, 150, 200, 250]` (default) | 1-by-M vector

Vector of input torque, breakpoints for efficiency, in N·m.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency speed breakpoints, omega_bpts` — Speed breakpoints

`[52.4 78.5 105 131 157 183 209 262 314 419 524]` (default) | 1-by-N vector

Vector of speed, breakpoints for efficiency, in rad/s.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency temperature breakpoints, Temp_bpts` — Temperature breakpoints

`[290 358]` (default) | 1-by-L vector

Vector of ambient temperature breakpoints for efficiency, in K.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Ambient temperature, Tamb` — Ambient temperature

`297.15` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter:

- Set **Efficiency factors** to `Driveshaft torque, speed and temperature`.
- Clear **Input temperature**.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

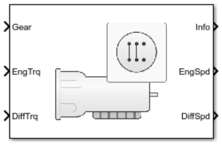
See Also

Limited Slip Differential

Ideal Fixed Gear Transmission

Ideal fixed gear transmission without clutch or synchronization

Library: Powertrain Blockset / Transmission / Transmission Systems
Vehicle Dynamics Blockset / Powertrain / Transmission



Description

The Ideal Fixed Gear Transmission implements an idealized fixed-gear transmission without a clutch or synchronization. Use the block to model the overall gear ratio and power loss when you do not need a detailed transmission model, for example, in component-sizing, fuel economy, and emission studies. The block implements a transmission model with minimal parameterization or computational cost.

To specify the block efficiency calculation, for **Efficiency factors**, select either of these options.

Setting	Block Implementation
`Gear only`	Efficiency determined from a 1D lookup table that is a function of the gear.
`Gear, input torque, input speed, and temperature`	Efficiency determined from a 4D lookup table that is a function of: • Gear • Input torque • Input speed • Oil temperature

The block uses this equation to determine the transmission dynamics:

$$\dot{\omega}_i \frac{J_N}{N^2} = \eta_N\left(\frac{T_o}{N} + T_i\right) - \frac{\omega_i}{N^2} b_N$$

$$\omega_i = N\omega_o$$

The block filters the gear command signal:

$$\frac{G}{G_{cmd}}(s) = \frac{1}{\tau_s s + 1}$$

Neutral Gear

When **Initial gear number, G_o** is equal to `0`, the initial gear is neutral. The block uses these parameters to decouple the input flywheel from the downstream gearing.

- **Initial input velocity, omega_o**
- **Initial neutral input velocity, omegainN_o**

The block uses these equations for the neutral gear speed and flywheel.

$$\dot{\omega}_{neutral}\frac{J_N}{N^2} = \eta_N\frac{T_o}{N} - \frac{\omega_{neutral}}{N^2}b_N$$

$$\omega_{neutral} = N\omega_o$$

$$\dot{\omega}_1 J_F = \eta_{@N\,=\,0}T_i - b_{@N\,=\,0}\omega_i$$

$$J_F = J_{@N\,=\,1} - J_{@N\,=\,0}$$

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Variable	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrEng`	Engine power	P_{eng}	$\omega_i T_i$
		`PwrDiffrntl`	Differential power	P_{diff}	$\omega_o T_o$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrEffLoss`	Mechanical power loss	$P_{effloss}$	$\omega_o T_o(\eta_N - 1)$
		`PwrDampLoss`	Mechanical damping loss	$P_{damploss}$	For G=0: $-\frac{b_N\omega_i^2}{\lvert N^2\rvert}$ For G ≠ 0: $-b_N\omega_i^2 - \frac{b_N\omega_{neutral}^2}{\lvert N^2\rvert}$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredTrans`	Rate change in rotational kinetic energy	P_{str}	For G=0: $\frac{J_N}{N^2}\dot{\omega}_i\omega_i$ For G ≠ 0: $J_F\dot{\omega}_i\omega_i + \frac{J_N}{N^2}\dot{\omega}_{neutral}\omega_{neutr}$

The equations use these variables.

b_N	Engaged gear viscous damping
J_N	Engaged gear rotational inertia
J_F	Flywheel rotational inertia
η_N	Engaged gear efficiency
G	Engaged gear number
G_{cmd}	Gear number to engage
N	Engaged gear ratio

T_i	Applied input torque, typically from the engine crankshaft or dual mass flywheel damper
T_o	Applied load torque, typically from the differential or drive shaft
ω_o	Initial input drive shaft rotational velocity
ω_i, $\acute{\omega}_i$	Applied drive shaft angular speed and acceleration
ω_{No}	Initial neutral gear input rotational velocity
$\omega_{neutral}$	Neutral gear drive shaft rotational velocity
τ_s	Shift time constant

Ports

Inputs

`Gear` — Gear number to engage

`scalar`

Integer value of gear number to engage, G_{cmd}.

`EngTrq` — Applied input torque

`scalar`

Applied input torque, T_i, typically from the engine crankshaft or dual mass flywheel damper, in N·m.

`DiffTrq` — Applied load torque

`scalar`

Applied load torque, T_o, typically from the differential, in N·m.

`Temp` — Oil temperature

`scalar`

Oil temperature, in K. To determine the efficiency, the block uses a 4D lookup table that is a function of:

- Gear
- Input torque
- Input speed
- Oil temperature

Dependencies

To enable this port, set **Efficiency factors** to `Gear, input torque, input speed, and temperature`.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal			Description	Variable	Units
`Eng`	`EngTrq`		Applied input torque, typically from the engine crankshaft or dual mass flywheel damper	T_i	N·m
	`EngSpd`		Applied drive shaft angular speed input	ω_i	rad/s
`Diff`	`DiffTrq`		Applied load torque, typically from the differential	T_o	N·m
	`DiffSpd`		Drive shaft angular speed output	ω_o	rad/s
`Trans`	`TransSpdRatio`		Input to output speed ratio at time t	$\Phi(t)$	N/A
	`TransEta`		Ratio of output power to input power	η_N	N/A
	`TransGearCmd`		Commanded gear	N_{cmd}	N/A
	`TransGear`		Engaged gear	N	N/A
`PwrInfo`	`PwrTrnsfrd`	`PwrEng`	Engine power	P_{eng}	W
		`PwrDiffrntl`	Differential power	P_{diff}	W
	`PwrNotTrnsfrd`	`PwrEffLoss`	Mechanical power loss	$P_{effloss}$	W
		`PwrDampLoss`	Mechanical damping loss	$P_{damploss}$	W
	`PwrStored`	`PwrStoredTrans`	Rate change in rotational kinetic energy	P_{str}	W

EngSpd — Angular speed

`scalar`

Applied drive shaft angular speed input, ω_i, in rad/s.

`DiffSpd` — Angular speed

`scalar`

Drive shaft angular speed output, ω_o, in rad/s.

Parameters

`Efficiency factors` — Specify efficiency calculation

`Gear only` (default) | `Gear, input torque, input speed, and temperature`

To specify the block efficiency calculation, for **Efficiency factors**, select either of these options.

Setting	Block Implementation
`Gear only`	Efficiency determined from a 1D lookup table that is a function of the gear.
`Gear, input torque, input speed, and temperature`	Efficiency determined from a 4D lookup table that is a function of: • Gear • Input torque • Input speed • Oil temperature

Dependencies

Setting Parameter To	Enables
`Gear only`	**Efficiency vector, eta**
`Gear, input torque, input speed, and temperature`	**Efficiency torque breakpoints, Trq_bpts** **Efficiency speed breakpoints, omega_bpts** **Efficiency temperature breakpoints, Temp_bpts** **Efficiency lookup table, eta_tbl**

`Gear property interpolation method` — Interpolation

`Nearest` (default) | `Linear` | `Flat` | `Cubic spline`

Method that the block uses to switch the gear ratio during gear shifting.

Transmission

`Gear number vector, G` — Specify number of transmission speeds

`[-1,0,1,2,3,4,5]` (default) | `vector`

Vector of integer gear commands used to specify the number of transmission speeds. Neutral gear is `0`. For example, you can set these parameter values.

To Specify	Set Gear number, G To
Four transmission speeds, including neutral	`[0,1,2,3,4]`
Three transmission speeds, including neutral and reverse	`[-1,0,1,2,3]`
Five transmission speeds, including neutral and reverse	`[-1,0,1,2,3,4,5]`

Vector dimensions for the **Gear number vector**, **Gear ratio vector**, **Inertia vector**, **Damping vector**, and **Efficiency vector** parameters must be equal.

`Efficiency torque breakpoints, Trq_bpts` — Breakpoints

`[25,50,75,100,150,200,250]` (default) | `vector`

Torque breakpoints for efficiency table.

Dependencies

To enable this parameter, set **Efficiency factors** to `Gear, input torque, input speed, and temperature`.

`Efficiency speed breakpoints, omega_bpts` — Breakpoints

`[52.4 78.5 105 131 157 183 209 262 314 419 524]` (default) | `vector`

Speed breakpoints for efficiency table.

Dependencies

To enable this parameter, set **Efficiency factors** to `Gear, input torque, input speed, and temperature`.

`Efficiency temperature breakpoints, Temp_bpts` — Breakpoints

`[313 358]` (default) | `vector`

Temperature breakpoints for efficiency table.

Dependencies

To enable this parameter, set **Efficiency factors** to `Gear, input torque, input speed, and temperature`.

`Gear ratio vector, N` — Ratio of input speed to output speed

`[-4.47,4.47,4.47,2.47,1.47,1,0.8]` (default) | `vector`

Vector of gear ratios (that is, input speed to output speed) with indices corresponding to the ratios specified in **Gear number, G**. For neutral, set the gear ratio to 1. For example, you can set these parameter values.

To Specify Gear Ratios For	Set Gear number, G To	Set Gear ratio, N To
Four transmission speeds, including neutral	`[0,1,2,3,4]`	`[1,4.47,2.47,1.47,1]`
Five transmission speeds, including neutral and reverse	`[-1,0,1,2,3,4,5]`	`[-4.47,1,4.47,2.47, 1.47,1,0.8]`

Vector dimensions for the **Gear number vector**, **Gear ratio vector**, **Inertia vector**, **Damping vector**, and **Efficiency vector** parameters must be equal.

`Inertia vector, Jout` — Gear rotational inertia

`[0.128 0.01 0.128 0.1 0.062 0.028 0.01]` (default) | `vector`

Vector of gear rotational inertias, J_N, with indices corresponding to the inertias specified in **Gear number, G**, in kg*m^2. For example, you can set these parameter values.

To Specify Inertia For	Set Gear number, G To	Set Inertia, J To
Four gears, including neutral	`[0,1,2,3,4]`	`[0.01,2.28,2.04, 0.32,0.028]`
Inertia for five gears, including reverse and neutral	`[-1,0,1,2,3,4,5]`	`[2.28,0.01,2.28, 2.04,0.32,0.028,0.01]`

Vector dimensions for the **Gear number vector**, **Gear ratio vector**, **Inertia vector**, **Damping vector**, and **Efficiency vector** parameters must be equal.

`Damping vector, bout` — Gear viscous damping coefficient

`[.003 .001 .003 .0025 .002 .001 .001]` (default) | `vector`

Vector of gear viscous damping coefficients, b_N, with indices corresponding to the coefficients specified in **Gear number, G**, in N·m·s/rad. For example, you can set these parameter values.

To Specify Damping For	Set Gear number, G To	Set Damping, b To
Four gears, including neutral	`[0,1,2,3,4]`	`[0.001,0.003, 0.0025,0.002,0.001]`
Five gears, including reverse and neutral	`[-1,0,1,2,3,4,5]`	`[0.003,0.001, 0.003,0.0025, 0.002,0.001,0.001]`

Vector dimensions for the **Gear number vector**, **Gear ratio vector**, **Inertia vector**, **Damping vector**, and **Efficiency vector** parameters must be equal.

`Efficiency vector, eta` — Gear efficiency

`[0.9,0.9,0.9,0.9,0.9,0.95,0.95]` (default) | `vector`

Vector of gear mechanical efficiency, η_N, with indices corresponding to the efficiencies specified in **Gear number, G**. For example, you can set these parameter values.

To Specify Efficiency For	Set Gear number, G To	Set Efficiency, eta To
Four gears, including neutral	`[0,1,2,3,4]`	`[0.9,0.9,0.9,0.9,0.95]`
Five gears, including reverse and neutral	`[-1,0,1,2,3,4,5]`	`[0.9,0.9,0.9, 0.9,0.9,0.95,0.95]`

Vector dimensions for the **Gear number vector**, **Gear ratio vector**, **Inertia vector**, **Damping vector**, and **Efficiency vector** parameters must be equal.

Dependencies

To enable this parameter, set **Efficiency factors** to `Gear only`.

`Efficiency lookup table, eta_tbl` — Gear efficiency

`array`

Table of gear mechanical efficiency, η_N as a function of gear, input torque, input speed, and temperature.

Dependencies

To enable this parameter, set **Efficiency factors** to `Gear, input torque, input speed, and temperature`.

`Initial gear number, G_o` — Gear
`0` (default) | `scalar`

Initial gear number, G_o, dimensionless.

`Initial output velocity, omega_o` — Output speed
`0` (default) | `scalar`

Transmission initial output rotational velocity, ω_o, in rad/s.

`Initial neutral input velocity, omegainN_o` — Neutral gear input speed
`0` (default) | `scalar`

Initial neutral gear input rotational velocity, ω_{No}, in rad/s.

`Shift time constant, tau_s` — Time
`.01` (default) | `scalar`

Shift time constant, τ_s, in s.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

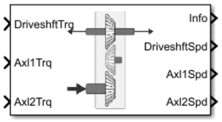
See Also

Limited Slip Differential | Open Differential

Transfer Case

Differential as a planetary bevel gear

Library: Powertrain Blockset / Drivetrain / Final Drive Unit
Vehicle Dynamics Blockset / Powertrain / Drivetrain / Final Drive Unit



Description

The Transfer Case block implements a differential as a planetary bevel gear train. The block matches the driveshaft bevel gear to the crown (ring) bevel gear. You can specify:

- Carrier-to-driveshaft ratio
- Crown wheel location
- Viscous and damping coefficients for the axles and carrier

Use the Transfer Case block to:

- Dynamically couple the post-transmission driveshaft to the wheel axles or universal joints
- Model simplified or older drivetrains when optimal traction control does not require passive or active torque vectoring
- Model mechanical power splitting in generic gearbox and drive line scenarios

The block is suitable for use in hardware-in-the-loop (HIL) and optimization workflows. All the parameters are tunable.

Efficiency

To account for the block efficiency, use the **Efficiency factors** parameter. This table summarizes the block implementation for each setting.

Setting	Implementation
`Constant`	Constant efficiency that you can set with the **Constant efficiency factor, eta** parameter.

Setting	**Implementation**
`Driveshaft torque, temperature and speed`	Efficiency as a function of base gear input torque, air temperature, and driveshaft speed. Use these parameters to specify the lookup table and breakpoints: • **Efficiency lookup table, eta_tbl** • **Efficiency torque breakpoints, Trq_bpts** • **Efficiency speed breakpoints, omega_bpts** • **Efficiency temperature breakpoints, Temp_bpts** For the air temperature, you can either: • Select **Input temperature** to create an input port. • Set a **Ambient temperature, Tamb** parameter value. To select the interpolation method, use the **Interpolation method** parameter. For more information, see "Interpolation Methods".

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			**Description**	**Equations**
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrDriveshft`	Mechanical power from driveshaft	$\eta T_d \omega_d$
		`PwrAxl1`	Mechanical power from axle 1	$\eta T_1 \omega_1$
		`PwrAxl2`	Mechanical power from axle 2	$\eta T_2 \omega_2$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrMechLoss`	Total power loss	$\dot{W}_{loss} = -(P_t + P_d) + P_s$ $P_t = \eta T_d \omega_d + \eta T_1 \omega_1 + \eta T_2 \omega_2$
		`PwrDampLoss`	Power loss due to damping	$P_d = -(b_1\|\omega_1\| + b_2\|\omega_2\| + b_d\|\omega_d\|)$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredShft`	Rate change of stored internal energy	$P_s = -(\omega_1 \dot{\omega}_1 J_1 + \omega_2 \dot{\omega}_2 J_2 + \omega_d \dot{\omega}_d J_d)$

Dynamics

The Transfer Case block implements these differential equations to represent the mechanical dynamic response for the crown gear, front axle, and rear axle.

Mechanical Dynamic Response	Differential Equation
Crown Gear	$\dot{\omega}_d J_d = \eta T_d - \omega_d b_d - T_i$
Front Axle	$\dot{\omega}_1 J_1 = \eta T_1 - \omega_1 b_1 - T_{i1}$
Rear Axle	$\dot{\omega}_2 J_2 = \eta T_2 - \omega_2 b_2 - T_{i2}$

The equations use these variables.

N	Carrier-to-driveshaft gear ratio
J_d	Rotational inertia of the crown gear assembly
b_d	Crown gear linear viscous damping
ω_d	Driveshaft angular speed
η	Differential efficiency
J_1	Axle 1 rotational inertia
b_1	Axle 1 linear viscous damping
ω_1	Axle 1 speed
J_2	Axle 2 rotational inertia
b_2	Axle 2 linear viscous damping
ω_2	Axle 2 angular speed
T_d	Driveshaft torque
T_1	Axle 1 torque
T_2	Axle 2 torque
T_i	Driveshaft internal resistance torque
T_{i1}	Axle 1 internal resistance torque
T_{i2}	Axle 2 internal resistance torque

Ports

Inputs

`DriveshftTrq` — Torque
`scalar`

Applied input torque, typically from the engine crankshaft, in N·m.

`Axl1Trq` — Torque
`scalar`

Axle 1 torque, T_1, in N·m.

`Axl2Trq` — Torque

`scalar`

Axle 2 torque, T_2, in N·m.

`Temp` — Temperature

`scalar`

Temperature, in K.

Dependencies

To enable this port:

- Set **Efficiency factors** to `Driveshaft torque, speed and temperature`.
- Select **Input temperature**.

`TrqSplitRatioConstant` — Front axle torque split ratio

`scalar`

Front axle torque split ratio.

Dependencies

To enable this port, select **Input front axle torque split ratio, TrqSplitRatio**.

`SpdLockConstant` — Axle speed lock

`scalar`

Axle speed lock.

Dependencies

To enable this port, select **Input axle speed lock, SpdLock**.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal			Description	Units
`Driveshft`	`DriveshftTrq`		Driveshaft torque	N·m
	`DriveshftSpd`		Driveshaft speed	rad/s
`Axl1`	`Axl1Trq`		Axle 1 torque	N·m
	`Axl1Spd`		Axle 1 speed	rad/s
`Axl2`	`Axl2Trq`		Axle 2 torque	N·m
	`Axl2Spd`		Axle 2 speed	rad/s
`PwrInfo`	`PwrTrnsfrd`	`PwrDriveshft`	Mechanical power from driveshaft	W

Signal			Description	Units
		`PwrAxl1`	Mechanical power from axle 1	W
		`PwrAxl2`	Mechanical power from axle 2	W
	`PwrTrnsfrd`	`PwrMechLoss`	Total power loss	W
		`PwrDampLoss`	Power loss due to damping	W
	`PwrStored`	`PwrStoredShft`	Rate change of stored internal energy	W

`DriveshftSpd` — Angular speed
`scalar`

Driveshaft angular speed, ω_d, in rad/s.

`Axl1Spd` — Angular speed
`scalar`

Axle 1 angular speed, ω_1, in rad/s.

`Axl2Spd` — Angular speed
`scalar`

Axle 2 angular speed, ω_2, in rad/s.

Parameters

Block Options

`Efficiency factors` — Specify configuration
`Constant` (default) | `Driveshaft torque, speed and temperature`

To account for the block efficiency, use the **Efficiency factors** parameter. This table summarizes the block implementation for each setting.

Setting	Implementation
`Constant`	Constant efficiency that you can set with the **Constant efficiency factor, eta** parameter.

Setting	Implementation
`Driveshaft torque, temperature and speed`	Efficiency as a function of base gear input torque, air temperature, and driveshaft speed. Use these parameters to specify the lookup table and breakpoints: • **Efficiency lookup table, eta_tbl** • **Efficiency torque breakpoints, Trq_bpts** • **Efficiency speed breakpoints, omega_bpts** • **Efficiency temperature breakpoints, Temp_bpts** For the air temperature, you can either: • Select **Input temperature** to create an input port. • Set a **Ambient temperature, Tamb** parameter value. To select the interpolation method, use the **Interpolation method** parameter. For more information, see “Interpolation Methods”.

`Interpolation method` — Method
`Flat` | `Nearest` | `Linear point-slope` | `Linear Lagrange` | `Cubic spline`

For more information, see “Interpolation Methods”.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Input temperature` — Create input port
`off` (default) | `on`

Select to create input port `Temp` for the temperature.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Input front axle torque split ratio, TrqSplitRatio` — Create input port
`off` (default) | `on`

Select to create input port `TrqSplitRatioConstant` for the front axle torque split ratio.

`Input axle speed lock, SpdLock` — Create input port
`off` (default) | `on`

Select to create input port `SpdLockConstant` for the axle speed lock.

`Crown wheel (ring gear) located` — Specify crown wheel connection
`To the left of center-line` (default) | `To the right of center-line`

Specify the crown wheel connection to the driveshaft.

`Carrier to drive shaft ratio, Ndiff` — Ratio
4 (default) | `scalar`

Carrier-to-driveshaft gear ratio, *N*, dimensionless.

`Carrier inertia, Jd` — Inertia
`.1` (default) | `scalar`

Rotational inertia of the crown gear assembly, J_d, in kg·m^2. You can include the driveshaft inertia.

`Carrier damping, bd` — Damping
`1e-3` (default) | `scalar`

Crown gear linear viscous damping, b_d, in N·m·s/rad.

`Axle 1 inertia, Jw1` — Inertia
`.1` (default) | `scalar`

Axle 1 rotational inertia, J_1, in kg·m^2.

`Axle 1 damping, bw1` — Damping
`1e-3` (default) | `scalar`

Axle 1 linear viscous damping, b_1, in N·m·s/rad.

`Axle 2 inertia, Jw2` — Inertia
`.1` (default) | `scalar`

Axle 2 rotational inertia, J_2, in kg·m^2.

`Axle 2 damping, bw2` — Damping
`1e-3` (default) | `scalar`

Axle 2 linear viscous damping, b_2, in N·m·s/rad.

`Axle 1 initial velocity, omegaw1o` — Angular velocity
`0` (default) | `scalar`

Axle 1 initial velocity, ω_{o1}, in rad/s.

`Axle 2 initial velocity, omegaw2o` — Angular velocity
`0` (default) | `scalar`

Axle 2 initial velocity, ω_{o2}, in rad/s.

Efficiency

`Constant efficiency factor, eta` — Efficiency
`1` (default) | `scalar`

Constant efficiency, η.

Dependencies

To enable this parameter, set **Efficiency factors** to `Constant`.

`Efficiency lookup table, eta_tbl` — Lookup table
`M`-by-`N`-by-`L` array

Dimensionless array of values for efficiency as a function of:

- `M` input torques
- `N` input speed
- `L` air temperatures

Each value specifies the efficiency for a specific combination of torque, speed, and temperature. The array size must match the dimensions defined by the torque, speed, and temperature breakpoint vectors.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency torque breakpoints, Trq_bpts` — Torque breakpoints

`[25, 50, 75, 100, 150, 200, 250]` (default) | 1-by-`M` vector

Vector of input torque, breakpoints for efficiency, in N·m.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency speed breakpoints, omega_bpts` — Speed breakpoints

`[52.4 78.5 105 131 157 183 209 262 314 419 524]` (default) | 1-by-`N` vector

Vector of speed, breakpoints for efficiency, in rad/s.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Efficiency temperature breakpoints, Temp_bpts` — Temperature breakpoints

`[290 358]` (default) | 1-by-`L` vector

Vector of ambient temperature breakpoints for efficiency, in K.

Dependencies

To enable this parameter, set **Efficiency factors** to `Driveshaft torque, speed and temperature`.

`Ambient temperature, Tamb` — Ambient temperature

`297.15` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter:

- Set **Efficiency factors** to `Driveshaft torque, speed and temperature`.
- Clear **Input temperature**.

`Front axle torque split ratio, TrqSplitRatio` — Front axle torque split ratio

`0.5` (default) | `scalar`

Front axle torque split ratio.

Dependencies

To enable this parameter, clear **Input front axle torque split ratio, TrqSplitRatio**.

`Axle speed lock, SpdLock` — Axle speed lock

`0` (default) | `scalar`

Axle speed lock. Set this value to 0 to make the front and rear axle rotational speed not fixed. Set this value to 1 to make the front and rear axle rotational speed fixed.

Dependencies

To enable this parameter, clear **Input axle speed lock, SpdLock**.

Version History

Introduced in R2021b

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

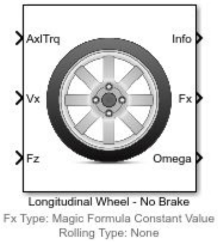
Limited Slip Differential

Wheel and Tire Blocks

Longitudinal Wheel

Longitudinal wheel with disc, drum, or mapped brake

Library:	Powertrain Blockset / Drivetrain / Wheels Vehicle Dynamics Blockset / Wheels and Tires



Description

The Longitudinal Wheel block implements the longitudinal behavior of an ideal wheel. You can specify the longitudinal force and rolling resistance calculation method, and brake type. Use the block in driveline and longitudinal vehicle simulations where low frequency tire-road and braking forces are required to determine vehicle acceleration, braking, and wheel-rolling resistance. For example, you can use the block to determine the torque and power requirements for a specified drive cycle or braking event. The block is not suitable for applications that require combined lateral slip.

There are four types of Longitudinal Wheel blocks. Each block implements a different brake type.

Block Name	Brake Type Setting	Brake Implementation
Longitudinal Wheel - No Brake	`None`	None
Longitudinal Wheel - Disc Brake	`Disc`	Brake that converts the brake cylinder pressure into a braking force.
Longitudinal Wheel - Drum Brake	`Drum`	Simplex drum brake that converts the applied force and brake geometry into a net braking torque.
Longitudinal Wheel - Mapped Brake	`Mapped`	Lookup table that is a function of the wheel speed and applied brake pressure.

The block models longitudinal force as a function of wheel slip relative to the road surface. To calculate the longitudinal force, specify one of these **Longitudinal Force** parameters.

Setting	Block Implementation
`Magic Formula constant value`	Magic Formula with constant coefficient for stiffness, shape, peak, and curvature.
`Magic Formula pure longitudinal slip`	Magic Formula with load-dependent coefficients that implement equations 4.E9 through 4.E18 in *Tire and Vehicle Dynamics*.
`Mapped force`	Lookup table that is a function of the normal force and wheel slip ratio.

To calculate the rolling resistance torque, specify one of these **Rolling Resistance** parameters.

Setting	Block Implementation
`None`	None
`Pressure and velocity`	Method in *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. The rolling resistance is a function of tire pressure, normal force, and velocity.
`ISO 28580`	Method specified in ISO 28580:2018, *Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results*.
`Magic Formula`	Magic formula equations from 4.E70 in *Tire and Vehicle Dynamics*. The magic formula is an empirical equation based on fitting coefficients.
`Mapped torque`	Lookup table that is a function of the normal force and spin axis longitudinal velocity.

To calculate vertical motion, specify one of these **Vertical Motion** parameters.

Setting	Block Implementation
`None`	Block passes the applied chassis forces directly through to the rolling resistance and longitudinal force calculations.
`Mapped stiffness and damping`	Vertical motion depends on wheel stiffness and damping. Stiffness is a function of tire sidewall displacement and pressure. Damping is a function of tire sidewall velocity and pressure.

Rotational Wheel Dynamics

The block calculates the inertial response of the wheel subject to:

- Axle losses
- Brake and drive torque
- Tire rolling resistance
- Ground contact through the tire-road interface

The input torque is the summation of the applied axle torque, braking torque, and moment arising from the combined tire torque.

$$T_i = T_a - T_b + T_d$$

For the moment arising from the combined tire torque, the block implements tractive wheel forces and rolling resistance with first order dynamics. The rolling resistance has a time constant parameterized in terms of a relaxation length.

$$T_d(s) = \frac{1}{\frac{L_e}{|\omega| R_e} s + 1}$$

To calculate the rolling resistance torque, you can specify one of these **Rolling Resistance** parameters.

Setting	Block Implementation
`None`	Block sets rolling resistance, M_y, to zero.
`Pressure and velocity`	Block uses the method in SAE *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. The rolling resistance is a function of tire pressure, normal force, and velocity. Specifically, $$M_y = R_e\left\{a + b\lvert V_x\rvert + cV_x2\right\}\left\{F_z\beta p_i\alpha\right\}\tanh(4V_x)$$
`ISO 28580`	Block uses the method specified in ISO 28580:2018, *Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results*. The method accounts for normal load, parasitic loss, and thermal corrections from test conditions. Specifically, $$M_y = R_e(\frac{F_zC_r}{1 + K_t(T_{amb} - T_{meas})} - F_{pl})\tanh(\omega)$$
`Magic Formula`	Block calculates the rolling resistance, M_y, using the Magic Formula equations from 4.E70 in *Tire and Vehicle Dynamics*. The magic formula is an empirical equation based on fitting coefficients.
`Mapped torque`	For the rolling resistance, M_y, the block uses a lookup table that is a function of the normal force and spin axis longitudinal velocity.

If the brakes are enabled, the block determines the braking locked or unlocked condition based on an idealized dry clutch friction model. Based on the lock-up condition, the block implements these friction and dynamic models.

If	Lock-Up Condition	Friction Model	Dynamic Model
$\omega \neq 0$ or $T_S < \lvert T_i + T_f - \omega b\rvert$	Unlocked	$T_f = T_k$ where, $T_k = F_cR_{eff}\mu_k\tanh[4(-\omega_d)]$ $T_s = F_cR_{eff}\mu_s$ $R_{eff} = \frac{2(R_o3 - R_i3)}{3(R_o2 - R_i2)}$	$\dot{\omega}J = -\omega b + T_i + T_o$
$\omega = 0$ and $T_S \geq \lvert T_i + T_f - \omega b\rvert$	Locked	$T_f = T_s$	$\omega = 0$

The equations use these variables.

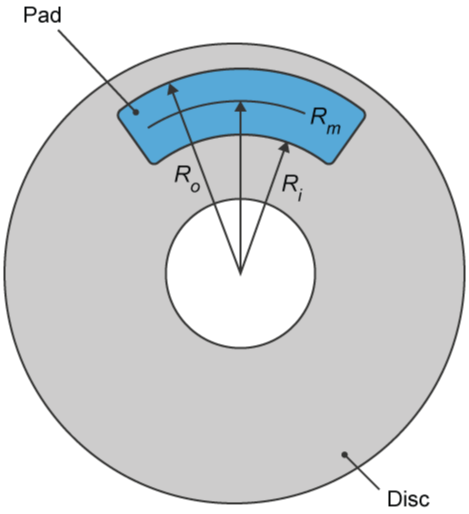
ω	Wheel angular velocity
a	Velocity-independent force component
b	Linear velocity force component
c	Quadratic velocity force component
L_e	Tire relaxation length
J	Moment of inertia

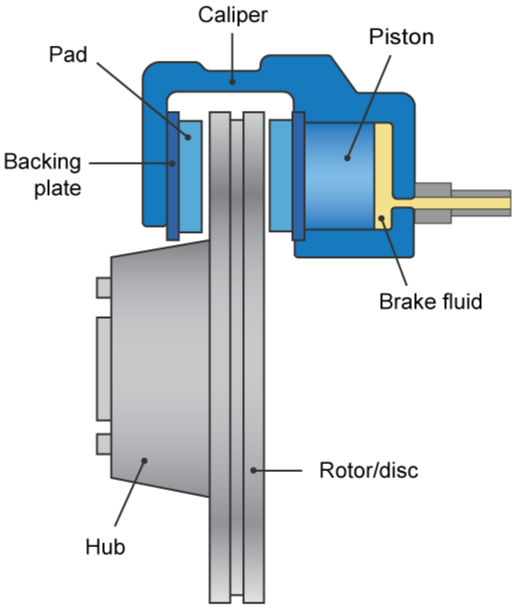
M_y	Rolling resistance torque
T_a	Applied axle torque
T_b	Braking torque
T_d	Combined tire torque
T_f	Frictional torque
T_i	Net input torque
T_k	Kinetic frictional torque
T_o	Net output torque
T_s	Static frictional torque
F_c	Applied clutch force
F_x	Longitudinal force developed by the tire road interface due to slip
R_{eff}	Effective clutch radius
R_o	Annular disk outer radius
R_i	Annular disk inner radius
R_e	Effective tire radius while under load and for a given pressure
V_x	Longitudinal axle velocity
F_z	Vehicle normal force
C_r	Rolling resistance constant
T_{amb}	Ambient temperature
T_{meas}	Measured temperature for rolling resistance constant
F_{pl}	Parasitic force loss
K_t	Thermal correction factor
α	Tire pressure exponent
β	Normal force exponent
p_i	Tire pressure
μ_s	Coefficient of static friction
μ_k	Coefficient of kinetic friction

Brakes

Disc

If you specify the **Brake Type** parameter `Disc`, the block implements a disc brake. This figure shows the side and front views of a disc brake.





A disc brake converts brake cylinder pressure from the brake cylinder into force. The disc brake applies the force at the brake pad mean radius.

The block uses these equations to calculate brake torque for the disc brake.

$$T = \begin{cases} \dfrac{\mu P \pi B_a{}^2 R_m N_{pads}}{4} & \text{when } N \neq 0 \\ \dfrac{\mu_{static} P \pi B_a{}^2 R_m N_{pads}}{4} & \text{when } N = 0 \end{cases}$$

$$Rm = \frac{Ro + Ri}{2}$$

The equations use these variables.

T	Brake torque
P	Applied brake pressure
N	Wheel speed
N_{pads}	Number of brake pads in disc brake assembly
μ_{static}	Disc pad-rotor coefficient of static friction
μ	Disc pad-rotor coefficient of kinetic friction
B_a	Brake actuator bore diameter
R_m	Mean radius of brake pad force application on brake rotor
R_o	Outer radius of brake pad

R_i	Inner radius of brake pad

Drum

If you specify the **Brake Type** parameter `Drum`, the block implements a static (steady-state) simplex drum brake. A simplex drum brake consists of a single two-sided hydraulic actuator and two brake shoes. The brake shoes do not share a common hinge pin.

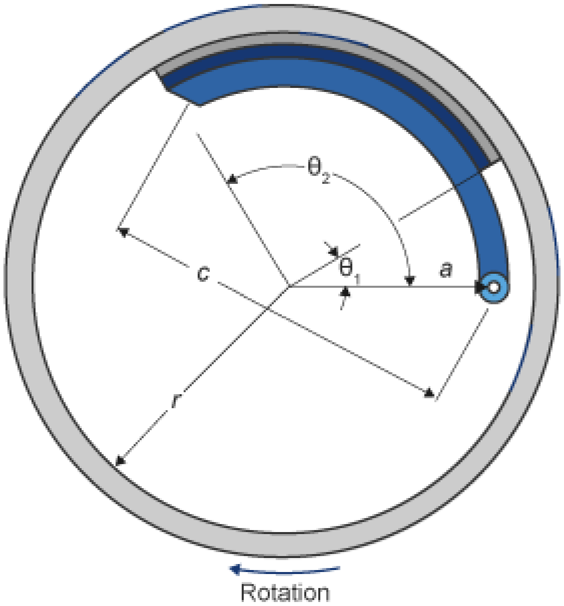
The simplex drum brake model uses the applied force and brake geometry to calculate a net torque for each brake shoe. The drum model assumes that the actuators and shoe geometry are symmetrical for both sides, allowing a single set of geometry and friction parameters to be used for both shoes.

The block implements equations that are derived from these equations in *Fundamentals of Machine Elements*.

$$T_{rshoe} = \left(\frac{\pi\mu c r(\cos\theta_2 - \cos\theta_1)B_a{}^2}{2\mu\left(2r\left(\cos\theta_2 - \cos\theta_1\right) + a\left(\cos^2\theta_2 - \cos^2\theta_1\right)\right) + ar(2\theta_1 - 2\theta_2 + \sin2\theta_2 - \sin2\theta_1)}\right)P$$

$$T_{lshoe} = \left(\frac{\pi\mu c r(\cos\theta_2 - \cos\theta_1)B_a{}^2}{-2\mu\left(2r\left(\cos\theta_2 - \cos\theta_1\right) + a\left(\cos^2\theta_2 - \cos^2\theta_1\right)\right) + ar(2\theta_1 - 2\theta_2 + \sin2\theta_2 - \sin2\theta_1)}\right)P$$

$$T = \begin{cases} T_{rshoe} + T_{lshoe} & \text{when } N \neq 0 \\ (T_{rshoe} + T_{lshoe})\dfrac{\mu_{static}}{\mu} & \text{when } N = 0 \end{cases}$$



The equations use these variables.

T	Brake torque
P	Applied brake pressure
N	Wheel speed

μ_{static}	Disc pad-rotor coefficient of static friction
μ	Disc pad-rotor coefficient of kinetic friction
T_{rshoe}	Right shoe brake torque
T_{lshoe}	Left shoe brake torque
a	Distance from drum center to shoe hinge pin center
c	Distance from shoe hinge pin center to brake actuator connection on brake shoe
r	Drum internal radius
B_a	Brake actuator bore diameter
Θ_1	Angle from shoe hinge pin center to start of brake pad material on shoe
Θ_2	Angle from shoe hinge pin center to end of brake pad material on shoe

Mapped

If you specify the **Brake Type** parameter `Mapped`, the block uses a lookup table to determine the brake torque.

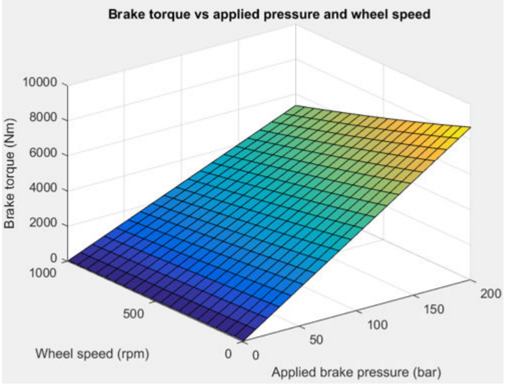
$$T = \begin{cases} f_{brake}(P, N) & \text{when } N \neq 0 \\ \left(\frac{\mu_{static}}{\mu}\right) f_{brake}(P, N) & \text{when } N = 0 \end{cases}$$

The equations use these variables.

T	Brake torque
$f_{brake}(P, N)$	Brake torque lookup table
P	Applied brake pressure
N	Wheel speed
μ_{static}	Friction coefficient of drum pad-face interface under static conditions
μ	Friction coefficient of disc pad-rotor interface

The lookup table for the brake torque, $f_{brake}(P, N)$, is a function of applied brake pressure and wheel speed, where:

- T is brake torque, in N·m.
- P is applied brake pressure, in bar.
- N is wheel speed, in rpm.



Longitudinal Force

To model the Longitudinal Wheel block longitudinal forces, you can use the Magic Formula. The model provides a steady-state *tire characteristic function* $F_x = f(\kappa, F_z)$, the longitudinal force F_x on the tire, based on:

- Vertical load F_z
- Wheel slip κ

The Magic Formula model uses these variables.

Ω	Wheel angular velocity
r_w	Wheel radius
V_x	Wheel hub longitudinal velocity
$r_w\Omega$	Tire tread longitudinal velocity
$V_{sx} = r_w\Omega - V_x$	Wheel slip velocity
$\kappa = V_{sx}/\lvert V_x\rvert$	Wheel slip
F_z, F_{z0}	Vertical load and nominal vertical load on tire
$F_x = f(\kappa, F_z)$	Longitudinal force exerted on the tire at the contact point. Also a characteristic function f of the tire.

Magic Formula Constant Value

If you set **Longitudinal Force** to `Magic Formula constant value`, the block implements the Magic Formula as a specific form of the tire characteristic function, characterized by four dimensionless coefficients (B, C, D, E), or stiffness, shape, peak, and curvature:

$$F_x = f(\kappa, F_z) = F_z D \sin\Big(C \tan^{-1}[\ \{B\kappa - E[B\kappa - \tan^{-1}(B\kappa)\ \Big]\Big\}\ ]\ )$$

The slope of f at $\kappa = 0$ is $BCD \cdot F_z$.

The coefficients are based on empirical tire data. These values are typical sets of constant Magic Formula coefficients for common road conditions.

Surface	B	C	D	E
Dry tarmac	10	1.9	1	0.97
Wet tarmac	12	2.3	0.82	1
Snow	5	2	0.3	1
Ice	4	2	0.1	1

Magic Formula Pure Longitudinal Slip

If you set **Longitudinal Force** to `Magic Formula pure longitudinal slip`, the block implements a more general Magic Formula using dimensionless coefficients that are functions of the tire load. The block implements the longitudinal force equations in Chapter 4 of *Tire and Vehicle Dynamics*, including 4.E9 through 4.E18:

$$F_{x0} = D_x \sin\Big(C_x \tan^{-1}[\ \{B_x\kappa_x - E_x[B_x\kappa_x - \tan^{-1}(B_x\kappa_x)\Big]\Big\}\ ]\ )\ + S_{Vx}$$

where:

$$\kappa_x = \kappa + S_{Hx}$$

$$C_x = p_{Cx1}\lambda_{Cx}$$

$$D_x = \mu_x F_z \varsigma_1$$

$$\mu_x = (p_{Dx1} + p_{Dx2}df_z)(1 + p_{px3}dp_i + p_{px4}dp_i^2)(1 - p_{Dx3}\gamma^2)\lambda^*_{\mu x}$$

$$E_x = (p_{Ex1} + p_{Ex2}df_z + p_{Ex3}df_z^2)[1 - p_{Ex4}\mathrm{sgn}(\kappa_x)]\ \lambda_{Ex}$$

$$K_{x\kappa} = F_z(p_{Kx1} + p_{Kx2}df_z)\exp(\mathrm{p}_{\mathrm{Kx3}}df_z)(1 + p_{px1}dp_i + p_{px2}dp_i^2)$$

$$B_x = K_{x\kappa}/(C_x D_x + \varepsilon_x)$$

$$S_{Hx} = p_{Hx1} + p_{Hx2}df_z$$

$$S_{Vx} = F_z \cdot (p_{Vx1} + p_{Vx2}df_z)\lambda_{Vx}\lambda'_{\mu x}\varsigma_1$$

S_{Hx} and S_{Vx} represent offsets to the slip and longitudinal force in the force-slip function, or horizontal and vertical offsets if the function is plotted as a curve. μ_x is the longitudinal load-dependent friction coefficient. ε_x is a small number inserted to prevent division by zero as F_z approaches zero.

Vertical Dynamics

If you select no vertical degrees-of-freedom by setting **Vertical Motion** to `None`, the block passes the applied chassis forces directly through to the rolling resistance and longitudinal force calculations.

If you set **Vertical Motion** to `Mapped stiffness and damping`, the vertical motion depends on wheel stiffness and damping. Stiffness is a function of tire sidewall displacement and pressure. Damping is a function of tire sidewall velocity and pressure.

$$Fztire(z, \dot{z}, P_{tire}) = F_{zk}(z, P_{tire}) + F_{zb}(\dot{z}, P_{tire})$$

The block determines the vertical response using this differential equation.

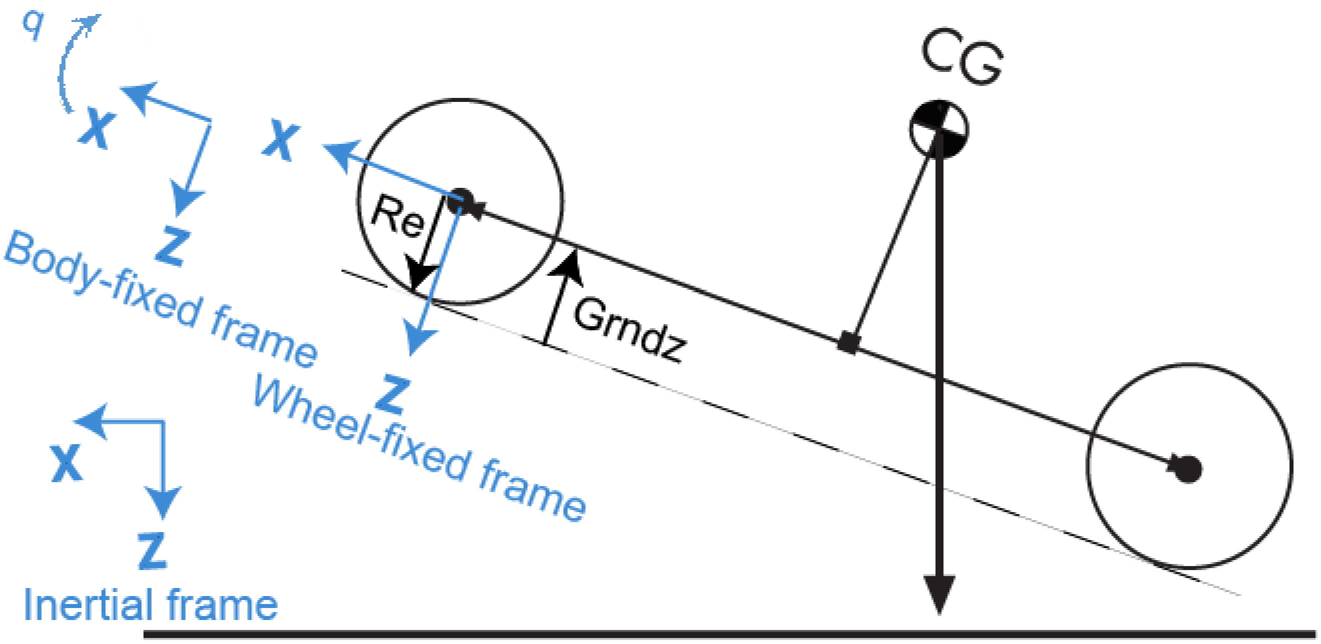
$$\ddot{z}m = Fztire - F_z - mg$$

When you disable the vertical degree-of-freedom, the input normal force from the vehicle passes directly to the longitudinal and rolling force calculations.

$$\ddot{z} = \dot{z} = m = 0$$

$$Fztire = mg$$

The block uses the wheel-fixed frame to resolve the vertical forces.



The equations use these variables.

$Fztire$	Tire normal force along the wheel-fixed z-axis
m	Axle mass
F_{zk}	Tire normal force due to wheel stiffness along the wheel-fixed z-axis
F_{zb}	Tire normal force due to wheel damping along the wheel-fixed z-axis
F_z	Suspension or vehicle normal force along the wheel-fixed z-axis
P_{Tire}	Tire pressure
$z, \dot{z}, \ddot{z}$	Tire displacement, velocity, and acceleration, respectively, along the wheel-fixed z-axis

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks	`PwrRoad`	Tractive power applied from the axle	$P_{road} = F_x V_x$
		`PwrAxlTrq`	External torque applied by the axle to the wheel	$P_T = T\omega$

Bus Signal			**Description**	**Equations**
	• Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrFz`	Vertical force applied to the wheel by the vehicle or suspension	$P_{Fz} = F_z\dot{z}$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrSlip`	Tractive power loss	$P_{\kappa} = F_xV_x + (-F_{cp}R_e + M_y)\omega$
		`PwrMyRoll`	Rolling resistance power	$P_{My} = M_y\omega$
		`PwrMyBrk`	Braking power	$P_{brk} = M_{brk}\omega$
		`PwrMyb`	Rolling viscous damping loss	$P_b = -b\omega^2$
		`PwrFzDamp`	Vertical damping power	$P_{Fzb} = \quad F_{zb}\dot{z}$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredzdot`	Rate of change of vertical kinetic energy	$P_{\dot{z}} = m\ddot{z}\dot{z}$
		`PwrStoredq`	Rate of change of rotational kinetic energy	$P_{\omega} = I_{yy}\dot{\omega}\omega$
		`PwrStoredFsFzSprng`	Rate of change of stored sidewall potential energy	$P_{Fzk} = F_{zk}\dot{z}_x$
		`PwrStoredGrvty`	Rate of change of gravitational potential energy	$P_g = -mg\dot{Z}$

The equations use these variables.

ω	Wheel angular velocity
b	Linear velocity force component
F_x	Longitudinal force developed by the tire road interface due to slip
F_{cp}	Tire slip force at contact patch
F_z	Vehicle normal force
F_{zb}	Tire normal force due to wheel damping
F_{zk}	Tire normal force due to wheel stiffness
I_{yy}	Wheel rotational inertia
M_{brk}	Braking moment
M_y	Rolling resistance torque
R_e	Effective tire radius while under load and for a given pressure
T	Axle torque applied on wheel
V_x	Longitudinal axle velocity

$z, \dot{z}, \ddot{z}$	Tire displacement, velocity, and acceleration, respectively
ω	Wheel angular velocity
$\dot{Z}$	Vehicle vertical velocity along the vehicle-fixed z-axis

Ports

Input

`BrkPrs` — Brake pressure
`scalar`

Brake pressure, in Pa.

Dependencies

To enable this port, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

`AxlTrq` — Axle torque
`scalar`

Axle torque, T_a, about wheel spin axis, in N·m.

`Vx` — Velocity
`scalar`

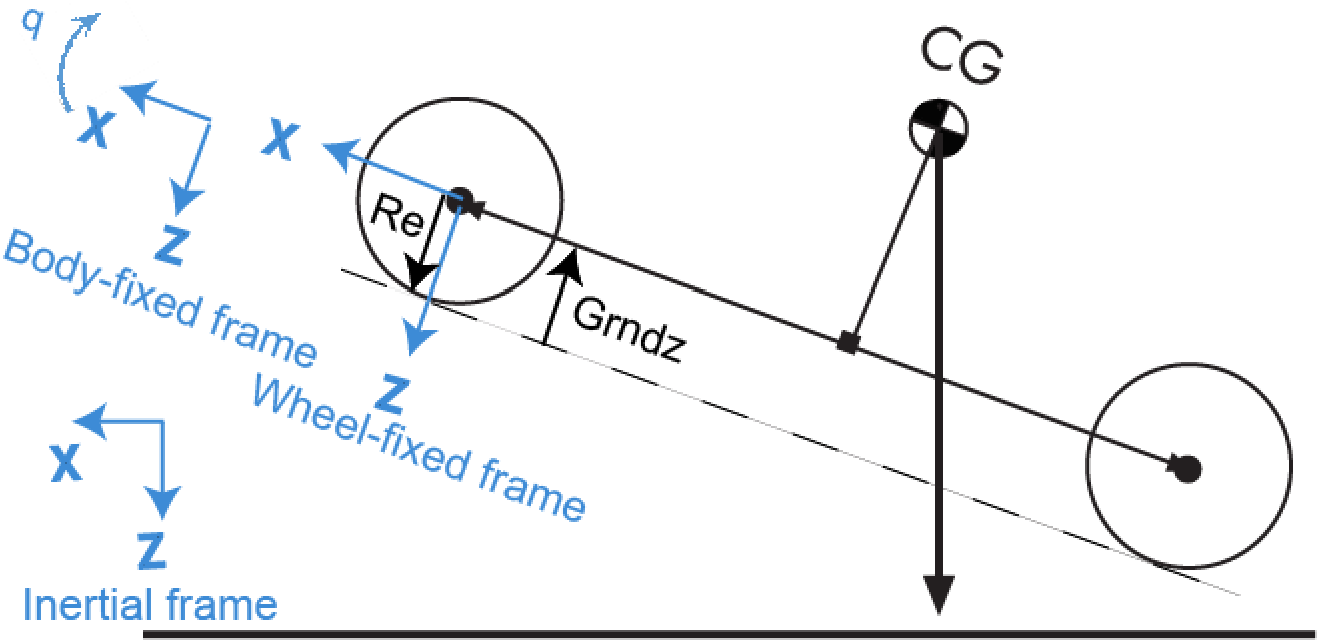
Axle longitudinal velocity along vehicle(body)-fixed x-axis, in m/s.

`Fz` — Normal force
`scalar`

Absolute value of suspension or vehicle normal force along body-fixed z-axis, in N.

`Gnd` — Ground displacement
`scalar`

Ground displacement, `Grndz`, along negative wheel-fixed z-axis, in m.



Dependencies

To create `Gnd`:

- Set **Vertical Motion** to `Mapped stiffness and damping`.
- On the **Vertical** pane, select **Input ground displacement**.

`lam_mux` — Friction scaling factor

`scalar`

Longitudinal friction scaling factor, dimensionless.

Dependencies

To enable this port, select **Input friction scale factor**.

`TirePrs` — Tire pressure

`scalar`

Tire pressure, in Pa.

Dependencies

To enable this port:

- Set one of these parameters:
  - **Longitudinal Force** to `Magic Formula pure longitudinal slip`.
  - **Rolling Resistance** to `Pressure and velocity` or `Magic Formula`.
  - **Vertical Motion** to `Mapped stiffness and damping`.

- On the **Wheel Dynamics** pane, select **Input tire pressure**.

`Tamb` — Ambient temperature

`scalar`

Ambient temperature, T_{amb}, in K.

The ambient temperature, T_{amb}, is the temperature near tire in application environment, in K. For example, the measured ambient temperature is the ambient temperature near the tire when the vehicle is on the road.

Select to create input port `Tamb` to input the measured ambient temperature.

Dependencies

To enable this port:

1. Set **Rolling Resistance** to `ISO 28580`.
2. On the **Rolling Resistance** pane, select to **Input ambient temperature**.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal	Description	Units
`AxlTrq`	Axle torque about body-fixed *y*-axis	N·m
`Omega`	Wheel angular velocity about body-fixed *y*-axis	rad/s
`Omegadot`	Wheel angular acceleration about body-fixed *y*-axis	rad/s^2
`Fx`	Longitudinal vehicle force along body-fixed *x*-axis	N
`Fz`	Vertical vehicle force along body-fixed *z*-axis	N
`Fzb`	Tire normal force due to wheel damping along the wheel-fixed *z*-axis	N
`Fzk`	Tire normal force due to wheel stiffness along the wheel-fixed *z*-axis	N
`My`	Rolling resistance torque about body-fixed *y*-axis	N·m
`Myb`	Rolling resistance torque due to damping about body-fixed *y*-axis	N·m
`Kappa`	Slip ratio	NA

Signal			Description	Units
`Vx`			Vehicle longitudinal velocity along body-fixed *x*-axis	m/s
`Re`			Wheel effective radius along wheel-fixed *z*-axis	m
`BrkTrq`			Brake torque about body-fixed *y*-axis	N·m
`BrkPrs`			Brake pressure	Pa
`z`			Wheel vertical deflection along wheel-fixed *z*-axis	m
`zdot`			Wheel vertical velocity along wheel-fixed *z*-axis	m/s
`zddot`			Wheel vertical acceleration along wheel-fixed *z*-axis	m/s^2
`Gndz`			Ground displacement along negative of wheel-fixed *z*-axis (positive input produces wheel lift)	m
`GndFz`			Vertical wheel force on ground along negative of wheel-fixed *z*-axis	N
`TirePrs`			Tire pressure	Pa
`Fpatch`			Tractive power applied from the axle	
`PwrInfo`	`PwrTrnsfrd`	`PwrRoad`	External torque applied by the axle to the wheel	W
		`PwrAxlTrq`	Vertical force applied to the wheel by the vehicle or suspension	W
		`PwrFz`	Tractive power loss	W
	`PwrNotTrnsfrd`	`PwrSlip`	Rolling resistance power	W
		`PwrMyRoll`	Braking power	W
		`PwrMyBrk`	Rolling viscous damping loss	W
		`PwrMyb`	Vertical damping power	W
		`PwrFzDamp`	Rate of change of vertical kinetic energy	W
	`PwrStored`	`PwrStoredzdot`	Rate of change of rotational kinetic energy	W
		`PwrStoredq`	Rate of change of stored sidewall potential energy	W
		`PwrStoredFsFzSprng`	Rate of change of gravitational potential energy	W

Signal			Description	Units
		`PwrStoredGrvty`	Tractive power applied from the axle	W

`Fx` — Longitudinal axle force
`scalar`

Longitudinal force acting on axle, along body-fixed *x*-axis, in N. Positive force acts to move the vehicle forward.

`Omega` — Wheel angular velocity
`scalar`

Wheel angular velocity, about body-fixed *y*-axis, in rad/s.

`z` — Wheel vertical deflection
`scalar`

Wheel vertical deflection along wheel-fixed *z*-axis, in m.

Dependencies

To enable this port, set **Vertical Motion** to `Mapped stiffness and damping`.

`zdot` — Wheel vertical velocity
`scalar`

Wheel vertical velocity along wheel-fixed *z*-axis, in m/s.

Dependencies

To enable this port, set **Vertical Motion** to `Mapped stiffness and damping`.

Parameters

Block Options

`Longitudinal Force` — Select type
`Magic Formula constant value` (default) | `Magic Formula pure longitudinal slip` | `Mapped force`

The block models longitudinal force as a function of wheel slip relative to the road surface. To calculate the longitudinal force, specify one of these **Longitudinal Force** parameters.

Setting	Block Implementation
`Magic Formula constant value`	Magic Formula with constant coefficient for stiffness, shape, peak, and curvature.
`Magic Formula pure longitudinal slip`	Magic Formula with load-dependent coefficients that implement equations 4.E9 through 4.E18 in *Tire and Vehicle Dynamics*.
`Mapped force`	Lookup table that is a function of the normal force and wheel slip ratio.

Dependencies

Selecting	Enables These Parameters
`Magic Formula constant value`	**Pure longitudinal peak factor, Dx** **Pure longitudinal shape factor, Cx** **Pure longitudinal stiffness factor, Bx** **Pure longitudinal curvature factor, Ex**

Selecting	Enables These Parameters
`Magic Formula pure longitudinal slip`	**Cfx shape factor, PCX1** **Longitudinal friction at nominal normal load, PDX1** **Frictional variation with load, PDX2** **Frictional variation with camber, PDX3** **Longitudinal curvature at nominal normal load, PEX1** **Variation of curvature factor with load, PEX2** **Variation of curvature factor with square of load, PEX3** **Longitudinal curvature factor with slip, PEX4** **Longitudinal slip stiffness at nominal normal load, PKX1** **Variation of slip stiffness with load, PKX2** **Slip stiffness exponent factor, PKX3** **Horizontal shift in slip ratio at nominal normal load, PHX1** **Variation of horizontal slip ratio with load, PHX2** **Vertical shift in load at nominal normal load, PVX1** **Variation of vertical shift with load, PVX2** **Linear variation of longitudinal slip stiffness with tire pressure, PPX1** **Quadratic variation of longitudinal slip stiffness with tire pressure, PPX2** **Linear variation of peak longitudinal friction with tire pressure, PPX3** **Quadratic variation of peak longitudinal friction with tire pressure, PPX4** **Linear variation of longitudinal slip stiffness with tire pressure, PPX1** **Slip speed decay function scaling factor, lam_muV** **Brake slip stiffness scaling factor, lam_Kxkappa** **Longitudinal shape scaling factor, lam_Cx** **Longitudinal curvature scaling factor, lam_Ex**

Selecting	Enables These Parameters
	Longitudinal horizontal shift scaling factor, lam_Hx **Longitudinal vertical shift scaling factor, lam_Vx**
`Mapped force`	**Slip ratio breakpoints, kappaFx** **Normal force breakpoints, FzFx** **Longitudinal force map, FxMap**

`Rolling Resistance` — Select type

`None` (default) | `Pressure and velocity` | `ISO 28580` | `Magic Formula` | `Mapped torque`

To calculate the rolling resistance torque, specify one of these **Rolling Resistance** parameters.

Setting	Block Implementation
`None`	None
`Pressure and velocity`	Method in *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. The rolling resistance is a function of tire pressure, normal force, and velocity.
`ISO 28580`	Method specified in ISO 28580:2018, *Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results*.
`Magic Formula`	Magic formula equations from 4.E70 in *Tire and Vehicle Dynamics*. The magic formula is an empirical equation based on fitting coefficients.
`Mapped torque`	Lookup table that is a function of the normal force and spin axis longitudinal velocity.

Dependencies

Selecting	Parameters
`Pressure and velocity`	**Velocity independent force coefficient, aMy** **Linear velocity force component, bMy** **Quadratic velocity force component, cMy** **Tire pressure exponent, alphaMy** **Normal force exponent, betaMy**

Selecting	Parameters
`ISO 28580`	**Parasitic losses force, Fpl** **Rolling resistance constant, Cr** **Thermal correction factor, Kt** **Measured temperature, Tmeas** **Parasitic losses force, Fpl** **Ambient temperature, Tamb**
`Magic Formula`	**Rolling resistance torque coefficient, QSY** **Longitudinal force rolling resistance coefficient, QSY2** **Linear rotational speed rolling resistance coefficient, QSY3** **Quartic rotational speed rolling resistance coefficient, QSY4** **Camber squared rolling resistance torque, QSY5** **Load based camber squared rolling resistance torque, QSY6** **Normal load rolling resistance coefficient, QSY7** **Pressure load rolling resistance coefficient, QSY8** **Rolling resistance scaling factor, lam_My**
`Mapped torque`	**Spin axis velocity breakpoints, VxMy** **Normal force breakpoints, FzMy** **Rolling resistance torque map, MyMap**

Brake Type — Select type
`None` | `Disc` | `Drum` | `Mapped`

There are four types of Longitudinal Wheel blocks. Each block implements a different brake type.

Block Name	Brake Type Setting	Brake Implementation
Longitudinal Wheel - No Brake	`None`	None
Longitudinal Wheel - Disc Brake	`Disc`	Brake that converts the brake cylinder pressure into a braking force.
Longitudinal Wheel - Drum Brake	`Drum`	Simplex drum brake that converts the applied force and brake geometry into a net braking torque.

Block Name	Brake Type Setting	Brake Implementation
Longitudinal Wheel - Mapped Brake	`Mapped`	Lookup table that is a function of the wheel speed and applied brake pressure.

`Vertical Motion` — Select type

`None` (default) | `Mapped stiffness and damping`

To calculate vertical motion, specify one of these **Vertical Motion** parameters.

Setting	Block Implementation
`None`	Block passes the applied chassis forces directly through to the rolling resistance and longitudinal force calculations.
`Mapped stiffness and damping`	Vertical motion depends on wheel stiffness and damping. Stiffness is a function of tire sidewall displacement and pressure. Damping is a function of tire sidewall velocity and pressure.

Selecting	Enables These Parameters	Creates These Output Ports
`Mapped stiffness and damping`	**Wheel and unsprung mass, m** **Initial deflection, zo** **Initial velocity, zdoto** **Gravitational acceleration, g** **Vertical deflection breakpoints, zFz** **Pressure breakpoints, pFz** **Force due to deflection, Fzz** **Vertical velocity breakpoints, zdotFz** **Force due to velocity, Fzzdot** **Ground displacement, Gndz** **Input ground displacement**	`z` `zdot`

`Longitudinal scaling factor, lam_x` — Friction scaling factor

`1` (default)

Longitudinal friction scaling factor, dimensionless.

Dependencies

To enable this parameter, clear **Input friction scale factor**.

`Input friction scale factor` — Selection

`Off` (default)

Create input port for longitudinal friction scaling factor.

Dependencies

Selecting this parameter:

- Creates input port `lam_mux`.
- Disables parameter **Longitudinal scaling factor, lam_x**.

Wheel Dynamics

`Axle viscous damping coefficient, br` — Damping

`0.001` (default) | `scalar`

Axle viscous damping coefficient, *br*, in N·m·s/rad.

`Wheel inertia, Iyy` — Inertia

`0.8` (default) | `scalar`

Wheel inertia, in kg·m^2.

`Wheel initial angular velocity, omegao` — Wheel speed

`0` (default) | `scalar`

Initial angular velocity of wheel, along body-fixed *y*-axis, in rad/s.

`Relaxation length, Lrel` — Relaxation length

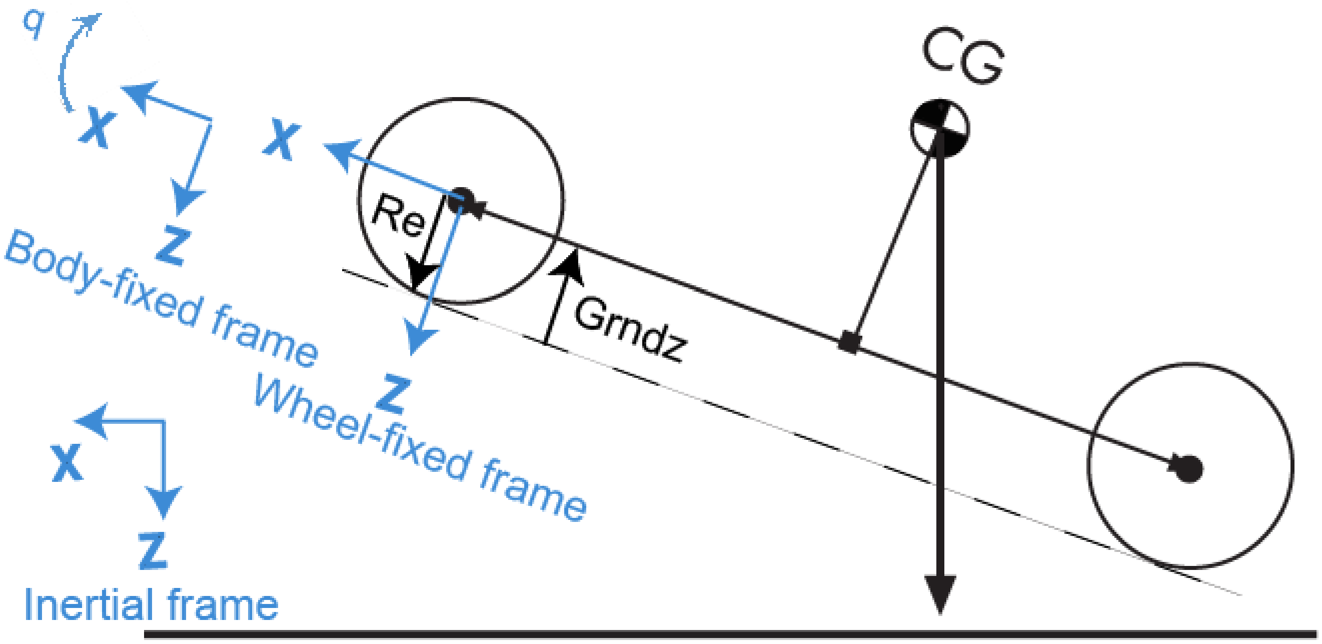
`0.5` (default) | `scalar`

Wheel relaxation length, in m.

`Loaded radius, Re` — Loaded radius

`0.3` (default) | `scalar`

Loaded wheel radius, Re, in m.



`Unloaded radius, UNLOADED_RADIUS` — Unloaded radius
`0.4` (default) | `scalar`

Unloaded wheel radius, in m.

Dependencies

To create this parameter, set **Rolling Resistance** to `Pressure and velocity` or `Magic Formula`.

`Nominal longitudinal speed, LONGVL` — Speed
`16` (default) | `scalar`

Nominal longitudinal speed along body-fixed *x*-axis, in m/s.

Dependencies

To enable this parameter, set **Longitudinal Force** to `Magic Formula pure longitudinal slip`.

`Nominal camber angle, gamma` — Camber
`0` (default) | `scalar`

Nominal camber angle, in rad.

Dependencies

To enable this parameter, set either:

- **Longitudinal Force** to `Magic Formula pure longitudinal slip`.
- **Rolling Resistance** to `Magic Formula`.

`Nominal pressure, NOMPRES` — Pressure
`220000` (default) | `scalar`

Nominal pressure, in Pa.

Dependencies

To enable this parameter, set either:

- **Longitudinal Force** to `Magic Formula pure longitudinal slip`.
- **Rolling Resistance** to `Magic Formula`.

`Pressure, press` — Pressure
`220000` (default) | `scalar`

Pressure, in Pa.

Dependencies

To enable this parameter:

- Set one of these:
  - **Longitudinal Force** to `Magic Formula pure longitudinal slip`.
  - **Rolling Resistance** to `Pressure and velocity` or `Magic Formula`.
  - **Vertical Motion** to `Mapped stiffness and damping`.
- On the **Wheel Dynamics** pane, clear **Input tire pressure**.

Longitudinal

Magic Formula Constant Value

`Pure longitudinal peak factor, Dx` — Factor
`1` (default) | `scalar`

Pure longitudinal peak factor, dimensionless.

The coefficients are based on empirical tire data. These values are typical sets of constant Magic Formula coefficients for common road conditions.

Surface	B	C	D	E
Dry tarmac	10	1.9	1	0.97
Wet tarmac	12	2.3	0.82	1
Snow	5	2	0.3	1
Ice	4	2	0.1	1

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula constant value`.

`Pure longitudinal shape factor, Cx` — Factor
`1.65` (default) | `scalar`

Pure longitudinal shape factor, dimensionless.

The coefficients are based on empirical tire data. These values are typical sets of constant Magic Formula coefficients for common road conditions.

Surface	B	C	D	E
Dry tarmac	10	1.9	1	0.97
Wet tarmac	12	2.3	0.82	1
Snow	5	2	0.3	1
Ice	4	2	0.1	1

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula constant value`.

`Pure longitudinal stiffness factor, Bx` — Factor

`10` (default) | `scalar`

Pure longitudinal stiffness factor, dimensionless.

The coefficients are based on empirical tire data. These values are typical sets of constant Magic Formula coefficients for common road conditions.

Surface	B	C	D	E
Dry tarmac	10	1.9	1	0.97
Wet tarmac	12	2.3	0.82	1
Snow	5	2	0.3	1
Ice	4	2	0.1	1

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula constant value`.

`Pure longitudinal curvature factor, Ex` — Factor

`0.01` (default) | `scalar`

Pure longitudinal curvature factor, dimensionless.

The coefficients are based on empirical tire data. These values are typical sets of constant Magic Formula coefficients for common road conditions.

Surface	B	C	D	E
Dry tarmac	10	1.9	1	0.97
Wet tarmac	12	2.3	0.82	1
Snow	5	2	0.3	1
Ice	4	2	0.1	1

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula constant value`.

Magic Formula Pure Longitudinal Slip

`Cfx shape factor, PCX1` — Factor
`1.6` (default) | `scalar`

Cfx shape factor, PCX1, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Longitudinal friction at nominal normal load, PDX1` — Factor
`1` (default) | `scalar`

Longitudinal friction at nominal normal load, PDX1, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Frictional variation with load, PDX2` — Factor
`-0.08` (default) | `scalar`

Frictional variation with load, PDX2, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Frictional variation with camber, PDX3` — Factor
`0` (default) | `scalar`

Frictional variation with camber, PDX3, 1/rad^2.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Longitudinal curvature at nominal normal load, PEX1` — Factor
`0.112` (default) | `scalar`

Longitudinal curvature at nominal normal load, PEX1, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Variation of curvature factor with load, PEX2` — Factor

`0.313` (default) | `scalar`

Variation of curvature factor with load, PEX2, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Variation of curvature factor with square of load, PEX3` — Factor

`0` (default) | `scalar`

Variation of curvature factor with square of load, PEX3, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Longitudinal curvature factor with slip, PEX4` — Factor

`0.0016` (default) | `scalar`

Longitudinal curvature factor with slip, PEX4, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Longitudinal slip stiffness at nominal normal load, PKX1` — Factor

`21.7` (default) | `scalar`

Longitudinal slip stiffness at nominal normal load, PKX1, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Variation of slip stiffness with load, PKX2` — Factor

`13.77` (default) | `scalar`

Variation of slip stiffness with load, PKX2, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Slip stiffness exponent factor, PKX3` — Factor

`-0.412` (default) | `scalar`

Slip stiffness exponent factor, PKX3, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Horizontal shift in slip ratio at nominal normal load, PHX1` — Factor

`2.1585E-4` (default) | `scalar`

Horizontal shift in slip ratio at nominal normal load, PHX1, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Variation of horizontal slip ratio with load, PHX2` — Factor

`0.00115` (default) | `scalar`

Variation of horizontal slip ratio with load, PHX2, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Vertical shift in load at nominal normal load, PVX1` — Factor

`1.5973E-5` (default) | `scalar`

Vertical shift in load at nominal normal load, PVX1, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Variation of vertical shift with load, PVX2` — Factor

`1.043E-4` (default) | `scalar`

Variation of vertical shift with load, PVX2, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Linear variation of longitudinal slip stiffness with tire pressure, PPX1` — Factor

`-0.3489` (default) | `scalar`

Linear variation of longitudinal slip stiffness with tire pressure, PPX1, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Quadratic variation of longitudinal slip stiffness with tire pressure, PPX2` — Factor

`0.382` (default) | `scalar`

Quadratic variation of longitudinal slip stiffness with tire pressure, PPX2, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

Linear variation of peak longitudinal friction with tire pressure, PPX3 — Factor

`-0.09634` (default) | `scalar`

Linear variation of peak longitudinal friction with tire pressure, PPX3, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

Quadratic variation of peak longitudinal friction with tire pressure, PPX4 — Factor

`0.06447` (default) | `scalar`

Quadratic variation of peak longitudinal friction with tire pressure, PPX4, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

Slip speed decay function scaling factor, lam_muV — Factor

`1` (default) | `scalar`

Slip speed decay function scaling factor, lam_muV, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

Brake slip stiffness scaling factor, lam_Kxkappa — Factor

`1` (default) | `scalar`

Brake slip stiffness scaling factor, lam_Kxkappa, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

Longitudinal shape scaling factor, lam_Cx — Factor

`1` (default) | `scalar`

Longitudinal shape scaling factor, lam_Cx, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Longitudinal curvature scaling factor, lam_Ex` — Factor

`0` (default) | `scalar`

Longitudinal curvature scaling factor, lam_Ex, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Longitudinal horizontal shift scaling factor, lam_Hx` — Factor

`1` (default) | `scalar`

Longitudinal horizontal shift scaling factor, lam_Hx, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

`Longitudinal vertical shift scaling factor, lam_Vx` — Factor

`1` (default) | `scalar`

Longitudinal vertical shift scaling factor, lam_Vx, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Magic Formula pure longitudinal slip`.

Mapped Force

`Slip ratio breakpoints, kappaFx` — Breakpoints

`vector`

Slip ratio breakpoints, dimensionless.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Mapped force`.

`Normal force breakpoints, FzFx` — Breakpoints

`vector`

Normal force breakpoints, N.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Mapped force`.

`Longitudinal force map, FxMap` — Lookup table

`array`

Longitudinal force versus slip ratio and normal force, N.

Dependencies

To create this parameter, select the **Longitudinal Force** parameter `Mapped force`.

Rolling Resistance

Pressure and Velocity

`Velocity independent force coefficient, aMy` — Force coefficient
`8e-4` (default) | `scalar`

Velocity-independent force coefficient, *a*, in s/m.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Linear velocity force component, bMy` — Force component
`.001` (default) | `scalar`

Linear velocity force component, *b*, in s/m.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Quadratic velocity force component, cMy` — Force component
`1.6e-4` (default) | `scalar`

Quadratic velocity force component, *c*, in s^2/m^2.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Tire pressure exponent, alphaMy` — Pressure exponent
`-0.003` (default) | `scalar`

Tire pressure exponent, α, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Normal force exponent, betaMy` — Force exponent
`0.97` (default) | `scalar`

Normal force exponent, β, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

ISO 28580

`Parasitic losses force, Fpl` — Force loss
`10` (default) | `scalar`

Parasitic force loss, F_{pl}, in N.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Rolling resistance constant, Cr` — Constant

`1e-3` (default) | `scalar`

Rolling resistance constant, C_r, in N/kN. ISO 28580 specifies the rolling resistance unit as one newton of tractive resistance for every kilonewtons of normal load.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Thermal correction factor, Kt` — Correction factor

`.008` (default) | `scalar`

Thermal correction factor, K_t, in 1/degC.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Measured temperature, Tmeas` — Temperature during testing

`298.15` (default) | `scalar`

Measured ambient temperature, T_{meas}, near tire during tire testing, in K.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Ambient temperature, Tamb` — Temperature

`298.15` (default) | `scalar`

Measured ambient temperature, T_{amb}, near tire in application environment, in K. For example, the measured ambient temperature is the ambient temperature near the tire when the vehicle is on the road.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Input ambient temperature` — Selection

`off` (default) | `on`

Select to create input port `Tamb` to input the measured ambient temperature.

The measured ambient temperature, T_{amb}, is the temperature near tire in application environment, in K. For example, the measured ambient temperature is the ambient temperature near the tire when the vehicle is on the road.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

Magic Formula

`Rolling resistance torque coefficient, QSY1` — Torque coefficient

`0.007` (default) | `scalar`

Rolling resistance torque coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Longitudinal force rolling resistance coefficient, QSY2` — Force resistance coefficient

`0` (default) | `scalar`

Longitudinal force rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Linear rotational speed rolling resistance coefficient, QSY3` — Linear speed coefficient

`0.0015` (default) | `scalar`

Linear rotational speed rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Quartic rotational speed rolling resistance coefficient, QSY4` — Quartic speed coefficient

`8.5e-05` (default) | `scalar`

Quartic rotational speed rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Camber squared rolling resistance torque, QSY5` — Camber resistance torque

`0` (default) | `scalar`

Camber squared rolling resistance torque, in 1/rad^2.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Load based camber squared rolling resistance torque, QSY6` — Load resistance torque

`0` (default) | `scalar`

Load based camber squared rolling resistance torque, in 1/rad^2.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Normal load rolling resistance coefficient, QSY7` — Normal resistance coefficient

`0.9` (default) | `scalar`

Normal load rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Pressure load rolling resistance coefficient, QSY8` — Pressure resistance coefficient

`-0.4` (default) | `scalar`

Pressure load rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Rolling resistance scaling factor, lam_My` — Scale

`1` (default) | `scalar`

Rolling resistance scaling factor, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

Mapped

`Spin axis velocity breakpoints, VxMy` — Breakpoints

`-20:1:20` (default) | `vector`

Spin axis velocity breakpoints, in m/s.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Mapped torque`.

`Normal force breakpoints, FzMy` — Breakpoints

`0:200:1e4` (default) | `vector`

Normal force breakpoints, in N.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Mapped torque`.

`Rolling resistance torque map, MyMap` — Lookup table

`array`

Rolling resistance torque versus axle speed and normal force, in N·m.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Mapped torque`.

Brake

`Static friction coefficient, mu_static` — Static friction

`.3` (default) | `scalar`

Static friction coefficient, specified as a scalar, dimensionless.

Dependencies

To enable this parameter, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

`Kinetic friction coefficient, mu_kinetic` — Kinetic friction

`.2` (default) | `scalar`

Kinematic friction coefficient, specified as a scalar, dimensionless.

Dependencies

To enable this parameter, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

Disc

`Disc brake actuator bore, disc_abore` — Bore distance

`.05` (default) | `scalar`

Disc brake actuator bore, specified as a scalar, in m.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

`Brake pad mean radius, Rm` — Radius

`.177` (default) | `scalar`

Brake pad mean radius, specified as a scalar, in m.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

`Number of brake pads, num_pads` — Count

`2` (default) | `scalar`

Number of brake pads, specified as a scalar, dimensionless.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

Drum

`Drum brake actuator bore, disc_abore` — Bore distance

`0.0508` (default) | `scalar`

Drum brake actuator bore, specified as a scalar, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to drum center distance, drum_a` — Distance

`0.123` (default) | `scalar`

Shoe pin to drum center distance, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin center to force application point distance, drum_c` — Distance

`0.212` (default) | `scalar`

Shoe pin center to force application point distance, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Drum internal radius, drum_r` — Radius

`0.15` (default) | `scalar`

Drum internal radius, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to pad start angle, drum_theta1` — Angle

`0` (default) | `scalar`

Shoe pin to pad start angle, in deg.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to pad end angle, drum_theta2` — Angle

`126` (default) | `scalar`

Shoe pin to pad end angle, in deg.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

Mapped

`Brake actuator pressure breakpoints, brake_p_bpt` — Breakpoints

`vector`

Brake actuator pressure breakpoints, in bar.

Dependencies

To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

`Wheel speed breakpoints, brake_n_bpt` — Breakpoints

`vector`

Wheel speed breakpoints, in rpm.

Dependencies

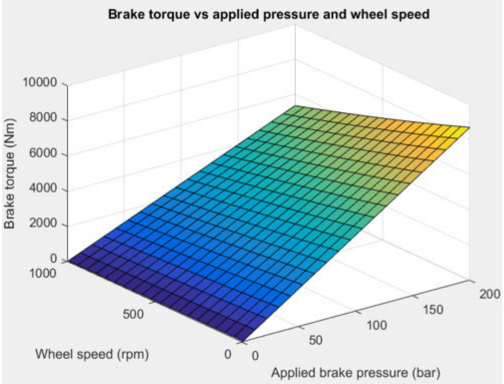
To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

`Brake torque map, f_brake_t` — Lookup table

`array`

The lookup table for the brake torque, $f_{brake}(P, N)$, is a function of applied brake pressure and wheel speed, where:

- T is brake torque, in N·m.
- P is applied brake pressure, in bar.
- N is wheel speed, in rpm.



Dependencies

To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

Vertical

`Nominal normal force, FNOMIN` — Force

`2000` (default) | `scalar`

Nominal rated wheel load along wheel-fixed z-axis, in N.

Dependencies

To enable this parameter, set either:

- **Longitudinal Force** to `Magic Formula pure longitudinal slip`.
- **Rolling Resistance** to `Magic Formula`.

`Nominal rated load scaling factor, lam_Fzo` — Factor

`1` (default) | `scalar`

Nominal rated load scaling factor, dimensionless. Used to scale the normal for specific applications and load conditions.

Dependencies

To enable this parameter, set **Longitudinal Force** to `Magic Formula pure longitudinal slip`.

`Wheel and unsprung mass, m` — Mass

`10` (default) | `scalar`

Wheel and unsprung mass, in kg. Used in the vertical motion calculations.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Initial deflection, zo` — Deflection

`0` (default) | `scalar`

Initial axle displacement along wheel-fixed *z*-axis, in m.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Initial velocity, zdoto` — Velocity

`0` (default) | `scalar`

Initial axle velocity along wheel-fixed *z*-axis, in m.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Gravitational acceleration, g` — Gravity

`9.81` (default) | `scalar`

Gravitational acceleration, in m/s^2.

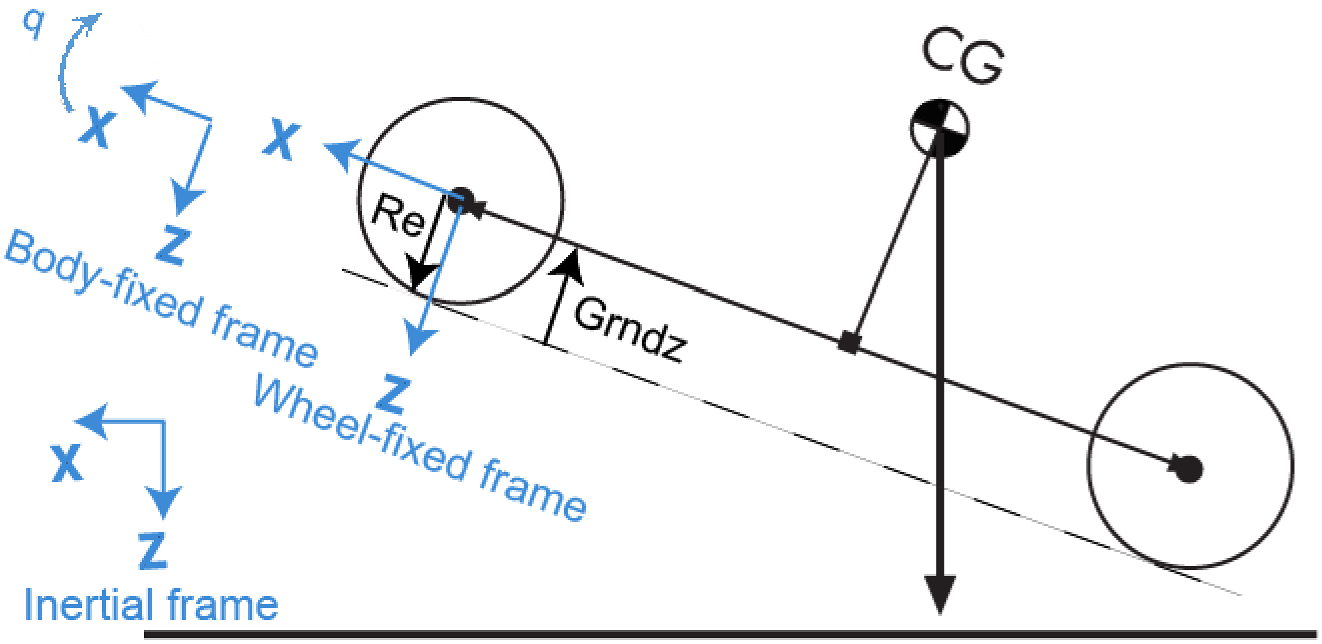
Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Ground displacement, Gndz` — Displacement

`0` (default) | `scalar`

Ground displacement, `Grndz`, along negative wheel-fixed *z*-axis, in m.



Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

Mapped Stiffness and Damping

`Vertical deflection breakpoints, zFz` — Breakpoints
`[0 .01 .1]` (default) | `vector`

Vector of sidewall deflection breakpoints corresponding to the force table, in m.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Pressure breakpoints, pFz` — Breakpoints
`[10000 1000000]` (default) | `vector`

Vector of pressure data points corresponding to the force table, in Pa.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Force due to deflection, Fzz` — Force
`[0 1e3 1e4; 0 1e4 1e5]` (default) | `vector`

Force due to sidewall deflection and pressure along wheel-fixed *z*-axis, in N.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Vertical velocity breakpoints, zdotFz` — Breakpoints
`[-20 0 20]` (default) | `scalar`

Vector of sidewall velocity breakpoints corresponding to the force due to velocity table, in m.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Force due to velocity, Fzzdot` — Force
`[500 0 -500;250 0 -250]` (default) | `array`

Force due to sidewall velocity and pressure along wheel-fixed *z*-axis, in N.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

Simulation Setup

`Minimum normal force, FZMIN` — Force
`0` (default) | `scalar`

Minimum normal force, in N. Used with all vertical force calculations.

`Maximum normal force, FZMAX` — Force
`10000` (default) | `scalar`

Maximum normal force, in N. Used with all vertical force calculations.

`Max allowable slip ratio (absolute), kappamax` — Ratio
`1.5` (default) | `scalar`

Maximum allowable absolute slip ratio, dimensionless.

`Velocity tolerance used to handle low velocity situations, VXLOW` — Tolerance
`1` (default) | `scalar`

Velocity tolerance used to handle low-velocity situations, in m/s.

`Minimum ambient temperature, TMIN` — Tmin
`0` (default) | `scalar`

Minimum ambient temperature, T_{MIN}, in K.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Maximum ambient temperature, TMAX` — Tmax
`400` (default) | `scalar`

Maximum ambient temperature, T_{MAX}, in K.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

Version History

Introduced in R2017a

References

[1] Highway Tire Committee. *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. Standard J2452_199906. Warrendale, PA: SAE International, June 1999.

[2] Pacejka, H. B. *Tire and Vehicle Dynamics*. 3rd ed. Oxford, United Kingdom: SAE and Butterworth-Heinemann, 2012.

[3] Schmid, Steven R., Bernard J. Hamrock, and Bo O. Jacobson. "Chapter 18: Brakes and Clutches." *Fundamentals of Machine Elements, SI Version*. 3rd ed. Boca Raton, FL: CRC Press, 2014.

[4] Shigley, Joseph E., and Larry Mitchel. *Mechanical Engineering Design*. 4th ed. New York, NY: McGraw Hill, 1983.

[5] ISO 28580:2018. *Passenger car, truck and bus tyre rolling resistance measurement method -- Single point test and correlation of measurement results*. ISO (International Organization for Standardization), 2018.

Extended Capabilities

C/C++ Code Generation

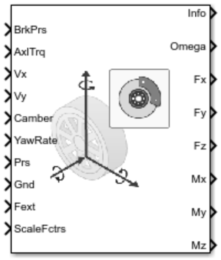
Generate C and C++ code using Simulink® Coder™.

See Also

Drive Cycle Source | Longitudinal Driver | Combined Slip Wheel 2DOF

Combined Slip Wheel 2DOF

Combined slip 2DOF wheel with disc, drum, or mapped brake
Library: Vehicle Dynamics Blockset / Wheels and Tires



Description

The Combined Slip Wheel 2DOF block implements the longitudinal and lateral behavior of a wheel characterized by the Magic Formula[1] and [2]. You can import your own tire data or use fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS). Use the block in driveline and vehicle simulations where low frequency tire-road and braking forces are required to determine vehicle acceleration, braking, and wheel-rolling resistance. The block is suitable for applications that require combined lateral slip, for example, in lateral motion and yaw stability studies.

Based on the driveline torque, brake pressure, road height, wheel camber angle, and inflation pressure, the block determines the wheel rotation rate, vertical motion, forces, and moments in all six degrees of freedom (DOF). Use the vertical DOF to study tire-suspension resonances from road profiles or chassis motion.

Use the **Tire type** parameter to select the source of the tire data.

Goal	Action
Implement the Magic Formula using empirical equations[1 and 2]. The equations use fitting coefficients that correspond to the block parameters.	Update the block parameters with fitting coefficients from a file: 1 Set **Tire type** to `External file`. 2 On the **Wheel and Tire Parameters** > **External tire source** pane, select **Select file**. 3 Select the tire coefficient file. 4 Select **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters. 5 Select **Apply**.

Goal	Action
Implement fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS).	Update the applicable block parameters with GCAPS fitted tire data: 1 Set **Tire type** to the tire that you want to implement. Options include: • `Light passenger car 205/60R15` • `Mid-size passenger car 235/45R18` • `Performance car 225/40R19` • `SUV 265/50R20` • `Light truck 275/65R18` • `Commercial truck 295/75R22.5` 2 Select **Update applicable Tire Parameters with tire type values**. On the **Tire Parameters** tab, the block updates the applicable parameters, including **Wheel width**, **Rim radius**, and **Wheel mass**. 3 Select **Apply**.

Use the **Brake Type** parameter to select the brake.

Goal	Brake Type Setting
No braking	`None`
Implement brake that converts the brake cylinder pressure into a braking force	`Disc`
Implement simplex drum brake that converts the applied force and brake geometry into a net braking torque	`Drum`
Implement lookup table that is a function of the wheel speed and applied brake pressure	`Mapped`

Rotational Wheel Dynamics

The block calculates the inertial response of the wheel subject to:

- Axle losses
- Brake and drive torque
- Tire rolling resistance
- Ground contact through the tire-road interface

To implement the Magic Formula, the block uses these equations.

Calculation	Equations
Longitudinal force	*Tire and Vehicle Dynamics*[2] equations 4.E9 through 4.E57

Calculation	Equations
Lateral force - pure sideslip	*Tire and Vehicle Dynamics*[2] equations 4.E19 through 4.E30
Lateral force - combined slip	*Tire and Vehicle Dynamics*[2] equations 4.E58 through 4.E67
Vertical dynamics	*Tire and Vehicle Dynamics*[2] equations 4.E68, 4.E1, 4.E2a, and 4.E2b
Overturning couple	*Tire and Vehicle Dynamics*[2] equation 4.E69
Rolling resistance	• *An improved Magic Formula/Swift tyre model that can handle inflation pressure changes*[2] equation 6.1.2 • *Tire and Vehicle Dynamics*[2] equation 4.E70
Aligning moment	*Tire and Vehicle Dynamics*[2] equation 4.E31 through 4.E49
Aligning torque - combined slip	*Tire and Vehicle Dynamics*[2] equation 4.E71 through 4.E78 If you clear **Include turn slip**, the block sets some of these equations to 1.

The input torque is the summation of the applied axle torque, braking torque, and moment arising from the combined tire torque.

$$T_i = T_a - T_b + T_d$$

For the moment arising from the combined tire torque, the block implements tractive wheel forces and rolling resistance with first-order dynamics. The rolling resistance has a time constant parameterized in terms of a relaxation length.

$$T_d(s) = \frac{1}{\frac{L_e}{|\omega| R_e} s + 1}$$

If the brakes are enabled, the block determines the braking locked or unlocked condition based on an idealized dry clutch friction model. Based on the lockup condition, the block implements these friction and dynamic models.

If	Lockup Condition	Friction Model	Dynamic Model
$\omega \neq 0$ or $T_S < \left\lvert T_i + T_f - \omega b \right\rvert$	Unlocked	$T_f = T_k$ where, $T_k = F_c R_{eff} \mu_k \tanh[4(-\omega_d)]$ $T_s = F_c R_{eff} \mu_s$ $R_{eff} = \frac{2(R_o{}^3 - R_i{}^3)}{3(R_o{}^2 - R_i{}^2)}$	$\dot{\omega} J = -\omega b + T_i + T_o$
$\omega = 0$ and $T_S \geq \left\lvert T_i + T_f - \omega b \right\rvert$	Locked	$T_f = T_s$	$\omega = 0$

The equations use these variables.

ω	Wheel angular velocity
a	Velocity independent force component
b	Linear velocity force component
c	Quadratic velocity force component
L_e	Tire relaxation length
J	Moment of inertia
M_y	Rolling resistance torque
T_a	Applied axle torque about wheel spin axis
T_b	Braking torque
T_d	Combined tire torque
T_f	Frictional torque
T_i	Net input torque
T_k	Kinetic frictional torque
T_o	Net output torque
T_s	Static frictional torque
F_c	Applied clutch force
F_x	Longitudinal force developed by the tire road interface due to slip
R_{eff}	Effective clutch radius
R_o	Annular disk outer radius
R_i	Annular disk inner radius
R_e	Effective tire radius while under load and for a given pressure
V_x	Longitudinal axle velocity
F_z	Vehicle normal force
α	Tire pressure exponent
β	Normal force exponent
p_i	Tire pressure
μ_s	Coefficient of static friction
μ_k	Coefficient of kinetic friction

Tire and Wheel Coordinate Systems

To resolve the forces and moments, the block uses the Z-Up orientation of the tire and wheel coordinate systems.

- Tire coordinate system axes (X_T, Y_T, Z_T) are fixed in a reference frame attached to the tire. The origin is at the tire contact with the ground.
- Wheel coordinate system axes (X_W, Y_W, Z_W) are fixed in a reference frame attached to the wheel. The origin is at the wheel center.

Z-Up Orientation[1]

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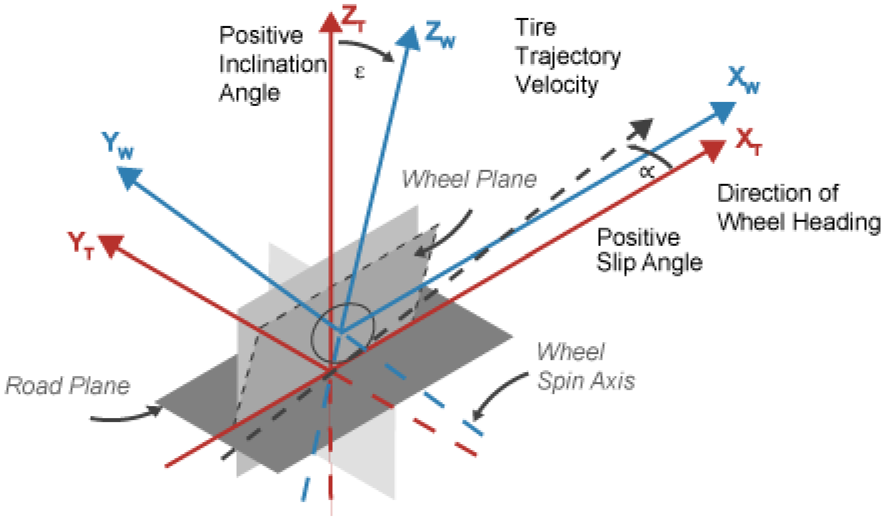
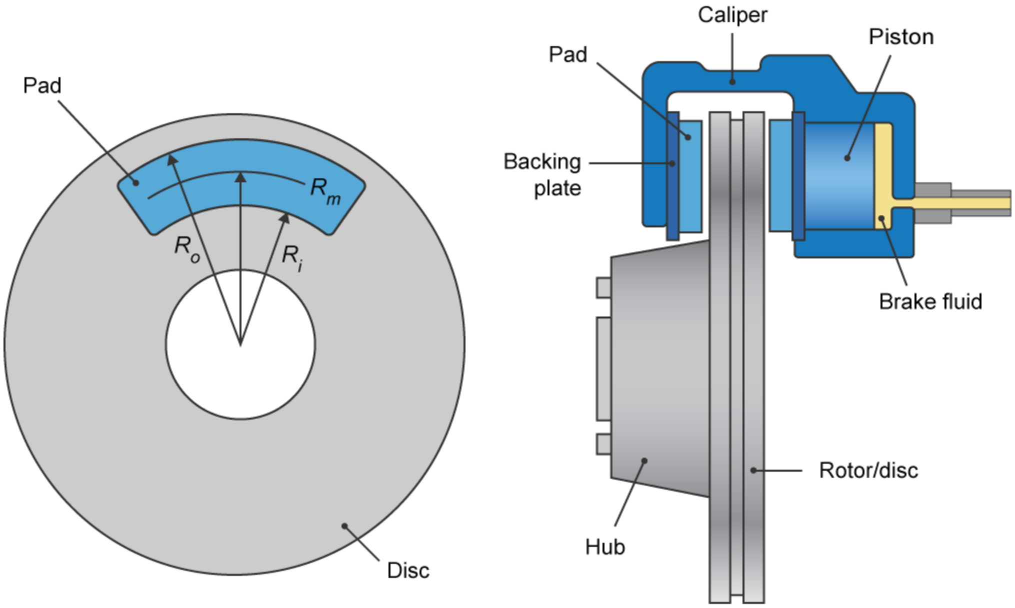


Brakes

Disc

If you specify the **Brake Type** parameter `Disc`, the block implements a disc brake. This figure shows the side and front views of a disc brake.



A disc brake converts brake cylinder pressure from the brake cylinder into force. The disc brake applies the force at the brake pad mean radius.

The block uses these equations to calculate brake torque for the disc brake.

$$T = \begin{cases} \dfrac{\mu P \pi B_a{}^2 R_m N_{pads}}{4} & \text{when } N \neq 0 \\ \dfrac{\mu_{static} P \pi B_a{}^2 R_m N_{pads}}{4} & \text{when } N = 0 \end{cases}$$

$$Rm = \frac{Ro + Ri}{2}$$

The equations use these variables.

T	Brake torque
P	Applied brake pressure
N	Wheel speed
N_{pads}	Number of brake pads in disc brake assembly
μ_{static}	Disc pad-rotor coefficient of static friction
μ	Disc pad-rotor coefficient of kinetic friction
B_a	Brake actuator bore diameter
R_m	Mean radius of brake pad force application on brake rotor
R_o	Outer radius of brake pad
R_i	Inner radius of brake pad

Drum

If you specify the **Brake Type** parameter `Drum`, the block implements a static (steady-state) simplex drum brake. A simplex drum brake consists of a single two-sided hydraulic actuator and two brake shoes. The brake shoes do not share a common hinge pin.

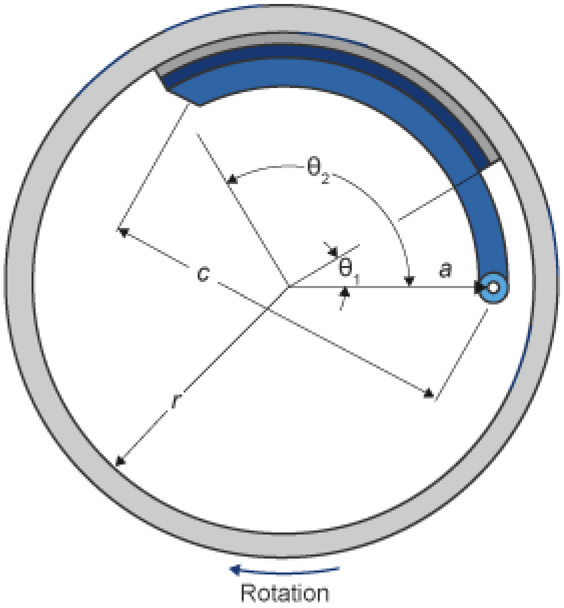
The simplex drum brake model uses the applied force and brake geometry to calculate a net torque for each brake shoe. The drum model assumes that the actuators and shoe geometry are symmetrical for both sides, allowing a single set of geometry and friction parameters to be used for both shoes.

The block implements equations that are derived from these equations in *Fundamentals of Machine Elements*.

$$T_{rshoe} = \left(\frac{\pi \mu c r (\cos\theta_2 - \cos\theta_1) B_a{}^2}{2\mu(2r(\cos\theta_2 - \cos\theta_1) + a(\cos^2\theta_2 - \cos^2\theta_1)) + ar(2\theta_1 - 2\theta_2 + \sin 2\theta_2 - \sin 2\theta_1)} \right) P$$

$$T_{lshoe} = \left(\frac{\pi \mu c r (\cos\theta_2 - \cos\theta_1) B_a{}^2}{-2\mu(2r(\cos\theta_2 - \cos\theta_1) + a(\cos^2\theta_2 - \cos^2\theta_1)) + ar(2\theta_1 - 2\theta_2 + \sin 2\theta_2 - \sin 2\theta_1)} \right) P$$

$$T = \begin{cases} T_{rshoe} + T_{lshoe} & \text{when } N \neq 0 \\ (T_{rshoe} + T_{lshoe}) \dfrac{\mu_{static}}{\mu} & \text{when } N = 0 \end{cases}$$



The equations use these variables.

T	Brake torque
P	Applied brake pressure
N	Wheel speed
μ_{static}	Disc pad-rotor coefficient of static friction
μ	Disc pad-rotor coefficient of kinetic friction
T_{rshoe}	Right shoe brake torque
T_{lshoe}	Left shoe brake torque
a	Distance from drum center to shoe hinge pin center
c	Distance from shoe hinge pin center to brake actuator connection on brake shoe
r	Drum internal radius
B_a	Brake actuator bore diameter
Θ_1	Angle from shoe hinge pin center to start of brake pad material on shoe
Θ_2	Angle from shoe hinge pin center to end of brake pad material on shoe

Mapped

If you specify the **Brake Type** parameter `Mapped`, the block uses a lookup table to determine the brake torque.

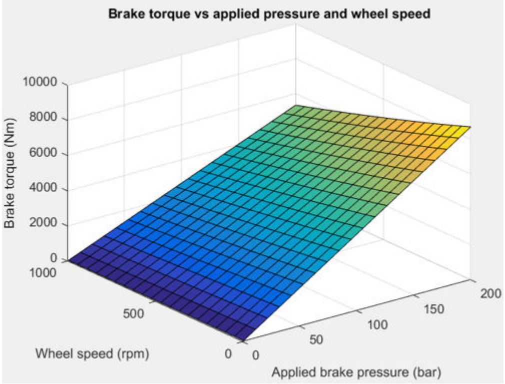
$$T = \begin{cases} f_{brake}(P, N) & \text{when } N \neq 0 \\ \left(\frac{\mu_{static}}{\mu}\right) f_{brake}(P, N) & \text{when } N = 0 \end{cases}$$

The equations use these variables.

T	Brake torque
$f_{brake}(P,N)$	Brake torque lookup table
P	Applied brake pressure
N	Wheel speed
μ_{static}	Friction coefficient of drum pad-face interface under static conditions
μ	Friction coefficient of disc pad-rotor interface

The lookup table for the brake torque, $f_{brake}(P,N)$, is a function of applied brake pressure and wheel speed, where:

- T is brake torque, in N·m.
- P is applied brake pressure, in bar.
- N is wheel speed, in rpm.



Ports

Input

`BrkPrs` — Brake pressure

`scalar` | N-by-1 vector

Brake pressure, in Pa.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

Dependencies

To enable this port, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

`AxlTrq` — Axle torque

`scalar` | N-by-1 vector

Axle torque, T_a, about wheel spin axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Vx` — Longitudinal velocity
`scalar` | N-by-1 vector

Axle longitudinal velocity, V_x, along tire-fixed *x*-axis, in m/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Vy` — Lateral velocity
`scalar` | N-by-1 vector

Axle lateral velocity, V_y, along tire-fixed *y*-axis, in m/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Camber` — Inclination angle
`scalar` | N-by-1 vector

Camber angle, γ, or inclination angle, ε, in rad.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`YawRate` — Tire angular velocity
`scalar` | N-by-1 vector

Tire angular velocity, *r*, about the tire-fixed *z*-axis (yaw rate), in rad/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Prs` — Tire inflation pressure
`scalar` | N-by-1 vector

Tire inflation pressure, p_i, in Pa.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Gnd` — Ground displacement
`scalar` | N-by-1 vector

Ground displacement along tire-fixed *z*-axis, in m. Positive input produces wheel lift.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fext` — Axle force applied to tire
`scalar` | N-by-1 vector

Axle force applied to tire, F_{ext}, along vehicle-fixed *z*-axis (positive input compresses the tire), in N.

Vector is the number of wheels, *N*, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

`ScaleFctrs` — Scale factors

27-by-N array

Magic Formula scale factor array. Array dimensions are 27 by the number of wheels, *N*.

The Magic Formula equations use scale factors to account for static or simulation run-time variations. Nominally, most are set to 1.

Array Element	Variable	Scale Factor
`ScaleFctrs(1,1)`	`lam_Fzo`	Nominal load
`ScaleFctrs(2,1)`	`lam_mux`	Longitudinal peak friction coefficient
`ScaleFctrs(3,1)`	`lam_muy`	Lateral peak friction coefficient
`ScaleFctrs(4,1)`	`lam_muV`	Slip speed, *Vs*, decaying friction
`ScaleFctrs(5,1)`	`lam_Kxkappa`	Brake slip stiffness
`ScaleFctrs(6,1)`	`lam_Kyalpha`	Cornering stiffness
`ScaleFctrs(7,1)`	`lam_Cx`	Longitudinal shape factor
`ScaleFctrs(8,1)`	`lam_Cy`	Lateral shape factor
`ScaleFctrs(9,1)`	`lam_Ex`	Longitudinal curvature factor
`ScaleFctrs(10,1)`	`lam_Ey`	Lateral curvature factor
`ScaleFctrs(11,1)`	`lam_Hx`	Longitudinal horizontal shift
`ScaleFctrs(12,1)`	`lam_Hy`	Lateral horizontal shift
`ScaleFctrs(13,1)`	`lam_Vx`	Longitudinal vertical shift
`ScaleFctrs(14,1)`	`lam_Vy`	Lateral vertical shift
`ScaleFctrs(15,1)`	`lam_Kygamma`	Camber force stiffness
`ScaleFctrs(16,1)`	`lam_Kzgamma`	Camber torque stiffness
`ScaleFctrs(17,1)`	`lam_t`	Pneumatic trail (effecting aligning torque stiffness)
`ScaleFctrs(18,1)`	`lam_Mr`	Residual torque
`ScaleFctrs(19,1)`	`lam_xalpha`	Alpha influence on *Fx* (kappa)
`ScaleFctrs(20,1)`	`lam_ykappa`	Kappa influence on *Fy* (alpha)
`ScaleFctrs(21,1)`	`lam_Vykappa`	Induced ply steer *Fy*
`ScaleFctrs(22,1)`	`lam_s`	Moment arm of *Fx*
`ScaleFctrs(23,1)`	`lam_Cz`	Radial tire stiffness
`ScaleFctrs(24,1)`	`lam_Mx`	Overturning couple stiffness
`ScaleFctrs(25,1)`	`lam_VMx`	Overturning couple vertical shift
`ScaleFctrs(26,1)`	`lam_My`	Rolling resistance moment
`ScaleFctrs(27,1)`	`lam_Mphi`	Parking torque *Mz*

Output

`Info` — Block data

bus

Block data, returned as a bus signal containing these block values.

Signal	Description	Units
`AxlTrq`	Axle torque about wheel-fixed *y*-axis	N·m
`Omega`	Wheel angular velocity about wheel-fixed *y*-axis	rad/s
`Fx`	Longitudinal vehicle force along tire-fixed *x*-axis	N
`Fy`	Lateral vehicle force along tire-fixed *y*-axis	N
`Fz`	Vertical vehicle force along tire-fixed *z*-axis	N
`Mx`	Overturning moment about tire-fixed *x*-axis	N·m
`My`	Rolling resistance torque about tire-fixed *y*-axis	N·m
`Mz`	Aligning moment about tire-fixed *z*-axis	N·m
`Vx`	Vehicle longitudinal velocity along tire-fixed *x*-axis	m/s
`Vy`	Vehicle lateral velocity along tire-fixed *y*-axis	m/s
`Re`	Loaded effective radius	m
`Kappa`	Longitudinal slip ratio	NA
`Alpha`	Side slip angle	rad
`a`	Contact patch half length	m
`b`	Contact patch half width	m
`Gamma`	Camber angle	rad
`psidot`	Tire angular velocity about the tire-fixed *z*-axis (yaw rate)	rad/s
`BrkTrq`	Brake torque about vehicle-fixed *y*-axis	N·m
`BrkPrs`	Brake pressure	Pa
`z`	Axle vertical displacement along tire-fixed *z*-axis	m
`zdot`	Axle vertical velocity along tire-fixed *z*-axis	m/s
`Gnd`	Ground displacement along tire-fixed *z*-axis (positive input produces wheel lift)	m
`GndFz`	Vertical sidewall force on ground along tire-fixed *z*-axis	N
`Prs`	Tire inflation pressure	Pa

`Omega` — Wheel angular velocity

`scalar` | N-by-1 vector

Wheel angular velocity, ω, about wheel-fixed *y*-axis, in rad/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fx` — Longitudinal axle force

`scalar` | N-by-1 vector

Longitudinal force acting on axle, F_x, along tire-fixed *x*-axis, in N. Positive force acts to move the vehicle forward.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fy` — Lateral axle force
`scalar` | N-by-1 vector

Lateral force acting on axle, F_y, along tire-fixed *y*-axis, in N.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fz` — Vertical axle force
`scalar` | N-by-1 vector

Vertical force acting on axle, F_z, along tire-fixed *z*-axis, in N.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Mx` — Overturning moment
`scalar` | N-by-1 vector

Longitudinal moment acting on axle, M_x, about tire-fixed *x*-axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`My` — Rolling resistive moment
`scalar` | N-by-1 vector

Lateral moment acting on axle, M_y, about tire-fixed *y*-axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Mz` — Aligning moment
`scalar` | N-by-1 vector

Vertical moment acting on axle, M_z, about tire-fixed *z*-axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

Parameters

Block Options

`Tire Type` — Select type
`External file` (default) | `Light passenger car 205/60R15` | `Mid-size passenger car 235/45R18` | `Performance car 225/40R19` | `SUV 265/50R20` | `Light truck 275/65R18` | `Commercial truck 295/75R22.5`

Use the **Tire type** parameter to select the source of the tire data.

Goal	Action
Implement the Magic Formula using empirical equations[1 and 2]. The equations use fitting coefficients that correspond to the block parameters.	Update the block parameters with fitting coefficients from a file: 1 Set **Tire type** to `External file`. 2 On the **Wheel and Tire Parameters** > **External tire source** pane, select **Select file**. 3 Select the tire coefficient file. 4 Select **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters. 5 Select **Apply**.
Implement fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS).	Update the applicable block parameters with GCAPS fitted tire data: 1 Set **Tire type** to the tire that you want to implement. Options include: • `Light passenger car 205/60R15` • `Mid-size passenger car 235/45R18` • `Performance car 225/40R19` • `SUV 265/50R20` • `Light truck 275/65R18` • `Commercial truck 295/75R22.5` 2 Select **Update applicable Tire Parameters with tire type values**. On the **Tire Parameters** tab, the block updates the applicable parameters, including **Wheel width**, **Rim radius**, and **Wheel mass**. 3 Select **Apply**.

Brake Type — Select type

`None` | `Disc` | `Drum` | `Mapped`

Use the **Brake Type** parameter to select the brake.

Goal	Brake Type Setting
No braking	`None`
Implement brake that converts the brake cylinder pressure into a braking force	`Disc`
Implement simplex drum brake that converts the applied force and brake geometry into a net braking torque	`Drum`

Goal	Brake Type Setting
Implement lookup table that is a function of the wheel speed and applied brake pressure	`Mapped`

`Ply steer` — Include ply steer

`on` (default) | `off`

Select to include ply steer in the Magic Formula equations.

By default, the blocks include ply steer and turn slip in the Magic Formula equations. The equations are fit to flat-belt test data and predict a number of tire effects, including ply steer and turn slip. Consider removing the effects if your:

- Test data does not include ply steer or turn slip data.
- Analysis does not require ply steer or turn slip effects.

If you clear **Ply steer**, the block internally sets these parameters to 0:

- **Vertical shift of overturning moment, QSX1**
- **Combined slip Fx shift factor reduction, RHX1**
- **Efy curvature constant camber dependency, PEY3**
- **SHY horizontal shift at FZNOM, PHY1**
- **SHY variation with load, PHY2**
- **Svy/Fz vertical shift at FZNOM, PVY1**
- **Svy/Fz variation with load, PVY2**
- **Fy shift reduction with slip angle, RBY3**
- **Slip ratio side force Svyk/Muy*Fz at FZNOM, RVY1**
- **Side force Svyk/Muy*Fz variation with load, RVY2**
- **Bpt slope variation with camber, QBZ4**
- **Dpt peak trail variation with camber, QDZ3**
- **Dmr peak residual torque, QDZ6**
- **Dmr peak residual torque variation with load, QDZ7**
- **Ept variation with sign of alpha-t, QEZ4**
- **Sht horizontal trail shift at FZNOM, QHZ1**
- **Sht variation with load, QHZ2**
- **Nominal value of s/R0: effect of Fx on Mz, SSZ1**

`Turn slip` — Include turn slip

`on` (default) | `off`

Select to include ply steer in Magic Formula equations.

By default, the blocks include ply steer and turn slip in the Magic Formula equations. The equations are fit to flat-belt test data and predict a number of tire effects, including ply steer and turn slip. Consider removing the effects if your:

- Test data does not include ply steer or turn slip data.
- Analysis does not require ply steer or turn slip effects.

If you clear **Turn slip**, the block internally:

- Sets the Magic Formula turn slip equations to 1. Specifically, equations 4.E77, 4.E79, 4.E81, 4.E83, 4.E84, 4.E92, 4.E102, 4.E101, and 4.E105.[2].
- Uses Magic Formula terms that effect horizontal shift.
- Uses Magic Formula small turn slip values in 4.E27[2].

Brake

`Static friction coefficient, mu_static` — Static friction

`.3` (default) | `scalar` | *N*-by-1 vector

Static friction coefficient, specified as a scalar or *N*-by-1 vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable this parameter, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

`Kinetic friction coefficient, mu_kinetic` — Kinetic friction

`.2` (default) | `scalar` | *N*-by-1 vector

Kinematic friction coefficient, specified as a scalar or *N*-by-1 vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable this parameter, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

Disc

`Disc brake actuator bore, disc_abore` — Bore distance

`.05` (default) | `scalar` | *N*-by-1 vector

Disc brake actuator bore, specified as a scalar or *N*-by-1 vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

`Brake pad mean radius, Rm` — Radius

`.177` (default) | `scalar` | *N*-by-`1` vector

Brake pad mean radius, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

`Number of brake pads, num_pads` — Count

`2` (default) | `scalar` | *N*-by-`1` vector

Number of brake pads, specified as a scalar or *N*-by-`1` vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

Drum

`Drum brake actuator bore, disc_abore` — Bore distance

`0.0508` (default) | `scalar` | *N*-by-`1` vector

Drum brake actuator bore, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to drum center distance, drum_a` — Distance

`0.123` (default) | `scalar`

Shoe pin to drum center distance, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin center to force application point distance, drum_c` — Distance

`0.212` (default) | `scalar`

Shoe pin center to force application point distance, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Drum internal radius, drum_r` — Radius

`0.15` (default) | `scalar`

Drum internal radius, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to pad start angle, drum_theta1` — Angle

`0` (default) | `scalar`

Shoe pin to pad start angle, in deg.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to pad end angle, drum_theta2` — Angle

`126` (default) | `scalar`

Shoe pin to pad end angle, in deg.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

Mapped

`Brake actuator pressure breakpoints, brake_p_bpt` — Breakpoints

`vector`

Brake actuator pressure breakpoints, in bar.

Dependencies

To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

`Wheel speed breakpoints, brake_n_bpt` — Breakpoints

`vector`

Wheel speed breakpoints, in rpm.

Dependencies

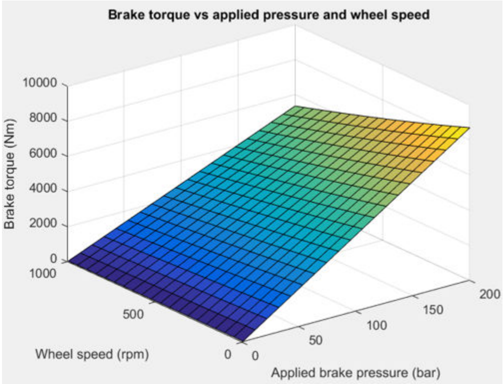
To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

`Brake torque map, f_brake_t` — Lookup table

`array`

The lookup table for the brake torque, $f_{brake}(P, N)$, is a function of applied brake pressure and wheel speed, where:

- *T* is brake torque, in N·m.
- *P* is applied brake pressure, in bar.
- *N* is wheel speed, in rpm.



Dependencies

To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

Tire

`Tire file or object, tireParamSet` — Tire file

`vdynPassCar.mat` (default) | `.tir` | `.txt`

Tire file `.tir` or object containing empirical data to model tire longitudinal and lateral behavior with the Magic Formula. If you provide an `.txt` file, make sure the file contains names that correspond to the block parameters.

Update the block parameters with fitting coefficients from a file:

1. Set **Tire type** to `External file`.
2. On the **Wheel and Tire Parameters** > **External tire source** pane, select **Select file**.
3. Select the tire coefficient file.
4. Select **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters.
5. Select **Apply**.

Simulation

`Maximum pressure, PRESMAX` — Pressure

`scalar`

Maximum pressure, *PRESMAX*, in Pa.

`Minimum pressure, PRESMIN` — Pressure

`scalar`

Minimum pressure, *PRESMIN*, in Pa.

`Maximum normal force, FZMAX` — Force

`10000` (default) | `scalar`

Maximum normal force, *FZMAX*, in N.

`Minimum normal force, FZMIN` — Force
`100` (default) | `scalar`

Minimum normal force, *FZMIN*, in N.

`Velocity tolerance used to handle low velocity situations, VXLOW` — Tolerance
`0.1` (default) | `scalar`

Velocity tolerance used to handle low velocity situations, *VXLOW*, in m/s.

`Max allowable slip ratio (absolute), KPUMAX` — Ratio
`scalar`

Max allowable slip ratio (absolute), *KPUMAX*, dimensionless.

`Minimum allowable slip ratio (absolute), KPUMIN` — Ratio
`scalar`

Minimum allowable slip ratio (absolute), *KPUMIN*, dimensionless.

`Max allowable slip angle (absolute), ALPMAX` — Angle
`scalar`

Max allowable slip angle (absolute), *ALPMAX*, in rad.

`Minimum allowable slip angle (absolute), ALPMIN` — Angle
`scalar`

Minimum allowable slip angle (absolute), *ALPMIN*, in rad.

`Maximum allowable camber angle, CAMMAX` — Angle
`scalar`

Maximum allowable camber angle *CAMMAX*, in rad.

`Minimum allowable camber angle, CAMMIN` — Angle
`scalar`

Minimum allowable camber angle, *CAMMIN*, in rad.

`Nominal longitudinal speed, LONGVL` — Speed
`16.7` (default) | `scalar`

Nominal longitudinal speed, *LONGVL*, in m/s.

Wheel

`Initial rotational velocity, omegao` — Velocity
`scalar` | *N*-by-1 vector

Initial rotational velocity, specified as a scalar or *N*-by-1 vector, in rad/s. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other rotational parameters.

N is the number of wheels and must match the input signal dimensions.

`Rotational damping, br` — Damping
`scalar` | *N*-by-`1` vector

Rotational damping, specified as a scalar or *N*-by-`1` vector, in N·m·s/rad. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other rotational parameters.

N is the number of wheels and must match the input signal dimensions.

`Unloaded radius, UNLOADED_RADIUS` — Radius
`0.309` (default) | `scalar`

Unloaded radius, *UNLOADED_RADIUS*, in m.

`Nominal pressure, NOMPRES` — Pressure
`224006` (default) | `scalar`

Nominal pressure, *NOMPRES*, in Pa.

`Nominal normal force, FNOMIN` — Force
`4025` (default) | `scalar`

Nominal normal force, *FNOMIN*, in N.

`Wheel width, WIDTH` — Width
`scalar`

Wheel width, *WIDTH*, in m.

`Rim radius, RIM_RADIUS` — Radius
`.19` (default) | `scalar`

Rim radius, *RIM_RADIUS*, in m.

Inertial

`Wheel mass, MASS` — Mass
`scalar` | *N*-by-`1` vector

Wheel mass, specified as a scalar or *N*-by-`1` vector, in kg. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other inertial parameters.

N is the number of wheels and must match the input signal dimensions.

`Rotational inertia (rolling axis), IYY` — Inertia
`scalar` | *N*-by-`1` vector

Rotational inertia (rolling axis), specified as a scalar or *N*-by-`1` vector, in kg·m^2. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other rotational parameters.

N is the number of wheels and must match the input signal dimensions.

`Gravity, GRAVITY` — Gravity
`scalar`

Gravity, *GRAVITY*, in m/s^2.

Vertical

`Initial tire displacement, zo` — Displacement
`0` (default) | `scalar` | *N*-by-`1` vector

Initial tire displacement, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other vertical parameters.

N is the number of wheels and must match the input signal dimensions.

`Initial wheel vertical velocity (wheel fixed frame), zdoto` — Velocity
`0` (default) | `scalar` | *N*-by-`1` vector

Initial wheel vertical velocity, specified as a scalar or *N*-by-`1` vector, in m/s. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other vertical parameters.

N is the number of wheels and must match the input signal dimensions.

`Effective rolling radius at low load stiffness, BREFF` — Stiffness
`8.25094594147963` (default) | `scalar`

Effective rolling radius at low load stiffness, *BREFF*, dimensionless.

`Effective rolling radius peak value, DREFF` — Radius
`0.260468730454265` (default) | `scalar`

Effective rolling radius peak value, *DREFF*, dimensionless.

`Effective rolling radius at high load stiffness, FREFF` — Radius
`0.0735298544471851` (default) | `scalar`

Effective rolling radius at high load stiffness, *FREFF*, dimensionless.

`Unloaded to nominal rolling radius ratio, Q_RE0` — Ratio
`1.00866439868088` (default) | `scalar`

Unloaded to nominal rolling radius ratio, *Q_RE0*, dimensionless.

`Radius rotational speed dependence, Q_V1` — Speed
`0.000760413786224011` (default) | `scalar`

Radius rotational speed dependence, *Q_V1*, dimensionless.

`Stiffness rotational speed dependence, Q_V2` — Speed
`0.0463384792019201` (default) | `scalar`

Stiffness rotational speed dependence, *Q_V2*, dimensionless.

`Linear load change with deflection, Q_FZ1` — Load change
`0` (default) | `scalar`

Linear load change with deflection, *Q_FZ1*, dimensionless.

`Quadratic load change with deflection, Q_FZ2` — Load change
`15.6870832810226` (default) | `scalar`

Quadratic load change with deflection, *Q_FZ2*, dimensionless.

`Linear load change with deflection and quadratic camber, Q_FZ3` — Load change
`0` (default) | `scalar`

Linear load change with deflection and quadratic camber, *Q_FZ3*, dimensionless.

`Load response to longitudinal force, Q_FCX` — Force
`0.138643970247602` (default) | `scalar`

Load response to longitudinal force, *Q_FCX*, dimensionless.

`Load response to lateral force, Q_FCY` — Force
`0.10843499565426` (default) | `scalar`

Load response to lateral force, *Q_FCY*, dimensionless.

`Vertical stiffness change due to lateral load dependency on lateral stiffness, Q_FCY2` — Stiffness
`-0.465763352339538` (default) | `scalar`

Vertical stiffness change due to lateral load dependency on lateral stiffness, *Q_FCY2*, dimensionless.

`Stiffness response to pressure, PFZ1` — Stiffness
`0.69958166705601` (default) | `scalar`

Stiffness response to pressure, *PFZ1*, dimensionless.

`Vertical tire stiffness, VERTICAL_STIFFNESS` — Stiffness
`207885.061134007` (default) | `scalar`

Vertical tire stiffness, *VERTICAL_STIFFNESS*, in N/m.

`Vertical tire damping, VERTICAL_DAMPING` — Damping
`494.649255786991` (default) | `scalar`

Vertical tire damping, *VERTICAL_DAMPING*, in N·s/m.

`Rim bottoming out offset, BOTTOM_OFFST` — Offset
`.01` (default) | `scalar`

Rim bottoming out offset, *BOTTOM_OFFST*, in m.

`Bottoming out stiffness, BOTTOM_STIFF` — Stiffness
`2e6` (default) | `scalar`

Bottoming out stiffness, *BOTTOM_STIFF*, in N/m.

Structural

`Longitudinal stiffness, LONGITUDINAL_STIFFNESS` — Stiffness
`scalar`

Longitudinal stiffness, *LONGITUDINAL_STIFFNESS*, in N/m.

`Lateral stiffness, LATERAL_STIFFNESS` — Stiffness
`scalar`

Longitudinal stiffness, *LATERAL_STIFFNESS*, in N/m.

`Linear vertical deflection influence on longitudinal stiffness, PCFX1` — Deflection influence
`scalar`

Linear vertical deflection influence on longitudinal stiffness, *PCFX1*, dimensionless.

`Quadratic vertical deflection influence on longitudinal stiffness, PCFX2` — Deflection influence
`scalar`

Quadratic vertical deflection influence on longitudinal stiffness, *PCFX2*, dimensionless.

`Pressure dependency on longitudinal stiffness, PCFX3` — Pressure dependency
`scalar`

Pressure dependency on longitudinal stiffness, *PCFX3*, dimensionless.

`Linear vertical deflection influence on lateral stiffness, PCFY1` — Deflection influence
`scalar`

Linear vertical deflection influence on lateral stiffness, *PCFY1*, dimensionless.

`Quadratic vertical deflection influence on lateral stiffness, PCFY2` — Deflection influence
`scalar`

Quadratic vertical deflection influence on lateral stiffness, *PCFY2*, dimensionless.

`Pressure dependency on longitudinal stiffness, PCFY3` — Pressure dependency
`scalar`

Pressure dependency on longitudinal stiffness, *PCFY3*, dimensionless.

Contact Patch

`Contact length square root term, Q_RA1` — Length term
`scalar`

Contact length square root term, *Q_RA1*, dimensionless.

`Contact length linear term, Q_RA2` — Length term
`scalar`

Contact length linear term, *Q_RA2*, dimensionless.

`Contact width root term, Q_RB1` — Width term
`scalar`

Contact width root term, *Q_RB1*, dimensionless.

`Contact width linear term, Q_RB2` — Width term
`scalar`

Contact width linear term, *Q_RB2*, dimensionless.

Longitudinal

`Cfx shape factor, PCX1` — Shape factor
`scalar`

Shape factor, C_{fx}, *PCX1*, dimensionless.

`Longitudinal friction at nominal normal load, PDX1` — Friction
`scalar`

Longitudinal friction at nominal normal load, *PDX1*, dimensionless.

`Frictional variation with load, PDX2` — Friction variation
`scalar`

Frictional variation with load, *PDX2*, dimensionless.

`Frictional variation with camber, PDX3` — Friction variation
`scalar`

Frictional variation with camber, *PDX3*, in 1/rad^2.

`Longitudinal curvature at nominal normal load, PEX1` — Curvature
`scalar`

Longitudinal curvature at nominal normal load, *PEX1*, dimensionless.

`Variation of curvature factor with load, PEX2` — Curvature variation
`scalar`

Variation of curvature factor with load, *PEX2*, dimensionless.

`Variation of curvature factor with square of load, PEX3` — Curvature variation
`scalar`

Variation of curvature factor with square of load, *PEX3*, dimensionless.

`Longitudinal curvature factor with slip, PEX4` — Curvature
`scalar`

Longitudinal curvature factor with slip, *PEX4*, dimensionless.

`Longitudinal slip stiffness at nominal normal load, PKX1` — Stiffness
`scalar`

Longitudinal slip stiffness at nominal normal load, *PKX1*, dimensionless.

Variation of slip stiffness with load, PKX2 — Stiffness variation
`scalar`

Variation of slip stiffness with load, *PKX2*, dimensionless.

Slip stiffness exponent factor, PKX3 — Slip stiffness
`scalar`

Slip stiffness exponent factor, *PKX3*, dimensionless.

Horizontal shift in slip ratio at nominal normal load, PHX1 — Slip ratio shift
`scalar`

Horizontal shift in slip ratio at nominal normal load, *PHX1*, dimensionless.

Variation of horizontal slip ratio with load, PHX2 — Slip variation
`scalar`

Variation of horizontal slip ratio with load, *PHX2*, dimensionless.

Vertical shift in load at nominal normal load, PVX1 — Load shift
`scalar`

Vertical shift in load at nominal normal load, *PVX1*, dimensionless.

Variation of vertical shift with load, PVX2 — Load variation
`scalar`

Variation of vertical shift with load, *PVX2*, dimensionless.

Linear variation of longitudinal slip stiffness with tire pressure, PPX1 — Stiffness variation
`scalar`

Linear variation of longitudinal slip stiffness with tire pressure, *PPX1*, dimensionless.

Quadratic variation of longitudinal slip stiffness with tire pressure, PPX2 — Stiffness variation
`scalar`

Quadratic variation of longitudinal slip stiffness with tire pressure, *PPX2*, dimensionless.

Linear variation of peak longitudinal friction with tire pressure, PPX3 — Friction variation
`scalar`

Linear variation of peak longitudinal friction with tire pressure, *PPX3*, dimensionless.

Quadratic variation of peak longitudinal friction with tire pressure, PPX4 — Friction variation
`scalar`

Quadratic variation of peak longitudinal friction with tire pressure, *PPX4*, dimensionless.

`Combined slip Fx slope factor reduction, RBX1` — Combined slip longitudinal force slope factor reduction
`scalar`

Combined slip longitudinal force, F_x, slope factor reduction, *RBX1*, dimensionless.

`Slip ratio Fx slope reduction variation, RBX2` — Slip ratio longitudinal force slope reduction variation
`scalar`

Slip ratio longitudinal force, F_x, slope reduction variation, *RBX2*, dimensionless.

`Camber influence on combined slip Fx stiffness, RBX3` — Camber influence on combined slip longitudinal force stiffness
`scalar`

Camber influence on combined slip longitudinal force, F_x, stiffness, *RBX3*, dimensionless.

`Shape factor for combined slip Fx reduction, RCX1` — Shape factor for combined slip longitudinal force reduction
`scalar`

Shape factor for combined slip longitudinal force, F_x, reduction, *RCX1*, dimensionless.

`Combined Fx curvature factor, REX1` — Combined longitudinal force curvature factor
`scalar`

Combined longitudinal force, F_x, curvature factor, *REX1*, dimensionless.

`Combined Fx curvature factor with load, REX2` — Combined longitudinal force curvature factor
`scalar`

Combined longitudinal force, F_x, curvature factor with load, *REX2*, dimensionless.

`Combined slip Fx shift factor reduction, RHX1` — Combined slip longitudinal force slip factor
`scalar`

Combined slip longitudinal force, F_x, shift factor reduction, *RHX1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

Overturning

`Vertical shift of overturning moment, QSX1` — Overturning moment
`scalar`

Vertical shift of overturning moment, *QSX1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Overturning moment due to camber, QSX2` — Overturning moment due to camber
`scalar`

Overturning moment due to camber, *QSX2*, dimensionless.

`Overturning moment due to Fy, QSX3` — Overturning moment due to lateral force
`scalar`

Overturning moment due to lateral force, *QSX3*, dimensionless.

`Mx combined lateral force load and camber, QSX4` — Overturning moment
`scalar`

Overturning moment, M_x, combined lateral force load and camber, *QSX4*, dimensionless.

`Mx load effect due to lateral force and camber, QSX5` — Overturning moment
`scalar`

Overturning moment, M_x, load effect due to lateral force and camber, *QSX5*, dimensionless.

`Mx load effect due to B-factor, QSX6` — Overturning moment
`scalar`

Overturning moment, M_x, load effect due to B-factor, *QSX6*, dimensionless.

`Mx due to camber and load, QSX7` — Overturning moment
`scalar`

Overturning moment, M_x, due to camber and load, *QSX7*, dimensionless.

`Mx due to lateral force and load, QSX8` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force and load, *QSX8*, dimensionless.

`Mx due to B-factor of lateral force and load, QSX9` — Overturning moment
`scalar`

Overturning moment, M_x, due to B-factor of lateral force and load, *QSX9*, dimensionless.

`Mx due to vertical force and camber, QSX10` — Overturning moment
`scalar`

Overturning moment, M_x, due to vertical force and camber, *QSX10*, dimensionless.

`Mx due to B-factor of vertical force and camber, QSX11` — Overturning moment
`scalar`

Overturning moment, M_x, due to B-factor of vertical force and camber, *QSX11*, dimensionless.

`Mx due to squared camber, QSX12` — Overturning moment
`scalar`

Overturning moment, M_x, due to squared camber, *QSX12*, dimensionless.

`Mx due to lateral force, QSX13` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force, *QSX13*, dimensionless.

`Mx due to lateral force with camber, QSX14` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force with camber, *QSX14*, dimensionless.

`Mx due to inflation pressure, PPMX1` — Overturning moment due to pressure
`scalar`

Overturning moment, M_x, due to inflation pressure, *PPMX1*, dimensionless.

Lateral

`Cfy shape factor for lateral force, PCY1` — Lateral force shape factor
`scalar`

Shape factor for lateral force, C_{fy}, *PCY1*, dimensionless.

`Lateral friction muy, PDY1` — Lateral friction
`scalar`

Lateral friction, μ_y, *PDY1*, dimensionless.

`Lateral friction variation of muy with load, PDY2` — Lateral friction variation
`scalar`

Variation of lateral friction, μ_y, with load, *PDY2*, dimensionless.

`Lateral friction variation of muy with squared camber, PDY3` — Lateral friction variation
`scalar`

Variation of lateral friction, μ_y, with squared camber, *PDY3*, dimensionless.

`Efy lateral curvature at nominal force FZNOM, PEY1` — Lateral curvature at nominal force
`scalar`

Lateral curvature, Ef_y, at nominal force, F_{ZNOM}, *PEY1*, dimensionless.

`Efy curvature variation with load, PEY2` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with load, *PEY2*, dimensionless.

`Efy curvature constant camber dependency, PEY3` — Lateral curvature constant
`scalar`

Lateral curvature, Ef_y, constant camber dependency, *PEY3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Efy curvature variation with camber, PEY4` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with camber, *PEY4*, dimensionless.

`Efy curvature variation with camber squared, PEY5` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with camber squared, *PEY5*, dimensionless.

`Maximum KFy/FZNOM stiffness, PKY1` — Maximum stiffness
`scalar`

Maximum lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, ratio, *PKY1*, dimensionless.

`Load at maximum KFy/FZNOM stiffness, PKY2` — Load
`scalar`

Load at maximum lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, ratio, *PKY2*, dimensionless.

`KFy/FZNOM stiffness variation with camber, PKY3` — Stiffness variation
`scalar`

Lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, stiffness variation with camber, *PKY3*, dimensionless.

`KFy curvature, PKY4` — Lateral force stiffness curvature
`scalar`

Lateral force stiffness, KF_y curvature, *PKY4*, dimensionless.

`Variation of peak stiffness with squared camber, PKY5` — Stiffness variation
`scalar`

Variation of peak stiffness with squared camber, *PKY5*, dimensionless.

`Fy camber stiffness factor, PKY6` — Lateral force camber stiffness factor
`scalar`

Lateral force, F_y, camber stiffness factor, *PKY6*, dimensionless.

`Camber stiffness vertical load dependency, PKY7` — Stiffness
`scalar`

Camber stiffness vertical load dependency, *PKY7*, dimensionless.

`SHY horizontal shift at FZNOM, PHY1` — Horizontal shift at nominal force
`scalar`

Horizontal shift, S_{HY}, at nominal force, F_{ZNOM}, *PHY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`SHY variation with load, PHY2` — Horizontal shift variation
`scalar`

Horizontal shift, S_{HY}, variation with load, *PHY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz vertical shift at FZNOM, PVY1` — Vertical shift at nominal force
`scalar`

Vertical shift, S_{vy}, at nominal force, F_{ZNOM}, *PVY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz variation with load, PVY2` — Vertical shift variation with load
`scalar`

Vertical shift, S_{vy}, variation with load, *PVY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz variation with camber, PVY3` — Vertical shift variation with camber
`scalar`

Vertical shift, S_{vy}, variation with camber, *PVY3*, dimensionless.

`Svy/Fz variation with load and camber, PVY4` — Vertical shift variation with load and camber
`scalar`

Vertical shift, S_{vy}, variation with load and camber, *PVY4*, dimensionless.

`Cornering stiffness variation with inflation pressure, PPY1` — Stiffness variation with pressure
`scalar`

Cornering stiffness variation with inflation pressure, *PPY1*, dimensionless.

`Cornering stiffness variation with inflation pressure induced nominal load dependency, PPY2` — Stiffness variation with pressure
`scalar`

Cornering stiffness variation with inflation pressure induced nominal load dependency, *PPY2*, dimensionless.

`Linear inflation pressure on peak lateral friction, PPY3` — Pressure
`scalar`

Linear inflation pressure on peak lateral friction, *PPY3*, dimensionless.

`Quadratic inflation pressure on peak lateral friction, PPY4` — Pressure
`scalar`

Quadratic inflation pressure on peak lateral friction, *PPY4*, dimensionless.

`Inflation pressure effect on camber stiffness, PPY5` — Pressure
`scalar`

Inflation pressure effect on camber stiffness, *PPY5*, dimensionless.

`Combined Fy reduction slope factor, RBY1` — Combined lateral force reduction slope factor
`scalar`

Combined lateral force, F_y, reduction slope factor, *RBY1*, dimensionless.

`Fy slope reduction with slip angle, RBY2` — Lateral force slope reduction with slip angle
`scalar`

Lateral force, F_y, slope reduction with slip angle, *RBY2*, dimensionless.

`Fy shift reduction with slip angle, RBY3` — Lateral force shift reduction with slip angle
`scalar`

Lateral force, F_y, shift reduction with slip angle, *RBY3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Fy combined stiffness variation from camber, RBY4` — Lateral force combined stiffness variation from camber
`scalar`

Lateral force, F_y, combined stiffness variation from camber, *RBY4*, dimensionless.

`Fy combined reduction shape factor, RCY1` — Lateral force combined reduction shape factor
`scalar`

Lateral force, F_y, combined reduction shape factor, *RCY1*, dimensionless.

`Fy combined curvature factor, REY1` — Lateral force combined curvature factor
`scalar`

Lateral force, F_y, combined curvature factor, *REY1*, dimensionless.

`Fy combined curvature factor with load, REY2` — Lateral force combined curvature factor with load
`scalar`

Lateral force, F_y, combined curvature factor with load, *REY2*, dimensionless.

`Fy combined reduction shift factor, RHY1` — Lateral force combined reduction shift factor
`scalar`

Lateral force, F_y, combined reduction shift factor, *RHY1*, dimensionless.

`Fy combined reduction shift factor with load, RHY2` — Lateral force combined reduction shift factor with load
`scalar`

Lateral force, F_y, combined reduction shift factor with load, *RHY2*, dimensionless.

`Slip ratio side force Svyk/Muy*Fz at FZNOM, RVY1` — Slip ratio slide force at nominal force
`scalar`

Slip ratio side force at nominal force, F_{ZNOM}, *RVY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Side force Svyk/Muy*Fz variation with load, RVY2` — Side force variation with load
`scalar`

Side force variation with load, *RVY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Side force Svyk/Muy*Fz variation with camber, RVY3` — Side force variation with camber
`scalar`

Side force variation with camber, *RVY3*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip angle, RVY4` — Side force variation with slip angle
`scalar`

Side force variation with slip angle, *RVY4*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip ratio, RVY5` — Side force variation with slip ratio
`scalar`

Side force variation with slip ratio, *RVY5*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip ratio arctangent, RVY6` — Side force variation with slip ratio arctangent
`scalar`

Side force variation with slip ratio arctangent, *RVY6*, dimensionless.

Rolling

`Torque resistance coefficient, QSY1` — Torque resistance
`scalar`

Torque resistance coefficient, *QSY1*, dimensionless.

`Torque resistance due to Fx, QSY2` — Torque resistance due to longitudinal force
`scalar`

Torque resistance due to longitudinal force, F_x, *QSY2*, dimensionless.

`Torque resistance due to speed, QSY3` — Torque resistance due to speed
`scalar`

Torque resistance due to speed, *QSY3*, dimensionless.

`Torque resistance due to speed^4, QSY4` — Torque resistance due to speed
`scalar`

Torque resistance due to speed^4, *QSY4*, dimensionless.

`Torque resistance due to square of camber, QSY5` — Torque resistance due to camber
`scalar`

Torque resistance due to square of camber, *QSY5*, dimensionless.

`Torque resistance due to square of camber and load, QSY6` — Torque resistance due to camber and load
`scalar`

Torque resistance due to square of camber and load, *QSY6*, dimensionless.

`Torque resistance due to load, QSY7` — Torque resistance due to load
`scalar`

Torque resistance due to load, *QSY7*, dimensionless.

`Torque resistance due to pressure, QSY8` — Torque resistance due to pressure
`scalar`

Torque resistance due to pressure, *QSY8*, dimensionless.

Aligning

`Trail slope factor for trail Bpt at FZNOM, QBZ1` — Trail slope factor at nominal force
`scalar`

Trail slope factor for trail *Bpt* at nominal force, F_{ZNOM}, *QBZ1*, dimensionless.

`Bpt slope variation with load, QBZ2` — Slope variation with load
`scalar`

Slope variation with load, *QBZ2*, dimensionless.

`Bpt slope variation with square of load, QBZ3` — Slope variation with load
`scalar`

Slope variation with square of load, *QBZ3*, dimensionless.

`Bpt slope variation with camber, QBZ4` — Slope variation with camber
`scalar`

Slope variation with camber, *QBZ4*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Bpt slope variation with absolute value of camber, QBZ5` — Slope variation with camber
`scalar`

Slope variation with absolute value of camber, *QBZ5*, dimensionless.

`Bpt slope variation with square of camber, QBZ6` — Slope variation with camber
`scalar`

Slope variation with square of camber, *QBZ6*, dimensionless.

`Br of Mzr slope scaling factor, QBZ9` — Slope scaling factor
`scalar`

Slope scaling factor, *QBZ9*, dimensionless.

`Br of Mzr cornering stiffness factor, QBZ10` — Cornering stiffness factor
`0` (default) | `scalar`

Br of *Mzr* cornering stiffness factor, *QBZ10*, dimensionless.

`Cpt pneumatic trail shape factor, QCZ1` — Pneumatic trail shape factor
`scalar`

Pneumatic trail shape factor, C_{pt}, *QCZ1*, dimensionless.

`Dpt peak trail, QDZ1` — Peak trail
`scalar`

Peak trail, D_{pt}, *QDZ1*, dimensionless.

`Dpt peak trail variation with load, QDZ2` — Peak trail variation with load
`scalar`

Peak trail, D_{pt}, variation with load, *QDZ2*, dimensionless.

`Dpt peak trail variation with camber, QDZ3` — Peak trail variation with camber
`scalar`

Peak trail, D_{pt}, variation with camber, *QDZ3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dpt peak trail variation with square of camber, QDZ4` — Peak trail variation with camber
`scalar`

Peak trail, D_{pt}, variation with square of camber, *QDZ4*, dimensionless.

`Dmr peak residual torque, QDZ6` — Peak residual torque

scalar

Peak residual torque, D_{mr}, *QDZ6*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dmr peak residual torque variation with load, QDZ7` — Peak residual torque variation with load

scalar

Peak residual torque, D_{mr}, variation with load, *QDZ7*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dmr peak residual torque variation with camber, QDZ8` — Peak residual torque variation with camber

scalar

Peak residual torque, D_{mr}, variation with camber, *QDZ8*, dimensionless.

`Dmr peak residual torque variation with camber and load, QDZ9` — Peak residual torque variation with camber and load

scalar

Peak residual torque, D_{mr}, variation with camber and load, *QDZ9*, dimensionless.

`Dmr peak residual torque variation with square of camber, QDZ10` — Peak residual torque variation with camber

scalar

Peak residual torque, D_{mr}, variation with square of camber, *QDZ10*, dimensionless.

`Dmr peak residual torque variation with square of load, QDZ11` — Peak residual torque variation with load

scalar

Peak residual torque, D_{mr}, variation with square of load, *QDZ11*, dimensionless.

`Ept trail curvature at FZNOM, QEZ1` — Trail curvature at nominal force

scalar

Trail curvature, E_{pt}, at nominal force, F_{ZNOM}, *QEZ1*, dimensionless.

`Ept variation with load, QEZ2` — Trail curvature variation with load

scalar

Trail curvature, E_{pt} variation with load, *QEZ2*, dimensionless.

`Ept variation with square of load, QEZ3` — Trail curvature variation with load

scalar

Trail curvature, E_{pt} variation with square of load, *QEZ3*, dimensionless.

`Ept variation with sign of alpha-t, QEZ4` — Trail curvature variation

`scalar`

Trail curvature, E_{pt} variation with sign of alpha-t, *QEZ4*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Ept variation with sign of alpha-t and camber, QEZ5` — Variation

`scalar`

Trail curvature, E_{pt} variation with sign of alpha-t and camber, *QEZ5*, dimensionless.

`Sht horizontal trail shift at FZNOM, QHZ1` — Horizontal trail shift at nominal load

`scalar`

Horizontal trail shift, Sh_t, at nominal load, F_{ZNOM}, *QHZ1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Sht variation with load, QHZ2` — Horizontal trail shift variation with load

`scalar`

Horizontal trail shift, Sh_t, variation with load, *QHZ2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Sht variation with camber, QHZ3` — Horizontal trail shift variation with camber

`scalar`

Horizontal trail shift, Sh_t, variation with camber, *QHZ3*, dimensionless.

`Sht variation with load and camber, QHZ4` — Horizontal trail shift variation with load and camber

`scalar`

Horizontal trail shift, Sh_t, variation with load and camber, *QHZ4*, dimensionless.

`Inflation pressure influence on trail length, PPZ1` — Pressure influence on trail length

`scalar`

Inflation pressure influence on trail length, *PPZ1*, dimensionless.

`Inflation pressure influence on residual aligning torque, PPZ2` — Pressure influence on aligning torque

`scalar`

Inflation pressure influence on residual aligning torque, *PPZ2*, dimensionless.

`Nominal value of s/R0: effect of Fx on Mz, SSZ1` — Effect of longitudinal force on aligning torque

`scalar`

Nominal value of s/R0: effect of longitudinal force, F_x, on aligning torque, M_z, *SSZ1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`s/R0 variation with lateral to nominal force ratio, SSZ2` — Variation with lateral to nominal force ratio

`scalar`

Variation with lateral to nominal force ratio, *SSZ2*, dimensionless.

`s/R0 variation with camber, SSZ3` — Variation with camber

`scalar`

Variation with camber, *SSZ3*, dimensionless.

`s/R0 variation with camber and load, SSZ4` — Variation with camber and load

`scalar`

Variation with camber and load, *SSZ4*, dimensionless.

Turnslip

`Fx peak reduction due to spin, PDXP1` — Longitudinal force peak reduction due to spin

`scalar`

Longitudinal force, F_x, peak reduction due to spin, *PDXP1*, dimensionless.

`Fx peak reduction due to spin with varying load, PDXP2` — Longitudinal force peak reduction due to spin

`scalar`

Longitudinal force, F_x, peak reduction due to spin with varying load, *PDXP2*, dimensionless.

`Fx peak reduction due to spin with slip ratio, PDXP3` — Longitudinal force peak reduction due to spin

`scalar`

Longitudinal force, F_x, peak reduction due to spin with slip ratio, *PDXP3*, dimensionless.

`Cornering stiffness reduction due to spin, PKYP1` — Stiffness reduction due to spin

`scalar`

Cornering stiffness reduction due to spin, *PKYP1*, dimensionless.

`Fy peak reduction due to spin, PDYP1` — Lateral force peak reduction due to spin

`scalar`

Lateral force, F_y, peak reduction due to spin, *PDYP1*, dimensionless.

`Fy peak reduction due to spin with varying load, PDYP2` — Lateral force peak reduction due to spin
`scalar`

Lateral force, F_y, peak reduction due to spin with varying load, *PDYP2*, dimensionless.

`Fy peak reduction due to spin with slip angle, PDYP3` — Lateral force peak reduction due to spin
`scalar`

Lateral force, F_y, peak reduction due to spin with slip angle, *PDYP3*, dimensionless.

`Fy peak reduction due to square root of spin, PDYP4` — Lateral force peak reduction due to spin
`scalar`

Lateral force, F_y, peak reduction due to square root of spin, *PDYP4*, dimensionless.

`Fy vs. slip angle response lateral shift limit, PHYP1` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response lateral shift limit, *PHYP1*, dimensionless.

`Fy vs. slip angle response max lateral shift limit, PHYP2` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response max lateral shift limit, *PHYP2*, dimensionless.

`Fy vs. slip angle response max lateral shift limit with load, PHYP3` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response max lateral shift limit with load, *PHYP3*, dimensionless.

`Fy vs. slip angle response lateral shift curvature factor, PHYP4` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response lateral shift curvature factor, *PHYP4*, dimensionless.

`Camber stiffness reduction due to spin, PECP1` — Camber stiffness reduction
`scalar`

Camber stiffness reduction due to spin, *PECP1*, dimensionless.

`Camber stiffness reduction due to spin with load, PECP2` — Camber stiffness reduction
`scalar`

Camber stiffness reduction due to spin with load, *PECP2*, dimensionless.

`Turn slip pneumatic trail reduction factor, QDTP1` — Turn slip pneumatic trail reduction factor
`scalar`

Turn slip pneumatic trail reduction factor, *QDTP1*, dimensionless.

`Turn moment for constant turning and zero longitudinal speed, QCRP1` — Turn moment for constant turning
`scalar`

Turn moment for constant turning and zero longitudinal speed, *QCRP1*, dimensionless.

`Turn slip moment increase with spin at 90deg slip angle, QCRP2` — Turn slip moment
`scalar`

Turn slip moment increase with spin at 90-degree slip angle, *QCRP2*, dimensionless.

`Residual spin torque reduction from side slip, QBRP1` — Residual spin torque reduction
`scalar`

Residual spin torque reduction from side slip, *QBRP1*, dimensionless.

`Turn slip moment peak magnitude, QDRP1` — Turn slip moment peak magnitude
`scalar`

Turn slip moment peak magnitude, *QDRP1*, dimensionless.

`Turn slip moment curvature, QDRP2` — Turn slip moment curvature
`scalar`

Turn slip moment curvature, *QDRP2*, dimensionless.

Version History

Introduced in R2018a

Specify Brake and Tire Parameters for Each Wheel

Behavior changed in R2022b

Starting from R2022b, you can to use the Combined Slip Wheel 2DOF block to specify brake and tire characteristics for each wheel on your vehicle. Specifically, the block allows *N*-by-1 vectors for these parameters:

- **Static friction coefficient, mu_static**
- **Kinetic friction coefficient, mu_kinetic**
- **Disc brake actuator bore, disc_abore**
- **Brake pad mean radius, Rm**
- **Number of brake pads, num_pads**
- **Drum brake actuator bore, disc_abore**
- **Initial rotational velocity, omegao**
- **Rotational damping, br**
- **Wheel mass, MASS**

- **Rotational inertia (rolling axis), IYY**
- **Initial tire displacement, zo**
- **Initial wheel vertical velocity (wheel fixed frame), zdoto**

N is the number of wheels and must match the input signal dimensions.

New Ply steer and Turn slip Parameters

Behavior changed in R2022b

Starting from R2022b, the Combined Slip Wheel 2DOF block includes **Ply steer** and **Turn slip** parameters. To remove ply steer and turn slip from the Magic Formula implementation of these blocks, clear the **Ply steer** and **Turn slip** parameters.

References

[1] Besselink, Igo, Antoine J. M. Schmeitz, and Hans B. Pacejka, "An improved Magic Formula/Swift tyre model that can handle inflation pressure changes," *Vehicle System Dynamics - International Journal of Vehicle Mechanics and Mobility* 48, sup. 1 (2010): 337–52, https://doi.org/10.1080/00423111003748088.

[2] Pacejka, H. B. *Tire and Vehicle Dynamics*. 3rd ed. Oxford, United Kingdom: SAE and Butterworth-Heinemann, 2012.

[3] Schmid, Steven R., Bernard J. Hamrock, and Bo O. Jacobson. *Fundamentals of Machine Elements, SI Version*. 3rd ed. Boca Raton: CRC Press, 2014.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

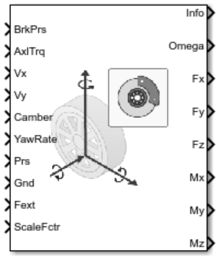
Combined Slip Wheel 2DOF CPI | Combined Slip Wheel 2DOF STI | Fiala Wheel 2DOF | Longitudinal Wheel

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Fiala Wheel 2DOF

Fiala wheel 2DOF wheel with disc, drum, or mapped brake
Library: Vehicle Dynamics Blockset / Wheels and Tires



Description

The Fiala Wheel 2DOF block implements a simplified tire with lateral and longitudinal slip capability based on the E. Fiala model[1]. The block uses a translational friction model to calculate the forces and moments during combined longitudinal and lateral slip, requiring fewer parameters than the Combined Slip Wheel 2DOF block. If you do not have the tire coefficients needed by the Magic Formula, consider using this block for studies that do not involve extensive nonlinear combined lateral slip or lateral dynamics. If your study does require nonlinear combined slip or lateral dynamics, consider using the Combined Slip Wheel 2DOF block.

The block determines the wheel rotation rate, vertical motion, and forces and moments in all six degrees-of-freedom (DOFs) based on the driveline torque, brake pressure, road height, wheel camber angle, and inflation pressure. You can use this block for these types of analyses:

- Driveline and vehicle simulations that require low frequency tire-road and braking forces for vehicle acceleration, braking, and wheel rolling resistance calculations with minimal tire parameters.
- Wheel interaction with an idealized road surface.
- Ride and handling maneuvers for vehicles undergoing mild combined slip. For this analysis, you can connect the block to driveline and chassis components such as differentials, suspension, and vehicle body systems.
- Yaw stability. For this analyses, you can connect this block to more detailed braking system models.
- Tire stiffness and unsprung mass interactions with ground variations, load transfer, or chassis motion using the block vertical DOF.

The block integrates rotational wheel, vertical mass, and braking dynamics models. For the slip-dependent tire forces and moments, the block implements the Fiala tire model.

Use the **Brake Type** parameter to select the brake.

Goal	Brake Type Setting
No braking	None

Goal	Brake Type Setting
Implement brake that converts the brake cylinder pressure into a braking force	`Disc`
Implement simplex drum brake that converts the applied force and brake geometry into a net braking torque	`Drum`
Implement lookup table that is a function of the wheel speed and applied brake pressure	`Mapped`

To calculate the rolling resistance torque, specify one of these **Rolling Resistance** parameters.

Setting	Block Implementation
`None`	None
`Pressure and velocity`	Method in *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. The rolling resistance is a function of tire pressure, normal force, and velocity.
`ISO 28580`	Method specified in ISO 28580:2018, *Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results*.
`Magic Formula`	Magic formula equations from 4.E70 in *Tire and Vehicle Dynamics*. The magic formula is an empirical equation based on fitting coefficients.
`Mapped torque`	Lookup table that is a function of the normal force and spin axis longitudinal velocity.

To calculate vertical motion, specify one of these **Vertical Motion** parameters.

Setting	Block Implementation
`None`	Block passes the applied chassis forces directly through to the rolling resistance and longitudinal force calculations.
`Mapped stiffness and damping`	Vertical motion depends on wheel stiffness and damping. Stiffness is a function of tire sidewall displacement and pressure. Damping is a function of tire sidewall velocity and pressure.

Rotational Wheel Dynamics

The block calculates the inertial response of the wheel subject to:

- Axle losses
- Brake and drive torque
- Tire rolling resistance
- Ground contact through the tire-road interface

The input torque is the summation of the applied axle torque, braking torque, and moment arising from the combined tire torque.

$$T_i = T_a - T_b + T_d$$

For the moment arising from the combined tire torque, the block implements tractive wheel forces and rolling resistance with first-order dynamics. The rolling resistance has a time constant parameterized in terms of a relaxation length.

$$T_d(s) = \frac{1}{\frac{L_e}{|\omega| R_e} s + 1}$$

To calculate the rolling resistance torque, you can specify one of these **Rolling Resistance** parameters.

Setting	Block Implementation
`None`	Block sets rolling resistance, M_y, to zero.
`Pressure and velocity`	Block uses the method in SAE *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. The rolling resistance is a function of tire pressure, normal force, and velocity. Specifically, $M_y = R_e\left\{a + b\lvert V_x\rvert + cV_x^2\right\}\left\{F_z^{\beta} p_i^{\alpha}\right\}\tanh(4V_x)$
`ISO 28580`	Block uses the method specified in ISO 28580:2018, *Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results*. The method accounts for normal load, parasitic loss, and thermal corrections from test conditions. Specifically, $M_y = R_e\left(\frac{F_z C_r}{1 + K_t(T_{amb} - T_{meas})} - F_{pl}\right)\tanh(\omega)$
`Magic Formula`	Block calculates the rolling resistance, M_y, using the Magic Formula equations from 4.E70 in *Tire and Vehicle Dynamics*. The magic formula is an empirical equation based on fitting coefficients.
`Mapped torque`	For the rolling resistance, M_y, the block uses a lookup table that is a function of the normal force and spin axis longitudinal velocity.

If the brakes are enabled, the block determines the braking locked or unlocked condition based on an idealized dry clutch friction model. Based on the lock-up condition, the block implements these friction and dynamic models.

If	Lock-Up Condition	Friction Model	Dynamic Model
$\omega \neq 0$ or $T_S < \lvert T_i + T_f - \omega b\rvert$	Unlocked	$T_f = T_k$ where, $T_k = F_c R_{eff} \mu_k \tanh[4(-\omega_d)]$ $T_s = F_c R_{eff} \mu_s$ $R_{eff} = \frac{2(R_o^3 - R_i^3)}{3(R_o^2 - R_i^2)}$	$\dot{\omega} J = -\omega b + T_i + T_o$

If	Lock-Up Condition	Friction Model	Dynamic Model
$\omega = 0$ and $T_S \geq \lvert T_i + T_f - \omega b \rvert$	Locked	$T_f = T_s$	$\omega = 0$

The equations use these variables.

ω	Wheel angular velocity
a	Velocity-independent force component
b	Linear velocity force component
c	Quadratic velocity force component
L_e	Tire relaxation length
J	Moment of inertia
M_y	Rolling resistance torque
T_a	Applied axle torque
T_b	Braking torque
T_d	Combined tire torque
T_f	Frictional torque
T_i	Net input torque
T_k	Kinetic frictional torque
T_o	Net output torque
T_s	Static frictional torque
F_c	Applied clutch force
F_x	Longitudinal force developed by the tire road interface due to slip
R_{eff}	Effective clutch radius
R_o	Annular disk outer radius
R_i	Annular disk inner radius
R_e	Effective tire radius while under load and for a given pressure
V_x	Longitudinal axle velocity
F_z	Vehicle normal force
C_r	Rolling resistance constant
T_{amb}	Ambient temperature
T_{meas}	Measured temperature for rolling resistance constant
F_{pl}	Parasitic force loss
K_t	Thermal correction factor
α	Tire pressure exponent
β	Normal force exponent
p_i	Tire pressure
μ_s	Coefficient of static friction

μ_k	Coefficient of kinetic friction

Longitudinal Force

The block implements the longitudinal force as a function of wheel slip relative to the road surface using these equations.

Calculation	Equation
Critical slip	$\kappa'_{Critical} = \left\lvert \frac{\mu F_z}{2C_\kappa} \right\rvert$
Longitudinal force	$F_x = \begin{cases} C_k \quad \kappa' & \text{when } \lvert\kappa'\rvert \le \kappa'_{Critical} \\ \tanh(4\kappa')\left(\mu\lvert F_z\rvert - \left\lvert \frac{(\mu F_z)^2}{4\kappa' C_\kappa} \right\rvert\right) & \text{when } \lvert\kappa'\rvert > \kappa'_{Critical} \end{cases}$
Friction coefficient	$\mu = (\mu_s - (\mu_s - \mu_k)\ \kappa_{k\alpha})\lambda_\mu$
Slip coefficient	$\kappa_{k\alpha} = \sqrt{\kappa'^2 + \tan^2(\alpha')}$

The equations use these variables.

κ'	Slip state
F_x	Longitudinal force acting on axle along tire-fixed x-axis,
C_κ	Longitudinal stiffness
F_z	Vertical contact patch normal force along tire-fixed z-axis,
μ	Friction coefficient
μ_s	Coefficient of static friction
μ_k	Coefficient of kinetic friction
κ_{ka}	Comprehensive slip coefficient
α'	Slip angle state
λ_μ	Friction scaling

Lateral Force

The block implements the lateral force as a function of wheel slip angle state using these equations.

Calculation	Equation
Critical slip angle	$\alpha'_{Critical} = \operatorname{atan}(\frac{3\mu\lvert F_z\rvert}{C_a})$
Lateral force	$F_y = \begin{cases} -\tanh(4\alpha')\mu\lvert F_z\rvert & \text{when } \lvert\alpha'\rvert > \alpha'_{Critical} \\ -\tanh(4\alpha')\mu\lvert F_z\rvert\left(1 - \xi^3\right) + \gamma C_\gamma & \text{when } \lvert\alpha'\rvert \le \alpha'_{Critical} \end{cases}$ $\xi = 1 - \frac{C_a\lvert\tan(\alpha')\rvert}{3\mu\lvert F_z\rvert}$

The equations use these variables.

α'	Slip angle state
F_y	Lateral force acting on axle along tire-fixed *y*-axis,
F_z	Vertical contact patch normal force along tire-fixed *z*-axis
C_γ	Camber stiffness
C_α	Lateral stiffness per slip angle
μ	Friction coefficient

Vertical Dynamics

For the vertical dynamics, the block implements these equations.

Calculation	Equation
Vertical response	$\ddot{z}m = F_{ztire} + mg - Fz$
Tire normal force	$F_{ztire} = \rho_z k - b\dot{z}$
Vertical sidewall deflection	$\rho_z = z_{gnd} - z, z \geq 0$

The equations use these variables.

z	Tire deflection along tire-fixed *z*-axis
z_{gnd}	Ground displacement along tire-fixed *z*-axis
F_{ztire}	Tire normal force along tire-fixed *z*-axis
F_z	Vertical force acting on axle along tire-fixed *z*-axis
ρ_z	Vertical sidewall deflection along tire-fixed *z*-axis
k	Vertical sidewall stiffness
b	Vertical sidewall damping

Overturning, Aligning, and Scaling

This table summarizes the overturning, aligning, and scaling implementation.

Calculation	Implementation
Overturning moment	The Fiala model does not define an overturning moment. The block implements this equation, requiring minimal parameters. $M_x = F_y R_e \cos(\gamma)$
Aligning moment	The block implements the aligning moment as a combination of yaw rate damping and slip angle state. $M_z = \begin{cases} \dot{\psi} b_{M_z} & \text{when } \lvert\alpha'\rvert > \alpha'_{Critical} \\ \tanh(4\alpha') w \mu \lvert \mathrm{F}_z \rvert (1-\xi)\xi^3 + \dot{\psi} b_{M_z} & \text{when } \lvert\alpha'\rvert \leq \alpha'_{Critical} \end{cases}$ $\xi = 1 - \frac{C_a \lvert\tan(\alpha')\rvert}{3\mu \lvert F_z \rvert}$
Friction scaling	To vary the coefficient of friction, use the `ScaleFctr` input port.

The equations use these variables.

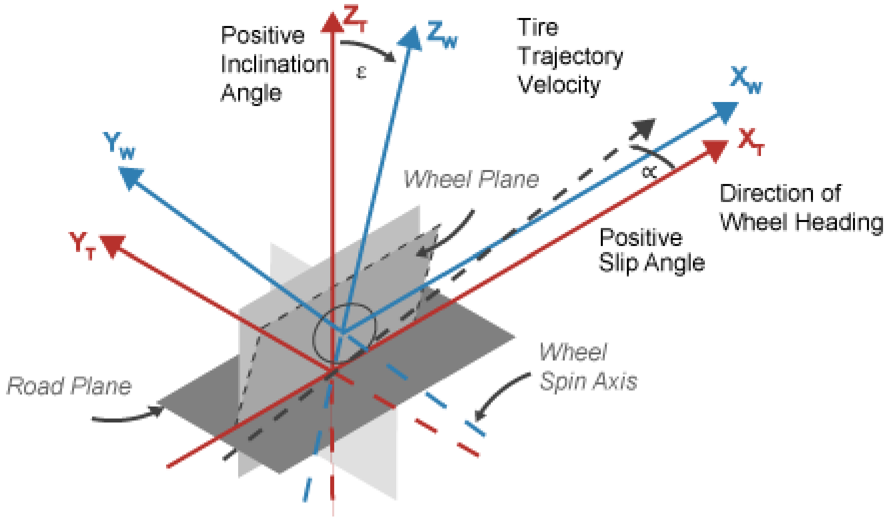
M_x	Overturning moment acting on axle about tire-fixed x-axis
M_z	Aligning moment acting on axle about tire-fixed z-axis
R_e	Effective contact patch to wheel carrier radial distance
γ	Camber angle
k	Vertical sidewall stiffness
b	Vertical sidewall damping
$\dot{\psi}$	Tire angular velocity about the tire-fixed z-axis (yaw rate)
w	Tire width
α'	Slip angle state
b_{Mz}	Linear yaw rate resistance
F_y	Lateral force acting on axle along tire-fixed y-axis
C_γ	Camber stiffness
C_α	Lateral stiffness per slip angle
μ	Friction coefficient
F_z	Vertical contact patch normal force along tire-fixed z-axis

Tire and Wheel Coordinate Systems

To resolve the forces and moments, the block uses the Z-Up orientation of the tire and wheel coordinate systems.

- Tire coordinate system axes (X_T, Y_T, Z_T) are fixed in a reference frame attached to the tire. The origin is at the tire contact with the ground.
- Wheel coordinate system axes (X_W, Y_W, Z_W) are fixed in a reference frame attached to the wheel. The origin is at the wheel center.

Z-Up Orientation[2]



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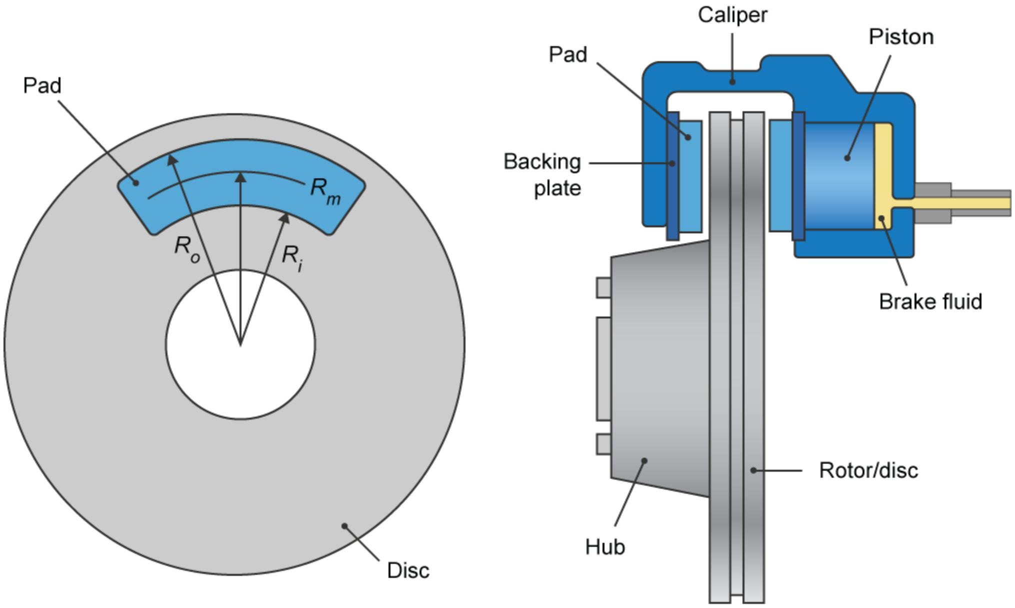
Brakes

Disc

If you specify the **Brake Type** parameter `Disc`, the block implements a disc brake. This figure shows the side and front views of a disc brake.



A disc brake converts brake cylinder pressure from the brake cylinder into force. The disc brake applies the force at the brake pad mean radius.

The block uses these equations to calculate brake torque for the disc brake.

$$T = \begin{cases} \dfrac{\mu P \pi B_a{}^2 R_m N_{pads}}{4} & \text{when } N \neq 0 \\ \dfrac{\mu_{static} P \pi B_a{}^2 R_m N_{pads}}{4} & \text{when } N = 0 \end{cases}$$

$$Rm = \frac{Ro + Ri}{2}$$

The equations use these variables.

T	Brake torque
P	Applied brake pressure
N	Wheel speed
N_{pads}	Number of brake pads in disc brake assembly

μ_{static}	Disc pad-rotor coefficient of static friction
μ	Disc pad-rotor coefficient of kinetic friction
B_a	Brake actuator bore diameter
R_m	Mean radius of brake pad force application on brake rotor
R_o	Outer radius of brake pad
R_i	Inner radius of brake pad

Drum

If you specify the **Brake Type** parameter `Drum`, the block implements a static (steady-state) simplex drum brake. A simplex drum brake consists of a single two-sided hydraulic actuator and two brake shoes. The brake shoes do not share a common hinge pin.

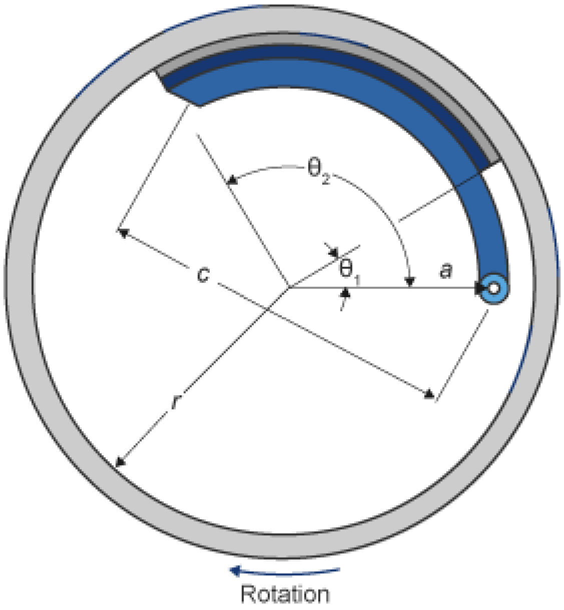
The simplex drum brake model uses the applied force and brake geometry to calculate a net torque for each brake shoe. The drum model assumes that the actuators and shoe geometry are symmetrical for both sides, allowing a single set of geometry and friction parameters to be used for both shoes.

The block implements equations that are derived from these equations in *Fundamentals of Machine Elements*.

$$T_{rshoe} = \left(\frac{\pi \mu c r (\cos\theta_2 - \cos\theta_1) B_a^2}{2\mu\left(2r\left(\cos\theta_2 - \cos\theta_1\right) + a\left(\cos^2\theta_2 - \cos^2\theta_1\right)\right) + ar(2\theta_1 - 2\theta_2 + \sin 2\theta_2 - \sin 2\theta_1)} \right) P$$

$$T_{lshoe} = \left(\frac{\pi \mu c r (\cos\theta_2 - \cos\theta_1) B_a^2}{-2\mu\left(2r\left(\cos\theta_2 - \cos\theta_1\right) + a\left(\cos^2\theta_2 - \cos^2\theta_1\right)\right) + ar(2\theta_1 - 2\theta_2 + \sin 2\theta_2 - \sin 2\theta_1)} \right) P$$

$$T = \begin{cases} T_{rshoe} + T_{lshoe} & \text{when } N \neq 0 \\ (T_{rshoe} + T_{lshoe}) \dfrac{\mu_{static}}{\mu} & \text{when } N = 0 \end{cases}$$



The equations use these variables.

T	Brake torque
P	Applied brake pressure
N	Wheel speed
μ_{static}	Disc pad-rotor coefficient of static friction
μ	Disc pad-rotor coefficient of kinetic friction
T_{rshoe}	Right shoe brake torque
T_{lshoe}	Left shoe brake torque
a	Distance from drum center to shoe hinge pin center
c	Distance from shoe hinge pin center to brake actuator connection on brake shoe
r	Drum internal radius
B_a	Brake actuator bore diameter
Θ_1	Angle from shoe hinge pin center to start of brake pad material on shoe
Θ_2	Angle from shoe hinge pin center to end of brake pad material on shoe

Mapped

If you specify the **Brake Type** parameter `Mapped`, the block uses a lookup table to determine the brake torque.

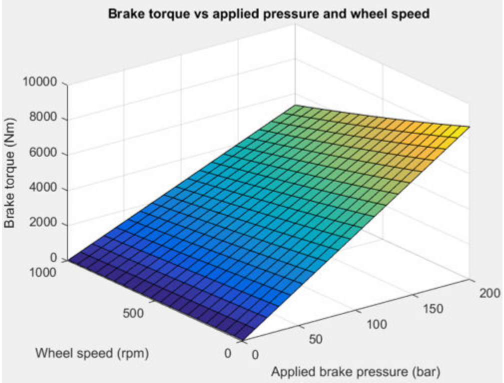
$$T = \begin{cases} f_{brake}(P, N) & \text{when } N \neq 0 \\ \left(\frac{\mu_{static}}{\mu}\right) f_{brake}(P, N) & \text{when } N = 0 \end{cases}$$

The equations use these variables.

T	Brake torque
$f_{brake}(P, N)$	Brake torque lookup table
P	Applied brake pressure
N	Wheel speed
μ_{static}	Friction coefficient of drum pad-face interface under static conditions
μ	Friction coefficient of disc pad-rotor interface

The lookup table for the brake torque, $f_{brake}(P, N)$, is a function of applied brake pressure and wheel speed, where:

- T is brake torque, in N·m.
- P is applied brake pressure, in bar.
- N is wheel speed, in rpm.



Ports

Input

`BrkPrs` — Brake pressure

`scalar` | N-by-1 vector

Brake pressure, in Pa.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

Dependencies

To enable this port, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

`AxlTrq` — Axle torque

`scalar` | N-by-1 vector

Axle torque, T_a, about wheel spin axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Vx` — Longitudinal velocity

`scalar` | N-by-1 vector

Axle longitudinal velocity, V_x, along tire-fixed *x*-axis, in m/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Vy` — Lateral velocity

`scalar` | N-by-1 vector

Axle lateral velocity, V_y, along tire-fixed *y*-axis, in m/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Camber` — Inclination angle
`scalar` | N-by-1 vector

Camber angle, γ, or inclination angle, ε, in rad.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`YawRate` — Tire angular velocity
`scalar` | N-by-1 vector

Tire angular velocity, r, about the tire-fixed z-axis (yaw rate), in rad/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Prs` — Tire inflation pressure
`scalar` | N-by-1 vector

Tire inflation pressure, p_i, in Pa.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Gnd` — Ground displacement
`scalar` | N-by-1 vector

Ground displacement along tire-fixed z-axis, in m. Positive input produces wheel lift.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fext` — Axle force applied to tire
`scalar` | N-by-1 vector

Axle force applied to tire, F_{ext}, along vehicle-fixed z-axis (positive input compresses the tire), in N.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`ScaleFctrs` — Scale factor
`scalar` | N-by-1 vector

Scale factor to account for variations in the coefficient of friction.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

Output

`Info` — Block data
bus

Block data, returned as a bus signal containing these block values.

Signal	Description	Units
`AxlTrq`	Axle torque about wheel-fixed *y*-axis	N·m
`Omega`	Wheel angular velocity about wheel-fixed *y*-axis	rad/s
`Fx`	Longitudinal vehicle force along tire-fixed *x*-axis	N
`Fy`	Lateral vehicle force along tire-fixed *y*-axis	N
`Fz`	Vertical vehicle force along tire-fixed *z*-axis	N
`Mx`	Overturning moment about tire-fixed *x*-axis	N·m
`My`	Rolling resistance torque about tire-fixed *y*-axis	N·m
`Mz`	Aligning moment about tire-fixed *z*-axis	N·m
`Vx`	Vehicle longitudinal velocity along tire-fixed *x*-axis	m/s
`Vy`	Vehicle lateral velocity along tire-fixed *y*-axis	m/s
`Re`	Loaded effective radius	m
`Kappa`	Longitudinal slip ratio	NA
`Alpha`	Side slip angle	rad
`a`	Contact patch half length	m
`b`	Contact patch half width	m
`Gamma`	Camber angle	rad
`psidot`	Tire angular velocity about the tire-fixed *z*-axis (yaw rate)	rad/s
`BrkTrq`	Brake torque about the vehicle-fixed *y*-axis	N·m
`BrkPrs`	Brake pressure	Pa
`z`	Axle vertical displacement along tire-fixed *z*-axis	m
`zdot`	Axle vertical velocity along tire-fixed *z*-axis	m/s
`Gnd`	Ground displacement along tire-fixed *z*-axis (positive input produces wheel lift)	m
`GndFz`	Vertical sidewall force on ground along tire-fixed *z*-axis	N
`Prs`	Tire inflation pressure	Pa

`Omega` — Wheel angular velocity

`scalar` | N-by-1 vector

Wheel angular velocity, ω, about wheel-fixed *y*-axis, in rad/s.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fx` — Longitudinal axle force

`scalar` | N-by-1 vector

Longitudinal force acting on axle, F_x, along tire-fixed *x*-axis, in N. Positive force acts to move the vehicle forward.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fy` — Lateral axle force

`scalar` | N-by-1 vector

Lateral force acting on axle, F_y, along tire-fixed y-axis, in N.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fz` — Vertical axle force

`scalar` | N-by-1 vector

Vertical force acting on axle, F_z, along tire-fixed z-axis, in N.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Mx` — Overturning moment

`scalar` | N-by-1 vector

Longitudinal moment acting on axle, M_x, about tire-fixed x-axis, in N·m.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`My` — Rolling resistive moment

`scalar` | N-by-1 vector

Lateral moment acting on axle, M_y, about tire-fixed y-axis, in N·m.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Mz` — Aligning moment

`scalar` | N-by-1 vector

Vertical moment acting on axle, M_z, about tire-fixed z-axis, in N·m.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

Parameters

Block Options

`Brake Type` — Select type

`None` | `Disc` | `Drum` | `Mapped`

Use the **Brake Type** parameter to select the brake.

Goal	Brake Type Setting
No braking	`None`

Goal	Brake Type Setting
Implement brake that converts the brake cylinder pressure into a braking force	`Disc`
Implement simplex drum brake that converts the applied force and brake geometry into a net braking torque	`Drum`
Implement lookup table that is a function of the wheel speed and applied brake pressure	`Mapped`

`Rolling Resistance` — Select type

`None` (default) | `Pressure and velocity` | `ISO 28580` | `Magic Formula` | `Mapped torque`

To calculate the rolling resistance torque, specify one of these **Rolling Resistance** parameters.

Setting	Block Implementation
`None`	None
`Pressure and velocity`	Method in *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. The rolling resistance is a function of tire pressure, normal force, and velocity.
`ISO 28580`	Method specified in ISO 28580:2018, *Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results*.
`Magic Formula`	Magic formula equations from 4.E70 in *Tire and Vehicle Dynamics*. The magic formula is an empirical equation based on fitting coefficients.
`Mapped torque`	Lookup table that is a function of the normal force and spin axis longitudinal velocity.

Dependencies

Selecting	Parameters
`Pressure and velocity`	**Velocity independent force coefficient, aMy** **Linear velocity force component, bMy** **Quadratic velocity force component, cMy** **Tire pressure exponent, alphaMy** **Normal force exponent, betaMy**

Selecting	Parameters
`ISO 28580`	**Parasitic losses force, Fpl** **Rolling resistance constant, Cr** **Thermal correction factor, Kt** **Measured temperature, Tmeas** **Parasitic losses force, Fpl** **Ambient temperature, Tamb**
`Magic Formula`	**Rolling resistance torque coefficient, QSY** **Longitudinal force rolling resistance coefficient, QSY2** **Linear rotational speed rolling resistance coefficient, QSY3** **Quartic rotational speed rolling resistance coefficient, QSY4** **Camber squared rolling resistance torque, QSY5** **Load based camber squared rolling resistance torque, QSY6** **Normal load rolling resistance coefficient, QSY7** **Pressure load rolling resistance coefficient, QSY8** **Rolling resistance scaling factor, lam_My**
`Mapped torque`	**Spin axis velocity breakpoints, VxMy** **Normal force breakpoints, FzMy** **Rolling resistance torque map, MyMap**

`Vertical Motion` — Select type

`None` (default) | `Mapped stiffness and damping`

To calculate vertical motion, specify one of these **Vertical Motion** parameters.

Setting	Block Implementation
`None`	Block passes the applied chassis forces directly through to the rolling resistance and longitudinal force calculations.
`Mapped stiffness and damping`	Vertical motion depends on wheel stiffness and damping. Stiffness is a function of tire sidewall displacement and pressure. Damping is a function of tire sidewall velocity and pressure.

Selecting	Enables These Parameters
`Mapped stiffness and damping`	**Wheel mass, MASS** **Initial tire displacement, zo** **Initial velocity, zdoto** **Initial wheel vertical velocity (wheel fixed frame), zdoto** **Vertical deflection breakpoints, zFz** **Pressure breakpoints, pFz** **Force due to deflection, Fzz** **Vertical velocity breakpoints, zdotFz** **Force due to velocity, Fzzdot**

Longitudinal and Lateral

`Longitudinal stiffness, Ckappa` — Longitudinal stiffness

`1e7` (default) | `scalar` | *N*-by-1 vector

Longitudinal stiffness, C_κ, specified as a scalar or *N*-by-1 vector, in N. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other longitudinal and lateral parameters.

N is the number of wheels and must match the input signal dimensions.

`Lateral stiffness per slip angle, Calpha` — Lateral stiffness

`4.5e4` (default) | `scalar` | *N*-by-1 vector

Lateral stiffness per slip angle, C_α, specified as a scalar or *N*-by-1 vector, in N/rad. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other longitudinal and lateral parameters.

N is the number of wheels and must match the input signal dimensions.

`Camber stiffness, Cgamma` — Camber stiffness

`1e3` (default) | `scalar` | *N*-by-1 vector

Camber stiffness, C_γ, specified as a scalar or *N*-by-1 vector, in N/rad. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other longitudinal and lateral parameters.

N is the number of wheels and must match the input signal dimensions.

`Kinematic friction, muMin` — Friction

`.8` (default) | `scalar` | *N*-by-1 vector

Kinematic friction, μ_k, specified as a scalar or *N*-by-1 vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other longitudinal and lateral parameters.

N is the number of wheels and must match the input signal dimensions.

`Static friction, muMax` — Friction

`1` (default) | `scalar` | *N*-by-`1` vector

Static friction, μ_s, specified as a scalar or *N*-by-`1` vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other longitudinal and lateral parameters.

N is the number of wheels and must match the input signal dimensions.

`Longitudinal relaxation length, Lrelx` — Length

`.05` (default) | `scalar` | *N*-by-`1` vector

Longitudinal relaxation length, L_{relx}, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other longitudinal and lateral parameters.

N is the number of wheels and must match the input signal dimensions.

`Lateral relaxation length, Lrely` — Length

`.15` (default) | `scalar` | *N*-by-`1` vector

Lateral relaxation length, L_{rely}, in m/rad.

Lateral relaxation length, L_{rely}, specified as a scalar or *N*-by-`1` vector, in m/rad. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other longitudinal and lateral parameters.

N is the number of wheels and must match the input signal dimensions.

Rolling

`Rotational damping, br` — Damping

`scalar` | *N*-by-`1` vector

Rotational damping, specified as a scalar or *N*-by-`1` vector, in N·m·s/rad. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other rotational parameters.

N is the number of wheels and must match the input signal dimensions.

`Rotational inertia (rolling axis), IYY` — Inertia

`scalar` | *N*-by-`1` vector

Rotational inertia (rolling axis), specified as a scalar or *N*-by-`1` vector, in kg·m^2. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other rotational parameters.

N is the number of wheels and must match the input signal dimensions.

`Initial rotational velocity, omegao` — Velocity

`scalar` | *N*-by-`1` vector

Initial rotational velocity, specified as a scalar or *N*-by-`1` vector, in rad/s. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other rotational parameters.

N is the number of wheels and must match the input signal dimensions.

`Unloaded radius, UNLOADED_RADIUS` — Radius
`0.309384029954441` (default) | `scalar`

Unloaded radius, in m.

Pressure and Velocity

`Velocity independent force coefficient, aMy` — Force coefficient
`8e-4` (default) | `scalar`

Velocity-independent force coefficient, *a*, in s/m.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Linear velocity force component, bMy` — Force component
`.001` (default) | `scalar`

Linear velocity force component, *b*, in s/m.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Quadratic velocity force component, cMy` — Force component
`1.6e-4` (default) | `scalar`

Quadratic velocity force component, *c*, in s^2/m^2.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Tire pressure exponent, alphaMy` — Pressure exponent
`-0.003` (default) | `scalar`

Tire pressure exponent, α, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

`Normal force exponent, betaMy` — Force exponent
`0.97` (default) | `scalar`

Normal force exponent, β, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Pressure and velocity`.

ISO 28580

`Parasitic losses force, Fpl` — Force loss

`10` (default) | `scalar`

Parasitic force loss, F_{pl}, in N.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Rolling resistance constant, Cr` — Constant

`1e-3` (default) | `scalar`

Rolling resistance constant, C_r, in N/kN. ISO 28580 specifies the rolling resistance unit as one newton of tractive resistance for every kilonewtons of normal load.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Thermal correction factor, Kt` — Correction factor

`.008` (default) | `scalar`

Thermal correction factor, K_t, in 1/degC.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Measured temperature, Tmeas` — Temperature during testing

`298.15` (default) | `scalar`

Measured ambient temperature, T_{meas}, near tire during tire testing, in K.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Ambient temperature, Tamb` — Temperature

`298.15` (default) | `scalar`

Measured ambient temperature, T_{amb}, near tire in application environment, in K. For example, the measured ambient temperature is the ambient temperature near the tire when the vehicle is on the road.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Input ambient temperature` — Selection

`off` (default) | `on`

Select to create input port `Tamb` to input the measured ambient temperature.

The measured ambient temperature, T_{amb}, is the temperature near tire in application environment, in K. For example, the measured ambient temperature is the ambient temperature near the tire when the vehicle is on the road.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

Magic Formula

`Rolling resistance torque coefficient, QSY1` — Torque coefficient
`0.007` (default) | `scalar`

Rolling resistance torque coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Longitudinal force rolling resistance coefficient, QSY2` — Force resistance coefficient
`0` (default) | `scalar`

Longitudinal force rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Linear rotational speed rolling resistance coefficient, QSY3` — Linear speed coefficient
`0.0015` (default) | `scalar`

Linear rotational speed rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Quartic rotational speed rolling resistance coefficient, QSY4` — Quartic speed coefficient
`8.5e-05` (default) | `scalar`

Quartic rotational speed rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Camber squared rolling resistance torque, QSY5` — Camber resistance torque
`0` (default) | `scalar`

Camber squared rolling resistance torque, in 1/rad^2.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Load based camber squared rolling resistance torque, QSY6` — Load resistance torque
`0` (default) | `scalar`

Load based camber squared rolling resistance torque, in 1/rad^2.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Normal load rolling resistance coefficient, QSY7` — Normal resistance coefficient

`0.9` (default) | `scalar`

Normal load rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Pressure load rolling resistance coefficient, QSY8` — Pressure resistance coefficient

`-0.4` (default) | `scalar`

Pressure load rolling resistance coefficient, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

`Rolling resistance scaling factor, lam_My` — Scale

`1` (default) | `scalar`

Rolling resistance scaling factor, dimensionless.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Magic Formula`.

Mapped

`Spin axis velocity breakpoints, VxMy` — Breakpoints

`-20:1:20` (default) | `vector`

Spin axis velocity breakpoints, in m/s.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Mapped torque`.

`Normal force breakpoints, FzMy` — Breakpoints

`0:200:1e4` (default) | `vector`

Normal force breakpoints, in N.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Mapped torque`.

`Rolling resistance torque map, MyMap` — Lookup table

`array`

Rolling resistance torque versus axle speed and normal force, in N·m.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `Mapped torque`.

Aligning

`Wheel width, WIDTH` — Width
`scalar`

Wheel width, *WIDTH*, in m.

`Linear yaw rate resistance, bMz` — Resistance
`0` | `scalar`

Linear yaw rate resistance, b_{Mz}, in N·m·s/rad.

Brake

`Static friction coefficient, mu_static` — Static friction
`.3` (default) | `scalar` | *N*-by-1 vector

Static friction coefficient, specified as a scalar or *N*-by-1 vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable this parameter, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

`Kinetic friction coefficient, mu_kinetic` — Kinetic friction
`.2` (default) | `scalar` | *N*-by-1 vector

Kinematic friction coefficient, specified as a scalar or *N*-by-1 vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable this parameter, for the **Brake Type** parameter, specify one of these types:

- `Disc`
- `Drum`
- `Mapped`

Disc

`Disc brake actuator bore, disc_abore` — Bore distance
`.05` (default) | `scalar` | *N*-by-1 vector

Disc brake actuator bore, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

`Brake pad mean radius, Rm` — Radius

`.177` (default) | `scalar` | *N*-by-`1` vector

Brake pad mean radius, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

`Number of brake pads, num_pads` — Count

`2` (default) | `scalar` | *N*-by-`1` vector

Number of brake pads, specified as a scalar or *N*-by-`1` vector, dimensionless. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the disc brake parameters, select `Disc` for the **Brake Type** parameter.

Drum

`Drum brake actuator bore, disc_abore` — Bore distance

`0.0508` (default) | `scalar` | *N*-by-`1` vector

Drum brake actuator bore, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other brake parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to drum center distance, drum_a` — Distance

`0.123` (default) | `scalar`

Shoe pin to drum center distance, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin center to force application point distance, drum_c` — Distance

`0.212` (default) | `scalar`

Shoe pin center to force application point distance, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Drum internal radius, drum_r` — Radius

`0.15` (default) | `scalar`

Drum internal radius, in m.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to pad start angle, drum_theta1` — Angle

`0` (default) | `scalar`

Shoe pin to pad start angle, in deg.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

`Shoe pin to pad end angle, drum_theta2` — Angle

`126` (default) | `scalar`

Shoe pin to pad end angle, in deg.

Dependencies

To enable the drum brake parameters, select `Drum` for the **Brake Type** parameter.

Mapped

`Brake actuator pressure breakpoints, brake_p_bpt` — Breakpoints

`vector`

Brake actuator pressure breakpoints, in bar.

Dependencies

To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

`Wheel speed breakpoints, brake_n_bpt` — Breakpoints

`vector`

Wheel speed breakpoints, in rpm.

Dependencies

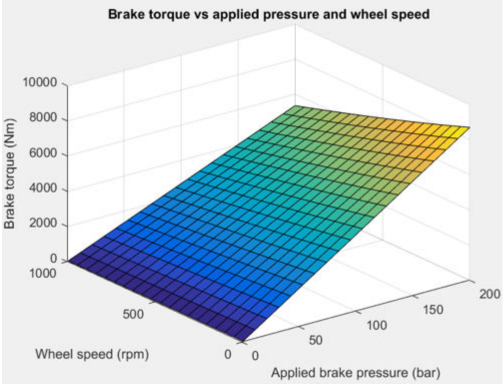
To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

`Brake torque map, f_brake_t` — Lookup table

`array`

The lookup table for the brake torque, $f_{brake}(P, N)$, is a function of applied brake pressure and wheel speed, where:

- *T* is brake torque, in N·m.
- *P* is applied brake pressure, in bar.
- *N* is wheel speed, in rpm.



Dependencies

To enable the mapped brake parameters, select `Mapped` for the **Brake Type** parameter.

Vertical

`Wheel mass, m` — Mass

`9.46491996974568` (default) | `scalar` | *N*-by-1 vector

Wheel mass, specified as a scalar or *N*-by-`1` vector, in kg. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other vertical parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Initial tire deflection, zo` — Deflection

`0` (default) | `scalar` | *N*-by-1 vector

Initial tire displacement, specified as a scalar or *N*-by-`1` vector, in m. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other vertical parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Initial wheel vertical velocity (wheel fixed frame), zdoto` — Velocity

`0` (default) | `scalar` | *N*-by-`1` vector

Initial wheel vertical velocity, specified as a scalar or *N*-by-`1` vector, in m/s. If you specify a scalar, the block uses that value for all wheels. If you specify a vector, you must specify vectors for the other vertical parameters.

N is the number of wheels and must match the input signal dimensions.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Gravitational acceleration, GRAVITY` — Gravity

`-9.81` (default) | `scalar`

Gravitational acceleration, in m/s^2.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

Mapped Stiffness and Damping

`Vertical deflection breakpoints, zFz` — Breakpoints

`[0 .01 .1]` (default) | `vector`

Vector of sidewall deflection breakpoints corresponding to the force table, in m.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Pressure breakpoints, pFz` — Breakpoints

`[10000 1000000]` (default) | `vector`

Vector of pressure data points corresponding to the force table, in Pa.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Force due to deflection, Fzz` — Force

`[0 1e3 1e4; 0 1e4 1e5]` (default) | `vector`

Force due to sidewall deflection and pressure along wheel-fixed *z*-axis, in N.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Vertical velocity breakpoints, zdotFz` — Breakpoints

`[-20 0 20]` (default) | `scalar`

Vector of sidewall velocity breakpoints corresponding to the force due to velocity table, in m.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

`Force due to velocity, Fzzdot` — Force
`[500 0 -500;250 0 -250]` (default) | `array`

Force due to sidewall velocity and pressure along wheel-fixed *z*-axis, in N.

Dependencies

To enable this parameter, set **Vertical Motion** to `Mapped stiffness and damping`.

Simulation

`Maximum normal force, FZMAX` — Force
`10000` (default) | `scalar`

Maximum normal force, in N. Used with all vertical force calculations.

`Minimum normal force, FZMIN` — Force
`0` (default) | `scalar`

Minimum normal force, in N. Used with all vertical force calculations.

`Maximum pressure, PRESMAX` — Pressure
`scalar`

Maximum pressure, *PRESMAX*, in Pa.

`Minimum pressure, PRESMIN` — Pressure
`scalar`

Minimum pressure, *PRESMIN*, in Pa.

`Max allowable slip ratio (absolute), KPUMAX` — Ratio
`scalar`

Max allowable slip ratio (absolute), *KPUMAX*, dimensionless.

`Minimum allowable slip ratio (absolute), KPUMIN` — Ratio
`scalar`

Minimum allowable slip ratio (absolute), *KPUMIN*, dimensionless.

`Max allowable slip angle (absolute), ALPMAX` — Angle
`scalar`

Max allowable slip angle (absolute), *ALPMAX*, in rad.

`Minimum allowable slip angle (absolute), ALPMIN` — Angle
`scalar`

Minimum allowable slip angle (absolute), *ALPMIN*, in rad.

`Maximum allowable camber angle, CAMMAX` — Angle
`scalar`

Maximum allowable camber angle *CAMMAX*, in rad.

`Minimum allowable camber angle, CAMMIN` — Angle

`scalar`

Minimum allowable camber angle, *CAMMIN*, in rad.

`Minimum ambient temperature, TMIN` — Tmin

`0` (default) | `scalar`

Minimum ambient temperature, T_{MIN}, in K.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

`Maximum ambient temperature, TMAX` — Tmax

`400` (default) | `scalar`

Maximum ambient temperature, T_{MAX}, in K.

Dependencies

To create this parameter, select the **Rolling Resistance** parameter `ISO 28580`.

Version History

Introduced in R2019a

Specify Brake and Tire Parameters for Each Wheel

Behavior changed in R2022b

Starting from R2022b, you can to use the Fiala Wheel 2DOF block to specify brake and tire characteristics for each wheel on your vehicle. Specifically, the block allows *N*-by-1 vectors for these parameters:

- **Static friction coefficient, mu_static**
- **Kinetic friction coefficient, mu_kinetic**
- **Disc brake actuator bore, disc_abore**
- **Brake pad mean radius, Rm**
- **Number of brake pads, num_pads**
- **Drum brake actuator bore, disc_abore**
- **Initial rotational velocity, omegao**
- **Rotational damping, br**
- **Wheel mass, m**
- **Rotational inertia (rolling axis), IYY**
- **Initial tire displacement, zo**
- **Initial wheel vertical velocity (wheel fixed frame), zdoto**
- **Longitudinal stiffness, Ckappa**
- **Lateral stiffness per slip angle, Calpha**
- **Camber stiffness, Cgamma**

- **Kinematic friction, muMin**
- **Static friction, muMax**
- **Longitudinal relaxation length, Lrelx**
- **Lateral relaxation length, Lrely**

N is the number of wheels and must match the input signal dimensions.

References

[1] Fiala, E. "Seitenkrafte am Rollenden Luftreifen." *VDI Zeitschrift, V.D.I.*. Vol 96, 1954.

[2] Highway Tire Committee. *Stepwise Coastdown Methodology for Measuring Tire Rolling Resistance*. Standard J2452_199906. Warrendale, PA: SAE International, June 1999.

[3] ISO 28580:2018. *Passenger car, truck and bus tyre rolling resistance measurement method — Single point test and correlation of measurement results*. ISO (International Organization for Standardization), 2018.

[4] Pacejka, H. B. *Tire and Vehicle Dynamics*. 3rd ed. Oxford, UK: SAE and Butterworth-Heinemann, 2012.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

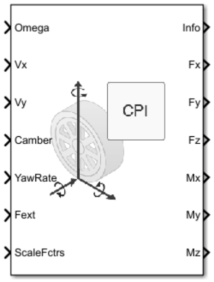
Combined Slip Wheel 2DOF | Combined Slip Wheel 2DOF CPI | Combined Slip Wheel 2DOF STI | Longitudinal Wheel

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Combined Slip Wheel CPI

Combined slip wheel compliant with CPI Tydex standard
Library: Vehicle Dynamics Blockset / Wheels and Tires



Description

The Combined Slip Wheel CPI block implements the longitudinal and lateral behavior of a wheel characterized by the Magic Formula[1, 2] that complies with the contact point interface (CPI) Tyre Data Exchange Format (TYDEX)[3] standard. You can import your own tire data or use fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS). Use the block in driveline and vehicle simulations where low-frequency tire-road interactions are required to determine vehicle acceleration, braking, and wheel-rolling resistance. The block is suitable for applications that require combined lateral slip, for example, in lateral motion and yaw stability studies.

Based on the wheel rotational velocity, longitudinal and lateral velocity, wheel camber angle, and inflation pressure, the block determines the vertical motion, forces, and moments in all six degrees of freedom (DOF). Use the vertical DOF to study tire-suspension resonances from road profiles or chassis motion.

Use the **Tire type** parameter to select the source of the tire data.

Goal	**Action**
Implement the Magic Formula using empirical equations[1, 2]. The equations use fitting coefficients that correspond to the block parameters.	Update the block parameters with fitting coefficients from a file: **1** Set **Tire type** to `External file`. **2** On the **External tire source** pane, Click **Select file**. **3** Select the tire coefficient file. **4** Click **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters. **5** Click **Apply**.

Goal	Action
Implement fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS).	Update the applicable block parameters with GCAPS fitted tire data: 1 Set **Tire type** to the tire that you want to implement. Options include: • `Light passenger car 205/60R15` • `Mid-size passenger car 235/45R18` • `Performance car 225/40R19` • `SUV 265/50R20` • `Light truck 275/65R18` • `Commercial truck 295/75R22.5` 2 Click **Update applicable Tire Parameters with tire type values**. On the **Tire Parameters** tab, the block updates the applicable parameters, including **Wheel width**, **Rim radius**, and **Wheel mass**. 3 Click **Apply**.

Rotational Wheel Dynamics

The block calculates the inertial response of the wheel subject to:

- Axle losses
- Tire rolling resistance
- Ground contact through the tire-road interface

To implement the Magic Formula, the block uses these equations.

Calculation	Equations
Longitudinal force	*Tire and Vehicle Dynamics*[2] equations 4.E9 through 4.E57
Lateral force - pure sideslip	*Tire and Vehicle Dynamics*[2] equations 4.E19 through 4.E30
Lateral force - combined slip	*Tire and Vehicle Dynamics*[2] equations 4.E58 through 4.E67
Vertical dynamics	*Tire and Vehicle Dynamics*[2] equations 4.E68, 4.E1, 4.E2a, and 4.E2b
Overturning couple	*Tire and Vehicle Dynamics*[2] equation 4.E69
Rolling resistance	• *An improved Magic Formula/Swift tyre model that can handle inflation pressure changes*[2] equation 6.1.2 • *Tire and Vehicle Dynamics*[2] equation 4.E70
Aligning moment	*Tire and Vehicle Dynamics*[2] equation 4.E31 through 4.E49
Aligning torque - combined slip	*Tire and Vehicle Dynamics*[2] equation 4.E71 through 4.E78 If you clear **Include turn slip**, the block sets some of these equations to 1.

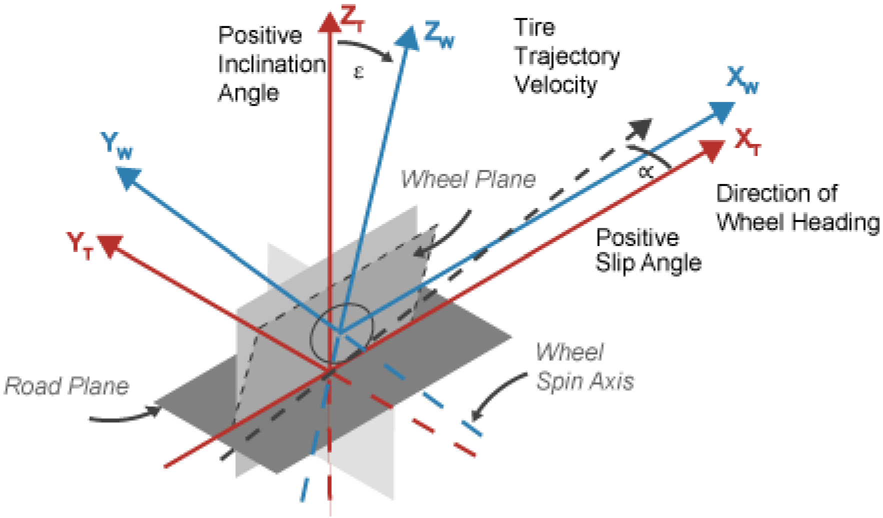
CPI Tire Coordinate System

The block uses tire coordinate system axes (X_T, Y_T, Z_T) that are fixed in a reference frame attached to the tire. The origin is at the tire contact with the ground.

The CPI tire coordinate system is shown in red.

Note The CPI tire coordinate system (red) is equivalent to the TYDEX wheel-axis coordinate system.

[3]



Axis	Description
X_T	X_T and Y_T are parallel to the road plane. The intersection of the wheel plane and the road plane define the orientation of the X_T axis.
Y_T	Y_T is the projection of the wheel spin axis on the ground.
Z_T	Z_T points upward.

Ports

Input

`Omega` — Rotational velocity
`scalar` | N-by-1 vector

Tire rotational velocity, ω, about wheel spin axis, in rad/s.

Vector is the number of wheels, N, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

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`Vx` — Longitudinal velocity

`scalar` | N-by-1 vector

Axle longitudinal velocity, V_x, along tire-fixed *x*-axis, in m/s.

Vector is the number of wheels, *N*, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

`Vy` — Lateral velocity

`scalar` | N-by-1 vector

Axle lateral velocity, V_y, along tire-fixed *y*-axis, in m/s.

Vector is the number of wheels, *N*, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

`Camber` — Inclination angle

`scalar` | N-by-1 vector

Camber angle, γ, or inclination angle, ε, in rad.

Vector is the number of wheels, *N*, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

`YawRate` — Tire angular velocity

`scalar` | N-by-1 vector

Tire angular velocity, *r*, about the tire-fixed *z*-axis (yaw rate), in rad/s.

Vector is the number of wheels, *N*, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

`Fext` — Axle force applied to tire

`scalar` | N-by-1 vector

Axle force applied to tire, F_{ext}, along vehicle-fixed *z*-axis (positive input compresses the tire), in N.

Vector is the number of wheels, *N*, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

`ScaleFctrs` — Road friction scale factors

2-by-N array

Magic formula road friction scale factor array. Array dimensions are 2 by the number of wheels, *N*.

The Magic Formula equations use scale factors to account for static or simulation run-time variations. Nominally, most are set to 1.

Array Element	Variable	Scale Factor
`ScaleFctrs(1,1)`	`lam_mux`	Longitudinal peak friction coefficient
`ScaleFctrs(2,1)`	`lam_muy`	Lateral peak friction coefficient

`Prs` — Tire inflation pressure

`scalar` | N-by-1 vector

Tire inflation pressure, p_i, in Pa.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

Dependencies

To create this port, select **Input tire pressure**.

Output

`Info` — Block data

bus

Block data, returned as a bus signal containing these block values.

Signal	Description	Units
`Omega`	Wheel angular velocity about wheel-fixed *y*-axis	rad/s
`Fx`	Longitudinal vehicle force along tire-fixed *x*-axis	N
`Fy`	Lateral vehicle force along tire-fixed *y*-axis	N
`Fz`	Vertical vehicle force along tire-fixed *z*-axis	N
`Mx`	Overturning moment about tire-fixed *x*-axis	N·m
`My`	Rolling resistance torque about tire-fixed *y*-axis	N·m
`Mz`	Aligning moment about tire-fixed *z*-axis	N·m
`Vx`	Vehicle longitudinal velocity along tire-fixed *x*-axis	m/s
`Vy`	Vehicle lateral velocity along tire-fixed *y*-axis	m/s
`Re`	Loaded effective radius	m
`Kappa`	Longitudinal slip ratio	NA
`Alpha`	Side slip angle	rad
`a`	Contact patch half length	m
`b`	Contact patch half width	m
`Gamma`	Camber angle	rad
`psidot`	Tire angular velocity about the tire-fixed *z*-axis (yaw rate)	rad/s
`rhoz`	Axle vertical displacement along tire-fixed *z*-axis	m
`FNormal`	Vertical sidewall force on ground along tire-fixed *z*-axis	N
`Prs`	Tire inflation pressure	Pa

Fx — Longitudinal axle force

`scalar` | N-by-1 vector

Longitudinal force acting on axle, F_x, along tire-fixed *x*-axis, in N. Positive force acts to move the vehicle forward.

Vector is the number of wheels, N, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fy` — Lateral axle force

`scalar` | N-by-1 vector

Lateral force acting on axle, F_y, along tire-fixed *y*-axis, in N.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Fz` — Vertical axle force

`scalar` | N-by-1 vector

Vertical force acting on axle, F_z, along tire-fixed *z*-axis, in N.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Mx` — Overturning moment

`scalar` | N-by-1 vector

Longitudinal moment acting on axle, M_x, about tire-fixed *x*-axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`My` — Rolling resistive moment

`scalar` | N-by-1 vector

Lateral moment acting on axle, M_y, about tire-fixed *y*-axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

`Mz` — Aligning moment

`scalar` | N-by-1 vector

Vertical moment acting on axle, M_z, about tire-fixed *z*-axis, in N·m.

Vector is the number of wheels, *N*, by `1`. If you provide a scalar value, the block assumes that number of wheels is one.

Parameters

Block Options

`Tire type` — Type

`External file` (default) | `Light passenger car 205/60R15` | `Mid-size passenger car 235/45R18` | `Performance car 225/40R19` | `SUV 265/50R20` | `Light truck 275/65R18` | `Commercial truck 295/75R22.5`

Use the **Tire type** parameter to select the source of the tire data.

Goal	Action
Implement the Magic Formula using empirical equations[1, 2]. The equations use fitting coefficients that correspond to the block parameters.	Update the block parameters with fitting coefficients from a file: 1 Set **Tire type** to `External file`. 2 On the **External tire source** pane, Click **Select file**. 3 Select the tire coefficient file. 4 Click **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters. 5 Click **Apply**.
Implement fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS).	Update the applicable block parameters with GCAPS fitted tire data: 1 Set **Tire type** to the tire that you want to implement. Options include: • `Light passenger car 205/60R15` • `Mid-size passenger car 235/45R18` • `Performance car 225/40R19` • `SUV 265/50R20` • `Light truck 275/65R18` • `Commercial truck 295/75R22.5` 2 Click **Update applicable Tire Parameters with tire type values**. On the **Tire Parameters** tab, the block updates the applicable parameters, including **Wheel width**, **Rim radius**, and **Wheel mass**. 3 Click **Apply**.

`Tire file or object, tireParamSet` — Tire file

`.mat` | `.tir` | `.txt`

Tire file `.tir` or object containing empirical data to model tire longitudinal and lateral behavior with the Magic Formula. If you provide an `.txt` file, make sure the file contains names that correspond to the block parameters.

Update the block parameters with fitting coefficients from a file:

- Set **Tire type** to `External file`.
- On the **External tire source** pane, select **Select file**.
- Select the tire coefficient file.
- Select **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters.
- Select **Apply**.

`Tire side` — Select tire side

`Right` (default) | `Left` | `Symmetric`

Specify the tire side.

`Tire pressure` — Pressure

`220000` (default) | `scalar`

Tire inflation pressure, *p*, in Pa.

Dependencies

To enable this parameter, clear **Input tire pressure**.

`Ply steer` — Include ply steer

`on` (default) | `off`

Select to include ply steer in the Magic Formula equations.

By default, the blocks include ply steer and turn slip in the Magic Formula equations. The equations are fit to flat-belt test data and predict a number of tire effects, including ply steer and turn slip. Consider removing the effects if your:

- Test data does not include ply steer or turn slip data.
- Analysis does not require ply steer or turn slip effects.

If you clear **Ply steer**, the block internally sets these parameters to 0:

- **Vertical shift of overturning moment, QSX1**
- **Combined slip Fx shift factor reduction, RHX1**
- **Efy curvature constant camber dependency, PEY3**
- **SHY horizontal shift at FZNOM, PHY1**
- **SHY variation with load, PHY2**
- **Svy/Fz vertical shift at FZNOM, PVY1**
- **Svy/Fz variation with load, PVY2**
- **Fy shift reduction with slip angle, RBY3**
- **Slip ratio side force Svyk/Muy*Fz at FZNOM, RVY1**
- **Side force Svyk/Muy*Fz variation with load, RVY2**
- **Bpt slope variation with camber, QBZ4**
- **Dpt peak trail variation with camber, QDZ3**
- **Dmr peak residual torque, QDZ6**
- **Dmr peak residual torque variation with load, QDZ7**
- **Ept variation with sign of alpha-t, QEZ4**
- **Sht horizontal trail shift at FZNOM, QHZ1**
- **Sht variation with load, QHZ2**
- **Nominal value of s/R0: effect of Fx on Mz, SSZ1**

`Turn slip` — Include turn slip

`on` (default) | `off`

Select to include ply steer in Magic Formula equations.

By default, the blocks include ply steer and turn slip in the Magic Formula equations. The equations are fit to flat-belt test data and predict a number of tire effects, including ply steer and turn slip. Consider removing the effects if your:

- Test data does not include ply steer or turn slip data.
- Analysis does not require ply steer or turn slip effects.

If you clear **Turn slip**, the block internally:

- Sets the Magic Formula turn slip equations to 1. Specifically, equations 4.E77, 4.E79, 4.E81, 4.E83, 4.E84, 4.E92, 4.E102, 4.E101, and 4.E105.[2].
- Uses Magic Formula terms that effect horizontal shift.
- Uses Magic Formula small turn slip values in 4.E27[2].

Simulation

`Maximum pressure, PRESMAX` — Pressure
`scalar`

Maximum pressure, *PRESMAX*, in Pa.

`Minimum pressure, PRESMIN` — Pressure
`scalar`

Minimum pressure, *PRESMIN*, in Pa.

`Maximum normal force, FZMAX` — Force
`scalar`

Maximum normal force, *FZMAX*, in N.

`Minimum normal force, FZMIN` — Force
`scalar`

Minimum normal force, *FZMIN*, in N.

`Velocity tolerance used to handle low velocity situations, VXLOW` — Tolerance
`scalar`

Velocity tolerance used to handle low-velocity situations, *VXLOW*, in m/s.

`Max allowable slip ratio (absolute), KPUMAX` — Ratio
`scalar`

Max allowable slip ratio (absolute), *KPUMAX*, dimensionless.

`Minimum allowable slip ratio (absolute), KPUMIN` — Ratio
`scalar`

Minimum allowable slip ratio (absolute), *KPUMIN*, dimensionless.

`Max allowable slip angle (absolute), ALPMAX` — Angle
`scalar`

Max allowable slip angle (absolute), *ALPMAX*, in rad.

`Minimum allowable slip angle (absolute), ALPMIN` — Angle
`scalar`

Minimum allowable slip angle (absolute), *ALPMIN*, in rad.

`Maximum allowable camber angle, CAMMAX` — Angle
`scalar`

Maximum allowable camber angle *CAMMAX*, in rad.

`Minimum allowable camber angle, CAMMIN` — Angle
`scalar`

Minimum allowable camber angle, *CAMMIN*, in rad.

`Nominal longitudinal speed, LONGVL` — Speed
`scalar`

Nominal longitudinal speed, *LONGVL*, in m/s.

`Default tyre side, tyreside` — Side
`'Right'` (default) | `char`

Default tyre side, *tyreside*, dimensionless.

Wheel

`Initial rotational velocity, omegao` — Velocity
`scalar`

Initial rotational velocity, specified as a scalar, in rad/s.

`Rotational damping, br` — Damping
`scalar`

Rotational damping, specified as a scalar, in N·m·s/rad.

`Unloaded radius, UNLOADED_RADIUS` — Radius
`scalar`

Unloaded radius, *UNLOADED_RADIUS*, in m.

`Nominal pressure, NOMPRES` — Pressure
`scalar`

Nominal pressure, *NOMPRES*, in Pa.

`Nominal normal force, FNOMIN` — Force
`scalar`

Nominal normal force, *FNOMIN*, in N.

`Wheel width, WIDTH` — Width
`scalar`

Wheel width, *WIDTH*, in m.

`Rim radius, RIM_RADIUS` — Radius
`scalar`

Rim radius, *RIM_RADIUS*, in m.

`Nominal aspect ratio, ASPECT_RATIO` — Ratio
`scalar`

Nominal aspect ratio, *ASPECT_RATIO*, dimensionless.

Inertial

`Wheel mass, MASS` — Mass
`scalar`

Wheel mass, specified as a scalar, in kg.

`Rotational inertia (rolling axis), IYY` — Inertia
`scalar`

Rotational inertia (rolling axis), specified as a scalar, in kg·m^2.

`Gravity, GRAVITY` — Gravity
`scalar`

Gravity, *GRAVITY*, in m/s^2.

Vertical

`Initial tire displacement, zo` — Displacement
`scalar`

Initial tire displacement, *zo*, in m.

`Initial wheel vertical velocity (wheel fixed frame), zdoto` — Velocity
`scalar`

Initial wheel vertical velocity (wheel fixed frame), *zdoto*, in m/s.

`Effective rolling radius at low load stiffness, BREFF` — Stiffness
`scalar`

Effective rolling radius at low load stiffness, *BREFF*, dimensionless.

`Effective rolling radius peak value, DREFF` — Radius
`scalar`

Effective rolling radius peak value, *DREFF*, dimensionless.

`Effective rolling radius at high load stiffness, FREFF` — Radius
`scalar`

Effective rolling radius at high load stiffness, *FREFF*, dimensionless.

`Unloaded to nominal rolling radius ratio, Q_RE0` — Ratio
`scalar`

Unloaded to nominal rolling radius ratio, *Q_RE0*, dimensionless.

`Radius rotational speed dependence, Q_V1` — Speed
`scalar`

Radius rotational speed dependence, *Q_V1*, dimensionless.

`Stiffness rotational speed dependence, Q_V2` — Speed
`scalar`

Stiffness rotational speed dependence, *Q_V2*, dimensionless.

`Linear load change with deflection, Q_FZ1` — Load change
`scalar`

Linear load change with deflection, *Q_FZ1*, dimensionless.

`Quadratic load change with deflection, Q_FZ2` — Load change
`scalar`

Quadratic load change with deflection, *Q_FZ2*, dimensionless.

`Linear load change with deflection and quadratic camber, Q_FZ3` — Load change
`scalar`

Linear load change with deflection and quadratic camber, *Q_FZ3*, dimensionless.

`Load response to longitudinal force, Q_FCX` — Force
`scalar`

Load response to longitudinal force, *Q_FCX*, dimensionless.

`Load response to lateral force, Q_FCY` — Force
`scalar`

Load response to lateral force, *Q_FCY*, dimensionless.

`Vertical stiffness change due to lateral load dependency on lateral stiffness, Q_FCY2` — Stiffness
`scalar`

Vertical stiffness change due to lateral load dependency on lateral stiffness, *Q_FCY2*, dimensionless.

`Stiffness response to pressure, PFZ1` — Stiffness
`scalar`

Stiffness response to pressure, *PFZ1*, dimensionless.

`Vertical tire stiffness, VERTICAL_STIFFNESS` — Stiffness
`scalar`

Vertical tire stiffness, *VERTICAL_STIFFNESS*, in N/m.

`Vertical tire damping, VERTICAL_DAMPING` — Damping
`scalar`

Vertical tire damping, *VERTICAL_DAMPING*, in N·s/m.

`Rim bottoming out offset, BOTTOM_OFFST` — Offset
`scalar`

Rim bottoming out offset, *BOTTOM_OFFST*, in m.

`Bottoming out stiffness, BOTTOM_STIFF` — Stiffness
`scalar`

Bottoming out stiffness, *BOTTOM_STIFF*, in N/m.

`Linear load dependent camber angle influence on vertical stiffness, Q_CAM1` — Stiffness
`scalar`

Linear load dependent camber angle influence on vertical stiffness, *Q_CAM1*, dimensionless.

`Quadratic load dependent camber angle influence on vertical stiffness, Q_CAM2` — Stiffness
`scalar`

Quadratic load dependent camber angle influence on vertical stiffness, *Q_CAM2*, dimensionless.

`Linear load and camber angle dependent reduction on vertical stiffness, Q_CAM3` — Stiffness
`scalar`

Linear load and camber angle dependent reduction on vertical stiffness, *Q_CAM3*, dimensionless.

Structural

`Longitudinal stiffness, LONGITUDINAL_STIFFNESS` — Stiffness
`scalar`

Longitudinal stiffness, *LONGITUDINAL_STIFFNESS*, in N/m.

`Lateral stiffness, LATERAL_STIFFNESS` — Stiffness
`scalar`

Longitudinal stiffness, *LATERAL_STIFFNESS*, in N/m.

`Linear vertical deflection influence on longitudinal stiffness, PCFX1` — Deflection influence
`scalar`

Linear vertical deflection influence on longitudinal stiffness, *PCFX1*, dimensionless.

`Quadratic vertical deflection influence on longitudinal stiffness, PCFX2` — Deflection influence
`scalar`

Quadratic vertical deflection influence on longitudinal stiffness, *PCFX2*, dimensionless.

`Pressure dependency on longitudinal stiffness, PCFX3` — Pressure dependency
`scalar`

Pressure dependency on longitudinal stiffness, *PCFX3*, dimensionless.

`Linear vertical deflection influence on lateral stiffness, PCFY1` — Deflection influence
`scalar`

Linear vertical deflection influence on lateral stiffness, *PCFY1*, dimensionless.

`Quadratic vertical deflection influence on lateral stiffness, PCFY2` — Deflection influence
`scalar`

Quadratic vertical deflection influence on lateral stiffness, *PCFY2*, dimensionless.

`Pressure dependency on longitudinal stiffness, PCFY3` — Pressure dependency
`scalar`

Pressure dependency on longitudinal stiffness, *PCFY3*, dimensionless.

Contact Patch

`Contact length square root term, Q_RA1` — Length term
`scalar`

Contact length square root term, *Q_RA1*, dimensionless.

`Contact length linear term, Q_RA2` — Length term
`scalar`

Contact length linear term, *Q_RA2*, dimensionless.

`Contact width root term, Q_RB1` — Width term
`scalar`

Contact width root term, *Q_RB1*, dimensionless.

`Contact width linear term, Q_RB2` — Width term
`scalar`

Contact width linear term, *Q_RB2*, dimensionless.

Longitudinal

`Cfx shape factor, PCX1` — Shape factor
`scalar`

Shape factor, C_{fx}, *PCX1*, dimensionless.

`Longitudinal friction at nominal normal load, PDX1` — Friction
`scalar`

Longitudinal friction at nominal normal load, *PDX1*, dimensionless.

`Frictional variation with load, PDX2` — Friction variation
`scalar`

Frictional variation with load, *PDX2*, dimensionless.

`Frictional variation with camber, PDX3` — Friction variation
`scalar`

Frictional variation with camber, *PDX3*, in 1/rad^2.

`Longitudinal curvature at nominal normal load, PEX1` — Curvature
`scalar`

Longitudinal curvature at nominal normal load, *PEX1*, dimensionless.

`Variation of curvature factor with load, PEX2` — Curvature variation
`scalar`

Variation of curvature factor with load, *PEX2*, dimensionless.

`Variation of curvature factor with square of load, PEX3` — Curvature variation
`scalar`

Variation of curvature factor with square of load, *PEX3*, dimensionless.

`Longitudinal curvature factor with slip, PEX4` — Curvature
`scalar`

Longitudinal curvature factor with slip, *PEX4*, dimensionless.

`Longitudinal slip stiffness at nominal normal load, PKX1` — Stiffness
`scalar`

Longitudinal slip stiffness at nominal normal load, *PKX1*, dimensionless.

`Variation of slip stiffness with load, PKX2` — Stiffness variation
`scalar`

Variation of slip stiffness with load, *PKX2*, dimensionless.

`Slip stiffness exponent factor, PKX3` — Slip stiffness
`scalar`

Slip stiffness exponent factor, *PKX3*, dimensionless.

`Horizontal shift in slip ratio at nominal normal load, PHX1` — Slip ratio shift
`scalar`

Horizontal shift in slip ratio at nominal normal load, *PHX1*, dimensionless.

`Variation of horizontal slip ratio with load, PHX2` — Slip variation
`scalar`

Variation of horizontal slip ratio with load, *PHX2*, dimensionless.

`Vertical shift in load at nominal normal load, PVX1` — Load shift
`scalar`

Vertical shift in load at nominal normal load, *PVX1*, dimensionless.

`Variation of vertical shift with load, PVX2` — Load variation
`scalar`

Variation of vertical shift with load, *PVX2*, dimensionless.

`Linear variation of longitudinal slip stiffness with tire pressure, PPX1` — Stiffness variation
`scalar`

Linear variation of longitudinal slip stiffness with tire pressure, *PPX1*, dimensionless.

`Quadratic variation of longitudinal slip stiffness with tire pressure, PPX2` — Stiffness variation
`scalar`

Quadratic variation of longitudinal slip stiffness with tire pressure, *PPX2*, dimensionless.

`Linear variation of peak longitudinal friction with tire pressure, PPX3` — Friction variation
`scalar`

Linear variation of peak longitudinal friction with tire pressure, *PPX3*, dimensionless.

`Quadratic variation of peak longitudinal friction with tire pressure, PPX4` — Friction variation
`scalar`

Quadratic variation of peak longitudinal friction with tire pressure, *PPX4*, dimensionless.

`Combined slip Fx slope factor reduction, RBX1` — Combined slip longitudinal force slope factor reduction
`scalar`

Combined slip longitudinal force, F_x, slope factor reduction, *RBX1*, dimensionless.

`Slip ratio Fx slope reduction variation, RBX2` — Slip ratio longitudinal force slope reduction variation
`scalar`

Slip ratio longitudinal force, F_x, slope reduction variation, *RBX2*, dimensionless.

`Camber influence on combined slip Fx stiffness, RBX3` — Camber influence on combined slip longitudinal force stiffness
`scalar`

Camber influence on combined slip longitudinal force, F_x, stiffness, *RBX3*, dimensionless.

`Shape factor for combined slip Fx reduction, RCX1` — Shape factor for combined slip longitudinal force reduction
`scalar`

Shape factor for combined slip longitudinal force, F_x, reduction, *RCX1*, dimensionless.

`Combined Fx curvature factor, REX1` — Combined longitudinal force curvature factor
`scalar`

Combined longitudinal force, F_x, curvature factor, *REX1*, dimensionless.

`Combined Fx curvature factor with load, REX2` — Combined longitudinal force curvature factor
`scalar`

Combined longitudinal force, F_x, curvature factor with load, *REX2*, dimensionless.

`Combined slip Fx shift factor reduction, RHX1` — Combined slip longitudinal force slip factor
`scalar`

Combined slip longitudinal force, F_x, shift factor reduction, *RHX1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

Overturning

`Vertical shift of overturning moment, QSX1` — Overturning moment
`scalar`

Vertical shift of overturning moment, *QSX1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Overturning moment due to camber, QSX2` — Overturning moment due to camber
`scalar`

Overturning moment due to camber, *QSX2*, dimensionless.

`Overturning moment due to Fy, QSX3` — Overturning moment due to lateral force
`scalar`

Overturning moment due to lateral force, *QSX3*, dimensionless.

`Mx combined lateral force load and camber, QSX4` — Overturning moment
`scalar`

Overturning moment, M_x, combined lateral force load and camber, *QSX4*, dimensionless.

`Mx load effect due to lateral force and camber, QSX5` — Overturning moment
`scalar`

Overturning moment, M_x, load effect due to lateral force and camber, *QSX5*, dimensionless.

`Mx load effect due to B-factor, QSX6` — Overturning moment
`scalar`

Overturning moment, M_x, load effect due to B-factor, *QSX6*, dimensionless.

`Mx due to camber and load, QSX7` — Overturning moment
`scalar`

Overturning moment, M_x, due to camber and load, *QSX7*, dimensionless.

`Mx due to lateral force and load, QSX8` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force and load, *QSX8*, dimensionless.

`Mx due to B-factor of lateral force and load, QSX9` — Overturning moment
`scalar`

Overturning moment, M_x, due to B-factor of lateral force and load, *QSX9*, dimensionless.

`Mx due to vertical force and camber, QSX10` — Overturning moment
`scalar`

Overturning moment, M_x, due to vertical force and camber, *QSX10*, dimensionless.

`Mx due to B-factor of vertical force and camber, QSX11` — Overturning moment
`scalar`

Overturning moment, M_x, due to B-factor of vertical force and camber, *QSX11*, dimensionless.

`Mx due to squared camber, QSX12` — Overturning moment
`scalar`

Overturning moment, M_x, due to squared camber, *QSX12*, dimensionless.

`Mx due to lateral force, QSX13` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force, *QSX13*, dimensionless.

`Mx due to lateral force with camber, QSX14` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force with camber, *QSX14*, dimensionless.

`Mx due to inflation pressure, PPMX1` — Overturning moment due to pressure
`scalar`

Overturning moment, M_x, due to inflation pressure, *PPMX1*, dimensionless.

Lateral

`Cfy shape factor for lateral force, PCY1` — Lateral force shape factor
`scalar`

Shape factor for lateral force, C_{fy}, *PCY1*, dimensionless.

`Lateral friction muy, PDY1` — Lateral friction
`scalar`

Lateral friction, μ_y, *PDY1*, dimensionless.

`Lateral friction variation of muy with load, PDY2` — Lateral friction variation
`scalar`

Variation of lateral friction, μ_y, with load, *PDY2*, dimensionless.

`Lateral friction variation of muy with squared camber, PDY3` — Lateral friction variation
`scalar`

Variation of lateral friction, μ_y, with squared camber, *PDY3*, dimensionless.

`Efy lateral curvature at nominal force FZNOM, PEY1` — Lateral curvature at nominal force
`scalar`

Lateral curvature, Ef_y, at nominal force, F_{ZNOM}, *PEY1*, dimensionless.

`Efy curvature variation with load, PEY2` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with load, *PEY2*, dimensionless.

`Efy curvature constant camber dependency, PEY3` — Lateral curvature constant
`scalar`

Lateral curvature, Ef_y, constant camber dependency, *PEY3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Efy curvature variation with camber, PEY4` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with camber, *PEY4*, dimensionless.

`Efy curvature variation with camber squared, PEY5` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with camber squared, *PEY5*, dimensionless.

`Maximum KFy/FZNOM stiffness, PKY1` — Maximum stiffness
`scalar`

Maximum lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, ratio, *PKY1*, dimensionless.

`Load at maximum KFy/FZNOM stiffness, PKY2` — Load
`scalar`

Load at maximum lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, ratio, *PKY2*, dimensionless.

`KFy/FZNOM stiffness variation with camber, PKY3` — Stiffness variation
`scalar`

Lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, stiffness variation with camber, *PKY3*, dimensionless.

`KFy curvature, PKY4` — Lateral force stiffness curvature
`scalar`

Lateral force stiffness, KF_y curvature, *PKY4*, dimensionless.

`Variation of peak stiffness with squared camber, PKY5` — Stiffness variation
scalar

Variation of peak stiffness with squared camber, *PKY5*, dimensionless.

`Fy camber stiffness factor, PKY6` — Lateral force camber stiffness factor
scalar

Lateral force, F_y, camber stiffness factor, *PKY6*, dimensionless.

`Camber stiffness vertical load dependency, PKY7` — Stiffness
scalar

Camber stiffness vertical load dependency, *PKY7*, dimensionless.

`SHY horizontal shift at FZNOM, PHY1` — Horizontal shift at nominal force
scalar

Horizontal shift, S_{HY}, at nominal force, F_{ZNOM}, *PHY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`SHY variation with load, PHY2` — Horizontal shift variation
scalar

Horizontal shift, S_{HY}, variation with load, *PHY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz vertical shift at FZNOM, PVY1` — Vertical shift at nominal force
scalar

Vertical shift, S_{vy}, at nominal force, F_{ZNOM}, *PVY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz variation with load, PVY2` — Vertical shift variation with load
scalar

Vertical shift, S_{vy}, variation with load, *PVY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz variation with camber, PVY3` — Vertical shift variation with camber
scalar

Vertical shift, S_{vy}, variation with camber, *PVY3*, dimensionless.

`Svy/Fz variation with load and camber, PVY4` — Vertical shift variation with load and camber
`scalar`

Vertical shift, S_{vy}, variation with load and camber, *PVY4*, dimensionless.

`Cornering stiffness variation with inflation pressure, PPY1` — Stiffness variation with pressure
`scalar`

Cornering stiffness variation with inflation pressure, *PPY1*, dimensionless.

`Cornering stiffness variation with inflation pressure induced nominal load dependency, PPY2` — Stiffness variation with pressure
`scalar`

Cornering stiffness variation with inflation pressure induced nominal load dependency, *PPY2*, dimensionless.

`Linear inflation pressure on peak lateral friction, PPY3` — Pressure
`scalar`

Linear inflation pressure on peak lateral friction, *PPY3*, dimensionless.

`Quadratic inflation pressure on peak lateral friction, PPY4` — Pressure
`scalar`

Quadratic inflation pressure on peak lateral friction, *PPY4*, dimensionless.

`Inflation pressure effect on camber stiffness, PPY5` — Pressure
`scalar`

Inflation pressure effect on camber stiffness, *PPY5*, dimensionless.

`Combined Fy reduction slope factor, RBY1` — Combined lateral force reduction slope factor
`scalar`

Combined lateral force, F_y, reduction slope factor, *RBY1*, dimensionless.

`Fy slope reduction with slip angle, RBY2` — Lateral force slope reduction with slip angle
`scalar`

Lateral force, F_y, slope reduction with slip angle, *RBY2*, dimensionless.

`Fy shift reduction with slip angle, RBY3` — Lateral force shift reduction with slip angle
`scalar`

Lateral force, F_y, shift reduction with slip angle, *RBY3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Fy combined stiffness variation from camber, RBY4` — Lateral force combined stiffness variation from camber
`scalar`

Lateral force, F_y, combined stiffness variation from camber, *RBY4*, dimensionless.

`Fy combined reduction shape factor, RCY1` — Lateral force combined reduction shape factor
`scalar`

Lateral force, F_y, combined reduction shape factor, *RCY1*, dimensionless.

`Fy combined curvature factor, REY1` — Lateral force combined curvature factor
`scalar`

Lateral force, F_y, combined curvature factor, *REY1*, dimensionless.

`Fy combined curvature factor with load, REY2` — Lateral force combined curvature factor with load
`scalar`

Lateral force, F_y, combined curvature factor with load, *REY2*, dimensionless.

`Fy combined reduction shift factor, RHY1` — Lateral force combined reduction shift factor
`scalar`

Lateral force, F_y, combined reduction shift factor, *RHY1*, dimensionless.

`Fy combined reduction shift factor with load, RHY2` — Lateral force combined reduction shift factor with load
`scalar`

Lateral force, F_y, combined reduction shift factor with load, *RHY2*, dimensionless.

`Slip ratio side force Svyk/Muy*Fz at FZNOM, RVY1` — Slip ratio slide force at nominal force
`scalar`

Slip ratio side force at nominal force, F_{ZNOM}, *RVY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Side force Svyk/Muy*Fz variation with load, RVY2` — Side force variation with load
`scalar`

Side force variation with load, *RVY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Side force Svyk/Muy*Fz variation with camber, RVY3` — Side force variation with camber
`scalar`

Side force variation with camber, *RVY3*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip angle, RVY4` — Side force variation with slip angle
`scalar`

Side force variation with slip angle, *RVY4*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip ratio, RVY5` — Side force variation with slip ratio
`scalar`

Side force variation with slip ratio, *RVY5*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip ratio arctangent, RVY6` — Side force variation with slip ratio arctangent
`scalar`

Side force variation with slip ratio arctangent, *RVY6*, dimensionless.

Rolling

`Torque resistance coefficient, QSY1` — Torque resistance
`scalar`

Torque resistance coefficient, *QSY1*, dimensionless.

`Torque resistance due to Fx, QSY2` — Torque resistance due to longitudinal force
`scalar`

Torque resistance due to longitudinal force, F_x, *QSY2*, dimensionless.

`Torque resistance due to speed, QSY3` — Torque resistance due to speed
`scalar`

Torque resistance due to speed, *QSY3*, dimensionless.

`Torque resistance due to speed^4, QSY4` — Torque resistance due to speed
`scalar`

Torque resistance due to speed^4, *QSY4*, dimensionless.

`Torque resistance due to square of camber, QSY5` — Torque resistance due to camber
`scalar`

Torque resistance due to square of camber, *QSY5*, dimensionless.

`Torque resistance due to square of camber and load, QSY6` — Torque resistance due to camber and load
`scalar`

Torque resistance due to square of camber and load, *QSY6*, dimensionless.

`Torque resistance due to load, QSY7` — Torque resistance due to load
`scalar`

Torque resistance due to load, *QSY7*, dimensionless.

`Torque resistance due to pressure, QSY8` — Torque resistance due to pressure
`scalar`

Torque resistance due to pressure, *QSY8*, dimensionless.

Aligning

`Trail slope factor for trail Bpt at FZNOM, QBZ1` — Trail slope factor at nominal force
`scalar`

Trail slope factor for trail *Bpt* at nominal force, F_{ZNOM}, *QBZ1*, dimensionless.

`Bpt slope variation with load, QBZ2` — Slope variation with load
`scalar`

Slope variation with load, *QBZ2*, dimensionless.

`Bpt slope variation with square of load, QBZ3` — Slope variation with load
`scalar`

Slope variation with square of load, *QBZ3*, dimensionless.

`Bpt slope variation with camber, QBZ4` — Slope variation with camber
`scalar`

Slope variation with camber, *QBZ4*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Bpt slope variation with absolute value of camber, QBZ5` — Slope variation with camber
`scalar`

Slope variation with absolute value of camber, *QBZ5*, dimensionless.

`Bpt slope variation with square of camber, QBZ6` — Slope variation with camber
`scalar`

Slope variation with square of camber, *QBZ6*, dimensionless.

`Br of Mzr slope scaling factor, QBZ9` — Slope scaling factor
`scalar`

Slope scaling factor, *QBZ9*, dimensionless.

`Br of Mzr cornering stiffness factor, QBZ10` — Cornering stiffness factor
`0` (default) | `scalar`

Br of *Mzr* cornering stiffness factor, *QBZ10*, dimensionless.

`Cpt pneumatic trail shape factor, QCZ1` — Pneumatic trail shape factor
`scalar`

Pneumatic trail shape factor, C_{pt}, *QCZ1*, dimensionless.

`Dpt peak trail, QDZ1` — Peak trail

`scalar`

Peak trail, D_{pt}, *QDZ1*, dimensionless.

`Dpt peak trail variation with load, QDZ2` — Peak trail variation with load

`scalar`

Peak trail, D_{pt}, variation with load, *QDZ2*, dimensionless.

`Dpt peak trail variation with camber, QDZ3` — Peak trail variation with camber

`scalar`

Peak trail, D_{pt}, variation with camber, *QDZ3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dpt peak trail variation with square of camber, QDZ4` — Peak trail variation with camber

`scalar`

Peak trail, D_{pt}, variation with square of camber, *QDZ4*, dimensionless.

`Dmr peak residual torque, QDZ6` — Peak residual torque

`scalar`

Peak residual torque, D_{mr}, *QDZ6*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dmr peak residual torque variation with load, QDZ7` — Peak residual torque variation with load

`scalar`

Peak residual torque, D_{mr}, variation with load, *QDZ7*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dmr peak residual torque variation with camber, QDZ8` — Peak residual torque variation with camber

`scalar`

Peak residual torque, D_{mr}, variation with camber, *QDZ8*, dimensionless.

`Dmr peak residual torque variation with camber and load, QDZ9` — Peak residual torque variation with camber and load

`scalar`

Peak residual torque, D_{mr}, variation with camber and load, *QDZ9*, dimensionless.

`Dmr peak residual torque variation with square of camber, QDZ10` — Peak residual torque variation with camber

scalar

Peak residual torque, D_{mr}, variation with square of camber, *QDZ10*, dimensionless.

`Dmr peak residual torque variation with square of load, QDZ11` — Peak residual torque variation with load

scalar

Peak residual torque, D_{mr}, variation with square of load, *QDZ11*, dimensionless.

`Ept trail curvature at FZNOM, QEZ1` — Trail curvature at nominal force

scalar

Trail curvature, E_{pt}, at nominal force, F_{ZNOM}, *QEZ1*, dimensionless.

`Ept variation with load, QEZ2` — Trail curvature variation with load

scalar

Trail curvature, E_{pt} variation with load, *QEZ2*, dimensionless.

`Ept variation with square of load, QEZ3` — Trail curvature variation with load

scalar

Trail curvature, E_{pt} variation with square of load, *QEZ3*, dimensionless.

`Ept variation with sign of alpha-t, QEZ4` — Trail curvature variation

scalar

Trail curvature, E_{pt} variation with sign of alpha-t, *QEZ4*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Ept variation with sign of alpha-t and camber, QEZ5` — Variation

scalar

Trail curvature, E_{pt} variation with sign of alpha-t and camber, *QEZ5*, dimensionless.

`Sht horizontal trail shift at FZNOM, QHZ1` — Horizontal trail shift at nominal load

scalar

Horizontal trail shift, Sh_t, at nominal load, F_{ZNOM}, *QHZ1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Sht variation with load, QHZ2` — Horizontal trail shift variation with load

scalar

Horizontal trail shift, Sh_t, variation with load, *QHZ2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Sht variation with camber, QHZ3` — Horizontal trail shift variation with camber

`scalar`

Horizontal trail shift, Sh_t, variation with camber, *QHZ3*, dimensionless.

`Sht variation with load and camber, QHZ4` — Horizontal trail shift variation with load and camber

`scalar`

Horizontal trail shift, Sh_t, variation with load and camber, *QHZ4*, dimensionless.

`Inflation pressure influence on trail length, PPZ1` — Pressure influence on trail length

`scalar`

Inflation pressure influence on trail length, *PPZ1*, dimensionless.

`Inflation pressure influence on residual aligning torque, PPZ2` — Pressure influence on aligning torque

`scalar`

Inflation pressure influence on residual aligning torque, *PPZ2*, dimensionless.

`Nominal value of s/R0: effect of Fx on Mz, SSZ1` — Effect of longitudinal force on aligning torque

`scalar`

Nominal value of s/R0: effect of longitudinal force, F_x, on aligning torque, M_z, *SSZ1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`s/R0 variation with lateral to nominal force ratio, SSZ2` — Variation with lateral to nominal force ratio

`scalar`

Variation with lateral to nominal force ratio, *SSZ2*, dimensionless.

`s/R0 variation with camber, SSZ3` — Variation with camber

`scalar`

Variation with camber, *SSZ3*, dimensionless.

`s/R0 variation with camber and load, SSZ4` — Variation with camber and load

`scalar`

Variation with camber and load, *SSZ4*, dimensionless.

Turnslip

`Fx peak reduction due to spin, PDXP1` — Longitudinal force peak reduction due to spin

`scalar`

Longitudinal force, F_x, peak reduction due to spin, *PDXP1*, dimensionless.

`Fx peak reduction due to spin with varying load, PDXP2` — Longitudinal force peak reduction due to spin
scalar

Longitudinal force, F_x, peak reduction due to spin with varying load, *PDXP2*, dimensionless.

`Fx peak reduction due to spin with slip ratio, PDXP3` — Longitudinal force peak reduction due to spin
scalar

Longitudinal force, F_x, peak reduction due to spin with slip ratio, *PDXP3*, dimensionless.

`Cornering stiffness reduction due to spin, PKYP1` — Stiffness reduction due to spin
scalar

Cornering stiffness reduction due to spin, *PKYP1*, dimensionless.

`Fy peak reduction due to spin, PDYP1` — Lateral force peak reduction due to spin
scalar

Lateral force, F_y, peak reduction due to spin, *PDYP1*, dimensionless.

`Fy peak reduction due to spin with varying load, PDYP2` — Lateral force peak reduction due to spin
scalar

Lateral force, F_y, peak reduction due to spin with varying load, *PDYP2*, dimensionless.

`Fy peak reduction due to spin with slip angle, PDYP3` — Lateral force peak reduction due to spin
scalar

Lateral force, F_y, peak reduction due to spin with slip angle, *PDYP3*, dimensionless.

`Fy peak reduction due to square root of spin, PDYP4` — Lateral force peak reduction due to spin
scalar

Lateral force, F_y, peak reduction due to square root of spin, *PDYP4*, dimensionless.

`Fy vs. slip angle response lateral shift limit, PHYP1` — Lateral force versus slip angle response
scalar

Lateral force, F_y, versus slip angle response lateral shift limit, *PHYP1*, dimensionless.

`Fy vs. slip angle response max lateral shift limit, PHYP2` — Lateral force versus slip angle response
scalar

Lateral force, F_y, versus slip angle response max lateral shift limit, *PHYP2*, dimensionless.

`Fy vs. slip angle response max lateral shift limit with load, PHYP3` — Lateral force versus slip angle response
scalar

Lateral force, F_y, versus slip angle response max lateral shift limit with load, *PHYP3*, dimensionless.

`Fy vs. slip angle response lateral shift curvature factor, PHYP4` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response lateral shift curvature factor, *PHYP4*, dimensionless.

`Camber stiffness reduction due to spin, PECP1` — Camber stiffness reduction
`scalar`

Camber stiffness reduction due to spin, *PECP1*, dimensionless.

`Camber stiffness reduction due to spin with load, PECP2` — Camber stiffness reduction
`scalar`

Camber stiffness reduction due to spin with load, *PECP2*, dimensionless.

`Turn slip pneumatic trail reduction factor, QDTP1` — Turn slip pneumatic trail reduction factor
`scalar`

Turn slip pneumatic trail reduction factor, *QDTP1*, dimensionless.

`Turn moment for constant turning and zero longitudinal speed, QCRP1` — Turn moment for constant turning
`scalar`

Turn moment for constant turning and zero longitudinal speed, *QCRP1*, dimensionless.

`Turn slip moment increase with spin at 90deg slip angle, QCRP2` — Turn slip moment
`scalar`

Turn slip moment increase with spin at 90-degree slip angle, *QCRP2*, dimensionless.

`Residual spin torque reduction from side slip, QBRP1` — Residual spin torque reduction
`scalar`

Residual spin torque reduction from side slip, *QBRP1*, dimensionless.

`Turn slip moment peak magnitude, QDRP1` — Turn slip moment peak magnitude
`scalar`

Turn slip moment peak magnitude, *QDRP1*, dimensionless.

`Turn slip moment curvature, QDRP2` — Turn slip moment curvature
`scalar`

Turn slip moment curvature, *QDRP2*, dimensionless.

Version History

Introduced in R2021b

New Ply steer and Turn slip Parameters

Behavior changed in R2022b

Starting from R2022b, the Combined Slip Wheel CPI block includes **Ply steer** and **Turn slip** parameters. To remove ply steer and turn slip from the Magic Formula implementation of these blocks, clear the **Ply steer** and **Turn slip** parameters.

References

[1] Besselink, Igo, Antoine J. M. Schmeitz, and Hans B. Pacejka, "An improved Magic Formula/Swift tyre model that can handle inflation pressure changes," *Vehicle System Dynamics - International Journal of Vehicle Mechanics and Mobility* 48, sup. 1 (2010): 337–52, https://doi.org/10.1080/00423111003748088.

[2] Pacejka, Hans B. *Tire and Vehicle Dynamics*. 3rd ed. Oxford, United Kingdom: SAE and Butterworth-Heinemann, 2012.

[3] Bohm, F., and H. P. Willumeit, "Tyre Models for Vehicle Dynamic Analysis: Proceedings of the 2nd International Colloquium on Tyre Models for Vehicle Dynamics Analysis, Held at the Technical University of Berlin, Germany, February 20-21, 1997." *Vehicle System Dynamics - International Journal of Vehicle Mechanics and Mobility* 27, sup. 1, 343–45. https://doi.org/0.1080/00423119708969669.

[4] Schmid, Steven R., Bernard J. Hamrock, and Bo O. Jacobson. *Fundamentals of Machine Elements, SI Version*. 3rd ed. Boca Raton: CRC Press, 2014.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

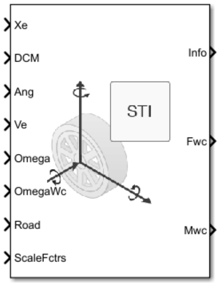
Combined Slip Wheel 2DOF | Combined Slip Wheel 2DOF STI | Fiala Wheel 2DOF | Longitudinal Wheel

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Combined Slip Wheel STI

Combined slip wheel compliant with STI Tydex standard
Library: Vehicle Dynamics Blockset / Wheels and Tires



Description

The Combined Slip Wheel STI block implements the longitudinal and lateral behavior of a wheel characterized by the Magic Formula[1, 2] that complies with the standard tire interface (STI) Tyre Data Exchange Format (TYDEX)[3] standard. You can import your own tire data or use fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS). Use the block in driveline and vehicle simulations where low-frequency tire road interactions are required to determine vehicle acceleration and wheel-rolling resistance. The block is suitable for applications that require combined lateral slip, for example, in lateral motion and yaw stability studies.

Based on the wheel rotational velocity, longitudinal and lateral velocity, wheel camber angle, and inflation pressure, the block determines the vertical motion, forces, and moments in all six degrees of freedom (DOF). Use the vertical DOF to study tire-suspension resonances from road profiles or chassis motion.

Use the **Tire type** parameter to select the source of the tire data.

Goal	Action
Implement the Magic Formula using empirical equations[1, 2]. The equations use fitting coefficients that correspond to the block parameters.	Update the block parameters with fitting coefficients from a file: 1 Set **Tire type** to `External file`. 2 On the **External tire source** pane, Click **Select file**. 3 Select the tire coefficient file. 4 Click **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters. 5 Click **Apply**.

Goal	**Action**
Implement fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS).	Update the applicable block parameters with GCAPS fitted tire data: 1 Set **Tire type** to the tire that you want to implement. Options include: • `Light passenger car 205/60R15` • `Mid-size passenger car 235/45R18` • `Performance car 225/40R19` • `SUV 265/50R20` • `Light truck 275/65R18` • `Commercial truck 295/75R22.5` 2 Click **Update applicable Tire Parameters with tire type values**. On the **Tire Parameters** tab, the block updates the applicable parameters, including **Wheel width**, **Rim radius**, and **Wheel mass**. 3 Click **Apply**.

Rotational Wheel Dynamics

The block calculates the inertial response of the wheel subject to:

- Axle losses
- Tire rolling resistance
- Ground contact through the tire-road interface

To implement the Magic Formula, the block uses these equations.

Calculation	**Equations**
Longitudinal force	*Tire and Vehicle Dynamics*[2] equations 4.E9 through 4.E57
Lateral force - pure sideslip	*Tire and Vehicle Dynamics*[2] equations 4.E19 through 4.E30
Lateral force - combined slip	*Tire and Vehicle Dynamics*[2] equations 4.E58 through 4.E67
Vertical dynamics	*Tire and Vehicle Dynamics*[2] equations 4.E68, 4.E1, 4.E2a, and 4.E2b
Overturning couple	*Tire and Vehicle Dynamics*[2] equation 4.E69
Rolling resistance	• *An improved Magic Formula/Swift tyre model that can handle inflation pressure changes*[2] equation 6.1.2 • *Tire and Vehicle Dynamics*[2] equation 4.E70
Aligning moment	*Tire and Vehicle Dynamics*[2] equation 4.E31 through 4.E49
Aligning torque - combined slip	*Tire and Vehicle Dynamics*[2] equation 4.E71 through 4.E78 If you clear **Include turn slip**, the block sets some of these equations to 1.

STI Wheel Coordinate System

The block uses wheel coordinate system axes (X_W, Y_W, Z_W) that are fixed in a reference frame attached to the wheel. The origin is at the wheel center.

The STI wheel coordinate system is shown in blue.

Note The STI wheel coordinate system (blue) is equivalent to the TYDEX centre-axis coordinate system.

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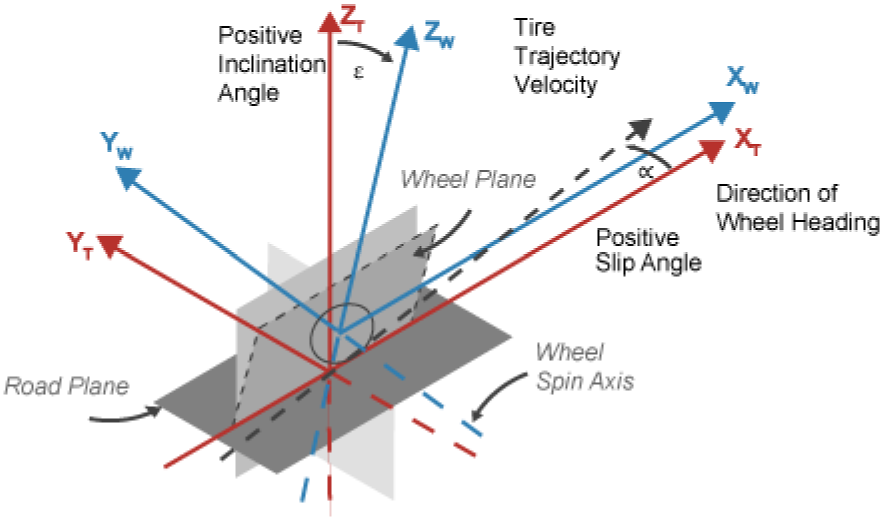
[4]



Axis	Description
X_W	X_W and Y_W are parallel to the wheel plane: • X_W is parallel to the local road plane. • Y_W is parallel to the wheel-spin axis.
Y_W	
Z_W	Z_W points upward.

Ports

Input

Xe — Wheel position in inertial reference frame

N-by-3 vector

Wheel position along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively, in m.

Vector is the number of wheels, *N*, by 3.

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`DCM` — Direction cosine matrix
3-by-3 vector

Transformation matrix from the wheel coordinate system to the Earth-fixed inertial coordinate system.

`Ang` — Rotation angle of the rim
3-by-3 vector

Rotation angle of rim with respect to the wheel center, in rad.

`Ve` — Wheel velocity in inertial reference frame
N-by-3 vector

Wheel velocity along inertial-fixed *X*-, *Y*-, and *Z*-axes, respectively, in m.

Vector is the number of wheels, *N*, by 3.

`Omega` — Rotational velocity
N-by-3 vector

Wheel rotational velocity along inertial-fixed *X*-, *Y*-, and *Z*-axes, respectively, in m.

Vector is the number of wheels, *N*, by 3.

`OmegaWc` — Rim rotational velocity
`scalar`

Rim rotational velocity, ω, about wheel spin axis, in rad/s.

`Road` — Wheel position, rotation matrix, velocity
1-by-18 vector

Vector containing wheel position, rotation, and velocity with respect to the Earth-fixed inertial coordinate system.

Vector Element	Description

`Road(1,1)`
`Road(1,2)`
`Road(1,3)`
	Wheel position along inertial-fixed *X*-, *Y*-, and *Z*-axes, respectively, in m.

Vector Element	Description

`Road(1,4)`
`Road(1,5)`
`Road(1,6)`
`Road(1,7)`
`Road(1,8)`
`Road(1,9)`
`Road(1,10)`
`Road(1,11)`
`Road(1,12)`
	Transformation matrix from the wheel coordinate system to the Earth-fixed inertial coordinate system.

`Road(1,13)`
`Road(1,14)`
`Road(1,15)`
	Wheel velocity along inertial-fixed *X*-, *Y*-, and *Z*-axes, respectively, in m/s.

`Road(1,16)`
`Road(1,17)`
`Road(1,18)`
	Wheel angular velocity along inertial-fixed *X*-, *Y*-, and *Z*-axes, respectively, in rad/s.

`ScaleFctrs` — Road friction scale factors

2-by-N array

Magic formula road friction scale factor array. Array dimensions are 2 by the number of wheels, *N*.

The Magic Formula equations use scale factors to account for static or simulation run-time variations. Nominally, most are set to 1.

Array Element	Variable	Scale Factor
`ScaleFctrs(1,1)`	`lam_mux`	Longitudinal peak friction coefficient
`ScaleFctrs(2,1)`	`lam_muy`	Lateral peak friction coefficient

`Prs` — Tire inflation pressure

`scalar` | N-by-1 vector

Tire inflation pressure, p_i, in Pa.

Vector is the number of wheels, *N*, by 1. If you provide a scalar value, the block assumes that number of wheels is one.

Dependencies

To create this port, select **Input tire pressure**.

Output

`Info` — Block data

bus

Block data, returned as a bus signal containing these block values.

Signal		Description	Units
`CPI_info`	`Omega`	Wheel angular velocity about wheel-fixed *y*-axis	rad/s
	`Fx`	Longitudinal vehicle force along tire-fixed *x*-axis	N
	`Fy`	Lateral vehicle force along tire-fixed *y*-axis	N
	`Fz`	Vertical vehicle force along tire-fixed *z*-axis	N
	`Mx`	Overturning moment about tire-fixed *x*-axis	N·m
	`My`	Rolling resistance torque about tire-fixed *y*-axis	N·m
	`Mz`	Aligning moment about tire-fixed *z*-axis	N·m
	`Vx`	Vehicle longitudinal velocity along tire-fixed *x*-axis	m/s
	`Vy`	Vehicle lateral velocity along tire-fixed *y*-axis	m/s
	`Re`	Loaded effective radius	m
	`Kappa`	Longitudinal slip ratio	NA
	`Alpha`	Side slip angle	rad
	`a`	Contact patch half length	m
	`b`	Contact patch half width	m
	`Gamma`	Camber angle	rad
	`psidot`	Tire angular velocity about the tire-fixed *z*-axis (yaw rate)	rad/s
	`rhoz`	Axle vertical displacement along tire-fixed *z*-axis	m
	`FNormal`	Vertical sidewall force on ground along tire-fixed *z*-axis	N
	`Prs`	Tire inflation pressure	Pa
`DCM`		Transformation matrix from the wheel coordinate system to the Earth-fixed inertial coordinate system	NA
`Xe`		Wheel position along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively	m
`Ang`		Rotation angle of the rim with respect to the wheel center	rad
`Omega`		Tire rotational velocity, ω, about wheel spin axis	rad/s

Signal	Description	Units
`Ve`	Wheel velocity along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively	m/s
`OmegaWc`	Rim rotational velocity, ω, about wheel spin axis	rad/s
`Road`	Vector containing wheel position, rotation, and velocity with respect to the Earth-fixed inertial coordinate system	NA

`Fwc` — Force at wheel center

1-by-3 vector

Force applied at wheel center by tire along wheel-fixed *x*-, *y*-, *z*-axes, respectively, in N.

`Mwc` — Moment at wheel center

1-by-3 vector

Moment applied at wheel center by tire about wheel-fixed *x*-, *y*-, *z*-axes, respectively, in N·m.

Parameters

Block Options

`Tire type` — Select type

`External file` (default) | `Light passenger car 205/60R15` | `Mid-size passenger car 235/45R18` | `Performance car 225/40R19` | `SUV 265/50R20` | `Light truck 275/65R18` | `Commercial truck 295/75R22.5`

Use the **Tire type** parameter to select the source of the tire data.

Goal	Action
Implement the Magic Formula using empirical equations$^{1,\ 2}$. The equations use fitting coefficients that correspond to the block parameters.	Update the block parameters with fitting coefficients from a file: 1 Set **Tire type** to `External file`. 2 On the **External tire source** pane, Click **Select file**. 3 Select the tire coefficient file. 4 Click **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters. 5 Click **Apply**.

Goal	Action
Implement fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS).	Update the applicable block parameters with GCAPS fitted tire data: 1 Set **Tire type** to the tire that you want to implement. Options include: • `Light passenger car 205/60R15` • `Mid-size passenger car 235/45R18` • `Performance car 225/40R19` • `SUV 265/50R20` • `Light truck 275/65R18` • `Commercial truck 295/75R22.5` 2 Click **Update applicable Tire Parameters with tire type values**. On the **Tire Parameters** tab, the block updates the applicable parameters, including **Wheel width**, **Rim radius**, and **Wheel mass**. 3 Click **Apply**.

`Tire file or object, tireParamSet` — Tire file

`.mat` | `.tir` | `.txt`

Tire file `.tir` or object containing empirical data to model tire longitudinal and lateral behavior with the Magic Formula. If you provide an `.txt` file, make sure the file contains names that correspond to the block parameters.

Update the block parameters with fitting coefficients from a file:

1. Set **Tire type** to `External file`.
2. On the **External tire source** pane, click **Select file**.
3. Select the tire coefficient file.
4. Click **Update mask values from file**. In the dialog box that prompts you for confirmation, click **OK**. The block updates the parameters.
5. Click **Apply**.

`Tire side` — Select tire side

`Right` (default) | `Left` | `Symmetric`

Specify the tire side.

`Tire pressure` — Select tire side

`220000` (default) | `scalar`

Tire inflation pressure, p, in Pa.

Dependencies

To enable this parameter, clear **Input tire pressure**.

`Ply steer` — Include ply steer

`on` (default) | `off`

Select to include ply steer in the Magic Formula equations.

By default, the blocks include ply steer and turn slip in the Magic Formula equations. The equations are fit to flat-belt test data and predict a number of tire effects, including ply steer and turn slip. Consider removing the effects if your:

- Test data does not include ply steer or turn slip data.
- Analysis does not require ply steer or turn slip effects.

If you clear **Ply steer**, the block internally sets these parameters to 0:

- **Vertical shift of overturning moment, QSX1**
- **Combined slip Fx shift factor reduction, RHX1**
- **Efy curvature constant camber dependency, PEY3**
- **SHY horizontal shift at FZNOM, PHY1**
- **SHY variation with load, PHY2**
- **Svy/Fz vertical shift at FZNOM, PVY1**
- **Svy/Fz variation with load, PVY2**
- **Fy shift reduction with slip angle, RBY3**
- **Slip ratio side force Svyk/Muy*Fz at FZNOM, RVY1**
- **Side force Svyk/Muy*Fz variation with load, RVY2**
- **Bpt slope variation with camber, QBZ4**
- **Dpt peak trail variation with camber, QDZ3**
- **Dmr peak residual torque, QDZ6**
- **Dmr peak residual torque variation with load, QDZ7**
- **Ept variation with sign of alpha-t, QEZ4**
- **Sht horizontal trail shift at FZNOM, QHZ1**
- **Sht variation with load, QHZ2**
- **Nominal value of s/R0: effect of Fx on Mz, SSZ1**

`Turn slip` — Include turn slip

on (default) | `off`

Select to include ply steer in Magic Formula equations.

By default, the blocks include ply steer and turn slip in the Magic Formula equations. The equations are fit to flat-belt test data and predict a number of tire effects, including ply steer and turn slip. Consider removing the effects if your:

- Test data does not include ply steer or turn slip data.
- Analysis does not require ply steer or turn slip effects.

If you clear **Turn slip**, the block internally:

- Sets the Magic Formula turn slip equations to 1. Specifically, equations 4.E77, 4.E79, 4.E81, 4.E83, 4.E84, 4.E92, 4.E102, 4.E101, and 4.E105.[2].
- Uses Magic Formula terms that effect horizontal shift.

- Uses Magic Formula small turn slip values in 4.E27[2].

Simulation

Maximum pressure, PRESMAX — Pressure
`scalar`

Maximum pressure, *PRESMAX*, in Pa.

Minimum pressure, PRESMIN — Pressure
`scalar`

Minimum pressure, *PRESMIN*, in Pa.

Maximum normal force, FZMAX — Force
`scalar`

Maximum normal force, *FZMAX*, in N.

Minimum normal force, FZMIN — Force
`scalar`

Minimum normal force, *FZMIN*, in N.

Velocity tolerance used to handle low velocity situations, VXLOW — Tolerance
`scalar`

Velocity tolerance used to handle low-velocity situations, *VXLOW*, in m/s.

Max allowable slip ratio (absolute), KPUMAX — Ratio
`scalar`

Max allowable slip ratio (absolute), *KPUMAX*, dimensionless.

Minimum allowable slip ratio (absolute), KPUMIN — Ratio
`scalar`

Minimum allowable slip ratio (absolute), *KPUMIN*, dimensionless.

Max allowable slip angle (absolute), ALPMAX — Angle
`scalar`

Max allowable slip angle (absolute), *ALPMAX*, in rad.

Minimum allowable slip angle (absolute), ALPMIN — Angle
`scalar`

Minimum allowable slip angle (absolute), *ALPMIN*, in rad.

Maximum allowable camber angle, CAMMAX — Angle
`scalar`

Maximum allowable camber angle *CAMMAX*, in rad.

Minimum allowable camber angle, CAMMIN — Angle
`scalar`

Minimum allowable camber angle, *CAMMIN*, in rad.

`Nominal longitudinal speed, LONGVL` — Speed
`scalar`

Nominal longitudinal speed, *LONGVL*, in m/s.

`Default tyre side, tyreside` — Side
`'Right'` (default) | `char`

Default tyre side, *tyreside*, dimensionless.

Wheel

`Initial rotational velocity, omegao` — Velocity
`scalar`

Initial rotational velocity, specified as a scalar, in rad/s.

`Rotational damping, br` — Damping
`scalar`

Rotational damping, specified as a scalar, in N·m·s/rad.

`Unloaded radius, UNLOADED_RADIUS` — Radius
`scalar`

Unloaded radius, *UNLOADED_RADIUS*, in m.

`Nominal pressure, NOMPRES` — Pressure
`scalar`

Nominal pressure, *NOMPRES*, in Pa.

`Nominal normal force, FNOMIN` — Force
`scalar`

Nominal normal force, *FNOMIN*, in N.

`Wheel width, WIDTH` — Width
`scalar`

Wheel width, *WIDTH*, in m.

`Rim radius, RIM_RADIUS` — Radius
`scalar`

Rim radius, *RIM_RADIUS*, in m.

`Nominal aspect ratio, ASPECT_RATIO` — Ratio
`scalar`

Nominal aspect ratio, *ASPECT_RATIO*, dimensionless.

Inertial

`Wheel mass, MASS` — Mass
`scalar`

Wheel mass, specified as a scalar, in kg.

`Rotational inertia (rolling axis), IYY` — Inertia
`scalar`

Rotational inertia (rolling axis), specified as a scalar, in kg·m^2.

`Gravity, GRAVITY` — Gravity
`scalar`

Gravity, *GRAVITY*, in m/s^2.

Vertical

`Initial tire displacement, zo` — Displacement
`scalar`

Initial tire displacement, *zo*, in m.

`Initial wheel vertical velocity (wheel fixed frame), zdoto` — Velocity
`scalar`

Initial wheel vertical velocity (wheel fixed frame), *zdoto*, in m/s.

`Effective rolling radius at low load stiffness, BREFF` — Stiffness
`scalar`

Effective rolling radius at low load stiffness, *BREFF*, dimensionless.

`Effective rolling radius peak value, DREFF` — Radius
`scalar`

Effective rolling radius peak value, *DREFF*, dimensionless.

`Effective rolling radius at high load stiffness, FREFF` — Radius
`scalar`

Effective rolling radius at high load stiffness, *FREFF*, dimensionless.

`Unloaded to nominal rolling radius ratio, Q_RE0` — Ratio
`scalar`

Unloaded to nominal rolling radius ratio, *Q_RE0*, dimensionless.

`Radius rotational speed dependence, Q_V1` — Speed
`scalar`

Radius rotational speed dependence, *Q_V1*, dimensionless.

`Stiffness rotational speed dependence, Q_V2` — Speed
`scalar`

Stiffness rotational speed dependence, *Q_V2*, dimensionless.

Linear load change with deflection, Q_FZ1 — Load change
scalar

Linear load change with deflection, *Q_FZ1*, dimensionless.

Quadratic load change with deflection, Q_FZ2 — Load change
scalar

Quadratic load change with deflection, *Q_FZ2*, dimensionless.

Linear load change with deflection and quadratic camber, Q_FZ3 — Load change
scalar

Linear load change with deflection and quadratic camber, *Q_FZ3*, dimensionless.

Load response to longitudinal force, Q_FCX — Force
scalar

Load response to longitudinal force, *Q_FCX*, dimensionless.

Load response to lateral force, Q_FCY — Force
scalar

Load response to lateral force, *Q_FCY*, dimensionless.

Vertical stiffness change due to lateral load dependency on lateral stiffness, Q_FCY2 — Stiffness
scalar

Vertical stiffness change due to lateral load dependency on lateral stiffness, *Q_FCY2*, dimensionless.

Stiffness response to pressure, PFZ1 — Stiffness
scalar

Stiffness response to pressure, *PFZ1*, dimensionless.

Vertical tire stiffness, VERTICAL_STIFFNESS — Stiffness
scalar

Vertical tire stiffness, *VERTICAL_STIFFNESS*, in N/m.

Vertical tire damping, VERTICAL_DAMPING — Damping
scalar

Vertical tire damping, *VERTICAL_DAMPING*, in N·s/m.

Rim bottoming out offset, BOTTOM_OFFST — Offset
scalar

Rim bottoming out offset, *BOTTOM_OFFST*, in m.

Bottoming out stiffness, BOTTOM_STIFF — Stiffness
scalar

Bottoming out stiffness, *BOTTOM_STIFF*, in N/m.

Linear load dependent camber angle influence on vertical stiffness, Q_CAM1 — Stiffness
scalar

Linear load dependent camber angle influence on vertical stiffness, *Q_CAM1*, dimensionless.

Quadratic load dependent camber angle influence on vertical stiffness, Q_CAM2 — Stiffness
scalar

Quadratic load dependent camber angle influence on vertical stiffness, *Q_CAM2*, dimensionless.

Linear load and camber angle dependent reduction on vertical stiffness, Q_CAM3 — Stiffness
scalar

Linear load and camber angle dependent reduction on vertical stiffness, *Q_CAM3*, dimensionless.

Structural

Longitudinal stiffness, LONGITUDINAL_STIFFNESS — Stiffness
scalar

Longitudinal stiffness, *LONGITUDINAL_STIFFNESS*, in N/m.

Lateral stiffness, LATERAL_STIFFNESS — Stiffness
scalar

Longitudinal stiffness, *LATERAL_STIFFNESS*, in N/m.

Linear vertical deflection influence on longitudinal stiffness, PCFX1 — Deflection influence
scalar

Linear vertical deflection influence on longitudinal stiffness, *PCFX1*, dimensionless.

Quadratic vertical deflection influence on longitudinal stiffness, PCFX2 — Deflection influence
scalar

Quadratic vertical deflection influence on longitudinal stiffness, *PCFX2*, dimensionless.

Pressure dependency on longitudinal stiffness, PCFX3 — Pressure dependency
scalar

Pressure dependency on longitudinal stiffness, *PCFX3*, dimensionless.

Linear vertical deflection influence on lateral stiffness, PCFY1 — Deflection influence
scalar

Linear vertical deflection influence on lateral stiffness, *PCFY1*, dimensionless.

`Quadratic vertical deflection influence on lateral stiffness, PCFY2` — Deflection influence
`scalar`

Quadratic vertical deflection influence on lateral stiffness, *PCFY2*, dimensionless.

`Pressure dependency on longitudinal stiffness, PCFY3` — Pressure dependency
`scalar`

Pressure dependency on longitudinal stiffness, *PCFY3*, dimensionless.

Contact Patch

`Contact length square root term, Q_RA1` — Length term
`scalar`

Contact length square root term, *Q_RA1*, dimensionless.

`Contact length linear term, Q_RA2` — Length term
`scalar`

Contact length linear term, *Q_RA2*, dimensionless.

`Contact width root term, Q_RB1` — Width term
`scalar`

Contact width root term, *Q_RB1*, dimensionless.

`Contact width linear term, Q_RB2` — Width term
`scalar`

Contact width linear term, *Q_RB2*, dimensionless.

Longitudinal

`Cfx shape factor, PCX1` — Shape factor
`scalar`

Shape factor, C_{fx}, *PCX1*, dimensionless.

`Longitudinal friction at nominal normal load, PDX1` — Friction
`scalar`

Longitudinal friction at nominal normal load, *PDX1*, dimensionless.

`Frictional variation with load, PDX2` — Friction variation
`scalar`

Frictional variation with load, *PDX2*, dimensionless.

`Frictional variation with camber, PDX3` — Friction variation
`scalar`

Frictional variation with camber, *PDX3*, in 1/rad^2.

Longitudinal curvature at nominal normal load, PEX1 — Curvature
scalar

Longitudinal curvature at nominal normal load, *PEX1*, dimensionless.

Variation of curvature factor with load, PEX2 — Curvature variation
scalar

Variation of curvature factor with load, *PEX2*, dimensionless.

Variation of curvature factor with square of load, PEX3 — Curvature variation
scalar

Variation of curvature factor with square of load, *PEX3*, dimensionless.

Longitudinal curvature factor with slip, PEX4 — Curvature
scalar

Longitudinal curvature factor with slip, *PEX4*, dimensionless.

Longitudinal slip stiffness at nominal normal load, PKX1 — Stiffness
scalar

Longitudinal slip stiffness at nominal normal load, *PKX1*, dimensionless.

Variation of slip stiffness with load, PKX2 — Stiffness variation
scalar

Variation of slip stiffness with load, *PKX2*, dimensionless.

Slip stiffness exponent factor, PKX3 — Slip stiffness
scalar

Slip stiffness exponent factor, *PKX3*, dimensionless.

Horizontal shift in slip ratio at nominal normal load, PHX1 — Slip ratio shift
scalar

Horizontal shift in slip ratio at nominal normal load, *PHX1*, dimensionless.

Variation of horizontal slip ratio with load, PHX2 — Slip variation
scalar

Variation of horizontal slip ratio with load, *PHX2*, dimensionless.

Vertical shift in load at nominal normal load, PVX1 — Load shift
scalar

Vertical shift in load at nominal normal load, *PVX1*, dimensionless.

Variation of vertical shift with load, PVX2 — Load variation
scalar

Variation of vertical shift with load, *PVX2*, dimensionless.

`Linear variation of longitudinal slip stiffness with tire pressure, PPX1` — Stiffness variation

`scalar`

Linear variation of longitudinal slip stiffness with tire pressure, *PPX1*, dimensionless.

`Quadratic variation of longitudinal slip stiffness with tire pressure, PPX2` — Stiffness variation

`scalar`

Quadratic variation of longitudinal slip stiffness with tire pressure, *PPX2*, dimensionless.

`Linear variation of peak longitudinal friction with tire pressure, PPX3` — Friction variation

`scalar`

Linear variation of peak longitudinal friction with tire pressure, *PPX3*, dimensionless.

`Quadratic variation of peak longitudinal friction with tire pressure, PPX4` — Friction variation

`scalar`

Quadratic variation of peak longitudinal friction with tire pressure, *PPX4*, dimensionless.

`Combined slip Fx slope factor reduction, RBX1` — Combined slip longitudinal force slope factor reduction

`scalar`

Combined slip longitudinal force, F_x, slope factor reduction, *RBX1*, dimensionless.

`Slip ratio Fx slope reduction variation, RBX2` — Slip ratio longitudinal force slope reduction variation

`scalar`

Slip ratio longitudinal force, F_x, slope reduction variation, *RBX2*, dimensionless.

`Camber influence on combined slip Fx stiffness, RBX3` — Camber influence on combined slip longitudinal force stiffness

`scalar`

Camber influence on combined slip longitudinal force, F_x, stiffness, *RBX3*, dimensionless.

`Shape factor for combined slip Fx reduction, RCX1` — Shape factor for combined slip longitudinal force reduction

`scalar`

Shape factor for combined slip longitudinal force, F_x, reduction, *RCX1*, dimensionless.

`Combined Fx curvature factor, REX1` — Combined longitudinal force curvature factor

`scalar`

Combined longitudinal force, F_x, curvature factor, *REX1*, dimensionless.

`Combined Fx curvature factor with load, REX2` — Combined longitudinal force curvature factor

`scalar`

Combined longitudinal force, F_x, curvature factor with load, *REX2*, dimensionless.

`Combined slip Fx shift factor reduction, RHX1` — Combined slip longitudinal force slip factor

`scalar`

Combined slip longitudinal force, F_x, shift factor reduction, *RHX1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

Overturning

`Vertical shift of overturning moment, QSX1` — Overturning moment

`scalar`

Vertical shift of overturning moment, *QSX1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Overturning moment due to camber, QSX2` — Overturning moment due to camber

`scalar`

Overturning moment due to camber, *QSX2*, dimensionless.

`Overturning moment due to Fy, QSX3` — Overturning moment due to lateral force

`scalar`

Overturning moment due to lateral force, *QSX3*, dimensionless.

`Mx combined lateral force load and camber, QSX4` — Overturning moment

`scalar`

Overturning moment, M_x, combined lateral force load and camber, *QSX4*, dimensionless.

`Mx load effect due to lateral force and camber, QSX5` — Overturning moment

`scalar`

Overturning moment, M_x, load effect due to lateral force and camber, *QSX5*, dimensionless.

`Mx load effect due to B-factor, QSX6` — Overturning moment

`scalar`

Overturning moment, M_x, load effect due to B-factor, *QSX6*, dimensionless.

`Mx due to camber and load, QSX7` — Overturning moment

`scalar`

Overturning moment, M_x, due to camber and load, *QSX7*, dimensionless.

`Mx due to lateral force and load, QSX8` — Overturning moment

`scalar`

Overturning moment, M_x, due to lateral force and load, *QSX8*, dimensionless.

`Mx due to B-factor of lateral force and load, QSX9` — Overturning moment
`scalar`

Overturning moment, M_x, due to B-factor of lateral force and load, *QSX9*, dimensionless.

`Mx due to vertical force and camber, QSX10` — Overturning moment
`scalar`

Overturning moment, M_x, due to vertical force and camber, *QSX10*, dimensionless.

`Mx due to B-factor of vertical force and camber, QSX11` — Overturning moment
`scalar`

Overturning moment, M_x, due to B-factor of vertical force and camber, *QSX11*, dimensionless.

`Mx due to squared camber, QSX12` — Overturning moment
`scalar`

Overturning moment, M_x, due to squared camber, *QSX12*, dimensionless.

`Mx due to lateral force, QSX13` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force, *QSX13*, dimensionless.

`Mx due to lateral force with camber, QSX14` — Overturning moment
`scalar`

Overturning moment, M_x, due to lateral force with camber, *QSX14*, dimensionless.

`Mx due to inflation pressure, PPMX1` — Overturning moment due to pressure
`scalar`

Overturning moment, M_x, due to inflation pressure, *PPMX1*, dimensionless.

Lateral

`Cfy shape factor for lateral force, PCY1` — Lateral force shape factor
`scalar`

Shape factor for lateral force, C_{fy}, *PCY1*, dimensionless.

`Lateral friction muy, PDY1` — Lateral friction
`scalar`

Lateral friction, μ_y, *PDY1*, dimensionless.

`Lateral friction variation of muy with load, PDY2` — Lateral friction variation
`scalar`

Variation of lateral friction, μ_y, with load, *PDY2*, dimensionless.

`Lateral friction variation of muy with squared camber, PDY3` — Lateral friction variation
`scalar`

Variation of lateral friction, μ_y, with squared camber, *PDY3*, dimensionless.

`Efy lateral curvature at nominal force FZNOM, PEY1` — Lateral curvature at nominal force
`scalar`

Lateral curvature, Ef_y, at nominal force, F_{ZNOM}, *PEY1*, dimensionless.

`Efy curvature variation with load, PEY2` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with load, *PEY2*, dimensionless.

`Efy curvature constant camber dependency, PEY3` — Lateral curvature constant
`scalar`

Lateral curvature, Ef_y, constant camber dependency, *PEY3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Efy curvature variation with camber, PEY4` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with camber, *PEY4*, dimensionless.

`Efy curvature variation with camber squared, PEY5` — Lateral curvature variation
`scalar`

Lateral curvature, Ef_y, variation with camber squared, *PEY5*, dimensionless.

`Maximum KFy/FZNOM stiffness, PKY1` — Maximum stiffness
`scalar`

Maximum lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, ratio, *PKY1*, dimensionless.

`Load at maximum KFy/FZNOM stiffness, PKY2` — Load
`scalar`

Load at maximum lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, ratio, *PKY2*, dimensionless.

`KFy/FZNOM stiffness variation with camber, PKY3` — Stiffness variation
`scalar`

Lateral force stiffness, KF_y, to nominal force, F_{ZNOM}, stiffness variation with camber, *PKY3*, dimensionless.

`KFy curvature, PKY4` — Lateral force stiffness curvature
`scalar`

Lateral force stiffness, KF_y curvature, *PKY4*, dimensionless.

`Variation of peak stiffness with squared camber, PKY5` — Stiffness variation
`scalar`

Variation of peak stiffness with squared camber, *PKY5*, dimensionless.

`Fy camber stiffness factor, PKY6` — Lateral force camber stiffness factor

scalar

Lateral force, F_y, camber stiffness factor, *PKY6*, dimensionless.

`Camber stiffness vertical load dependency, PKY7` — Stiffness

scalar

Camber stiffness vertical load dependency, *PKY7*, dimensionless.

`SHY horizontal shift at FZNOM, PHY1` — Horizontal shift at nominal force

scalar

Horizontal shift, S_{HY}, at nominal force, F_{ZNOM}, *PHY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`SHY variation with load, PHY2` — Horizontal shift variation

scalar

Horizontal shift, S_{HY}, variation with load, *PHY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz vertical shift at FZNOM, PVY1` — Vertical shift at nominal force

scalar

Vertical shift, S_{vy}, at nominal force, F_{ZNOM}, *PVY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz variation with load, PVY2` — Vertical shift variation with load

scalar

Vertical shift, S_{vy}, variation with load, *PVY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Svy/Fz variation with camber, PVY3` — Vertical shift variation with camber

scalar

Vertical shift, S_{vy}, variation with camber, *PVY3*, dimensionless.

`Svy/Fz variation with load and camber, PVY4` — Vertical shift variation with load and camber

scalar

Vertical shift, S_{vy}, variation with load and camber, *PVY4*, dimensionless.

`Cornering stiffness variation with inflation pressure, PPY1` — Stiffness variation with pressure
`scalar`

Cornering stiffness variation with inflation pressure, *PPY1*, dimensionless.

`Cornering stiffness variation with inflation pressure induced nominal load dependency, PPY2` — Stiffness variation with pressure
`scalar`

Cornering stiffness variation with inflation pressure induced nominal load dependency, *PPY2*, dimensionless.

`Linear inflation pressure on peak lateral friction, PPY3` — Pressure
`scalar`

Linear inflation pressure on peak lateral friction, *PPY3*, dimensionless.

`Quadratic inflation pressure on peak lateral friction, PPY4` — Pressure
`scalar`

Quadratic inflation pressure on peak lateral friction, *PPY4*, dimensionless.

`Inflation pressure effect on camber stiffness, PPY5` — Pressure
`scalar`

Inflation pressure effect on camber stiffness, *PPY5*, dimensionless.

`Combined Fy reduction slope factor, RBY1` — Combined lateral force reduction slope factor
`scalar`

Combined lateral force, F_y, reduction slope factor, *RBY1*, dimensionless.

`Fy slope reduction with slip angle, RBY2` — Lateral force slope reduction with slip angle
`scalar`

Lateral force, F_y, slope reduction with slip angle, *RBY2*, dimensionless.

`Fy shift reduction with slip angle, RBY3` — Lateral force shift reduction with slip angle
`scalar`

Lateral force, F_y, shift reduction with slip angle, *RBY3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Fy combined stiffness variation from camber, RBY4` — Lateral force combined stiffness variation from camber
`scalar`

Lateral force, F_y, combined stiffness variation from camber, *RBY4*, dimensionless.

`Fy combined reduction shape factor, RCY1` — Lateral force combined reduction shape factor

`scalar`

Lateral force, F_y, combined reduction shape factor, *RCY1*, dimensionless.

`Fy combined curvature factor, REY1` — Lateral force combined curvature factor

`scalar`

Lateral force, F_y, combined curvature factor, *REY1*, dimensionless.

`Fy combined curvature factor with load, REY2` — Lateral force combined curvature factor with load

`scalar`

Lateral force, F_y, combined curvature factor with load, *REY2*, dimensionless.

`Fy combined reduction shift factor, RHY1` — Lateral force combined reduction shift factor

`scalar`

Lateral force, F_y, combined reduction shift factor, *RHY1*, dimensionless.

`Fy combined reduction shift factor with load, RHY2` — Lateral force combined reduction shift factor with load

`scalar`

Lateral force, F_y, combined reduction shift factor with load, *RHY2*, dimensionless.

`Slip ratio side force Svyk/Muy*Fz at FZNOM, RVY1` — Slip ratio slide force at nominal force

`scalar`

Slip ratio side force at nominal force, F_{ZNOM}, *RVY1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Side force Svyk/Muy*Fz variation with load, RVY2` — Side force variation with load

`scalar`

Side force variation with load, *RVY2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Side force Svyk/Muy*Fz variation with camber, RVY3` — Side force variation with camber

`scalar`

Side force variation with camber, *RVY3*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip angle, RVY4` — Side force variation with slip angle

`scalar`

Side force variation with slip angle, *RVY4*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip ratio, RVY5` — Side force variation with slip ratio
`scalar`

Side force variation with slip ratio, *RVY5*, dimensionless.

`Side force Svyk/Muy*Fz variation with slip ratio arctangent, RVY6` — Side force variation with slip ratio arctangent
`scalar`

Side force variation with slip ratio arctangent, *RVY6*, dimensionless.

Rolling

`Torque resistance coefficient, QSY1` — Torque resistance
`scalar`

Torque resistance coefficient, *QSY1*, dimensionless.

`Torque resistance due to Fx, QSY2` — Torque resistance due to longitudinal force
`scalar`

Torque resistance due to longitudinal force, F_x, *QSY2*, dimensionless.

`Torque resistance due to speed, QSY3` — Torque resistance due to speed
`scalar`

Torque resistance due to speed, *QSY3*, dimensionless.

`Torque resistance due to speed^4, QSY4` — Torque resistance due to speed
`scalar`

Torque resistance due to speed^4, *QSY4*, dimensionless.

`Torque resistance due to square of camber, QSY5` — Torque resistance due to camber
`scalar`

Torque resistance due to square of camber, *QSY5*, dimensionless.

`Torque resistance due to square of camber and load, QSY6` — Torque resistance due to camber and load
`scalar`

Torque resistance due to square of camber and load, *QSY6*, dimensionless.

`Torque resistance due to load, QSY7` — Torque resistance due to load
`scalar`

Torque resistance due to load, *QSY7*, dimensionless.

`Torque resistance due to pressure, QSY8` — Torque resistance due to pressure
`scalar`

Torque resistance due to pressure, *QSY8*, dimensionless.

Aligning

`Trail slope factor for trail Bpt at FZNOM, QBZ1` — Trail slope factor at nominal force
`scalar`

Trail slope factor for trail *Bpt* at nominal force, F_{ZNOM}, *QBZ1*, dimensionless.

`Bpt slope variation with load, QBZ2` — Slope variation with load
`scalar`

Slope variation with load, *QBZ2*, dimensionless.

`Bpt slope variation with square of load, QBZ3` — Slope variation with load
`scalar`

Slope variation with square of load, *QBZ3*, dimensionless.

`Bpt slope variation with camber, QBZ4` — Slope variation with camber
`scalar`

Slope variation with camber, *QBZ4*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Bpt slope variation with absolute value of camber, QBZ5` — Slope variation with camber
`scalar`

Slope variation with absolute value of camber, *QBZ5*, dimensionless.

`Bpt slope variation with square of camber, QBZ6` — Slope variation with camber
`scalar`

Slope variation with square of camber, *QBZ6*, dimensionless.

`Br of Mzr slope scaling factor, QBZ9` — Slope scaling factor
`scalar`

Slope scaling factor, *QBZ9*, dimensionless.

`Br of Mzr cornering stiffness factor, QBZ10` — Cornering stiffness factor
`0` (default) | `scalar`

Br of *Mzr* cornering stiffness factor, *QBZ10*, dimensionless.

`Cpt pneumatic trail shape factor, QCZ1` — Pneumatic trail shape factor
`scalar`

Pneumatic trail shape factor, C_{pt}, *QCZ1*, dimensionless.

`Dpt peak trail, QDZ1` — Peak trail
`scalar`

Peak trail, D_{pt}, *QDZ1*, dimensionless.

`Dpt peak trail variation with load, QDZ2` — Peak trail variation with load

`scalar`

Peak trail, D_{pt}, variation with load, *QDZ2*, dimensionless.

`Dpt peak trail variation with camber, QDZ3` — Peak trail variation with camber

`scalar`

Peak trail, D_{pt}, variation with camber, *QDZ3*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dpt peak trail variation with square of camber, QDZ4` — Peak trail variation with camber

`scalar`

Peak trail, D_{pt}, variation with square of camber, *QDZ4*, dimensionless.

`Dmr peak residual torque, QDZ6` — Peak residual torque

`scalar`

Peak residual torque, D_{mr}, *QDZ6*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dmr peak residual torque variation with load, QDZ7` — Peak residual torque variation with load

`scalar`

Peak residual torque, D_{mr}, variation with load, *QDZ7*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Dmr peak residual torque variation with camber, QDZ8` — Peak residual torque variation with camber

`scalar`

Peak residual torque, D_{mr}, variation with camber, *QDZ8*, dimensionless.

`Dmr peak residual torque variation with camber and load, QDZ9` — Peak residual torque variation with camber and load

`scalar`

Peak residual torque, D_{mr}, variation with camber and load, *QDZ9*, dimensionless.

`Dmr peak residual torque variation with square of camber, QDZ10` — Peak residual torque variation with camber

`scalar`

Peak residual torque, D_{mr}, variation with square of camber, *QDZ10*, dimensionless.

`Dmr peak residual torque variation with square of load, QDZ11` — Peak residual torque variation with load

scalar

Peak residual torque, D_{mr}, variation with square of load, *QDZ11*, dimensionless.

`Ept trail curvature at FZNOM, QEZ1` — Trail curvature at nominal force

scalar

Trail curvature, E_{pt}, at nominal force, F_{ZNOM}, *QEZ1*, dimensionless.

`Ept variation with load, QEZ2` — Trail curvature variation with load

scalar

Trail curvature, E_{pt} variation with load, *QEZ2*, dimensionless.

`Ept variation with square of load, QEZ3` — Trail curvature variation with load

scalar

Trail curvature, E_{pt} variation with square of load, *QEZ3*, dimensionless.

`Ept variation with sign of alpha-t, QEZ4` — Trail curvature variation

scalar

Trail curvature, E_{pt} variation with sign of alpha-t, *QEZ4*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Ept variation with sign of alpha-t and camber, QEZ5` — Variation

scalar

Trail curvature, E_{pt} variation with sign of alpha-t and camber, *QEZ5*, dimensionless.

`Sht horizontal trail shift at FZNOM, QHZ1` — Horizontal trail shift at nominal load

scalar

Horizontal trail shift, Sh_t, at nominal load, F_{ZNOM}, *QHZ1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Sht variation with load, QHZ2` — Horizontal trail shift variation with load

scalar

Horizontal trail shift, Sh_t, variation with load, *QHZ2*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`Sht variation with camber, QHZ3` — Horizontal trail shift variation with camber

scalar

Horizontal trail shift, Sh_t, variation with camber, *QHZ3*, dimensionless.

`Sht variation with load and camber, QHZ4` — Horizontal trail shift variation with load and camber

`scalar`

Horizontal trail shift, Sh_t, variation with load and camber, *QHZ4*, dimensionless.

`Inflation pressure influence on trail length, PPZ1` — Pressure influence on trail length

`scalar`

Inflation pressure influence on trail length, *PPZ1*, dimensionless.

`Inflation pressure influence on residual aligning torque, PPZ2` — Pressure influence on aligning torque

`scalar`

Inflation pressure influence on residual aligning torque, *PPZ2*, dimensionless.

`Nominal value of s/R0: effect of Fx on Mz, SSZ1` — Effect of longitudinal force on aligning torque

`scalar`

Nominal value of s/R0: effect of longitudinal force, F_x, on aligning torque, M_z, *SSZ1*, dimensionless.

Dependencies

If you clear **Ply steer**, the block internally sets this parameter to 0 in the Magic Formula equations.

`s/R0 variation with lateral to nominal force ratio, SSZ2` — Variation with lateral to nominal force ratio

`scalar`

Variation with lateral to nominal force ratio, *SSZ2*, dimensionless.

`s/R0 variation with camber, SSZ3` — Variation with camber

`scalar`

Variation with camber, *SSZ3*, dimensionless.

`s/R0 variation with camber and load, SSZ4` — Variation with camber and load

`scalar`

Variation with camber and load, *SSZ4*, dimensionless.

Turnslip

`Fx peak reduction due to spin, PDXP1` — Longitudinal force peak reduction due to spin

`scalar`

Longitudinal force, F_x, peak reduction due to spin, *PDXP1*, dimensionless.

`Fx peak reduction due to spin with varying load, PDXP2` — Longitudinal force peak reduction due to spin

`scalar`

Longitudinal force, F_x, peak reduction due to spin with varying load, *PDXP2*, dimensionless.

`Fx peak reduction due to spin with slip ratio, PDXP3` — Longitudinal force peak reduction due to spin
`scalar`

Longitudinal force, F_x, peak reduction due to spin with slip ratio, *PDXP3*, dimensionless.

`Cornering stiffness reduction due to spin, PKYP1` — Stiffness reduction due to spin
`scalar`

Cornering stiffness reduction due to spin, *PKYP1*, dimensionless.

`Fy peak reduction due to spin, PDYP1` — Lateral force peak reduction due to spin
`scalar`

Lateral force, F_y, peak reduction due to spin, *PDYP1*, dimensionless.

`Fy peak reduction due to spin with varying load, PDYP2` — Lateral force peak reduction due to spin
`scalar`

Lateral force, F_y, peak reduction due to spin with varying load, *PDYP2*, dimensionless.

`Fy peak reduction due to spin with slip angle, PDYP3` — Lateral force peak reduction due to spin
`scalar`

Lateral force, F_y, peak reduction due to spin with slip angle, *PDYP3*, dimensionless.

`Fy peak reduction due to square root of spin, PDYP4` — Lateral force peak reduction due to spin
`scalar`

Lateral force, F_y, peak reduction due to square root of spin, *PDYP4*, dimensionless.

`Fy vs. slip angle response lateral shift limit, PHYP1` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response lateral shift limit, *PHYP1*, dimensionless.

`Fy vs. slip angle response max lateral shift limit, PHYP2` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response max lateral shift limit, *PHYP2*, dimensionless.

`Fy vs. slip angle response max lateral shift limit with load, PHYP3` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response max lateral shift limit with load, *PHYP3*, dimensionless.

`Fy vs. slip angle response lateral shift curvature factor, PHYP4` — Lateral force versus slip angle response
`scalar`

Lateral force, F_y, versus slip angle response lateral shift curvature factor, *PHYP4*, dimensionless.

`Camber stiffness reduction due to spin, PECP1` — Camber stiffness reduction
`scalar`

Camber stiffness reduction due to spin, *PECP1*, dimensionless.

`Camber stiffness reduction due to spin with load, PECP2` — Camber stiffness reduction
`scalar`

Camber stiffness reduction due to spin with load, *PECP2*, dimensionless.

`Turn slip pneumatic trail reduction factor, QDTP1` — Turn slip pneumatic trail reduction factor
`scalar`

Turn slip pneumatic trail reduction factor, *QDTP1*, dimensionless.

`Turn moment for constant turning and zero longitudinal speed, QCRP1` — Turn moment for constant turning
`scalar`

Turn moment for constant turning and zero longitudinal speed, *QCRP1*, dimensionless.

`Turn slip moment increase with spin at 90deg slip angle, QCRP2` — Turn slip moment
`scalar`

Turn slip moment increase with spin at 90-degree slip angle, *QCRP2*, dimensionless.

`Residual spin torque reduction from side slip, QBRP1` — Residual spin torque reduction
`scalar`

Residual spin torque reduction from side slip, *QBRP1*, dimensionless.

`Turn slip moment peak magnitude, QDRP1` — Turn slip moment peak magnitude
`scalar`

Turn slip moment peak magnitude, *QDRP1*, dimensionless.

`Turn slip moment curvature, QDRP2` — Turn slip moment curvature
`scalar`

Turn slip moment curvature, *QDRP2*, dimensionless.

Version History

Introduced in R2021b

New Ply steer and Turn slip Parameters
Behavior changed in R2022b

Starting from R2022b, the Combined Slip Wheel STI block includes **Ply steer** and **Turn slip** parameters. To remove ply steer and turn slip from the Magic Formula implementation of these blocks, clear the **Ply steer** and **Turn slip** parameters.

References

[1] Besselink, Igo, Antoine J. M. Schmeitz, and Hans B. Pacejka, "An improved Magic Formula/Swift tyre model that can handle inflation pressure changes," *Vehicle System Dynamics - International Journal of Vehicle Mechanics and Mobility* 48, sup. 1 (2010): 337–52, https://doi.org/10.1080/00423111003748088.

[2] Pacejka, Hans B. *Tire and Vehicle Dynamics*. 3rd ed. Oxford, United Kingdom: SAE and Butterworth-Heinemann, 2012.

[3] Bohm, F., and H. P. Willumeit, "Tyre Models for Vehicle Dynamic Analysis: Proceedings of the 2nd International Colloquium on Tyre Models for Vehicle Dynamics Analysis, Held at the Technical University of Berlin, Germany, February 20-21, 1997." *Vehicle System Dynamics - International Journal of Vehicle Mechanics and Mobility* 27, sup. 1, 343–45. https://doi.org/0.1080/00423119708969669.

[4] Schmid, Steven R., Bernard J. Hamrock, and Bo O. Jacobson. *Fundamentals of Machine Elements, SI Version*. 3rd ed. Boca Raton: CRC Press, 2014.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Combined Slip Wheel 2DOF | Combined Slip Wheel 2DOF CPI | Fiala Wheel 2DOF | Longitudinal Wheel

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

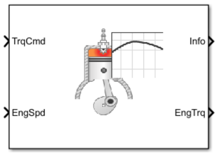
4

Propulsion Blocks

Simple Engine

Simplified engine model using lookup tables

Library: Powertrain Blockset / Propulsion / Combustion Engines
Vehicle Dynamics Blockset / Powertrain / Propulsion



Description

The Simple Engine block implements a simplified engine model using a maximum torque vs engine speed table, two scalar fuel mass properties, and one scalar engine efficiency parameter to estimate engine torque and fuel flow. You can use the block for:

- Hardware-in-the-loop (HIL) engine control design
- Vehicle-level fuel economy and performance simulations

Ports

Input

`TrqCmd` — Commanded torque
`scalar`

Torque, in N·m.

`EngSpd` — Engine speed
`scalar`

Engine speed, in rpm.

Output

`Info` — Bus signal
bus

Bus signal containing these block calculations.

Signal	Description	Units
`IntkGasMassFlw` (zeroed out intentionally)	Engine air mass flow output	kg/s
`NrmlzdAirChrg` (zeroed out intentionally)	Normalized engine cylinder air mass	N/A
`Afr` (zeroed out intentionally)	Air-fuel ratio (AFR)	N/A
`FuelMassFlw`	Engine fuel flow output	kg/s
`FuelVolFlw`	Volumetric fuel flow	m^3/s
`ExhManGasTemp` (zeroed out intentionally)	Engine exhaust gas temperature	K

Signal			Description	Units
`EngTrq`			Engine torque output	N·m
`EngSpd`			Engine speed	rpm
`CrkAng` (zeroed out intentionally)			Engine crankshaft absolute angle $\int_{0}^{(360)Cps} EngSpd\frac{180}{30}d\theta$ where Cps is crankshaft revolutions per power stroke.	degrees crank angle
`Bsfc`			Engine brake-specific fuel consumption (BSFC)	g/kWh
`EoHC` (zeroed out intentionally)			Engine out hydrocarbon emission mass flow	kg/s
`EoCO` (zeroed out intentionally)			Engine out carbon monoxide emission mass flow rate	kg/s
`EoNOx` (zeroed out intentionally)			Engine out nitric oxide and nitrogen dioxide emissions mass flow	kg/s
`EoCO2` (zeroed out intentionally)			Engine out carbon dioxide emission mass flow	kg/s
`EoPM` (zeroed out intentionally)			Engine out particulate matter emission mass flow	kg/s
`PwrInfo`	`PwrTrnsfrd`	`PwrCrkshft`	Crankshaft power	W
	`PwrNotTrnsfrd`	`PwrFuel`	Fuel input power	W
		`PwrLoss`	Power loss	W
	`PwrStored`		*Not used*	

`EngTrq` — Engine brake torque
`scalar`

Engine brake torque, in N·m.

Parameters

`Engine maximum torque, f_tqmax` — Breakpoints
`[75.679776480773256 75.679776480773256 97.173658538143172 116.84042599160529 152.21029882684542 175 174.99889520597083 174.99996520122858 175 175 175 175 175 175 175 175]` (default)

Breakpoints, in N·m.

`Breakpoints for engine speed input, f_tqmax_n_bpt` — Breakpoints
`[0 750 1053.57142857143 1357.14285714286 1660.71428571429 1964.28571428571 2267.85714285714 2571.42857142857 2875 3178.57142857143 3482.14285714286 3785.71428571429 4089.28571428571 4392.85714285714 4696.42857142857 5000]` (default)

Breakpoints, in rpm.

`Fuel lower heating value, Lhv` — Heating value
`4.6E+7` (default)

Fuel lower heating value, in J/kg.

`Fuel specific gravity, Sg` — Specific gravity
`0.745` (default)

Specific gravity of fuel, dimensionless.

`Average brake specific fuel consumption, BsfcAvg` — Average brake specific fuel consumption
`350` (default)

Average brake specific fuel consumption, in g/kwh.

Version History

Introduced in R2021b

Extended Capabilities

C/C++ Code Generation

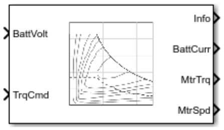
Generate C and C++ code using Simulink® Coder™.

See Also

Mapped Motor

Mapped motor and drive electronics operating in torque-control mode

Library: Powertrain Blockset / Propulsion / Electric Motors and Inverters
Vehicle Dynamics Blockset / Powertrain / Propulsion



Description

The Mapped Motor block implements a mapped motor and drive electronics operating in torque-control mode. The output torque tracks the torque reference demand and includes a motor-response and drive-response time constant. Use the block for fast system-level simulations when you do not know detailed motor parameters, for example, for motor power and torque tradeoff studies. The block assumes that the speed fluctuations due to mechanical load do not affect the motor torque tracking.

You can specify:

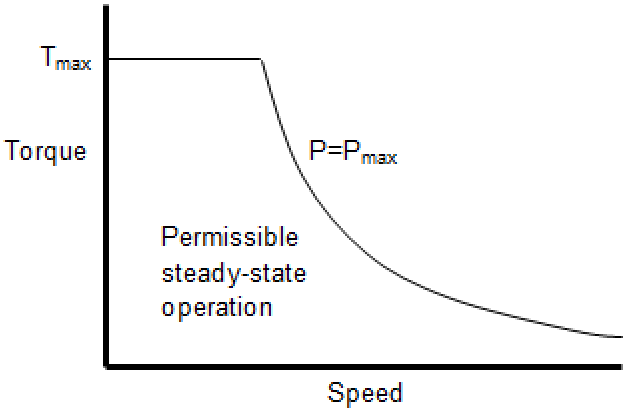
- Port configuration — Input torque or speed.
- Electrical torque range — Torque speed envelope or maximum motor power and torque.
- Electrical loss — Single operating point, measured efficiency, or measured loss. If you have Model-Based Calibration Toolbox™, you can virtually calibrate the measured loss tables.

Electrical Torque

To specify the range of torque and speed that the block allows, on the **Electrical Torque** tab, for **Parametrized by**, select one of these options.

Setting	Block Implementation
`Tabulated torque-speed envelope`	Range specified as a set of speed data points and corresponding maximum torque values.
`Maximum torque and power`	Range specified with maximum torque and maximum power.

For either method, the block implements an envelope similar to this.



Electrical Losses

To specify the electrical losses, on the **Electrical Losses** tab, for **Parameterize losses by**, select one of these options.

Setting	Block Implementation
`Single efficiency measurement`	Sum of these terms, measured at a single measurement point: - Fixed losses independent of torque and speed, P_0. Use P_0 to account for fixed converter losses. - A torque-dependent electrical loss $k\tau^2$, where k is a constant and τ is the torque. Represents ohmic losses in the copper windings. - A speed-dependent electrical loss $k_w\omega^2$, where k_w is a constant and ω is the speed. Represents iron losses due to eddy currents.
`Tabulated loss data`	Loss lookup table that is a function of motor speeds and load torques. If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 2D lookup tables using measured data.
`Tabulated loss data with temperature`	Loss lookup table that is a function of motor speeds, load torques, and operating temperature. If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 3D lookup tables using measured data.

Setting	Block Implementation
`Tabulated efficiency data`	2D efficiency lookup table that is a function of motor speeds and load torques: • Converts the efficiency values you provide into losses and uses the tabulated losses for simulation. • Ignores efficiency values you provide for zero speed or zero torque. Losses are assumed zero when either torque or speed is zero. • Uses linear interpolation to determine losses. Provide tabulated data for low speeds and low torques, as required, to get the desired level of accuracy for lower power conditions. • Does not extrapolate loss values for speed and torque magnitudes that exceed the range of the table.
`Tabulated efficiency data with temperature`	3D efficiency lookup table that is a function of motor speeds, load torques, and operating temperature: • Converts the efficiency values you provide into losses and uses the tabulated losses for simulation. • Ignores efficiency values you provide for zero speed or zero torque. Losses are assumed zero when either torque or speed is zero. • Uses linear interpolation to determine losses. Provide tabulated data for low speeds and low torques, as required, to get the desired level of accuracy for lower power conditions. • Does not extrapolate loss values for speed, torque, or temperature magnitudes that exceed the range of the table.

For best practice, use `Tabulated loss data` instead of `Tabulated efficiency data`:

- Efficiency becomes ill defined for zero speed or zero torque.
- You can account for fixed losses that are still present for zero speed or torque.

Note Due to system losses, the motor can draw a current when the motor torque is zero.

Virtual Calibration

If you have Model-Based Calibration Toolbox, you can virtually calibrate the measured loss lookup tables.

1. On the **Electrical Losses** tab, set **Parameterize losses by** to either:
   - `Tabulated loss data`
   - `Tabulated loss data with temperature`
2. Click **Calibrate Maps**.

The dialog box steps through these tasks.

<table>
<tr><th>Task</th><th>Description</th></tr>
<tr><td>Import Loss Data</td><td>Import this loss data from a file. For example, open `<matlabroot>/toolbox/autoblks/autoblksshared/mbctemplates/MappedMotorDataset.xlsx`.
For more information, see “Using Data” (Model-Based Calibration Toolbox).
<table>
<tr><th>Parameterize losses by</th><th>Required Data</th></tr>
<tr><td><code>Tabulated loss data</code></td><td>• Motor speed, rad/s
• Motor torque, N·m
• Power loss, W</td></tr>
<tr><td><code>Tabulated loss data with temperature</code></td><td>• Motor speed, rad/s
• Motor torque, N·m
• Motor temperature, K
• Power loss, W</td></tr>
</table>
Collect motor data at steady-state operating conditions. Data should cover the motor speed, torque, and temperature operating range.
To filter or edit the data, select **Edit in Application**. The Model-Based Calibration Toolbox Data Editor opens.</td></tr>
<tr><td>Generate Response Models</td><td>Model-Based Calibration Toolbox uses test plans to fit data to Gaussian process models (GPMs).
To assess or adjust the response model fit, select **Edit in Application**. The Model-Based Calibration Toolbox Model Browser opens. For more information, see “Model Assessment” (Model-Based Calibration Toolbox).</td></tr>
<tr><td>Generate Calibration</td><td>Model-Based Calibration Toolbox calibrates the response models and generates calibrated tables.
To assess or adjust the calibration, select **Edit in Application**. The Model-Based Calibration Toolbox CAGE Browser opens. For more information, see “Calibration Lookup Tables” (Model-Based Calibration Toolbox).</td></tr>
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<tr><td>Update block parameters</td><td>Update these parameters with the calibration.
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<tr><th>Parameterize losses by</th><th>Parameters</th></tr>
<tr><td><code>Tabulated loss data</code></td><td>• Vector of speeds(w) for tabulated losses, w_eff_bp
• Vector of torques (T) for tabulated losses, T_eff_bp
• Corresponding losses, losses_table</td></tr>
<tr><td><code>Tabulated loss data with temperature</code></td><td>• Vector of speeds(w) for tabulated losses, w_eff_bp
• Vector of torques (T) for tabulated losses, T_eff_bp
• Vector of temperatures for tabulated losses, Temp_eff_bp
• Corresponding losses, losses_table_3d</td></tr>
</table>
</td></tr>
</table>

Battery Current

The block calculates the battery current using the mechanical power, power loss, and battery voltage. Positive current indicates battery discharge. Negative current indicates battery charge.

$$BattAmp = \frac{MechPwr + PwrLoss}{BattVolt}$$

The equation uses these variables.

$BattVolt$	Battery voltage
$MechPwr$	Mechanical power
$PwrLoss$	Power loss
$BattCurr$	Battery current

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Variable	Equations
`PwrInfo`	`PwrTrnsfrd` • Positive signals indicate power flow into the block. • Negative signals indicate power flow out of the block.	`PwrMtr`	Mechanical power	P_{mot}	$P_{mot} = \omega_m T_e$
		`PwrBus`	Electrical power	P_{bus}	$P_{bus} = P_{mot} + P_{loss}$
	`PwrNotTrnsfrd` • Negative signals indicate power loss.	`PwrLoss`	Motor power loss	P_{loss}	$P_{stored} = \omega_m \dot{\omega}_m J$

Bus Signal			Description	Variable	Equations
	`PwrStored` - Positive signals indicate power gain.	`PwrStoredShft`	Motor power stored	P_{str}	$P_{loss} = \quad - (P_{mot} + P_{loss} - \quad P_{stored})$

The equations use these variables.

T_e	Motor output shaft torque
ω	Motor shaft speed
J	Motor inertia

Ports

Input

`BattVolt` — Battery voltage
`scalar`

Battery voltage, *BattVolt*, in V.

`TrqCmd` — Commanded motor torque
`scalar`

Commanded motor torque, Trq_{cmd}, in N·m.

Dependencies

To create this input port, for the **Port configuration**, select `Torque`.

`MtrSpd` — Motor output shaft speed
`scalar`

Motor shaft speed, Mtr_{spd}, in rad/s.

Dependencies

To create this input port, for the **Port configuration**, select `Speed`.

Output

`Info` — Bus signal
bus

The bus signal contains these block calculations.

Signal			Description	Units
`MechPwr`			Mechanical power	W
`PwrLoss`			Internal inverter and motor power loss	N·m
`PwrInfo`	`PwrTrnsfrd`	`PwrMtr`	Mechanical power	W
		`PwrBus`	Electrical power	W

Signal			Description	Units
	`PwrNotTrnsfrd`	`PwrLoss`	Motor power loss	W
	`PwrStored`	`PwrStored Shft`	Motor power stored	W

`BattCurr` — Battery current

`scalar`

Battery current draw or demand, I_{batt}, in A.

`MtrTrq` — Motor torque

`scalar`

Motor output shaft torque, Mtr_{trq}, in N·m.

`MtrSpd` — Motor shaft speed

`scalar`

Motor shaft speed, Mtr_{spd}, in rad/s.

Dependencies

To create this output port, for the **Port configuration**, select `Torque`.

Parameters

Block Options

`Port configuration` — Select port configuration

`Torque` (default) | `Speed`

This table summarizes the port configurations.

Port Configuration	Creates Ports
`Torque`	Outpost `MtrSpd`
`Speed`	Input `MtrSpd`

`Calibrate Maps` — Calibrate tables with measured data

`selection`

If you have Model-Based Calibration Toolbox, you can virtually calibrate the measured loss lookup tables.

1. On the **Electrical Losses** tab, set **Parameterize losses by** to either:
   - `Tabulated loss data`
   - `Tabulated loss data with temperature`
2. Click **Calibrate Maps**.

The dialog box steps through these tasks.

<table>
<tr><th>Task</th><th>Description</th></tr>
<tr><td>Import Loss Data</td><td>Import this loss data from a file. For example, open <code><<i>matlabroot</i>>/toolbox/autoblks/autoblksshared/mbctemplates/MappedMotorDataset.xlsx</code>.
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• Motor temperature, K
• Power loss, W</td></tr>
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Collect motor data at steady-state operating conditions. Data should cover the motor speed, torque, and temperature operating range.
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Vector of torques (T) for tabulated losses, T_eff_bp
Vector of temperatures for tabulated losses, Temp_eff_bp
Corresponding losses, losses_table_3d</td></tr>
</table></td></tr>
</table>

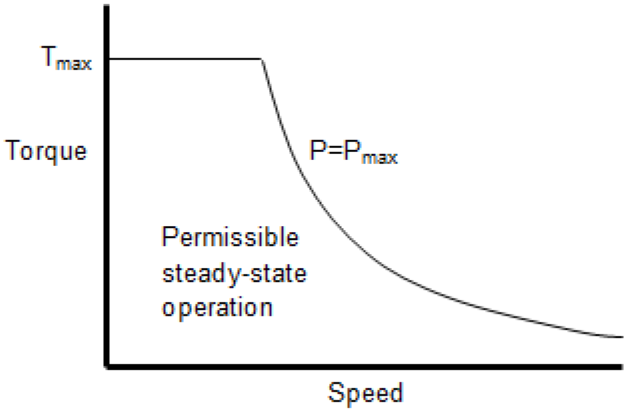
Electrical Torque

`Parameterized by` — Select type

`Tabulated torque-speed envelope` (default) | `Maximum torque and power`

Setting	Block Implementation
`Tabulated torque-speed envelope`	Range specified as a set of speed data points and corresponding maximum torque values.
`Maximum torque and power`	Range specified with maximum torque and maximum power.

For either method, the block implements an envelope similar to this.



`Vector of rotational speeds, w_t` — Rotational speeds

`[0 375 750 800]` (default) | `vector`

Rotational speeds for permissible steady-state operation, in rad/s. To avoid poor performance due to an infinite slope in the torque-speed curve, specify a vector of rotational speeds that does not contain duplicate consecutive values.

Dependencies

To create this parameter, for the **Parameterized by** parameter, select `Tabulated torque-speed envelope`.

`Vector of maximum torque values, T_t` — Torque
`[0.09 0.08 0.07 0]` (default) | `vector`

Maximum torque values for permissible steady state, in N·m.

Dependencies

To create this parameter, for the **Parameterized by** parameter, select `Tabulated torque-speed envelope`.

`Maximum torque, torque_max` — Torque
`.1` (default) | `scalar`

The maximum permissible motor torque, in N·m.

Dependencies

To create this parameter, for the **Parameterized by** parameter, select `Maximum torque and power`.

`Maximum power, power_max` — Power
`30` (default) | `scalar`

The maximum permissible motor power, in W.

Dependencies

To create this parameter, for the **Parameterized by** parameter, select `Maximum torque and power`.

`Torque control time constant, Tc` — Time constant
`0.02` (default) | `scalar`

Time constant with which the motor driver tracks a torque demand, in s.

Electrical Losses

`Parameterize losses by` — Select type
`Single efficiency measurement` (default) | `Tabulated loss data` | `Tabulated efficiency data`

Setting	Block Implementation
`Single efficiency measurement`	Sum of these terms, measured at a single measurement point: • Fixed losses independent of torque and speed, P_0. Use P_0 to account for fixed converter losses. • A torque-dependent electrical loss $k\tau^2$, where k is a constant and τ is the torque. Represents ohmic losses in the copper windings. • A speed-dependent electrical loss $k_w\omega^2$, where k_w is a constant and ω is the speed. Represents iron losses due to eddy currents.
`Tabulated loss data`	Loss lookup table that is a function of motor speeds and load torques. If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 2D lookup tables using measured data.
`Tabulated loss data with temperature`	Loss lookup table that is a function of motor speeds, load torques, and operating temperature. If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 3D lookup tables using measured data.
`Tabulated efficiency data`	2D efficiency lookup table that is a function of motor speeds and load torques: • Converts the efficiency values you provide into losses and uses the tabulated losses for simulation. • Ignores efficiency values you provide for zero speed or zero torque. Losses are assumed zero when either torque or speed is zero. • Uses linear interpolation to determine losses. Provide tabulated data for low speeds and low torques, as required, to get the desired level of accuracy for lower power conditions. • Does not extrapolate loss values for speed and torque magnitudes that exceed the range of the table.

Setting	Block Implementation
`Tabulated efficiency data with temperature`	3D efficiency lookup table that is a function of motor speeds, load torques, and operating temperature: • Converts the efficiency values you provide into losses and uses the tabulated losses for simulation. • Ignores efficiency values you provide for zero speed or zero torque. Losses are assumed zero when either torque or speed is zero. • Uses linear interpolation to determine losses. Provide tabulated data for low speeds and low torques, as required, to get the desired level of accuracy for lower power conditions. • Does not extrapolate loss values for speed, torque, or temperature magnitudes that exceed the range of the table.

For best practice, use `Tabulated loss data` instead of `Tabulated efficiency data`:

- Efficiency becomes ill defined for zero speed or zero torque.
- You can account for fixed losses that are still present for zero speed or torque.

Note Due to system losses, the motor can draw a current when the motor torque is zero.

`Motor and drive overall efficiency, eff` — Efficiency

`100` (default) | `scalar`

The block defines overall efficiency as:

$$\eta = 100\frac{\tau_0\omega_0}{\tau_0\omega_0 + P_0 + k\tau_0^2 + k_w\omega_0^2}$$

The equation uses these variables.

τ_0	Torque at which efficiency is measured
ω_0	Speed at which efficiency is measured
P_0	Fixed losses independent of torque or speed
$k\tau_0^2$	Torque-dependent electrical losses
$k_w\omega^2$	Speed-dependent iron losses

At initialization, the block solves the efficiency equation for k. The block neglects losses associated with the rotor damping.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Single efficiency measurement`.

`Speed at which efficiency is measured, w_eff` — Speed

`375` (default) | `scalar`

Speed at which efficiency is measured, in rad/s.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Single efficiency measurement`.

`Torque at which efficiency is measured, T_eff` — Torque

`0.08` (default) | `scalar`

Torque at which efficiency is measured, in N·m.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Single efficiency measurement`.

`Iron losses, Piron` — Power

`0` (default) | `scalar`

Iron losses at the speed and torque at which efficiency is defined, in W.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Single efficiency measurement`.

`Fixed losses independent of torque and speed, Pbase` — Power

`0` (default) | `scalar`

Fixed electrical loss associated with the driver when the motor current and torque are zero, in W.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Single efficiency measurement`.

`Vector of speeds (w) for tabulated losses, w_eff_bp` — Breakpoints

`[-8000 -4000 0 4000 8000]` (default) | 1-by-`M` vector

Speed breakpoints for lookup table when calculating losses, in rad/s. Array dimensions are `1` by the number of speed breakpoints, `M`.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select one of these:

- `Tabulated loss data`
- `Tabulated loss data with temperature`
- `Tabulated efficiency data`
- `Tabulated efficiency data with temperature`

`Vector of torques (T) for tabulated losses, T_eff_bp` — Breakpoints

`[0 0.03 0.06 0.09]` (default) | 1-by-`N` vector

Torque breakpoints for lookup table when calculating losses, in N·m. Array dimensions are `1` by the number of torque breakpoints, `N`.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select one of these:

- `Tabulated loss data`
- `Tabulated loss data with temperature`
- `Tabulated efficiency data`
- `Tabulated efficiency data with temperature`

`Vector of temperatures for tabulated losses, Temp_eff_bp` — Breakpoints

`[233.15 293.15 373.15]` (default) | `1`-by-`L` vector

Temperature breakpoints for lookup table when calculating losses, in K. Array dimensions are `1` by the number of temperature breakpoints, `L`.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select one of these:

- `Tabulated loss data with temperature`
- `Tabulated efficiency data with temperature`

`Corresponding losses, losses_table` — 2D lookup table

`M`-by-`N` matrix

Array of values for electrical losses as a function of speed and torque, in W. Each value specifies the losses for a specific combination of speed and torque. The array dimensions must match the speed, `M`, and torque, `N`, breakpoint vector dimensions.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Tabulated loss data`.

`Corresponding losses, losses_table_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

Array of values for electrical losses as a function of speed, torque, and temperature, in W. Each value specifies the losses for a specific combination of speed, torque, and temperature. The array dimensions must match the speed, `M`, torque, `N`, and temperature, `L`, breakpoint vector dimensions.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Tabulated loss data with temperature`.

`Corresponding efficiency, efficiency_table` — 2D lookup table

`M`-by-`N` matrix

Array of efficiency as a function of speed and torque, in %. Each value specifies the losses for a specific combination of speed and torque. The array dimensions must match the speed, `M`, and torque, `N`, breakpoint vector dimensions.

The block ignores efficiency values for zero speed or zero torque. Losses are zero when either torque or speed is zero. The block uses linear interpolation.

To get the desired level of accuracy for lower power conditions, you can provide tabulated data for low speeds and low torques.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Tabulated efficiency data`.

`Corresponding efficiency, efficiency_table_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

Array of efficiency as a function of speed and torque, in %. Each value specifies the losses for a specific combination of speed and torque. The array dimensions must match the speed, `M`, torque, `N`, and temperature, `L`, breakpoint vector dimensions.

The block ignores efficiency values for zero speed or zero torque. Losses are zero when either torque or speed is zero. The block uses linear interpolation.

To get the desired level of accuracy for lower power conditions, you can provide tabulated data for low speeds and low torques.

Dependencies

To create this parameter, for the **Parameterize losses by** parameter, select `Tabulated efficiency data`.

Mechanical

`Rotor inertia, J` — Inertia

`5e-6` (default) | `scalar`

Rotor resistance to change in motor motion, in kg*m^2. The value can be zero.

Dependencies

To create this parameter, for the **Port configuration** parameter, select `Torque`.

`Rotor damping, b` — Damping

`1e-5` (default) | `scalar`

Rotor damping, in N·m/(rad/s). The value can be zero.

Dependencies

To create this parameter, for the **Port configuration** parameter, select `Torque`.

`Initial rotor speed, omega_o` — Speed

`0` (default) | `scalar`

Rotor speed at the start of the simulation, in rad/s.

Dependencies

To create this parameter, for the **Port configuration** parameter, select `Torque`.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

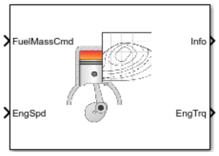
See Also

Open Differential

Mapped CI Engine

Compression-ignition engine model using lookup tables

Library: Powertrain Blockset / Propulsion / Combustion Engines
Vehicle Dynamics Blockset / Powertrain / Propulsion



Description

The Mapped CI Engine block implements a mapped compression-ignition (CI) engine model using power, air mass flow, fuel flow, exhaust temperature, efficiency, and emission performance lookup tables. You can use the block for:

- Hardware-in-the-loop (HIL) engine control design
- Vehicle-level fuel economy and performance simulations

The lookup tables, developed with the Model-Based Calibration Toolbox, are functions of injected fuel mass, F, engine torque, T, engine speed, N, and engine temperature, $Temp_{Eng}$.

Input Command Setting	Input Engine Temperature Parameter Setting	Lookup Tables
`Fuel mass`	`off`	$f(F,N)$
	`on`	$f(F,N,Temp_{Eng})$
`Torque`	`off`	$f(T,N)$
	`on`	$f(T,N,Temp_{Eng})$

The block enables you to specify lookup tables for these engine characteristics:

- Power
- Air
- Fuel
- Temperature
- Efficiency
- Hydrocarbon (HC) emissions
- Carbon monoxide (CO) emissions
- Nitric oxide and nitrogen dioxide (NOx) emissions
- Carbon dioxide (CO_2) emissions
- Particulate matter (PM) emissions

To bound the Mapped CI Engine block output, the block does not extrapolate the lookup table data.

Virtual Calibration

If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 2D lookup tables using measured data. The dialog box steps through these tasks.

<table>
<tr><th>Task</th><th>Description</th></tr>
<tr><td>Import firing data</td><td>
<p>Import this loss data from a file. For example, open <code><matlabroot>/toolbox/mbc/mbctraining/CiEngineData.xlsx</code>.</p>
<p>For more information, see “Using Data” (Model-Based Calibration Toolbox).</p>
<table>
<tr><th>Input command</th><th>Required Data</th><th>Optional Data</th></tr>
<tr><td><code>Fuel mass</code></td><td>Engine speed, rpm
Commanded fuel mass per injection, mg
Engine torque, N·m</td><td rowspan="2">Air mass flow rate, kg/s
Brake specific fuel consumption, g/(kW·h)
CO2 mass flow rate, kg/s
CO mass flow rate, kg/s
Exhaust temperature, K
Fuel mass flow rate, kg/s
HC mass flow rate, kg/s
NOx mass flow rate, kg/s
Particulate matter mass flow rate, kg/s</td></tr>
<tr><td><code>Torque</code></td><td>Engine speed, rpm
Engine torque, N·m</td></tr>
</table>
<p>Collect firing data at steady-state operating conditions when injectors deliver the fuel. Data should cover the engine speed and torque operating range. Model-Based Calibration Toolbox uses the firing data boundary as the maximum torque.</p>
<p>To filter or edit the data, select Edit in Application. The Model-Based Calibration Toolbox Data Editor opens.</p>
</td></tr>
<tr><td>Import non-firing data</td><td>
<p>Import this non-firing data from a file. For example, open <code><matlabroot>/toolbox/autoblks/autodemos/projectsrc/CIDynamometer/CalMappedEng/CiEngineData.xlsx</code>.</p>
Engine speed, rpm
Engine torque, N·m
<p>Collect non-firing (motoring) data at steady-state operating conditions when fuel is cut off. All non-firing torque points must be less than zero. Non-firing data is a function of engine speed only.</p>
</td></tr>
<tr><td>Generate response models</td><td>
<p>For both firing and non-firing data, the Model-Based Calibration Toolbox uses test plans to fit data to Gaussian process models (GPMs).</p>
<p>To assess or adjust the response model fit, select Edit in Application. The Model-Based Calibration Toolbox Model Browser opens. For more information, see “Model Assessment” (Model-Based Calibration Toolbox).</p>
</td></tr>
</table>

Task	Description
Generate calibration	Model-Based Calibration Toolbox calibrates the firing and non-firing response models and generates calibrated tables. To assess or adjust the calibration, select **Edit in Application**. The Model-Based Calibration Toolbox CAGE Browser opens. For more information, see “Calibration Lookup Tables” (Model-Based Calibration Toolbox).
Update block parameters	Update the block lookup table and breakpoint parameters with the calibration.

Cylinder Air Mass

The block calculates the normalized cylinder air mass using these equations.

$$M_{Nom} = \frac{P_{std}V_d}{N_{cyl}R_{air}T_{std}}$$

$$L = \frac{\left(\frac{60s}{min}\right)Cps \cdot \dot{m}_{air}}{\left(\frac{1000g}{Kg}\right)N_{cyl} \cdot N \cdot M_{Nom}}$$

The equations use these variables.

L	Normalized cylinder air mass
M_{Nom}	Nominal engine cylinder air mass at standard temperature and pressure, piston at bottom dead center (BDC) maximum volume, in kg
Cps	Crankshaft revolutions per power stroke, rev/stroke
P_{std}	Standard pressure
T_{std}	Standard temperature
R_{air}	Ideal gas constant for air and burned gas mixture
V_d	Displaced volume
N_{cyl}	Number of engine cylinders
N	Engine speed
$\dot{m}_{intk}$	Engine air mass flow, in g/s

Turbocharger Lag

To model turbocharger lag, select **Include turbocharger lag effect**. Turbocharger lag limits the maximum fuel mass per injection. To model the maximum fuel mass per injection, the block uses a first-order system with a time constant. At low torque, the engine does not require boost to provide sufficient air flow. When the requested fuel mass requires boost, the block uses a time constant to determine the maximum fuel mass per injection. The block uses these equations for the specified **Input command** setting.

Calculation	**Input command Parameter Setting**	
	`Fuel mass`	**`Torque`**
Dynamic torque	$\frac{dF_{max}}{dt} = \frac{1}{\tau_{eng}}(F_{cmd} - F_{max})$	$\frac{dT_{max}}{dt} = \frac{1}{\tau_{eng}}(T_{cmd} - T_{max})$
Fuel mass per injection or torque - with turbocharger lag	$F = \begin{cases} F_{cmd} & \text{when } F_{cmd} < F_{\max} \\ F_{max} & \text{when } F_{cmd} \geq F_{\max} \end{cases}$	$T_{target} = \begin{cases} T_{cmd} & \text{when } T_{cmd} < T_{\max} \\ T_{max} & \text{when } T_{cmd} \geq T_{\max} \end{cases}$
Fuel mass per injection or torque- without turbocharger lag	$F = F_{cmd} = F_{max}$	$T_{target} = T_{cmd} = T_{max}$
Boost time constant	$\tau_{bst} = \begin{cases} \tau_{bst,\, rising} & \text{when } F_{cmd} > F_{\max} \\ \tau_{bst,\, falling} & \text{when } F_{cmd} \leq F_{\max} \end{cases}$	$\tau_{bst} = \begin{cases} \tau_{bst,\, rising} & \text{when } T_{cmd} > T_{\max} \\ \tau_{bst,\, falling} & \text{when } T_{cmd} \leq T_{\max} \end{cases}$
Final time constant	$\tau_{eng} = \begin{cases} \tau_{nat} & \text{when } T_{brake} < f_{bst}(N) \\ \tau_{bst} & \text{when } T_{brake} \geq f_{bst}(N) \end{cases}$	

The equations use these variables.

T_{brake}	Brake torque
F	Fuel mass per injection
F_{cmd}, F_{max}	Commanded and maximum fuel mass per injection, respectively
T_{target}, T_{cmd}, T_{max}	Target, commanded, and maximum torque, respectively
τ_{bst}	Boost time constant
$\tau_{bst,rising}$, $\tau_{bst,falling}$	Boost rising and falling time constant, respectively
τ_{eng}	Final time constant
τ_{nat}	Time constant below the boost torque speed line
$f_{bst}(N)$	Boost torque/speed line
N	Engine speed

Fuel Flow

To calculate the fuel economy for high-fidelity models, the block uses the volumetric fuel flow.

$$Q_{fuel} = \frac{\dot{m}_{fuel}}{\left(\frac{1000kg}{m^3}\right)Sg_{fuel}}$$

The equation uses these variables.

$\dot{m}_{fuel}$	Fuel mass flow
Sg_{fuel}	Specific gravity of fuel

Q_{fuel}	Volumetric fuel flow

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrCrkshft`	Crankshaft power	$-\tau_{eng}\omega$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrFuel`	Fuel input power	$\dot{m}_{fuel}LHV$
		`PwrLoss`	Power loss	$\tau_{eng}\omega - \dot{m}_{fuel}LHV$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease		*Not used*	

The equations use these variables.

LHV	Fuel lower heating value
ω	Engine speed, rad/s
$\dot{m}_{fuel}$	Fuel mass flow
τ_{eng}	Fuel mass per injection time constant

Ports

Input

`FuelMassCmd` — Injected fuel mass command

`scalar`

Injected fuel mass command, F, in mg/inj.

Dependencies

To enable this port, for **Input command**, select `Fuel mass`.

`TrqCmd` — Torque command

`scalar`

Torque command, T, in N·m.

Dependencies

To enable this port, for **Input command**, select `Torque`.

`EngSpd` — Engine speed

scalar

Engine speed, N, in rpm.

`EngTemp` — Engine temperature

scalar

Engine temperature, $Temp_{Eng}$, in K.

Dependencies

To enable this port, select **Input engine temperature**.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal	Description	Units
`IntkGasMassFlw`	Engine air mass flow output	kg/s
`NrmlzdAirChrg`	Normalized engine cylinder air mass	N/A
`Afr`	Air-fuel ratio (AFR)	N/A
`FuelMassFlw`	Engine fuel flow output	kg/s
`FuelVolFlw`	Volumetric fuel flow	m^3/s
`ExhManGasTemp`	Engine exhaust gas temperature	K
`EngTrq`	Engine torque output	N·m
`EngSpd`	Engine speed	rpm
`CrkAng`	Engine crankshaft absolute angle $\int_0^{(360)Cps} EngSpd\frac{180}{30}d\theta$ where Cps is crankshaft revolutions per power stroke.	degrees crank angle
`Bsfc`	Engine brake-specific fuel consumption (BSFC)	g/kWh
`EoHC`	Engine out hydrocarbon emission mass flow	kg/s
`EoCO`	Engine out carbon monoxide emission mass flow rate	kg/s
`EoNOx`	Engine out nitric oxide and nitrogen dioxide emissions mass flow	kg/s
`EoCO2`	Engine out carbon dioxide emission mass flow	kg/s

Signal			Description	Units
`EoPM`			Engine out particulate matter emission mass flow	kg/s
`PwrInfo`	`PwrTrnsfrd`	`PwrCrkshft`	Crankshaft power	W
	`PwrNotTrnsfrd`	`PwrFuel`	Fuel input power	W
		`PwrLoss`	Power loss	W
	`PwrStored`		*Not used*	

`EngTrq` — Power

`scalar`

Engine power, T_{brake}, in N·m.

Parameters

Block Options

`Input command` — Table functions

`Fuel mass` (default) | `Torque`

The lookup tables, developed with the Model-Based Calibration Toolbox, are functions of injected fuel mass, F, engine torque, T, engine speed, N, and engine temperature, $Temp_{Eng}$.

Input Command Setting	Input Engine Temperature Parameter Setting	Lookup Tables
`Fuel mass`	`off`	$f(F,N)$
	`on`	$f(F,N,Temp_{Eng})$
`Torque`	`off`	$f(T,N)$
	`on`	$f(T,N,Temp_{Eng})$

Dependencies

- Selecting `Fuel mass` enables **Breakpoints for commanded fuel mass input, f_tbrake_f_bpt**.
- Selecting `Torque` enables **Breakpoints for commanded torque input, f_tbrake_t_bpt**.
- Selecting **Input engine temperature** enables **Breakpoints for temperature input, f_tbrake_engtmp_bpt**.

`Include turbocharger lag effect` — Increase time constant

`off` (default)

To model turbocharger lag, select **Include turbocharger lag effect**. Turbocharger lag limits the maximum fuel mass per injection. To model the maximum fuel mass per injection, the block uses a first-order system with a time constant. At low torque, the engine does not require boost to provide sufficient air flow. When the requested fuel mass requires boost, the block uses a time constant to determine the maximum fuel mass per injection. The block uses these equations for the specified **Input command** setting.

Calculation	**Input command Parameter Setting**	
	`Fuel mass`	**`Torque`**
Dynamic torque	$\frac{dF_{max}}{dt} = \frac{1}{\tau_{eng}}(F_{cmd} - F_{max})$	$\frac{dT_{max}}{dt} = \frac{1}{\tau_{eng}}(T_{cmd} - T_{max})$
Fuel mass per injection or torque - with turbocharger lag	$F =$ $\begin{cases} F_{cmd} & \text{when } F_{cmd} < F_{\text{max}} \\ F_{max} & \text{when } F_{cmd} \geq F_{\text{max}} \end{cases}$	$T_{target} =$ $\begin{cases} T_{cmd} & \text{when } T_{cmd} < T_{\text{max}} \\ T_{max} & \text{when } T_{cmd} \geq T_{\text{max}} \end{cases}$
Fuel mass per injection or torque- without turbocharger lag	$F = F_{cmd} = F_{max}$	$T_{target} = T_{cmd} = T_{max}$
Boost time constant	$\tau_{bst} =$ $\begin{cases} \tau_{bst,\,rising} & \text{when } F_{cmd} > F_{\text{max}} \\ \tau_{bst,\,falling} & \text{when } F_{cmd} \leq F_{\text{max}} \end{cases}$	$\tau_{bst} =$ $\begin{cases} \tau_{bst,\,rising} & \text{when } T_{cmd} > T_{\text{max}} \\ \tau_{bst,\,falling} & \text{when } T_{cmd} \leq T_{\text{max}} \end{cases}$
Final time constant	$\tau_{eng} = \begin{cases} \tau_{nat} & \text{when } T_{brake} < f_{bst}(N) \\ \tau_{bst} & \text{when } T_{brake} \geq f_{bst}(N) \end{cases}$	

The equations use these variables.

T_{brake}	Brake torque
F	Fuel mass per injection
F_{cmd}, F_{max}	Commanded and maximum fuel mass per injection, respectively
T_{target}, T_{cmd}, T_{max}	Target, commanded, and maximum torque, respectively
τ_{bst}	Boost time constant
$\tau_{bst,rising}$, $\tau_{bst,falling}$	Boost rising and falling time constant, respectively
τ_{eng}	Final time constant
τ_{nat}	Time constant below the boost torque speed line
$f_{bst}(N)$	Boost torque/speed line
N	Engine speed

Dependencies

Selecting **Include turbocharger lag effect** enables these parameters:

- **Boost torque line, f_tbrake_bst**
- **Time constant below boost line, tau_nat**
- **Rising maximum fuel mass boost time constant, tau_bst_rising**
- **Falling maximum fuel mass boost time constant, tau_bst_falling**

`Input engine temperature` — Create input port

`off` (default) | `on`

Select this to create the `EngTemp` input port.

The lookup tables, developed with the Model-Based Calibration Toolbox, are functions of injected fuel mass, *F*, engine torque, *T*, engine speed, *N*, and engine temperature, $Temp_{Eng}$.

Input Command Setting	Input Engine Temperature Parameter Setting	Lookup Tables
`Fuel mass`	`off`	$f(F,N)$
	`on`	$f(F,N,Temp_{Eng})$
`Torque`	`off`	$f(T,N)$
	`on`	$f(T,N,Temp_{Eng})$

Configuration

`Calibrate Maps` — Calibrate tables with measured data

`selection`

If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 2D lookup tables using measured data. The dialog box steps through these tasks.

<table>
<tr><th>Task</th><th>Description</th></tr>
<tr><td>Import firing data</td><td>
<p>Import this loss data from a file. For example, open <code><matlabroot>/toolbox/mbc/mbctraining/CiEngineData.xlsx</code>.</p>
<p>For more information, see “Using Data” (Model-Based Calibration Toolbox).</p>
<table>
<tr><th>Input command</th><th>Required Data</th><th>Optional Data</th></tr>
<tr><td><code>Fuel mass</code></td><td>Engine speed, rpm
Commanded fuel mass per injection, mg
Engine torque, N·m</td><td rowspan="2">Air mass flow rate, kg/s
Brake specific fuel consumption, g/(kW·h)
CO2 mass flow rate, kg/s
CO mass flow rate, kg/s
Exhaust temperature, K
Fuel mass flow rate, kg/s
HC mass flow rate, kg/s
NOx mass flow rate, kg/s
Particulate matter mass flow rate, kg/s</td></tr>
<tr><td><code>Torque</code></td><td>Engine speed, rpm
Engine torque, N·m</td></tr>
</table>
<p>Collect firing data at steady-state operating conditions when injectors deliver the fuel. Data should cover the engine speed and torque operating range. Model-Based Calibration Toolbox uses the firing data boundary as the maximum torque.</p>
<p>To filter or edit the data, select Edit in Application. The Model-Based Calibration Toolbox Data Editor opens.</p>
</td></tr>
</table>

Task	Description
Import non-firing data	Import this non-firing data from a file. For example, open `<matlabroot>/toolbox/autoblks/autodemos/projectsrc/CIDynamometer/CalMappedEng/CiEngineData.xlsx`. • Engine speed, rpm • Engine torque, N·m Collect non-firing (motoring) data at steady-state operating conditions when fuel is cut off. All non-firing torque points must be less than zero. Non-firing data is a function of engine speed only.
Generate response models	For both firing and non-firing data, the Model-Based Calibration Toolbox uses test plans to fit data to Gaussian process models (GPMs). To assess or adjust the response model fit, select **Edit in Application**. The Model-Based Calibration Toolbox Model Browser opens. For more information, see “Model Assessment” (Model-Based Calibration Toolbox).
Generate calibration	Model-Based Calibration Toolbox calibrates the firing and non-firing response models and generates calibrated tables. To assess or adjust the calibration, select **Edit in Application**. The Model-Based Calibration Toolbox CAGE Browser opens. For more information, see “Calibration Lookup Tables” (Model-Based Calibration Toolbox).
Update block parameters	Update the block lookup table and breakpoint parameters with the calibration.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Breakpoints for commanded fuel mass input, f_tbrake_f_bpt` — Breakpoints

1-by-M vector

Breakpoints, in mg/inj.

Dependencies

Setting **Input command** to `Fuel mass` enables this parameter.

`Breakpoints for commanded torque input, f_tbrake_t_bpt` — Breakpoints

1-by-M vector

Breakpoints, in N·m.

Dependencies

Setting **Input command** to `Torque` enables this parameter.

`Breakpoints for engine speed input, f_tbrake_n_bpt` — Breakpoints

1-by-N vector

Breakpoints, in rpm.

`Breakpoints for temperature input, f_tbrake_engtmp_bpt` — Breakpoints
`[233.15 273.15 373.15]` (default) | 1-by-L vector

Breakpoints, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

`Number of cylinders, NCyl` — Number
`4` (default) | `scalar`

Number of cylinders.

`Crank revolutions per power stroke, Cps` — Crank revolutions
`2` (default) | `scalar`

Crank revolutions per power stroke.

`Total displaced volume, Vd` — Volume
`0.0015` (default) | `scalar`

Volume displaced by engine, in m^3.

`Fuel lower heating value, Lhv` — Heating value
`45e6` (default) | `scalar`

Fuel lower heating value, *LHV*, in J/kg.

`Fuel specific gravity, Sg` — Specific gravity
`0.832` (default) | `scalar`

Specific gravity of fuel, Sg_{fuel}, dimensionless.

`Ideal gas constant air, Rair` — Constant
`287` (default) | `scalar`

Ideal gas constant of air and residual gas entering the engine intake port, in J/(kg·K).

`Air standard pressure, Pstd` — Pressure
`101325` (default) | `scalar`

Standard air pressure, in Pa.

`Air standard temperature, Tstd` — Temperature
`293.15` (default) | `scalar`

Standard air temperature, in K.

`Boost torque line, f_tbrake_bst` — Boost lag
`[90,95,95,95,96,100,104,104,104,100,95,85,75,67,60,55]` (default) | 1-by-M vector

Boost torque line, $f_{bst}(N)$, in N·m.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

`Time constant below boost line` — Time constant below

`0.1` (default) | `scalar`

Time constant below boost line, τ_{nat}, in s.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

`Rising maximum fuel mass boost time constant, tau_bst_rising` — Rising time constant

`1.0` (default) | `scalar`

Rising maximum fuel mass boost time constant, $\tau_{bst,rising}$, in s.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

`Falling maximum fuel mass boost time constant, tau_bst_falling` — Falling time constant

`0.7` (default) | `scalar`

Falling maximum fuel mass boost time constant, $\tau_{bst,falling}$, in s.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

`Turbocharger time constant blend fuel mass fraction, f_blend_frac` — Time constant

`0.01` (default) | `scalar`

Turbocharger time constant blend fuel mass fraction, in s.

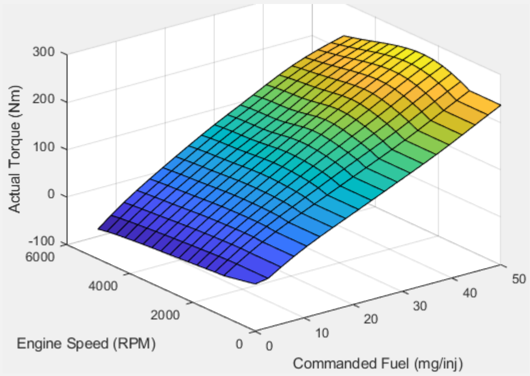
Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

Power

`Brake torque map, f_tbrake` — 2D lookup table

`M`-by-`N` matrix

Input Command Setting	Description
`Fuel mass`	The engine brake torque lookup table is a function of commanded fuel mass and engine speed, T_{brake} = ƒ(F, N), where: • T_{brake} is engine torque, in N·m. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. 
`Torque`	The engine brake torque lookup table is a function of target torque and engine speed, T_{brake} = ƒ(T_{target}, N), where: • T_{brake} is engine torque, in N·m. • T_{target} is target torque, in N·m. • N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot brake torque map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Brake torque map, f_tbrake_3d` — 3D lookup table

M-by-N-by-L array

Input Command Setting	Description
`Fuel mass`	The engine brake torque lookup table is a function of commanded fuel mass and engine speed, T_{brake} = ƒ(F, N, $Temp_{Eng}$), where: • T_{brake} is engine torque, in N·m. • F is commanded fuel mass, in mg per injection. • $Temp_{Eng}$ is engine temperature, in K.

Input Command Setting	Description
`Torque`	The engine brake torque lookup table is a function of target torque and engine speed, $T_{brake} = f(T_{target}, N, Temp_{Eng})$, where: • T_{brake} is engine torque, in N·m. • T_{target} is target torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

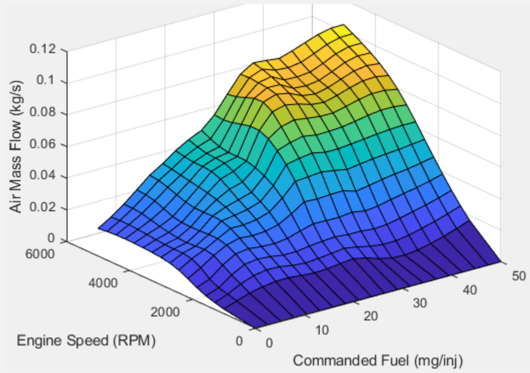
Dependencies

To enable this parameter, select **Input engine temperature**.

Air

`Air mass flow map, f_air` — 2D lookup table

M-by-N matrix

Input Command Setting	Description
`Fuel mass`	The air mass flow lookup table is a function of commanded fuel mass and engine speed, $\dot{m}_{intk} = f(F_{max}, N)$, where: • $\dot{m}_{intk}$ is engine air mass flow, in kg/s. • F_{max} is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. 
`Torque`	The air mass flow lookup table is a function of maximum torque and engine speed, $\dot{m}_{intk} = f(T_{max}, N)$, where: • $\dot{m}_{intk}$ is engine air mass flow, in kg/s. • T_{max} is maximum torque, in N·m. • N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot air mass map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Air mass flow map, f_air_3d` — 3D lookup table

M-by-N-by-L array

Input Command Setting	Description
`Fuel mass`	The air mass flow lookup table is a function of commanded fuel mass and engine speed, $\dot{m}_{intk} = f(F_{max}, N, Temp_{Eng})$, where: • $\dot{m}_{intk}$ is engine air mass flow, in kg/s. • F_{max} is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The air mass flow lookup table is a function of maximum torque and engine speed, $\dot{m}_{intk} = f(T_{max}, N, Temp_{Eng})$, where: • $\dot{m}_{intk}$ is engine air mass flow, in kg/s. • T_{max} is maximum torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

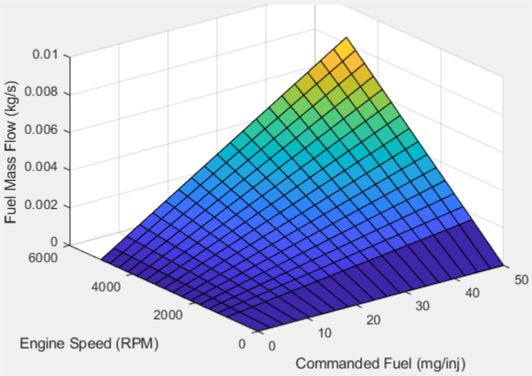
Dependencies

To enable this parameter, select **Input engine temperature**.

Fuel

`Fuel flow map, f_fuel` — 2D lookup table

M-by-N matrix

Input Command Setting	Description
`Fuel mass`	The engine fuel flow lookup table is a function of commanded fuel mass and engine speed, *MassFlow*= ƒ(*F*, *N*), where: • *MassFlow* is engine fuel mass flow, in kg/s. • *F* is commanded fuel mass, in mg per injection. • *N* is engine speed, in rpm. 
`Torque`	The engine fuel flow lookup table is a function of target torque and engine speed, *MassFlow* = ƒ(T_{target}, *N*), where: • *MassFlow* is engine fuel mass flow, in kg/s. • T_{target} is target torque, in N·m. • *N* is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot fuel flow map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Fuel flow map, f_fuel_3d` — 3D lookup table

M-by-N-by-L array

Input Command Setting	Description
`Fuel mass`	The engine fuel flow lookup table is a function of commanded fuel mass, engine speed, and engine temperature, $MassFlow = f(F, N, Temp_{Eng})$, where: - $MassFlow$ is engine fuel mass flow, in kg/s. - F is commanded fuel mass, in mg per injection. - N is engine speed, in rpm. - $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The engine fuel flow lookup table is a function of target torque and engine speed, and engine temperature, $MassFlow = f(T_{target}, N, Temp_{Eng})$, where: - $MassFlow$ is engine fuel mass flow, in kg/s. - T_{target} is target torque, in N·m. - N is engine speed, in rpm. - $Temp_{Eng}$ is engine temperature, in K.

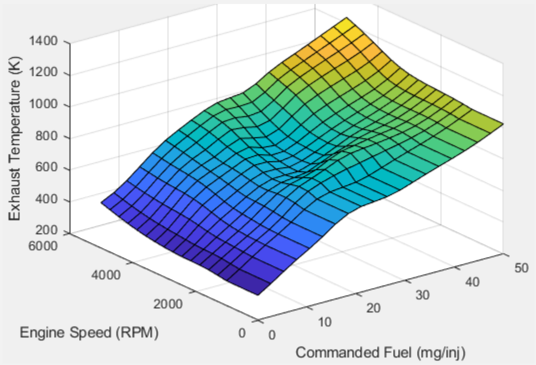
Dependencies

To enable this parameter, select **Input engine temperature**.

Temperature

`Exhaust temperature map, f_texh` — 2D lookup table

M-by-N matrix

Input Command Setting	Description
`Fuel mass`	The engine exhaust temperature table is a function of commanded fuel mass and engine speed, $T_{exh} = f(F, N)$, where: - T_{exh} is exhaust temperature, in K. - F is commanded fuel mass, in mg per injection. - N is engine speed, in rpm. 

Input Command Setting	Description
`Torque`	The engine exhaust temperature table is a function of target torque and engine speed, $T_{exh} = f(T_{target}, N)$, where: • T_{exh} is exhaust temperature, in K. • T_{target} is target torque, in N·m. • N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot exhaust temperature map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Exhaust temperature map, f_texh_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

Input Command Setting	Description
`Fuel mass`	The engine exhaust temperature table is a function of commanded fuel mass and engine speed, $T_{exh}= f(F, N, Temp_{Eng})$, where: • $T_{exh}$is exhaust temperature, in K. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The engine exhaust temperature table is a function of target torque and engine speed, $T_{exh} = f(T_{target}, N, Temp_{Eng})$, where: • T_{exh} is exhaust temperature, in K. • T_{target} is target torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

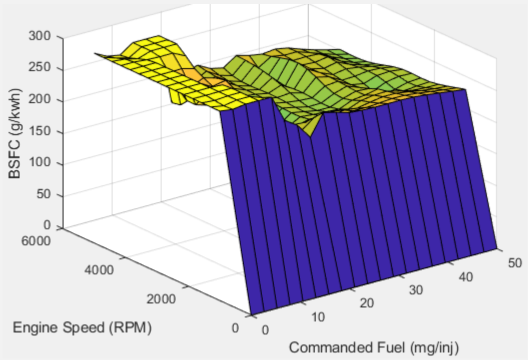
Dependencies

To enable this parameter, select **Input engine temperature**.

Efficiency

`BSFC map, f_eff` — 2D lookup table

`M`-by-`N` matrix

Input Command Setting	Description
`Fuel mass`	The brake-specific fuel consumption (BSFC) efficiency is a function of commanded fuel mass and engine speed, $BSFC = f(F, N)$, where: • $BSFC$ is BSFC, in g/kWh. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. 
`Torque`	The brake-specific fuel consumption (BSFC) efficiency is a function of target torque and engine speed, $BSFC = f(T_{target}, N)$, where: • $BSFC$ is BSFC, in g/kWh. • T_{target} is target torque, in N·m. • N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot BSFC map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`BSFC map, f_eff_3d` — 3D lookup table

M-by-N-by-L array

Input Command Setting	Description
`Fuel mass`	The brake-specific fuel consumption (BSFC) efficiency is a function of commanded fuel mass and engine speed, $BSFC = f(F, N, Temp_{Eng})$, where: • $BSFC$ is BSFC, in g/kWh. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

Input Command Setting	Description
`Torque`	The brake-specific fuel consumption (BSFC) efficiency is a function of target torque and engine speed, $BSFC = f(T_{target}, N, Temp_{Eng})$, where: • $BSFC$ is BSFC, in g/kWh. • T_{target} is target torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

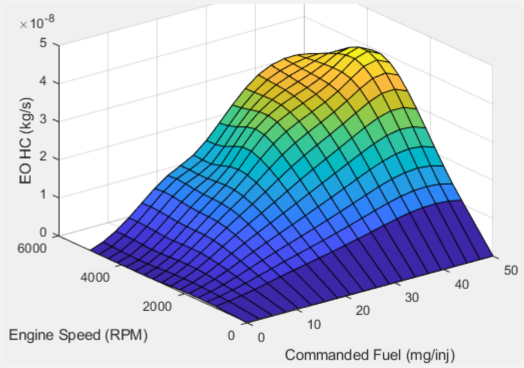
HC

`EO HC map, f_hc` — 2D lookup table

M-by-N matrix

<table>
<tr><th>Input Command Setting</th><th>Description</th></tr>
<tr><td><code>Fuel mass</code></td><td>The engine-out hydrocarbon emissions are a function of commanded fuel mass and engine speed, $EO\ HC = f(F, N)$, where:

- $EO\ HC$ is engine-out hydrocarbon emissions, in kg/s.
- F is commanded fuel mass, in mg per injection.
- N is engine speed, in rpm.


</td></tr>
<tr><td><code>Torque</code></td><td>The engine-out hydrocarbon emissions are a function of target torque and engine speed, $EO\ HC = f(T_{target}, N)$, where:

- $EO\ HC$ is engine-out hydrocarbon emissions, in kg/s.
- T_{target} is target torque, in N·m.
- N is engine speed, in rpm.</td></tr>
</table>

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO HC map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO HC map, f_hc_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

Input Command Setting	Description
`Fuel mass`	The engine-out hydrocarbon emissions are a function of commanded fuel mass and engine speed, $EO\ HC = f(F, N, Temp_{Eng})$, where: • $EO\ HC$ is engine-out hydrocarbon emissions, in kg/s. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The engine-out hydrocarbon emissions are a function of target torque and engine speed, $EO\ HC = f(T_{target}, N, Temp_{Eng})$, where: • $EO\ HC$ is engine-out hydrocarbon emissions, in kg/s. • T_{target} is target torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

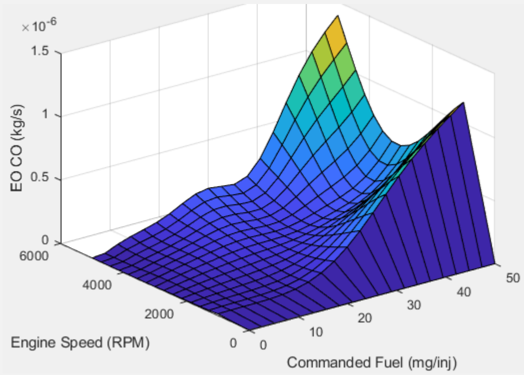
Dependencies

To enable this parameter, select **Input engine temperature**.

CO

`EO CO map, f_co` — 2D lookup table

`M`-by-`N` matrix

Input Command Setting	**Description**
`Fuel mass`	The engine-out carbon monoxide emissions are a function of commanded fuel mass and engine speed, $EO\ CO = f(F, N)$, where: • $EO\ CO$ is engine-out carbon monoxide emissions, in kg/s. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. 
`Torque`	The engine-out carbon monoxide emissions are a function of target torque and engine speed, $EO\ CO = f(T_{target}, N)$, where: • $EO\ CO$ is engine-out carbon monoxide emissions, in kg/s. • T_{target} is target torque, in N·m. • N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO CO map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO CO map, f_co_3d` — 3D lookup table

M-by-N-by-L array

Input Command Setting	Description
`Fuel mass`	The engine-out carbon monoxide emissions are a function of commanded fuel mass and engine speed, $EO\ CO = ƒ(F, N, Temp_{Eng})$, where: - $EO\ CO$ is engine-out carbon monoxide emissions, in kg/s. - F is commanded fuel mass, in mg per injection. - N is engine speed, in rpm. - $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The engine-out carbon monoxide emissions are a function of target torque and engine speed, $EO\ CO = ƒ(T_{target}, N, Temp_{Eng})$, where: - $EO\ CO$ is engine-out carbon monoxide emissions, in kg/s. - T_{target} is target torque, in N·m. - N is engine speed, in rpm. - $Temp_{Eng}$ is engine temperature, in K.

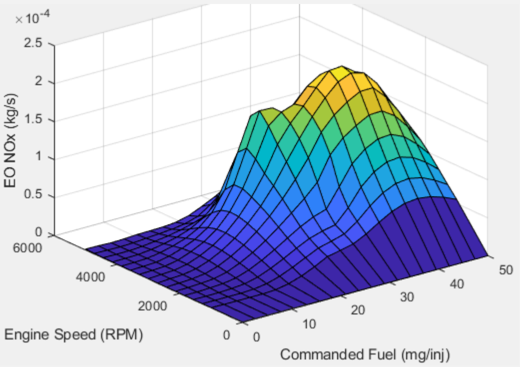
Dependencies

To enable this parameter, select **Input engine temperature**.

NOx

`EO NOx map, f_nox` — 2D lookup table

M-by-N matrix

Input Command Setting	Description
`Fuel mass`	The engine-out nitric oxide and nitrogen dioxide emissions are a function of commanded fuel mass and engine speed, $EO\ NOx = ƒ(F, N)$, where: - $EO\ NOx$ is engine-out nitric oxide and nitrogen dioxide emissions, in kg/s. - F is commanded fuel mass, in mg per injection. - N is engine speed, in rpm. 

Input Command Setting	Description
`Torque`	The engine-out nitric oxide and nitrogen dioxide emissions are a function of target torque and engine speed, $EO\ NOx = f(T_{target}, N)$, where: • $EO\ NOx$ is engine-out nitric oxide and nitrogen dioxide emissions, in kg/s. • T_{target} is target torque, in N·m. • N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO NOx map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO NOx map, f_nox_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

Input Command Setting	Description
`Fuel mass`	The engine-out nitric oxide and nitrogen dioxide emissions are a function of commanded fuel mass, engine speed, and engine temperature, $EO\ NOx= f(F, N, Temp_{Eng})$, where: • $EO\ NOx$ is engine-out nitric oxide and nitrogen dioxide emissions, in kg/s. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The engine-out nitric oxide and nitrogen dioxide emissions are a function of target torque, engine speed, and engine temperature, $EO\ NOx = f(T_{target}, N, Temp_{Eng})$, where: • $EO\ NOx$ is engine-out nitric oxide and nitrogen dioxide emissions, in kg/s. • T_{target} is target torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

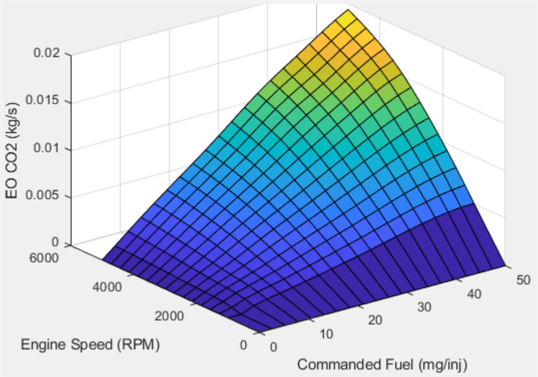
Dependencies

To enable this parameter, select **Input engine temperature**.

CO2

`EO CO2 map, f_co2` — 2D lookup table

M-by-N matrix

Input Command Setting	Description
`Fuel mass`	The engine-out carbon dioxide emissions are a function of commanded fuel mass and engine speed, $EO\ CO2 = f(F, N)$, where: - $EO\ CO2$ is engine-out carbon dioxide emissions, in kg/s. - F is commanded fuel mass, in mg per injection. - N is engine speed, in rpm. 
`Torque`	The engine-out carbon dioxide emissions are a function of target torque and engine speed, $EO\ CO2 = f(T_{target}, N)$, where: - $EO\ CO2$ is engine-out carbon dioxide emissions, in kg/s. - T_{target} is target torque, in N·m. - N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot CO2 map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO CO2 map, f_co2_3d` — 3D lookup table

M-by-N-by-L array

Input Command Setting	Description
`Fuel mass`	The engine-out carbon dioxide emissions are a function of commanded fuel mass, engine speed, and engine temperature, $EO\ CO2 = f(F, N, Temp_{Eng})$, where: • $EO\ CO2$ is engine-out carbon dioxide emissions, in kg/s. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The engine-out carbon dioxide emissions are a function of target torque, engine speed, and engine temperature, $EO\ CO2 = f(T_{target}, N, Temp_{Eng})$, where: • $EO\ CO2$ is engine-out carbon dioxide emissions, in kg/s. • T_{target} is target torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

PM

`EO PM map, f_pm` — 2D lookup table

M-by-N matrix

Input Command Setting	Description
`Fuel mass`	The engine-out PM emissions are a function of commanded fuel mass and engine speed, where: • $EO\ PM$ is engine-out PM emissions, in kg/s. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm.
`Torque`	The engine-out PM emissions are a function of target torque and engine speed, $EO\ PM = f(T_{target}, N)$, where: • $EO\ PM$ is engine-out PM emissions, in kg/s. • T_{target} is target torque, in N·m. • N is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO PM map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO PM map, f_pm_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

Input Command Setting	Description
`Fuel mass`	The engine-out PM emissions are a function of commanded fuel mass, engine speed, and engine temperature, where: • $EO\ PM$ is engine-out PM emissions, in kg/s. • F is commanded fuel mass, in mg per injection. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.
`Torque`	The engine-out PM emissions are a function of target torque, engine speed, and engine temperature, $EO\ PM = f(T_{target}, N, T)$, where: • $EO\ PM$ is engine-out PM emissions, in kg/s. • T_{target} is target torque, in N·m. • N is engine speed, in rpm. • $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Mapped Motor | Mapped SI Engine

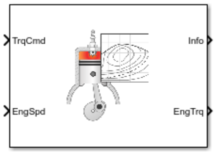
Topics

"Engine Calibration Maps"
"Model-Based Calibration Toolbox"

Mapped SI Engine

Spark-ignition engine model using lookup tables

Library: Powertrain Blockset / Propulsion / Combustion Engines
Vehicle Dynamics Blockset / Powertrain / Propulsion



Description

The Mapped SI Engine block implements a mapped spark-ignition (SI) engine model using power, air mass flow, fuel flow, exhaust temperature, efficiency, and emission performance lookup tables. You can use the block for:

- Hardware-in-the-loop (HIL) engine control design
- Vehicle-level fuel economy and performance simulations

The block enables you to specify lookup tables for these engine characteristics. The lookup tables, developed with the Model-Based Calibration Toolbox, are functions of commanded torque, T_{cmd}, brake torque, T_{brake}, and engine speed, N. If you select **Input engine temperature**, the tables are also a function of engine temperature, $Temp_{Eng}$.

Table	Input Engine Temperature Parameter Setting	
	`off`	on
Power	$f(T_{cmd},N)$	$f(T_{cmd},N,Temp_{Eng})$
Air	$f(T_{brake},N)$	$f(T_{brake},N,Temp_{Eng})$
Fuel		
Temperature		
Efficiency		
HC		
CO		
NOx		
CO2		
PM		

To bound the Mapped SI Engine block output, the block does not extrapolate the lookup table data.

Virtual Calibration

If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 2D lookup tables using measured data. The dialog box steps through these tasks.

<table>
<tr><th>Task</th><th>Description</th></tr>
<tr><td>Import firing data</td><td>Import this loss data from a file. For example, open <code><matlabroot>/toolbox/mbc/mbctraining/SiEngineData.xlsx</code>.
For more information, see “Using Data” (Model-Based Calibration Toolbox).
<table>
<tr><th>Required Data</th><th>Optional Data</th></tr>
<tr><td>• Engine speed, rpm
• Engine torque, N·m</td><td>• Air mass flow rate, kg/s
• Brake specific fuel consumption, g/(kW·h)
• CO2 mass flow rate, kg/s
• CO mass flow rate, kg/s
• Exhaust temperature, K
• Fuel mass flow rate, kg/s
• HC mass flow rate, kg/s
• NOx mass flow rate, kg/s
• Particulate matter mass flow rate, kg/s</td></tr>
</table>
Collect firing data at steady-state operating conditions when injectors deliver the fuel. Data should cover the engine speed and torque operating range. Model-Based Calibration Toolbox uses the firing data boundary as the maximum torque.
To filter or edit the data, select Edit in Application. The Model-Based Calibration Toolbox Data Editor opens.</td></tr>
<tr><td>Import non-firing data</td><td>Import this non-firing data from a file. For example, open <code><matlabroot>/toolbox/autoblks/autodemos/projectsrc/SIDynamometer/CalMappedEng/SiEngineData.xlsx</code>.
• Engine speed, rpm
• Engine torque, N·m
Collect non-firing (motoring) data at steady-state operating conditions when fuel is cut off. All non-firing torque points must be less than zero. Non-firing data is a function of engine speed only.</td></tr>
<tr><td>Generate response models</td><td>For both firing and non-firing data, the Model-Based Calibration Toolbox uses test plans to fit data to Gaussian process models (GPMs).
To assess or adjust the response model fit, select Edit in Application. The Model-Based Calibration Toolbox Model Browser opens. For more information, see “Model Assessment” (Model-Based Calibration Toolbox).</td></tr>
<tr><td>Generate calibration</td><td>Model-Based Calibration Toolbox calibrates the firing and non-firing response models and generates calibrated tables.
To assess or adjust the calibration, select Edit in Application. The Model-Based Calibration Toolbox CAGE Browser opens. For more information, see “Calibration Lookup Tables” (Model-Based Calibration Toolbox).</td></tr>
</table>

Task	Description
Update block parameters	Update the block lookup table and breakpoint parameters with the calibration.

Cylinder Air Mass

The block calculates the normalized cylinder air mass using these equations.

$$M_{Nom} = \frac{P_{std}V_d}{N_{cyl}R_{air}T_{std}}$$

$$L = \frac{\left(\frac{60s}{min}\right)Cps \cdot \dot{m}_{air}}{\left(\frac{1000g}{Kg}\right)N_{cyl} \cdot N \cdot M_{Nom}}$$

The equations use these variables.

L	Normalized cylinder air mass
M_{Nom}	Nominal engine cylinder air mass at standard temperature and pressure, piston at bottom dead center (BDC) maximum volume, in kg
Cps	Crankshaft revolutions per power stroke, rev/stroke
P_{std}	Standard pressure
T_{std}	Standard temperature
R_{air}	Ideal gas constant for air and burned gas mixture
V_d	Displaced volume
N_{cyl}	Number of engine cylinders
N	Engine speed
$\dot{m}_{intk}$	Engine air mass flow, in g/s

Turbocharger Lag

To model turbocharger lag, select **Include turbocharger lag effect**. During throttle control, the time constant models the manifold filling and emptying dynamics. When the torque request requires a turbocharger boost, the block uses a larger time constant to represent the turbocharger lag. The block uses these equations.

Dynamic torque	$\frac{dT_{brake}}{dt} = \frac{1}{\tau_{eng}}(T_{stdy} - T_{brake})$
Boost time constant	$\tau_{bst} = \begin{cases} \tau_{bst,\,rising} & \text{when } T_{stdy} > T_{brake} \\ \tau_{bst,\,falling} & \text{when } T_{stdy} \le T_{brake} \end{cases}$
Final time constant	$\tau_{eng} = \begin{cases} \tau_{thr} & \text{when } T_{brake} < f_{bst}(N) \\ \tau_{bst} & \text{when } T_{brake} \ge f_{bst}(N) \end{cases}$

The equations use these variables.

T_{brake}	Brake torque

T_{stdy}	Steady-state target torque
τ_{bst}	Boost time constant
$\tau_{bst,rising}$, $\tau_{bst,falling}$	Boost rising and falling time constant, respectively
τ_{eng}	Final time constant
τ_{thr}	Time constant during throttle control
$f_{bst}(N)$	Boost torque speed line
N	Engine speed

Fuel Flow

To calculate the fuel economy for high-fidelity models, the block uses the volumetric fuel flow.

$$Q_{fuel} = \frac{\dot{m}_{fuel}}{\left(\frac{1000kg}{m^3}\right)Sg_{fuel}}$$

The equation uses these variables.

$\dot{m}_{fuel}$	Fuel mass flow
Sg_{fuel}	Specific gravity of fuel
Q_{fuel}	Volumetric fuel flow

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrCrkshft`	Crankshaft power	$-\tau_{eng}\omega$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrFuel`	Fuel input power	$\dot{m}_{fuel}LHV$
		`PwrLoss`	Power loss	$\tau_{eng}\omega - \dot{m}_{fuel}LHV$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease		*Not used*	

The equations use these variables.

LHV	Fuel lower heating value

ω	Engine speed, rad/s
$\dot{m}_{fuel}$	Fuel mass flow
τ_{eng}	Fuel mass per injection time constant

Ports

Input

`TrqCmd` — Commanded torque
`scalar`

Torque, T_{cmd}, in N·m.

`EngSpd` — Engine speed
`scalar`

Engine speed, N, in rpm.

`EngTemp` — Engine temperature
`scalar`

Engine temperature, $Temp_{Eng}$, in K.

Dependencies

To enable this port, select **Input engine temperature**.

Output

`Info` — Bus signal
bus

Bus signal containing these block calculations.

Signal	Description	Units
`IntkGassMassFlw`	Engine air mass flow output	kg/s
`NrmlzdAirChrg`	Normalized engine cylinder air mass	N/A
`Afr`	Air-fuel ratio (AFR)	N/A
`FuelMassFlw`	Engine fuel flow output	kg/s
`FuelVolFlw`	Volumetric fuel flow	m^3/s
`ExhManGasTemp`	Engine exhaust gas temperature	K
`EngTrq`	Engine torque output	N·m
`EngSpd`	Engine speed	rpm

Signal			Description	Units
`CrkAng`			Engine crankshaft absolute angle $\int_{0}^{(360)Cps} EngSpd\frac{180}{30}d\theta$ where *Cps* is crankshaft revolutions per power stroke.	degrees crank angle
`Bsfc`			Engine brake-specific fuel consumption (BSFC)	g/kWh
`EoHC`			Engine out hydrocarbon emission mass flow	kg/s
`EoCO`			Engine out carbon monoxide emission mass flow rate	kg/s
`EoNOx`			Engine out nitric oxide and nitrogen dioxide emissions mass flow	kg/s
`EoCO2`			Engine out carbon dioxide emission mass flow	kg/s
`EoPM`			Engine out particulate matter emission mass flow	kg/s
`PwrInfo`	`PwrTrnsfrd`	`PwrCrkshft`	Crankshaft power	W
	`PwrNotTrnsfrd`	`PwrFuel`	Fuel input power	W
		`PwrLoss`	Power loss	W
	`PwrStored`		*Not used*	

`EngTrq` — Engine brake torque
`scalar`

Engine brake torque, T_{brake}, in N·m.

Parameters

Block Options

`Include turbocharger lag effect` — Increase time constant
`off` (default)

To model turbocharger lag, select **Include turbocharger lag effect**. During throttle control, the time constant models the manifold filling and emptying dynamics. When the torque request requires a turbocharger boost, the block uses a larger time constant to represent the turbocharger lag. The block uses these equations.

Dynamic torque	$\frac{dT_{brake}}{dt} = \frac{1}{\tau_{eng}}(T_{stdy} - T_{brake})$

Boost time constant	$\tau_{bst} = \begin{cases} \tau_{bst,\,rising} & \text{when } T_{stdy} > T_{brake} \\ \tau_{bst,\,falling} & \text{when } T_{stdy} \leq T_{brake} \end{cases}$
Final time constant	$\tau_{eng} = \begin{cases} \tau_{thr} & \text{when } T_{brake} < f_{bst}(N) \\ \tau_{bst} & \text{when } T_{brake} \geq f_{bst}(N) \end{cases}$

The equations use these variables.

T_{brake}	Brake torque
T_{stdy}	Steady-state target torque
τ_{bst}	Boost time constant
$\tau_{bst,rising}$, $\tau_{bst,falling}$	Boost rising and falling time constant, respectively
τ_{eng}	Final time constant
τ_{thr}	Time constant during throttle control
$f_{bst}(N)$	Boost torque speed line
N	Engine speed

Dependencies

Selecting **Include turbocharger lag effect** enables these parameters:

- **Boost torque line, f_tbrake_bst**
- **Time constant below boost line, tau_thr**
- **Rising torque boost time constant, tau_bst_rising**
- **Falling torque boost time constant, tau_bst_falling**

`Input engine temperature` — Create input port

`off` (default) | `on`

Select this to create the `EngTemp` input port.

The block enables you to specify lookup tables for these engine characteristics. The lookup tables, developed with the Model-Based Calibration Toolbox, are functions of commanded torque, T_{cmd}, brake torque, T_{brake}, and engine speed, N. If you select **Input engine temperature**, the tables are also a function of engine temperature, $Temp_{Eng}$.

Table	**Input Engine Temperature Parameter Setting**	
	`off`	**`on`**
Power	$f(T_{cmd},N)$	$f(T_{cmd},N,Temp_{Eng})$
Air	$f(T_{brake},N)$	$f(T_{brake},N,Temp_{Eng})$
Fuel		
Temperature		
Efficiency		
HC		
CO		

Table	**Input Engine Temperature Parameter Setting**	
	`off`	**`on`**
NOx		
CO2		
PM		

Configuration

`Calibrate Maps` — Calibrate tables with measured data

`selection`

If you have Model-Based Calibration Toolbox, click **Calibrate Maps** to virtually calibrate the 2D lookup tables using measured data. The dialog box steps through these tasks.

<table>
<tr><th>Task</th><th>Description</th></tr>
<tr><td>Import firing data</td><td>Import this loss data from a file. For example, open <code><matlabroot>/toolbox/mbc/mbctraining/SiEngineData.xlsx</code>.
For more information, see “Using Data” (Model-Based Calibration Toolbox).
<table>
<tr><th>Required Data</th><th>Optional Data</th></tr>
<tr><td>• Engine speed, rpm
• Engine torque, N·m</td><td>• Air mass flow rate, kg/s
• Brake specific fuel consumption, g/(kW·h)
• CO2 mass flow rate, kg/s
• CO mass flow rate, kg/s
• Exhaust temperature, K
• Fuel mass flow rate, kg/s
• HC mass flow rate, kg/s
• NOx mass flow rate, kg/s
• Particulate matter mass flow rate, kg/s</td></tr>
</table>
Collect firing data at steady-state operating conditions when injectors deliver the fuel. Data should cover the engine speed and torque operating range. Model-Based Calibration Toolbox uses the firing data boundary as the maximum torque.
To filter or edit the data, select Edit in Application. The Model-Based Calibration Toolbox Data Editor opens.</td></tr>
</table>

Task	Description
Import non-firing data	Import this non-firing data from a file. For example, open `<matlabroot>/toolbox/autoblks/autodemos/projectsrc/SIDynamometer/CalMappedEng/SiEngineData.xlsx`. • Engine speed, rpm • Engine torque, N·m Collect non-firing (motoring) data at steady-state operating conditions when fuel is cut off. All non-firing torque points must be less than zero. Non-firing data is a function of engine speed only.
Generate response models	For both firing and non-firing data, the Model-Based Calibration Toolbox uses test plans to fit data to Gaussian process models (GPMs). To assess or adjust the response model fit, select **Edit in Application**. The Model-Based Calibration Toolbox Model Browser opens. For more information, see “Model Assessment” (Model-Based Calibration Toolbox).
Generate calibration	Model-Based Calibration Toolbox calibrates the firing and non-firing response models and generates calibrated tables. To assess or adjust the calibration, select **Edit in Application**. The Model-Based Calibration Toolbox CAGE Browser opens. For more information, see “Calibration Lookup Tables” (Model-Based Calibration Toolbox).
Update block parameters	Update the block lookup table and breakpoint parameters with the calibration.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Breakpoints for commanded torque, f_tbrake_t_bpt` — Breakpoints

1-by-M vector

Breakpoints, in N·m.

`Breakpoints for engine speed input, f_tbrake_n_bpt` — Breakpoints

1-by-N vector

Breakpoints, in rpm.

`Breakpoints for temperature input, f_tbrake_engtmp_bpt` — Breakpoints

`[233.15 273.15 373.15]` (default) | 1-by-L vector

Breakpoints, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

`Number of cylinders, NCyl` — Number

4 (default) | `scalar`

Number of cylinders.

`Crank revolutions per power stroke, Cps` — Crank revolutions

`2` (default) | `scalar`

Crank revolutions per power stroke.

`Total displaced volume, Vd` — Volume

`0.0015` (default) | `scalar`

Volume displaced by engine, in m^3.

`Fuel lower heating value, Lhv` — Heating value

`45e6` (default) | `scalar`

Fuel lower heating value, *LHV*, in J/kg.

`Fuel specific gravity, Sg` — Specific gravity

`0.745` (default) | `scalar`

Specific gravity of fuel, Sg_{fuel}, dimensionless.

`Ideal gas constant air, Rair` — Constant

`287` (default) | `scalar`

Ideal gas constant of air and residual gas entering the engine intake port, in J/(kg*K).

`Air standard pressure, Pstd` — Pressure

`101325` (default) | `scalar`

Standard air pressure, in Pa.

`Air standard temperature, Tstd` — Temperature

`293.15` (default) | `scalar`

Standard air temperature, in K.

`Boost torque line, f_tbrake_bst` — Boost lag

1-by-`M` vector

Boost torque line, $f_{bst}(N)$, in N·m.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

`Time constant below boost line` — Time constant below

`0.2` (default) | `scalar`

Time constant below boost line, τ_{thr}, in s.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

`Rising torque boost time constant, tau_bst_rising` — Rising time constant

`1.5` (default) | `scalar`

Rising torque boost time constant, $\tau_{bst,rising}$, in s.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

`Falling torque boost time constant, tau_bst_falling` — Falling time constant

`1` (default) | `scalar`

Falling torque boost time constant, $\tau_{bst,falling}$, in s.

Dependencies

To enable this parameter, select **Include turbocharger lag effect**.

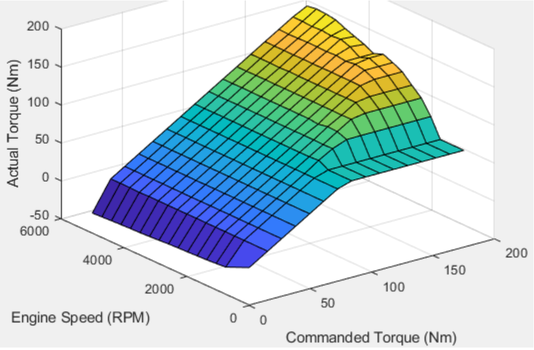
Power

`Brake torque map, f_tbrake` — 2D lookup table

`M`-by-`N` matrix

The engine torque lookup table is a function of commanded engine torque and engine speed, $T = f(T_{cmd}, N)$, where:

- T is engine torque, in N·m.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



`Plot brake torque map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Brake torque map, f_tbrake_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

The engine torque lookup table is a function of commanded engine torque, engine speed, and engine temperature, $T = f(T_{cmd}, N, Temp_{Eng})$, where:

- T is engine torque, in N·m.
- T_{cmd} is commanded engine torque, in N·m.

- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

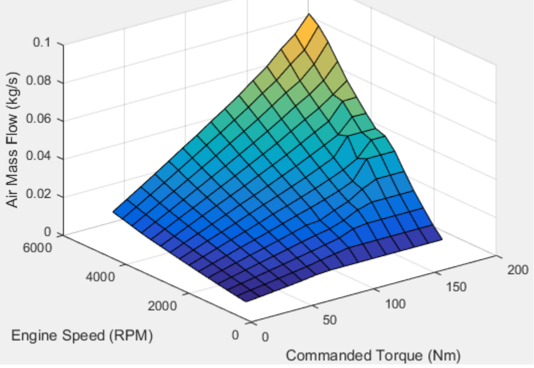
Air

`Air mass flow map, f_air` — 2D lookup table

M-by-N matrix

The engine air mass flow lookup table is a function of commanded engine torque and engine speed, $\dot{m}_{intk} = f(T_{cmd}, N)$, where:

- $\dot{m}_{intk}$ is engine air mass flow, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot air mass map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Air mass flow map, f_air_3d` — 3D lookup table

M-by-N-by-L array

The engine air mass flow lookup table is a function of commanded engine torque, engine speed, and engine temperature, $\dot{m}_{intk} = f(T_{cmd}, N, Temp_{Eng})$, where:

- $\dot{m}_{intk}$ is engine air mass flow, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.

- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

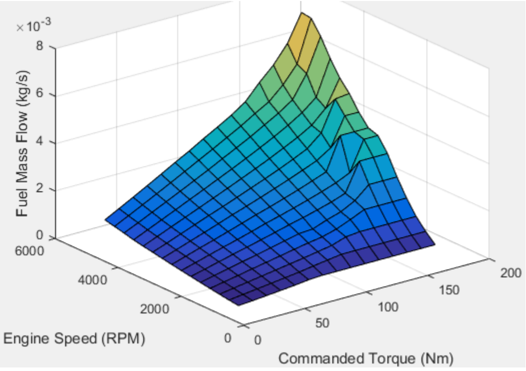
Fuel

`Fuel flow map, f_fuel` — 2D lookup table

M-by-N matrix

The engine fuel mass flow lookup table is a function of commanded engine torque and engine speed, $MassFlow = f(T_{cmd}, N)$, where:

- $MassFlow$ is engine fuel mass flow, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot fuel flow map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Fuel flow map, f_fuel_3d` — 3D lookup table

M-by-N-by-L array

The engine fuel mass flow lookup table is a function of commanded engine torque, engine speed, and engine temperature, $MassFlow = f(T_{cmd}, N, Temp_{Eng})$, where:

- $MassFlow$ is engine fuel mass flow, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.

- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

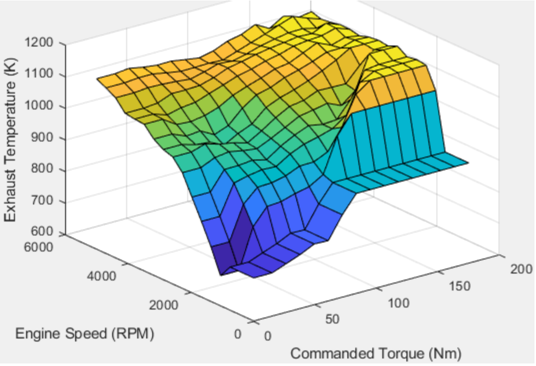
Temperature

`Exhaust temperature map, f_texh` — 2D lookup table

M-by-N matrix

The engine exhaust temperature lookup table is a function of commanded engine torque and engine speed, $T_{exh} = f(T_{cmd}, N)$, where:

- T_{exh} is exhaust temperature, in K.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot exhaust temperature map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Exhaust temperature map, f_texh_3d` — 3D lookup table

`array`

The engine exhaust temperature lookup table is a function of commanded engine torque, engine speed, and engine temperature, $T_{exh} = f(T_{cmd}, N, Temp_{Eng})$, where:

- T_{exh} is exhaust temperature, in K.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

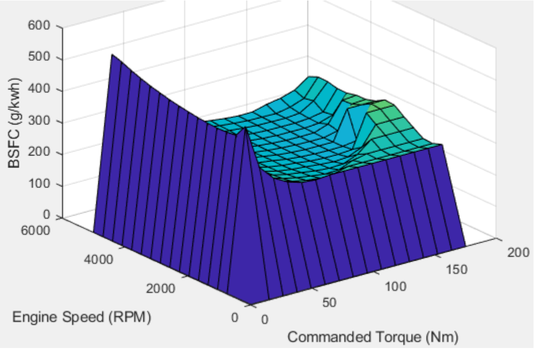
Efficiency

`BSFC map, f_eff` — 2D lookup table

`M`-by-`N`-by-`L` array

The brake-specific fuel consumption (BSFC) efficiency is a function of commanded engine torque and engine speed, $BSFC = f(T_{cmd}, N)$, where:

- $BSFC$ is BSFC, in g/kWh.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot BSFC map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`BSFC map, f_eff_3d` — 3D lookup table

`M`-by-`N`-by-`L` array

The brake-specific fuel consumption (BSFC) efficiency is a function of commanded engine torque, engine speed, and engine temperature, $BSFC = f(T_{cmd}, N, Temp_{Eng})$, where:

- $BSFC$ is BSFC, in g/kWh.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

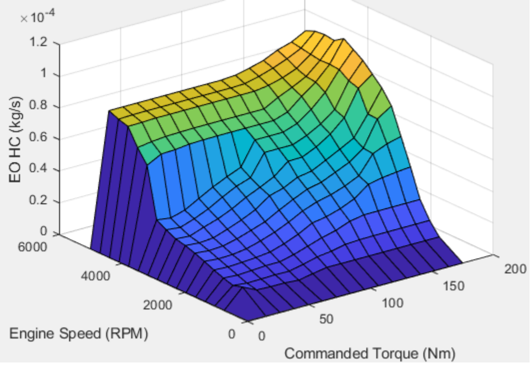
HC

`EO HC map, f_hc` — 2D lookup table

M-by-N matrix

The engine-out hydrocarbon emissions are a function of commanded engine torque and engine speed, $EO\ HC = f(T_{cmd}, N)$, where:

- $EO\ HC$ is engine-out hydrocarbon emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO HC map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO HC map, f_hc_3d` — 3D lookup table

M-by-N-by-L array

The engine-out hydrocarbon emissions are a function of commanded engine torque, engine speed, and engine temperature, $EO\ HC = f(T_{cmd}, N, Temp_{Eng})$, where:

- $EO\ HC$ is engine-out hydrocarbon emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

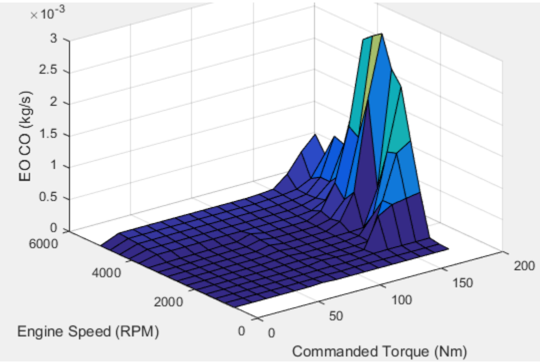
CO

`EO CO map, f_co` — 2D lookup table

M-by-N matrix

The engine-out carbon monoxide emissions are a function of commanded engine torque and engine speed, $EO\ CO = f(T_{cmd}, N)$, where:

- $EO\ CO$ is engine-out carbon monoxide emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO CO map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO HC map, f_hc_3d` — 3D lookup table

M-by-N-by-L array

The engine-out hydrocarbon emissions are a function of commanded engine torque, engine speed, and engine temperature, $EO\ HC = f(T_{cmd}, N, Temp_{Eng})$, where:

- $EO\ HC$ is engine-out hydrocarbon emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

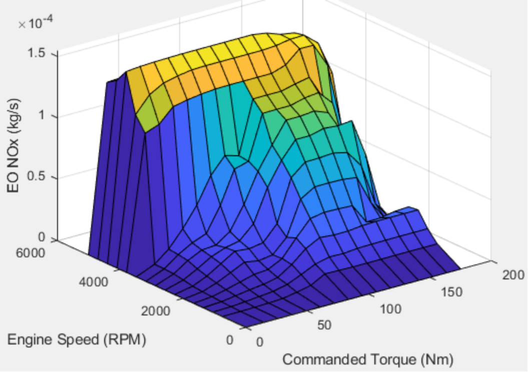
NOx

`EO NOx map, f_nox` — 2D lookup table

M-by-N matrix

The engine-out nitric oxide and nitrogen dioxide emissions are a function of commanded engine torque and engine speed, $EO\ NOx = f(T_{cmd}, N)$, where:

- $EO\ NOx$ is engine-out nitric oxide and nitrogen dioxide emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO NOx map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO NOx map, f_nox_3d` — 3D lookup table

M-by-N-by-L array

The engine-out nitric oxide and nitrogen dioxide emissions are a function of commanded engine torque, engine speed, and engine temperature, $EO\ NOx = f(T_{cmd}, N, Temp_{Eng})$, where:

- $EO\ NOx$ is engine-out nitric oxide and nitrogen dioxide emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

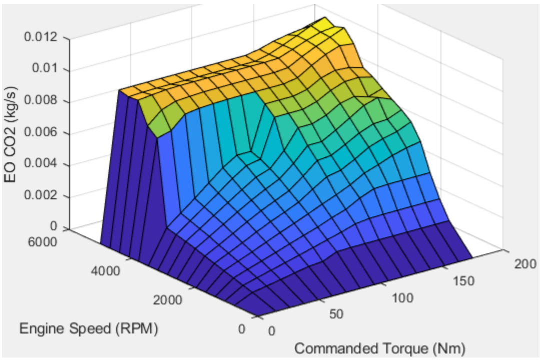
CO2

`EO CO2 map, f_co2` — 2D lookup table

M-by-N matrix

The engine-out carbon dioxide emissions are a function of commanded engine torque and engine speed, $EO\ CO2 = f(T_{cmd}, N)$, where:

- $EO\ CO2$ is engine-out carbon dioxide emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.



Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot CO2 map` — Plot table

button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO CO2 map, f_co2_3d` — 3D lookup table

M-by-N-by-L array

The engine-out carbon dioxide emissions are a function of commanded engine torque, engine speed, and engine temperature, $EO\ CO2 = f(T_{cmd}, N, Temp_{Eng})$, where:

- $EO\ CO2$ is engine-out carbon dioxide emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- N is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

PM

`EO PM map, f_pm` — 2D lookup table
`M`-by-`N` matrix

The engine-out particulate matter emissions are a function of commanded engine torque and engine speed, where:

- *EO PM* is engine-out PM emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- *N* is engine speed, in rpm.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`Plot EO PM map` — Plot table
button

Click to plot table.

Dependencies

To enable this parameter, clear **Input engine temperature**.

`EO PM map, f_pm_3d` — 3D lookup table
`M`-by-`N`-by-`L` array

The engine-out particulate matter emissions are a function of commanded engine torque, engine speed, and engine temperature, where:

- *EO PM* is engine-out PM emissions, in kg/s.
- T_{cmd} is commanded engine torque, in N·m.
- *N* is engine speed, in rpm.
- $Temp_{Eng}$ is engine temperature, in K.

Dependencies

To enable this parameter, select **Input engine temperature**.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

See Also
Mapped Motor | Mapped CI Engine

Topics

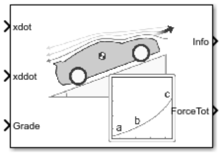
“Engine Calibration Maps”
“Model-Based Calibration Toolbox”

Vehicle Dynamics Blocks

Vehicle Body Total Road Load

Vehicle motion using coast-down testing coefficients

Library: Powertrain Blockset / Vehicle Dynamics
Vehicle Dynamics Blockset / Vehicle Body



Description

The Vehicle Body Total Road Load block implements a one degree-of-freedom (1DOF) rigid vehicle model using coast-down testing coefficients. You can use this block in a vehicle model to represent the load that the driveline and chassis applies to a transmission or engine. It is suitable for system-level performance, component sizing, fuel economy, or drive cycle tracking studies. The block calculates the dynamic powertrain load with minimal parameterization or computational cost.

You can configure the block for kinematic, force, or total power input.

- Kinematic — Block uses the vehicle longitudinal velocity and acceleration to calculate the tractive force and power.
- Force — Block uses the tractive force to calculate the vehicle longitudinal displacement and velocity.
- Power — Block uses the engine or transmission power to calculate the vehicle longitudinal displacement and velocity.

Dynamics

To calculate the total road load acting on the vehicle, the block implements this equation.

$$F_{road} = a + b\dot{x} + c\dot{x}^2 + mg\sin(\theta)$$

To determine the coefficients a, b, and c, you can use a test procedure similar to the one described in *Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques*. You can also use Simulink® Design Optimization™ to fit the coefficients to measured data.

To calculate the vehicle motion, the block uses Newton's law for rigid bodies.

$$F_{total} = m\ddot{x} + F_{road}$$

Total power input is a product of the total force and longitudinal velocity. Power due to road and gravitational forces is a product of the road force and longitudinal velocity.

$$P_{total} = F_{total}\dot{x}$$
$$P_{road} = F_{road}\dot{x}$$

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Variable	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrFxExt`	Externally applied force power	P_{FxExt}	$P_{FxExt} = F_{total}\dot{x}$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrFxDrag`	Drag force power	P_D	$P_d = -(a + b\dot{x} + c\dot{x}^2)\dot{x}$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`wrStoredGrvty`	Rate change in gravitational potential energy	P_g	$P_g = -mg\dot{Z}$
		`PwrStoredxdot`	Rate in change of longitudinal kinetic energy	P_{xdot}	$P_{\dot{x}} = m\ddot{x}\dot{x}$

The equations use these variables.

a	Steady-state rolling resistance coefficient
b	Viscous driveline and rolling resistance coefficient
c	Aerodynamic drag coefficient
g	Gravitational acceleration
x	Vehicle longitudinal displacement with respect to ground, in the vehicle-fixed frame
$\dot{x}$	Vehicle longitudinal velocity with respect to ground, in the vehicle-fixed frame
$\ddot{x}$	Vehicle longitudinal acceleration with respect to ground, vehicle-fixed frame
m	Vehicle body mass
Θ	Road grade angle
F_{total}	Total force acting on vehicle
F_{road}	Resistive road load due to losses and gravitational load
P_{total}	Total tractive input power
P_{road}	Total power due to losses and gravitational load
$\dot{Z}$	Vehicle vertical velocity along the vehicle-fixed `z`-axis

Ports

Input

`xdot` — Vehicle longitudinal velocity

`scalar`

Vehicle total longitudinal velocity, $\dot{x}$, in m/s.

Dependencies

To enable this port, for the **Input Mode** parameter, select `Kinematic`.

`xddot` — Vehicle longitudinal acceleration

`scalar`

Vehicle total longitudinal acceleration, $\ddot{x}$, in m/s^2.

Dependencies

To enable this port, for the **Input Mode** parameter, select `Kinematic`.

`PwrTot` — Tractive input power

`scalar`

Tractive input power, P_{total}, in W.

Dependencies

To enable this port, for the **Input Mode** parameter, select `Power`.

`ForceTot` — Tractive input force

`scalar`

Tractive input force, F_{total}, in N.

Dependencies

To enable this port, for the **Input Mode** parameter, select `Force`.

`Grade` — Road grade angle

`scalar`

Road grade angle, Θ, in deg.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal				Description	Value	Units
`Iner`	`Cg`	`Disp`	`X`	Vehicle CG displacement along earth-fixed X-axis	Computed	m

Signal				**Description**	**Value**	**Units**
`tFrm`			`Y`	Vehicle CG displacement along earth-fixed Y-axis	`0`	m
			`Z`	Vehicle CG displacement along earth-fixed Z-axis	Computed	m
		`Vel`	`Xdot`	Vehicle CG velocity along earth-fixed X-axis	Computed	m/s
			`Ydot`	Vehicle CG velocity along earth-fixed Y-axis	`0`	m/s
			`Zdot`	Vehicle CG velocity along earth-fixed Z-axis	Computed	m/s
		`Ang`	`phi`	Rotation of vehicle-fixed frame about the earth-fixed X-axis (roll)	`0`	rad
			`theta`	Rotation of vehicle-fixed frame about the earth-fixed Y-axis (pitch)	Computed	rad
			`psi`	Rotation of vehicle-fixed frame about the earth-fixed Z-axis (yaw)	`0`	rad
`BdyFrm`	`Cg`	`Disp`	`x`	Vehicle CG displacement along the vehicle-fixed x-axis	Computed	m
			`y`	Vehicle CG displacement along the vehicle-fixed y-axis	`0`	m
			`z`	Vehicle CG displacement along the vehicle-fixed z-axis	`0`	m
		`Vel`	`xdot`	Vehicle CG velocity along the vehicle-fixed x-axis	Computed	m/s
			`ydot`	Vehicle CG velocity along the vehicle-fixed y-axis	`0`	m/s
			`zdot`	Vehicle CG velocity along the vehicle-fixed z-axis	`0`	m/s
		`Acc`	`ax`	Vehicle CG acceleration along the vehicle-fixed x-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed y-axis	`0`	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed z-axis	`0`	gn
	`Forces`	`Body`	`Fx`	Net force on vehicle CG along the vehicle-fixed x-axis	Computed	N
			`Fy`	Net force on vehicle CG along the vehicle-fixed y-axis	`0`	N
			`Fz`	Net force on vehicle CG along the vehicle-fixed z-axis	`0`	N
		`Ext`	`Fx`	External force on vehicle CG along the vehicle-fixed x-axis	Computed	N

Signal				Description	Value	Units
			`Fy`	External force on vehicle CG along the vehicle-fixed `y`-axis	`0`	N
			`Fz`	External force on vehicle CG along the vehicle-fixed `z`-axis	`0`	N
		`Drag`	`Fx`	Drag force on vehicle CG along the vehicle-fixed `x`-axis	Computed	N
			`Fy`	Drag force on vehicle CG along the vehicle-fixed `y`-axis	`0`	N
			`Fz`	Drag force on vehicle CG along the vehicle-fixed `z`-axis	`0`	N
		`Grvty`	`Fx`	Gravity force on vehicle CG along the vehicle-fixed `x`-axis	Computed	N
			`Fy`	Gravity force on vehicle CG along the vehicle-fixed `y`-axis	`0`	N
			`Fz`	Gravity force on vehicle CG along the vehicle-fixed `z`-axis	Computed	N
	`Pwr`	`PwrExt`		Applied external power	Computed	W
		`Drag`		Power loss due to drag	Computed	W
`PwrInfo`	`PwrTrnsfrd`	`PwrFxExt`		Externally applied force power	P_{FxExt}	W
	`PwrNotTrnsfrd`	`PwrFxDrag`		Drag force power	P_D	W
	`PwrStored`	`wrStoredGrvty`		Rate change in gravitational potential energy	P_g	W
		`PwrStoredxdot`		Rate in change of longitudinal kinetic energy	P_{xdot}	W

`xdot` — Vehicle longitudinal velocity

`scalar`

Vehicle total longitudinal velocity, $\dot{x}$, in m/s.

Dependencies

To enable this port, for the **Input Mode** parameter, select `Power` or `Force`.

`ForceTot` — Tractive input force

`scalar`

Tractive input force, F_{total}, in N.

Dependencies

To enable this port, for the **Input Mode** parameter, select `Kinematic`.

Parameters

`Input Mode` — Specify input mode

`Kinematic` (default) | `Force` | `Power`

Specify the input type.

- `Kinematic` — Block uses the vehicle longitudinal velocity and acceleration to calculate the tractive force and power. Use this configuration for powertrain, driveline, and braking system design, or component sizing.
- `Force` — Block uses the tractive force to calculate the vehicle longitudinal displacement and velocity. Use this configuration for system-level performance, fuel economy, or drive cycle tracking studies.
- `Power` — Block uses the engine or transmission power to calculate the vehicle longitudinal displacement and velocity. Use this configuration for system-level performance, fuel economy, or drive cycle tracking studies.

Dependencies

This table summarizes the port and input mode configurations.

Input Mode	Creates Ports
`Kinematic`	`xdot` `xddot`
`Force`	`Force`
`Power`	`Power`

`Mass` — Vehicle body mass

`1200` (default) | `scalar`

Vehicle body mass, *m*, in kg.

`Rolling resistance coefficient, a` — Rolling

`196` (default) | `scalar`

Steady-state rolling resistance coefficient, *a*, in N.

`Rolling and driveline resistance coefficient, b` — Rolling and driveline

`2.232` (default) | `scalar`

Viscous driveline and rolling resistance coefficient, *b*, in N*s/m.

`Aerodynamic drag coefficient, c` — Drag

`0.389` (default) | `scalar`

Aerodynamic drag coefficient, *c*, in N·s^2/m.

`Gravitational acceleration, g` — Gravity

`9.81` (default) | `scalar`

Gravitational acceleration, *g*, in m/s^2.

`Initial position, x_o` — Position
`0` (default) | `scalar`

Vehicle longitudinal initial position, in m.

`Initial velocity, xdot_o` — Velocity
`0` (default) | `scalar`

Vehicle longitudinal initial velocity with respect to ground, in m/s.

Version History

Introduced in R2017a

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

[2] Light Duty Vehicle Performance And Economy Measure Committee. *Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques*. Standard J1263_201003. SAE International, March 2010.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Drive Cycle Source | Vehicle Body 1DOF Longitudinal | Vehicle Body 3DOF Longitudinal

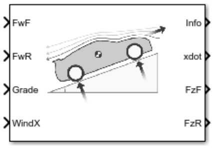
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Vehicle Body 1DOF Longitudinal

Two-axle vehicle in forward and reverse motion

Library: Powertrain Blockset / Vehicle Dynamics
Vehicle Dynamics Blockset / Vehicle Body



Description

The Vehicle Body 1DOF Longitudinal block implements a one degree-of-freedom (1DOF) rigid vehicle body with constant mass undergoing longitudinal (that is, forward and reverse) motion. Use the block:

- In powertrain and fuel economy studies to represent the vehicle inertial and drag loads when weight transfer from vertical and pitch motions are negligible.
- To determine the engine torque and power required for the vehicle to follow a specified drive cycle.

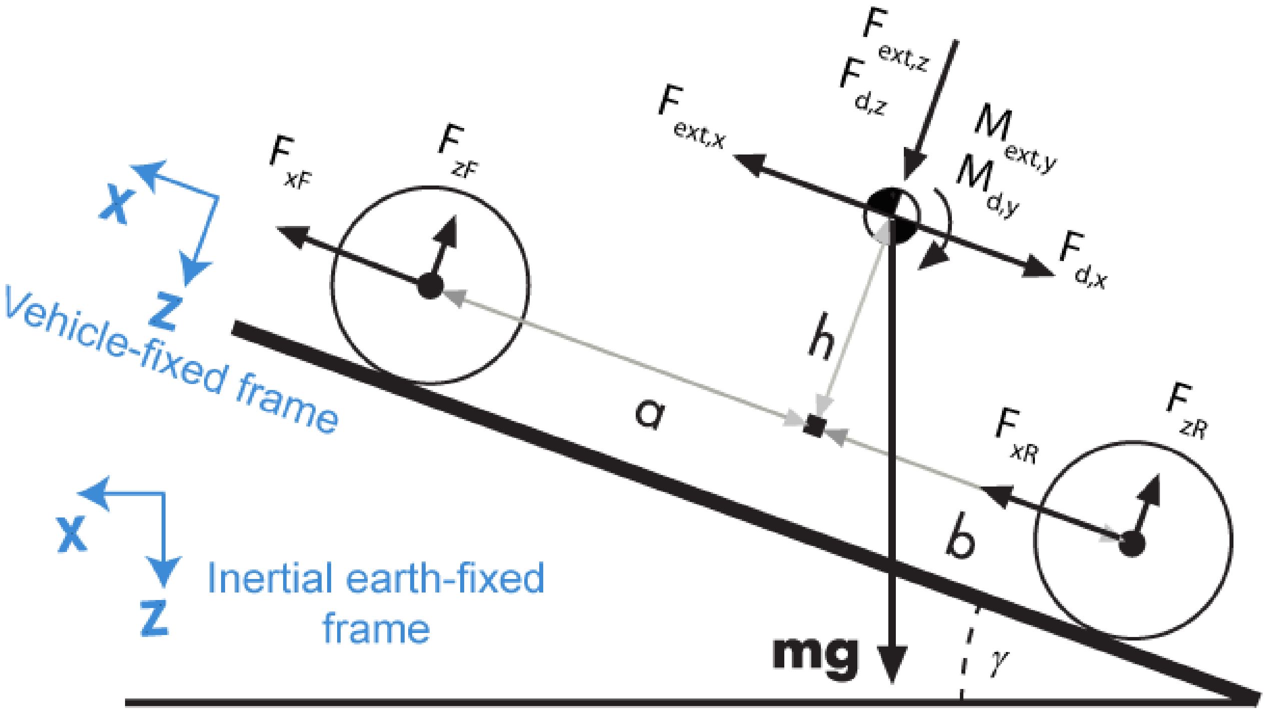
You can select block options to create input ports for external forces, moments, air temperature, and wind speed.

Block Option Setting	External Input Ports	Description
External forces	`FExt`	External force applied to vehicle CG in the vehicle-fixed frame.
External moments	`MExt`	External moment about vehicle CG in the vehicle-fixed frame.
Air temperature	`AirTemp`	Ambient air temperature. Consider this option if you want to vary the temperature during run-time.
Wind X,Y,Z	`WindXYZ`	Wind speed along earth-fixed *X*-, *Y*-, and *Z*-axes. If you do not select this option, the block implements input port `WindX` — Longitudinal wind speed along the earth-fixed *X*-axis.

Vehicle Body Model

The vehicle axles are parallel and form a plane. The longitudinal direction lies in this plane and is perpendicular to the axles. If the vehicle is traveling on an inclined slope, the normal direction is not parallel to gravity but is always perpendicular to the axle-longitudinal plane.

The block uses the net effect of all the forces and torques acting on it to determine the vehicle motion. The longitudinal tire forces push the vehicle forward or backward. The weight of the vehicle acts through its center of gravity (CG). The grade angle changes the direction of the resolved gravitational force acting on the vehicle CG. Similarly, the block resolves the resistive aerodynamic drag force on the vehicle CM.



The Vehicle Body 1DOF Longitudinal block implements these equations.

$$F_b = m\ddot{x}$$

$$F_b = F_{xF} + F_{xR} - F_{d,x} + F_{ext,x} - mg\sin\gamma$$

Zero normal acceleration and zero pitch torque determine the normal force on each front and rear axles.

$$F_{zF} = \frac{-M_{ext,y} - M_{d,y} + b(F_{d,z} + F_{ext,z} + mg\cos\gamma) - h(-F_{ext,x} + F_{d,x} + mg\sin\gamma + m\ddot{x})}{N_F(a + b)}$$

$$F_{zR} = \frac{M_{ext,y} + M_{d,y} + a(F_{d,z} + F_{ext,z} + mg\cos\gamma) + h(-F_{ext,x} + F_{d,x} + mg\sin\gamma + m\ddot{x})}{N_R(a + b)}$$

The wheel normal forces satisfy this equation.

$$N_F F_{zF} + N_R F_{zR} - F_{ext,z} = mg\cos\gamma$$

Wind and Drag Forces

The block subtracts the wind speeds from the vehicle velocity components to obtain a net relative airspeed. To calculate the drag force and moments acting on the vehicle, the block uses the net relative airspeed.

$$F_{d,x} = \frac{1}{2TR}C_dA_fP_{abs}(\dot{x}$$

$$F_{d,z} = \frac{1}{2TR}C_lA_fP_{abs}(\dot{x}$$

$$M_{d,y} = \frac{1}{2TR}C_{pm}A_fP_{abs}(\dot{x}(a + b)$$

By default, to calculate the wind speed along the vehicle-fixed *x*-axis, the block uses the longitudinal wind speed along the earth-fixed *X*-axis. If you select **WindX,Y,Z**, the block uses the wind speed along the earth-fixed *X*-, *Y*-, *Z*-axes.

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrFxExt`	Externally applied force power	$P_{FxExt} = F_{xExt}\dot{x}$
		`PwrFwFx`	Longitudinal force power applied at the front axle	$P_{FwFx} = F_{wF}\dot{x}$
		`PwrFwRx`	Longitudinal force power applied at the rear axle	$P_{FwRx} = F_{wR}\dot{x}$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrFxDrag`	Drag force power	$P_d = -\frac{0.5C_dA_fP_{abs}\left(\dot{x}^2 - w_x\right)^2}{287.058T}\dot{x}$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`wrStoredGrvty`	Rate change in gravitational potential energy	$P_g = -mg\dot{Z}$
		`PwrStoredxdot`	Rate in change of longitudinal kinetic energy	$P_{\dot{x}} = m\ddot{x}\dot{x}$

The equations use these variables.

F_{xf}, F_{xr}	Longitudinal forces on each wheel at the front and rear ground contact points, respectively

F_{zf}, F_{zr}	Normal load forces on each wheel at the front and rear ground contact points, respectively
F_{wF}, F_{wR}	Longitudinal force on front and rear axles along vehicle-fixed x-axis
F_{xExt}, F_{wR}	External force along the vehicle-fixed x-axis
$F_{d,x}$, $F_{d,z}$	Longitudinal and normal drag force on vehicle CG
$M_{d,y}$	Torque due to drag on vehicle about the vehicle-fixed y-axis
F_d	Aerodynamic drag force
V_x	Velocity of the vehicle. When $V_x > 0$, the vehicle moves forward. When $V_x < 0$, the vehicle moves backward.
N_f, N_r	Number of wheels on front and rear axle, respectively
γ	Angle of road grade
m	Vehicle body mass
a,b	Distance of front and rear axles, respectively, from the normal projection point of vehicle CG onto the common axle plane
h	Height of vehicle CG above the axle plane
C_d	Frontal air drag coefficient
A_f	Frontal area
P_{abs}	Absolute pressure
ρ	Mass density of air
x, $\dot{x}$, $\ddot{x}$	Vehicle longitudinal position, velocity, and acceleration along the vehicle-fixed x-axis
w_x	Wind speed along the vehicle-fixed x-axis
$\dot{Z}$	Vehicle vertical velocity along the vehicle-fixed z-axis

Limitations

The Vehicle Body 1DOF Longitudinal block lets you model only longitudinal dynamics, parallel to the ground and oriented along the direction of motion. The vehicle is assumed to be in pitch and normal equilibrium. The block does not model pitch or vertical movement. To model a vehicle with three degrees-of-freedom (DOF), use the Vehicle Body 3DOF Longitudinal.

Ports

Input

`FExt` — External force on vehicle CG

`array`

External forces applied to vehicle CG, F_{xext}, F_{yext}, F_{zext}, in vehicle-fixed frame, in N. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, select **External forces**.

`MExt` — External moment about vehicle CG

`array`

External moment about vehicle CG, M_x, M_y, M_z, in the vehicle-fixed frame, in N·m. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, select **External moments**.

`FwF` — Total longitudinal force on front axle

`scalar`

Longitudinal force on the front axle, F_{xf}, along vehicle-fixed `x`-axis, in N.

`FwR` — Total longitudinal force on rear axle

`scalar`

Longitudinal force on the rear axle, Fw_R, along vehicle-fixed `x`-axis, in N.

`Grade` — Road grade angle

`scalar`

Road grade angle, γ, in deg.

`WindX` — Longitudinal wind speed

`scalar`

Longitudinal wind speed, W_w, along earth-fixed `X`-axis, in m/s.

Dependencies

To enable this port, clear **Wind X,Y,Z components**.

`WindXYZ` — Wind speed

`array`

Wind speed, W_w, W_{wY}, W_{wZ} along inertial X-, Y-, and Z-axes, in m/s. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, select **Wind X,Y,Z components**.

`AirTemp` — Ambient air temperature

`scalar`

Ambient air temperature, T_{air}, in K. Considering this option if you want to vary the temperature during run-time.

Dependencies

To enable this port, select **Air temperature**.

Output

`Info` — Bus signal

bus

Bus signal containing these block values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CG displacement along earth-fixed X-axis	Computed	m
			`Y`	Vehicle CG displacement along earth-fixed Y-axis	`0`	m
			`Z`	Vehicle CG displacement along earth-fixed Z-axis	Computed	m
		`Vel`	`Xdot`	Vehicle CG velocity along earth-fixed X-axis	Computed	m/s
			`Ydot`	Vehicle CG velocity along earth-fixed Y-axis	`0`	m/s
			`Zdot`	Vehicle CG velocity along earth-fixed Z-axis	Computed	m/s
		`Ang`	`phi`	Rotation of vehicle-fixed frame about the earth-fixed X-axis (roll)	`0`	rad
			`theta`	Rotation of vehicle-fixed frame about the earth-fixed Y-axis (pitch)	Computed (input - grade angle)	rad
			`psi`	Rotation of vehicle-fixed frame about the earth-fixed Z-axis (yaw)	`0`	rad
	`FrntAxl`	`Disp`	`X`	Front axle displacement along the earth-fixed X-axis	Computed	m
			`Y`	Front axle displacement along the earth-fixed Y-axis	`0`	m
			`Z`	Front axle displacement along the earth-fixed Z-axis	Computed	m
		`Vel`	`Xdot`	Front axle velocity along the earth-fixed X-axis	Computed	m/s
			`Ydot`	Front axle velocity along the earth-fixed Y-axis	`0`	m/s
			`Zdot`	Front axle velocity along the earth-fixed Z-axis	Computed	m/s
	`RearAxl`	`Disp`	`X`	Rear axle displacement along the earth-fixed X-axis	Computed	m
			`Y`	Rear axle displacement along the earth-fixed Y-axis	`0`	m
			`Z`	Rear axle displacement along the earth-fixed Z-axis	Computed	m

Signal				Description	Value	Units
		`Vel`	`Xdot`	Rear axle velocity along the earth-fixed X-axis	Computed	m/s
			`Ydot`	Rear axle velocity along the earth-fixed Y-axis	`0`	m/s
			`Zdot`	Rear axle velocity along the earth-fixed Z-axis	Computed	m/s
`BdyFrm`	`Cg`	`Disp`	`x`	Vehicle CG displacement along the vehicle-fixed x-axis	Computed	m
			`y`	Vehicle CG displacement along the vehicle-fixed y-axis	`0`	m
			`z`	Vehicle CG displacement along the vehicle-fixed z-axis	`0`	m
		`Vel`	`xdot`	Vehicle CG velocity along the vehicle-fixed x-axis	Computed	m/s
			`ydot`	Vehicle CG velocity along the vehicle-fixed y-axis	`0`	m/s
			`zdot`	Vehicle CG velocity along the vehicle-fixed z-axis	`0`	m/s
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed x-axis (roll rate)	`0`	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed y-axis (pitch rate)	`0`	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed z-axis (yaw rate)	`0`	rad/s
		`Accel`	`ax`	Vehicle CG acceleration along the vehicle-fixed x-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed y-axis	`0`	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed z-axis	`0`	gn
	`Forces`	`Body`	`Fx`	Net force on vehicle CG along the vehicle-fixed x-axis	`0`	N

Signal					Description	Value	Units
			Fy		Net force on vehicle CG along the vehicle-fixed y-axis	0	N
			Fz		Net force on vehicle CG along the vehicle-fixed z-axis	0	N
		Ext	Fx		External force on vehicle CG along the vehicle-fixed x-axis	Computed	N
			Fy		External force on vehicle CG along the vehicle-fixed y-axis	Computed	N
			Fz		External force on vehicle CG along the vehicle-fixed z-axis	Computed	N
		FrntAxl	Fx		Longitudinal force on front axle, along the vehicle-fixed x-axis	0	N
			Fy		Lateral force on front axle, along the vehicle-fixed y-axis	0	N
			Fz		Normal force on front axle, along the vehicle-fixed z-axis	Computed	N
		RearAxl	Fx		Longitudinal force on rear axle, along the vehicle-fixed x-axis	0	N
			Fy		Lateral force on rear axle, along the vehicle-fixed y-axis	0	N
			Fz		Normal force on rear axle, along the vehicle-fixed z-axis	Computed	N
		Tires	FrntTire	Fx	Front tire force, along the vehicle-fixed x-axis	0	N
				Fy	Front tire force, along the vehicle-fixed y-axis	0	N
				Fz	Front tire force, along the vehicle-fixed z-axis	Computed	N
			RearTire	Fx	Rear tire force, along the vehicle-fixed x-axis	0	N
				Fy	Rear tire force, along the vehicle-fixed y-axis	0	N

Signal					Description	Value	Units
				Fz	Rear tire force, along the vehicle-fixed z-axis	Computed	N
		Drag	Fx		Drag force on vehicle CG along the vehicle-fixed x-axis	Computed	N
			Fy		Drag force on vehicle CG along the vehicle-fixed y-axis	Computed	N
			Fz		Drag force on vehicle CG along the vehicle-fixed z-axis	Computed	N
		Grvty	Fx		Gravity force on vehicle CG along the vehicle-fixed x-axis	Computed	N
			Fy		Gravity force on vehicle CG along the vehicle-fixed y-axis	0	N
			Fz		Gravity force on vehicle CG along the vehicle-fixed z-axis	Computed	N
	Moments	Body	Mx		Net moment on vehicle CG about the vehicle-fixed x-axis	0	N·m
			My		Net moment on vehicle CG about the vehicle-fixed y-axis	0	N·m
			Mz		Net moment on vehicle CG about the vehicle-fixed z-axis	0	N·m
		Drag	Mx		Drag moment on vehicle CG about the vehicle-fixed x-axis	Computed	N·m
			My		Drag moment on vehicle CG about the vehicle-fixed y-axis	Computed	N·m
			Mz		Drag moment on vehicle CG about the vehicle-fixed z-axis	Computed	N·m
		Ext	Fx		External moment on vehicle CG about the vehicle-fixed x-axis	Computed	N·m
			Fy		External moment on vehicle CG about the vehicle-fixed y-axis	Computed	N·m

Signal				Description	Value	Units
			Fz	External moment on vehicle CG about the vehicle-fixed z-axis	Computed	N·m
	FrntAxl	Disp	x	Front axle displacement along the vehicle-fixed x-axis	Computed	m
			y	Front axle displacement along the vehicle-fixed y-axis	0	m
			z	Front axle displacement along the vehicle-fixed z-axis	Computed	m
		Vel	xdot	Front axle velocity along the vehicle-fixed x-axis	Computed	m/s
			ydot	Front axle velocity along the vehicle-fixed y-axis	0	m/s
			zdot	Front axle velocity along the vehicle-fixed z-axis	Computed	m/s
		Steer	WhlAngFL	Front left wheel steering angle	Computed	rad
			WhlAngFR	Front right wheel steering angle	Computed	rad
	RearAxl	Disp	x	Rear axle displacement along the vehicle-fixed x-axis	Computed	m
			y	Rear axle displacement along the vehicle-fixed y-axis	0	m
			z	Rear axle displacement along the vehicle-fixed z-axis	Computed	m
		Vel	xdot	Rear axle velocity along the vehicle-fixed x-axis	Computed	m/s
			ydot	Rear axle velocity along the vehicle-fixed y-axis	0	m/s
			zdot	Rear axle velocity along the vehicle-fixed z-axis	Computed	m/s
		Steer	WhlAngRL	Rear left wheel steering angle	Computed	rad
			WhlAngRR	Rear right wheel steering angle	Computed	rad
	Pwr	PwrExt		Applied external power	Computed	W
		Drag		Power loss due to drag	Computed	W

Signal			Description	Value	Units
`PwrInfo`	`PwrTrnsfrd`	`PwrFxExt`	Externally applied force power	Computed	W
		`PwrFwFx`	Longitudinal force power applied at the front axle	Computed	W
		`PwrFwRx`	Longitudinal force power applied at the rear axle	Computed	W
	`PwrNotTrnsfrd`	`PwrFxDrag`	Drag force power	Computed	W
	`PwrStored`	`wrStoredGrvty`	Rate change in gravitational potential energy	Computed	W
		`PwrStoredxdot`	Rate in change of longitudinal kinetic energy	Computed	W

`xdot` — Vehicle body longitudinal velocity
`scalar`

Vehicle body longitudinal velocity along the vehicle-fixed reference frame `x`-axis, in m/s.

`FzF` — Front axle normal force
`scalar`

Normal load force on the front axle, F_{zf}, along vehicle-fixed `z`-axis, in N.

`FzR` — Rear axle normal force
`scalar`

Normal force on rear axle, F_{zr}, along the vehicle-fixed `z`-axis, in N.

Parameters

Options

`External forces` — FExt input port
`off` (default) | `on`

Specify to create input port `FExt`.

`External moments` — MExt input port
`off` (default) | `on`

Specify to create input port `MExt`.

`Air temperature` — AirTemp input port
`off` (default) | `on`

Specify to create input port `AirTemp`.

`Wind X,Y,Z components` — WindXYZ input port
`off` (default) | `on`

Specify to create input port `WindXYZ`.

Longitudinal

`Number of wheels on front axle, NF` — Front wheel count
`2` (default) | `scalar`

Number of wheels on front axle, N_F. The value is dimensionless.

`Number of wheels on rear axle, NR` — Rear wheel count
`2` (default) | `scalar`

Number of wheels on rear axle, N_R. The value is dimensionless.

`Mass, m` — Vehicle mass
`1500` (default) | `scalar`

Vehicle mass, M, in kg.

`Horizontal distance from CG to front axle, a` — Front axle distance
`1.4` (default) | `scalar`

Horizontal distance a from the vehicle CG to the front wheel axle, in m.

`Horizontal distance from CG to rear axle, b` — Rear axle distance
`1.8` (default) | `scalar`

Horizontal distance b from the vehicle CG to the rear wheel axle, in m.

`CG height above axles, h` — Height
`.35` (default) | `scalar`

Height of vehicle CG above the ground, h, in m.

`Longitudinal drag coefficient, Cd` — Drag
`.3` (default) | `scalar`

Air drag coefficient, C_d. The value is dimensionless.

`Longitudinal lift coefficient, Cl` — Lift
`0` (default) | `scalar`

Air lift coefficient, C_l. The value is dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`0` (default) | `scalar`

Pitch drag moment coefficient, C_{pm}. The value is dimensionless.

`Frontal area, Af` — Area
`4` (default) | `scalar`

Effective vehicle cross-sectional area, A, to calculate the aerodynamic drag force on the vehicle, in m^2.

`Initial position, x_o` — Position
`0` (default) | `scalar`

Vehicle body longitudinal initial position along the vehicle-fixed x-axis, x_o, in m.

`Initial velocity, xdot_o` — Velocity
`0` (default) | `scalar`

Vehicle body longitudinal initial velocity along the vehicle-fixed x-axis, $\dot{x}_0$, in m/s.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar`

Environmental air absolute pressure, P_{abs}, in Pa.

`Air temperature, T` — Ambient air temperature
`273` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity
`9.81` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

Version History

Introduced in R2017a

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Vehicle Body 3DOF Longitudinal | Vehicle Body Total Road Load

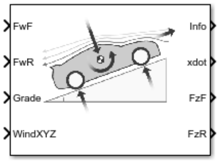
Topics

"Coordinate Systems in Vehicle Dynamics Blockset"

Vehicle Body 3DOF Longitudinal

3DOF rigid vehicle body to calculate longitudinal, vertical, and pitch motion

Library:	Powertrain Blockset / Vehicle Dynamics Vehicle Dynamics Blockset / Vehicle Body



Description

The Vehicle Body 3DOF Longitudinal block implements a three degrees-of-freedom (3DOF) rigid vehicle body model with configurable axle stiffness to calculate longitudinal, vertical, and pitch motion. The block accounts for body mass, aerodynamic drag, road incline, and weight distribution between the axles due to acceleration and the road profile.

You can specify the type of axle attachment to the vehicle:

- Grade angle — Vertical axle displacement from road surface to axles remains constant. The block uses tabular stiffness and damping parameters to model the suspension forces acting between the vehicle body and axles.
- Axle displacement — Axles have input-provided vertical displacement and velocity with respect to the road grade. The block uses tabular stiffness and damping parameters to model the suspension forces acting between the vehicle body and axle.
- External suspension — Axles have externally applied forces for coupling the vehicle body to custom suspension models.

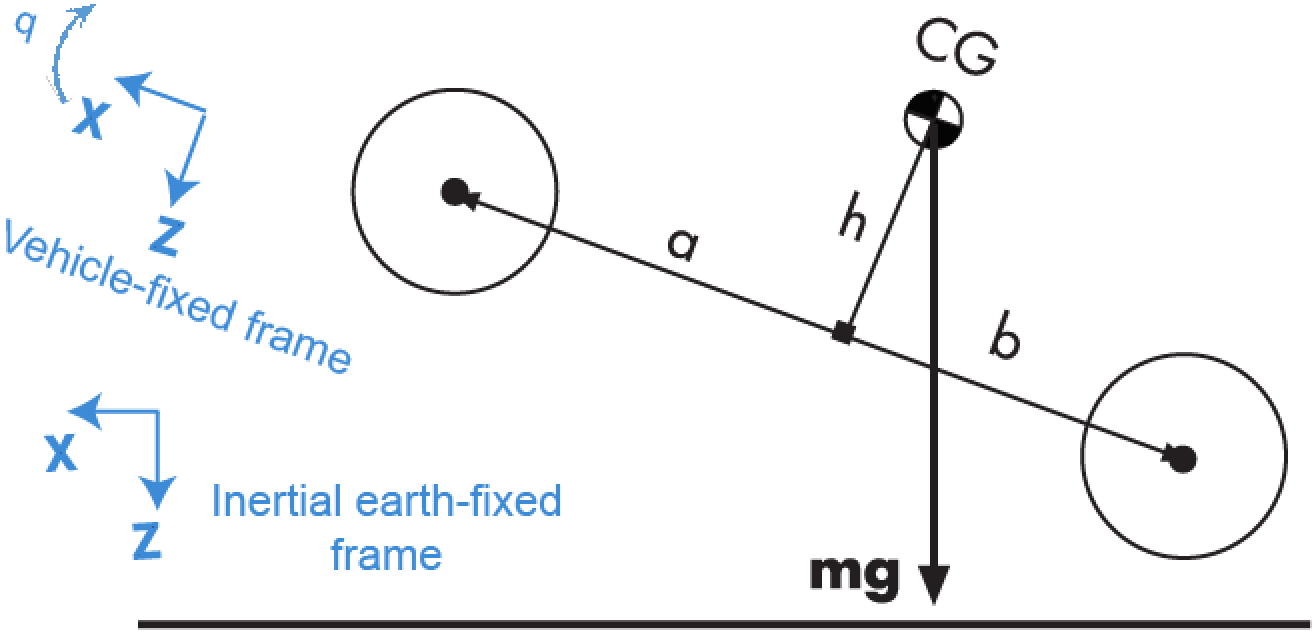
If the weight transfer from vertical and pitch motions are not negligible, consider using this block to represent vehicle motion in powertrain and fuel economy studies. For example, in studies with heavy breaking or acceleration or road profiles that contain larger vertical changes.

The block uses rigid-body vehicle motion, suspension system forces, and wind and drag forces to calculate the normal forces on the front and rear axles. The block resolves the force components and moments on the rigid vehicle body frame:

$$F_x = F_{wF} + F_{wR} - F_{d,x} - F_{sx,F} - F_{sx,R} + F_{g,x}$$

$$F_z = F_{d,z} - F_{sz,F} - F_{sz,R} + F_{g,z}$$

$$M_y = aF_{sz,F} - bF_{sz,R} + h(F_{wF} + F_{wR} + F_{sx,F} + F_{sx,R}) - M_{d,y}$$



Rigid-Body Vehicle Motion

The vehicle axles are parallel and form a plane. The longitudinal direction lies in this plane and is perpendicular to the axles. If the vehicle is traveling on an inclined slope, the normal direction is not parallel to gravity but is always perpendicular to the axle-longitudinal plane.

The block uses the net effect of all the forces and torques acting on it to determine the vehicle motion. The longitudinal tire forces push the vehicle forward or backward. The weight of the vehicle acts through its center of gravity (CG). Depending on the inclined angle, the weight pulls the vehicle to the ground and either forward or backward. Whether the vehicle travels forward or backward, aerodynamic drag slows it down. For simplicity, the drag is assumed to act through the CG.

The Vehicle Body 3DOF Longitudinal implements these equations.

$$\ddot{x} = \frac{F_x}{m} - qz$$

$$\ddot{z} = \frac{F_z}{m} - qx$$

$$\dot{q} = \frac{M_y}{I_{yy}}$$

$$\dot{\theta} = q$$

Suspension System Forces

If you configure the block with the **Ground interaction type** parameter `Grade angle` or `Axle displacement, velocity`, the block uses nonlinear stiffness and damping parameters to model the suspension system.

The front and rear axle suspension forces are given by:

$$Fs_F = N_F[Fk_F + Fb_F]$$

$$Fs_R = N_R[Fk_R + Fb_R]$$

The block uses lookup tables to implement the front and rear suspension stiffness. To account for kinematic and material nonlinearities, including collisions with end-stops, the tables are functions of the stroke.

$$Fk_F = f(dZ_F)$$

$$Fk_R = f(dZ_R)$$

The block uses lookup tables to implement the front and rear suspension damping. To account for nonlinearities, compression, and rebound, the tables are functions of the stroke rate.

$$Fb_F = f(d\dot{Z}_F)$$

$$Fb_R = f(d\dot{Z}_R)$$

The stroke is the difference in the vehicle vertical and axle positions. The stroke rate is the difference in the vertical and axle velocities.

$$dZ_F = Z_F - \bar{Z}_F$$

$$dZ_R = Z_R - \bar{Z}_R$$

$$d\dot{Z}_F = \dot{Z}_F - \dot{\bar{Z}}_F$$

$$d\dot{Z}_R = \dot{Z}_R - \dot{\bar{Z}}_R$$

When the **Ground interaction type** parameter is `Grade angle`, the axle vertical positions ($\bar{Z}_F, \bar{Z}_R$) and velocities ($\dot{\bar{Z}}_F, \dot{\bar{Z}}_R$) are set to `0`.

Wind and Drag Forces

The block subtracts the wind speeds from the vehicle velocity components to obtain a net relative airspeed. To calculate the drag force and moments acting on the vehicle, the block uses the net relative airspeed:

$$F_{d,x} = \frac{1}{2TR}C_d A_f P_{abs}(^{\dot{x}}$$

$$F_{d,z} = \frac{1}{2TR}C_l A_f P_{abs}(^{\dot{x}}$$

$$M_{d,y} = \frac{1}{2TR}C_{pm} A_f P_{abs}(^{\dot{x}}(a + b)$$

Power Accounting

For the power accounting, the block implements these equations.

Bus Signal			Description	Equations
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrFxExt`	Externally applied longitudinal force power	$P_{FxExt} = F_{xExt}\dot{x}$
		`PwrFzExt`	Externally applied longitudinal force power	$P_{FzExt} = F_{zExt}\dot{z}$
		`PwrMyExt`	Externally applied pitch moment power	$P_{MzExt} = M_{zExt}\dot{\theta}$
		`PwrFwFx`	Longitudinal force applied at the front axle	$P_{FwFx} = F_{wF}\dot{x}$
		`PwrFwRx`	Longitudinal force applied at the rear axle	$P_{FwRx} = F_{wR}\dot{x}$
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrFsF`	Internal power transferred between suspension and vehicle body at the front axle	$P_{Fs,F} = -P_{FwFx} + P_{FsbF} + P_{Fsk,F} + F_{xF}\dot{x}_F + F_{zF}\dot{z}_F$
		`PwrFsR`	Internal power transferred between suspension and vehicle body at the rear axle	$P_{Fs,R} = -P_{FwRx} + P_{Fsb,R} + P_{Fsk,R} + F_{xF}\dot{x}_F + F_{zF}\dot{z}_F$
		`PwrFxDrag`	Longitudinal drag force power	$P_{d,x} = F_{d,x}\dot{x}$
		`PwrFzDrag`	Vertical drag force power	$P_{d,z} = F_{d,z}\dot{z}$
		`PwrMyDrag`	Drag pitch moment power	$P_{d,My} = M_{d,y}\dot{\theta}$
		`PwrFsb`	Total suspension damping power	$P_{Fsb} = \sum_{i=F,R} F_{sb,i}\dot{z}_i$
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredGrvty`	Rate change in gravitational potential energy	$P_g = -mg\dot{Z}$
		`PwrStoredxdot`	Rate of change of longitudinal kinetic energy	$P_{\dot{x}} = m\ddot{x}\dot{x}$
		`PwrStoredzdot`	Rate of change of longitudinal kinetic energy	$P_{\dot{z}} = m\ddot{z}\dot{z}$

Bus Signal			Description	Equations
		`PwrStoredq`	Rate of change of rotational pitch kinetic energy	$P_{\dot{\theta}} = I_{yy}\ddot{\theta}\dot{\theta}$
		`PwrStoredFsFzSprng`	Stored spring energy from front suspension	$P_{FskF} = F_{sk,F}\dot{z}_F$
		`PwrStoredFsRzSprng`	Stored spring energy from rear suspension	$P_{FskF} = F_{sk,R}\dot{z}_R$

The equations use these variables.

F_x	Longitudinal force on vehicle
F_z	Normal force on vehicle
M_y	Torque on vehicle about the vehicle-fixed *y*-axis
F_{wF}, F_{wR}	Longitudinal force on front and rear axles along vehicle-fixed *x*-axis
$F_{d,x}$, $F_{d,z}$	Longitudinal and normal drag force on vehicle CG
$F_{sx,F}$, $F_{sx,R}$	Longitudinal suspension force on front and rear axles
$F_{sz,F}$, $F_{sz,R}$	Normal suspension force on front and rear axles
$F_{g,x}$,$F_{g,z}$	Longitudinal and normal gravitational force on vehicle along the vehicle-fixed frame
$M_{d,y}$	Torque due to drag on vehicle about the vehicle-fixed *y*-axis
a,b	Distance of front and rear axles, respectively, from the normal projection point of vehicle CG onto the common axle plane
h	Height of vehicle CG above the axle plane along vehicle-fixed *z*-axis
Fs_F, Fs_R	Front and rear axle suspension force along vehicle-fixed *z*-axis
Z_{wF}, Z_{wR}	Front and rear vehicle normal position along earth-fixed *z*-axis
Θ	Vehicle pitch angle about the vehicle-fixed *y*-axis
m	Vehicle body mass
N_F, N_R	Number of front and rear wheels
I_{yy}	Vehicle body moment of inertia about the vehicle-fixed *y*-axis
x, $\dot{x}$, $\ddot{x}$	Vehicle longitudinal position, velocity, and acceleration along the vehicle-fixed *x*-axis
z, $\dot{z}$, $\ddot{z}$	Vehicle normal position, velocity, and acceleration along the vehicle-fixed *z*-axis
Fk_F, Fk_R	Front and rear wheel suspension stiffness force along vehicle-fixed *z*-axis
Fb_F, Fb_R	Front and rear wheel suspension damping force along vehicle-fixed *z*-axis
Z_F, Z_R	Front and rear vehicle vertical position along earth-fixed *Z*-axis
$\dot{Z}_F, \dot{Z}_R$	Front and rear vehicle vertical velocity along vehicle-fixed *z*-axis
$\bar{Z}_F, \bar{Z}_R$	Front and rear wheel axle vertical position along vehicle-fixed *z*-axis
$\dot{\bar{Z}}_F, \dot{\bar{Z}}_R$	Front and rear wheel axle vertical velocity along earth-fixed *z*-axis

dZ_F, dZ_R	Front and rear axle suspension deflection along vehicle-fixed *z*-axis
$d\dot{Z}_F, d\dot{Z}_R$	Front and rear axle suspension deflection rate along vehicle-fixed *z*-axis
C_d	Frontal air drag coefficient acting along the vehicle-fixed *x*-axis
C_l	Lateral air drag coefficient acting along the vehicle-fixed *z*-axis
C_{pm}	Air drag pitch moment acting about the vehicle-fixed *y*-axis
A_f	Frontal area
P_{abs}	Environmental absolute pressure
R	Atmospheric specific gas constant
T	Environmental air temperature
w_x	Wind speed along the vehicle-fixed *x*-axis

Ports

Input

`FExt` — External force on vehicle CG

`array`

External forces applied to vehicle CG, F_{xext}, F_{yext}, F_{zext}, in vehicle-fixed frame, in N. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, select **External forces**.

`MExt` — External moment about vehicle CG

`array`

External moment about vehicle CG, M_x, M_y, M_z, in the vehicle-fixed frame, in N·m. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, select **External moments**.

`FwF` — Total longitudinal force on the front axle

`scalar`

Longitudinal force on the front axle, Fw_F, along vehicle-fixed *x*-axis, in N.

`FwR` — Total longitudinal force on the rear axle

`scalar`

Longitudinal force on the rear axle, Fw_R, along vehicle-fixed *x*-axis, in N.

`Grade` — Road grade angle

`scalar`

Road grade angle, γ, in deg.

`FsF` — Suspension force on front axle per wheel

`vector`

Suspension force on front axle, Fs_F, along the vehicle-fixed *z*-axis, in N.

Dependencies

To enable this port, for the **Ground interaction type** parameter, select `External suspension`.

`FsR` — Suspension force on rear axle per wheel

`vector`

Suspension force on rear axle, Fs_R, along the vehicle-fixed *z*-axis, in N.

Dependencies

To enable this port, for the **Ground interaction type** parameter, select `External suspension`.

`WindXYZ` — Wind speed

`array`

Wind speed, W_X, W_Y, W_Z along earth-fixed *X*-, *Y*-, and *Z*-axes, in m/s. Signal vector dimensions are `[1x3]` or `[3x1]`.

`AirTemp` — Ambient air temperature

`scalar`

Ambient air temperature, T_{air}, in K. Considering this option if you want to vary the temperature during run-time.

Dependencies

To enable this port, select **Air temperature**.

`zF,R` — Forward and rear axle positions

`vector`

Forward and rear axle positions along the vehicle-fixed *z*-axis, $\bar{Z}_F$, $\bar{Z}_R$, in m.

Dependencies

To enable this port, for the **Ground interaction type** parameter, select `Axle displacement, velocity`.

`zdotF,R` — Forward and rear axle velocities

`vector`

Forward and rear axle velocities along the vehicle-fixed *z*-axis, $\dot{\bar{Z}}_F$, $\dot{\bar{Z}}_R$, in m/s.

Dependencies

To enable this port, for the **Ground interaction type** parameter, select `Axle displacement, velocity`.

Output

`Info` — Bus signal

bus

Bus signal containing these block values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CG displacement along earth-fixed *X*-axis	Computed	m
			`Y`	Vehicle CG displacement along earth-fixed *Y*-axis	`0`	m
			`Z`	Vehicle CG displacement along earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Vehicle CG velocity along earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Vehicle CG velocity along earth-fixed *Y*-axis	`0`	m/s
			`Zdot`	Vehicle CG velocity along earth-fixed *Z*-axis	Computed	m/s
		`Ang`	`phi`	Rotation of vehicle-fixed frame about the earth-fixed *X*-axis (roll)	`0`	rad
			`theta`	Rotation of vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	Computed	rad
			`psi`	Rotation of vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	`0`	rad
	`FrntAxl`	`Disp`	`X`	Front axle displacement along the earth-fixed *X*-axis	Computed	m
			`Y`	Front axle displacement along the earth-fixed *Y*-axis	`0`	m
			`Z`	Front axle displacement along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Front axle velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Front axle velocity along the earth-fixed *Y*-axis	`0`	m/s
			`Zdot`	Front axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`RearAxl`	`Disp`	`X`	Rear axle displacement along the earth-fixed *X*-axis	Computed	m
			`Y`	Rear axle displacement along the earth-fixed *Y*-axis	`0`	m
			`Z`	Rear axle displacement along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Rear axle velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Rear axle velocity along the earth-fixed *Y*-axis	`0`	m/s

Signal				Description	Value	Units
			`Zdot`	Rear axle velocity along the earth-fixed *Z*-axis	Computed	m/s
`BdyFrm`	`Cg`	`Disp`	`x`	Vehicle CG displacement along the vehicle-fixed *x*-axis	Computed	m
			`y`	Vehicle CG displacement along the vehicle-fixed *y*-axis	`0`	m
			`z`	Vehicle CG displacement along the vehicle-fixed *z*-axis	Computed	m
		`Vel`	`xdot`	Vehicle CG velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle CG velocity along the vehicle-fixed *y*-axis	`0`	m/s
			`zdot`	Vehicle CG velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	`0`	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed y-axis (pitch rate)	Computed	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	`0`	rad/s
		`Accel`	`ax`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	`0`	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	Computed	gn
	`Forces`	`Body`	`Fx`	Net force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`	Net force on vehicle CG along the vehicle-fixed *y*-axis	`0`	N
			`Fz`	Net force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N

Signal					Description	Value	Units
		Ext	Fx		External force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			Fy		External force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			Fz		External force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
		FrntAxl	Fx		Longitudinal force on front axle, along the vehicle-fixed *x*-axis	Computed	N
			Fy		Lateral force on front axle, along the vehicle-fixed *y*-axis	0	N
			Fz		Normal force on front axle, along the vehicle-fixed *z*-axis	Computed	N
		RearAxl	Fx		Longitudinal force on rear axle, along the vehicle-fixed *x*-axis	Computed	N
			Fy		Lateral force on rear axle, along the vehicle-fixed *y*-axis	0	N
			Fz		Normal force on rear axle, along the vehicle-fixed *z*-axis	Computed	N
		Tires	FrntTire	Fx	Front tire force, along the vehicle-fixed *x*-axis	0	N
				Fy	Front tire force, along the vehicle-fixed *y*-axis	0	N
				Fz	Front tire force, along the vehicle-fixed *z*-axis	Computed	N
			RearTire	Fx	Rear tire force, along the vehicle-fixed *x*-axis	0	N
				Fy	Rear tire force, along the vehicle-fixed *y*-axis	0	N
				Fz	Rear tire force, along the vehicle-fixed *z*-axis	Computed	N
		Drag	Fx		Drag force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N

Signal				Description	Value	Units
			Fy	Drag force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			Fz	Drag force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
		Grvty	Fx	Gravity force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			Fy	Gravity force on vehicle CG along the vehicle-fixed *y*-axis	0	N
			Fz	Gravity force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
	Moments	Body	Mx	Body moment on vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My	Body moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz	Body moment on vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		Drag	Mx	Drag moment on vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My	Drag moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz	Drag moment on vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		Ext	Fx	External moment on vehicle CG about the vehicle-fixed *x*-axis	Computed	N·m
			Fy	External moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Fz	External moment on vehicle CG about the vehicle-fixed *z*-axis	Computed	N·m
	FrntAxl	Disp	x	Front axle displacement along the vehicle-fixed *x*-axis	Computed	m

Signal				Description	Value	Units
			`y`	Front axle displacement along the vehicle-fixed *y*-axis	`0`	m
			`z`	Front axle displacement along the vehicle-fixed *z*-axis	Computed	m
		`Vel`	`xdot`	Front axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Front axle velocity along the vehicle-fixed *y*-axis	`0`	m/s
			`zdot`	Front axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Steer`	`WhlAngFL`	Front left wheel steering angle	Computed	rad
			`WhlAngFR`	Front right wheel steering angle	Computed	rad
	`RearAxl`	`Disp`	`x`	Rear axle displacement along the vehicle-fixed *x*-axis	Computed	m
			`y`	Rear axle displacement along the vehicle-fixed *y*-axis	`0`	m
			`z`	Rear axle displacement along the vehicle-fixed *z*-axis	Computed	m
		`Vel`	`xdot`	Rear axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Rear axle velocity along the vehicle-fixed *y*-axis	`0`	m/s
			`zdot`	Rear axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Steer`	`WhlAngRL`	Rear left wheel steering angle	Computed	rad
			`WhlAngRR`	Rear right wheel steering angle	Computed	rad
	`Pwr`	`PwrExt`		Applied external power	Computed	W
		`Drag`		Power loss due to drag	Computed	W
`PwrInfo`	`PwrTrnsfrd`	`PwrFxExt`		Externally applied longitudinal force power	Computed	W
		`PwrFzExt`		Externally applied longitudinal force power	Computed	W
		`PwrMyExt`		Externally applied pitch moment power	Computed	W

Signal			Description	Value	Units
		`PwrFwFx`	Longitudinal force applied at the front axle	Computed	W
		`PwrFwRx`	Longitudinal force applied at the rear axle	Computed	W
	`PwrNotTrnsfrd`	`PwrFsF`	Internal power transferred between suspension and vehicle body at the front axle	Computed	W
		`PwrFsR`	Internal power transferred between suspension and vehicle body at the rear axle	Computed	W
		`PwrFxDrag`	Longitudinal drag force power	Computed	W
		`PwrFzDrag`	Vertical drag force power	Computed	W
		`PwrMyDrag`	Drag pitch moment power	Computed	W
		`PwrFsb`	Total suspension damping power	Computed	W
	`PwrStored`	`PwrStoredGrvty`	Rate change in gravitational potential energy	Computed	W
		`PwrStoredxdot`	Rate of change of longitudinal kinetic energy	Computed	W
		`PwrStoredzdot`	Rate of change of longitudinal kinetic energy	Computed	W
		`PwrStoredq`	Rate of change of rotational pitch kinetic energy	Computed	W
		`PwrStoredFsFzSprng`	Stored spring energy from front suspension	Computed	W
		`PwrStoredFsRzSprng`	Stored spring energy from rear suspension	Computed	W

xdot — Vehicle longitudinal velocity
`scalar`

Vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

FzF — Front axle normal force
`scalar`

Normal force on front axle, Fz_F, along the vehicle-fixed *z*-axis, in N.

FzR — Rear axle normal force
`scalar`

Normal force on rear axle, Fz_R, along the vehicle-fixed *z*-axis, in N.

Parameters

Options

`External forces` — FExt input port
`off` (default) | `on`

Specify to create input port `FExt`.

`External moments` — `MExt` input port
`off` (default) | `on`

Specify to create input port `MExt`.

`Air temperature` — AirTemp input port
`off` (default) | `on`

Specify to create input port `AirTemp`.

Longitudinal

`Number of wheels on front axle, NF` — Front wheel count
2 (default) | `scalar`

Number of wheels on front axle, N_F. The value is dimensionless.

`Number of wheels on rear axle, NR` — Rear wheel count
2 (default) | `scalar`

Number of wheels on rear axle, N_R. The value is dimensionless.

`Mass, m` — Vehicle mass
`1200` (default) | `scalar`

Vehicle mass, *m*, in kg.

`Horizontal distance from CG to front axle, a` — Front axle distance
`1.4` (default) | `scalar`

Horizontal distance *a* from the vehicle CG to the front wheel axle, in m.

`Horizontal distance from CG to rear axle, b` — Rear axle distance
`1.8` (default) | `scalar`

Horizontal distance *b* from the vehicle CG to the rear wheel axle, in m.

`CG height above axles, h` — Height
`0.35` (default) | `scalar`

Height of vehicle CG above the axles, *h*, in m.

`Longitudinal drag coefficient, Cd` — Drag
`.3` (default) | `scalar`

Air drag coefficient, C_d. The value is dimensionless.

`Frontal area, Af` — Area
`2` (default) | `scalar`

Effective vehicle cross-sectional area, A_f to calculate the aerodynamic drag force on the vehicle, in m^2.

`Initial position, x_o` — Position
`0` (default) | `scalar`

Vehicle body longitudinal initial position along earth-fixed *x*-axis, x_o, in m.

`Initial velocity, xdot_o` — Velocity
`0` (default) | `scalar`

Vehicle body longitudinal initial velocity along earth-fixed *x*-axis, $\dot{x}_0$, in m/s.

Vertical

`Longitudinal lift coefficient, Cl` — Lift
`.1` (default) | `scalar`

Lift coefficient, C_l. The value is dimensionless.

`Initial vertical position, z_o` — Position
`-.35` (default) | `scalar`

Initial vertical CG position, z_o, along the vehicle-fixed *z*-axis, in m.

`Initial vertical velocity, zdot_o` — Velocity
`0` (default) | `scalar`

Initial vertical CG velocity, $zdot_o$, along the vehicle-fixed *z*-axis, in m.

Pitch

`Inertia, Iyy` — About body y-axis
`3500` (default) | `scalar`

Vehicle body moment of inertia about body *z*-axis.

`Longitudinal drag pitch moment, Cpm` — Drag coefficient
`.1` (default) | `scalar`

Pitch drag moment coefficient. The value is dimensionless.

`Initial pitch angle, theta_o` — Pitch
`0` (default) | `scalar`

Initial pitch angle about body *z*-axis, in rad.

`Initial angular velocity, q_o` — Pitch velocity
`0` (default) | `scalar`

Initial vehicle body angular velocity about body *z*-axis, in rad/s.

Suspension

`Front axle stiffness force data, FskF` — Force

`[-50, -1, 0, 2, 3, 52].*1.5e4` (default) | `vector`

Front axle stiffness force data, Fk_F, in N.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

`Front axle displacement data, dzsF` — Displacement

`[-5e-3, -1e-4, 0, .2, .2001, .2051]` (default) | `vector`

Front axle displacement data, in m.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

`Front axle damping force data, FsbF` — Damping force

`[-10000 -100 -10 0 10 100 10000]` (default) | `vector`

Front axle damping force, in N.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

`Front axle velocity data, dzdotsF` — Velocity

`[-10 -1 -.1 0 .1 1 10]` (default) | `vector`

Front axle velocity data, in m/s.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

`Rear axle stiffness force data, FskR` — Force

`[-50, -1, 0, 2, 3, 52].*1e4` (default) | `vector`

Rear axle stiffness force data, in N.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

`Rear axle displacement data, dzsR` — Displacement

`[-5e-3, -1e-4, 0, .2, .2001, .2051]` (default) | `vector`

Rear axle displacement data, in m.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

`Rear axle damping force data, FsbR` — Damping force

`[-10000 -100 -10 0 10 100 10000]` (default) | `vector`

Rear axle damping force, in N.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

`Rear axle velocity data, dzdotsR` — Velocity

`[-10 -1 -.1 0 .1 1 10]` (default) | `vector`

Rear axle velocity data, in m/s.

Dependencies

To enable this parameter, for the **Ground interaction type** parameter, select `Grade angle` or `Axle displacement, velocity`.

Environment

`Absolute air pressure, Pabs` — Pressure

`101325` (default) | `scalar`

Environmental air absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Ambient air temperature

`273` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity

`9.81` (default)

Gravitational acceleration, g, in m/s^2.

Version History

Introduced in R2017a

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers, 1992.

[2] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[3] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

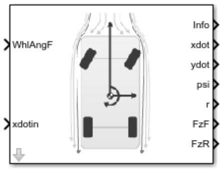
Vehicle Body 1DOF Longitudinal | Vehicle Body Total Road Load

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"

Vehicle Body 3DOF

3DOF rigid vehicle body to calculate longitudinal, lateral, and yaw motion
Library: Vehicle Dynamics Blockset / Vehicle Body

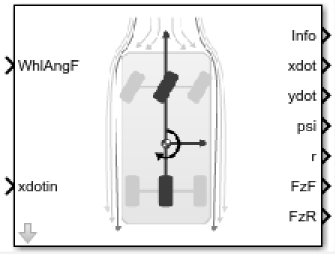
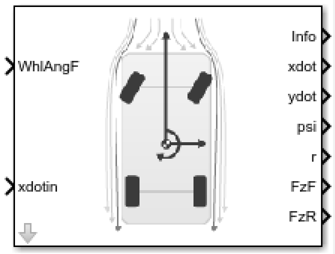


Description

The Vehicle Body 3DOF block implements a rigid two-axle vehicle body model to calculate longitudinal, lateral, and yaw motion. The block accounts for body mass and aerodynamic drag between the axles due to acceleration and steering.

Use this block in vehicle dynamics and automated driving studies to model nonholonomic vehicle motion when vehicle pitch, roll, and vertical motion are not significant.

In the Vehicle Dynamics Blockset library, there are two types of Vehicle Body 3DOF blocks that model longitudinal, lateral, and yaw motion.

Block	Vehicle Track Setting	Implementation
Vehicle Body 3DOF Single Track 	`Single (bicycle)`	- Forces act along the center line at the front and rear axles. - No lateral load transfer.
Vehicle Body 3DOF Dual Track 	`Dual`	Forces act at the four vehicle corners or *hard points*.

Use the **Axle forces** parameter to specify the type of force.

Axle Forces Setting	Implementation

`External longitudinal velocity`	• The block assumes that the external longitudinal velocity is in a quasi-steady state, so the longitudinal acceleration is approximately zero.
	• Because the motion is quasi-steady, the block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Generate virtual sensor signal data.
	  • Conduct high-level software studies that are not impacted by driveline or nonlinear tire responses.

`External longitudinal forces`	• The block uses the external longitudinal force to accelerate or brake the vehicle.
	• The block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Account for changes in the longitudinal velocity on the lateral and yaw motion.
	  • Specify the external longitudinal motion through a force instead of an external longitudinal velocity.
	  • Connect the block to tractive actuators, wheels, brakes, and hitches.

`External forces`	• The block uses the external lateral and longitudinal forces to steer, accelerate, or brake the vehicle. • The block does not use the steering input to calculate vehicle motion. • Consider this setting when you need tire models with more accurate nonlinear combined lateral and longitudinal slip.

You can use these block parameters to create additional input ports. This table summarizes the settings.

Input Signals Pane Parameter	Input Port	Description
Front wheel steering	`WhlAngF`	Front wheel angle, δ_F
External wind	`WindXYZ`	Wind speed, W_X, W_Y, W_Z, in the inertial reference frame
External forces	`FExt`	External force on vehicle center of gravity (CG), F_x, F_y, F_z, in the vehicle-fixed frame
Rear wheel steering	`WhlAngR`	Rear wheel angle, δ_R
External friction	`Mu`	Friction coefficient
External moments	`MExt`	External moment about vehicle CG, M_x, M_y, M_z, in vehicle-fixed frame

Input Signals Pane Parameter	Input Port	Description
Hitch forces	`Fh`	Hitch force applied to the body at the hitch location, Fh_x, Fh_y, and Fh_z, in the vehicle-fixed frame
Hitch moments	`Mh`	Hitch moment at the hitch location, Mh_x, Mh_y, and Mh_z, about the vehicle-fixed frame
Initial longitudinal position	`X_o`	Initial vehicle CG displacement along the earth-fixed X-axis, in m
Initial lateral position	`Y_o`	Initial vehicle CG displacement along the earth-fixed Y-axis, in m
Initial longitudinal velocity	`xdot_o`	Initial vehicle CG velocity along the vehicle-fixed x-axis, in m/s
Initial lateral velocity	`ydot_o`	Initial vehicle CG velocity along the vehicle-fixed y-axis, in m/s
Initial yaw angle	`psi_o`	Initial rotation of the vehicle-fixed frame about the earth-fixed Z-axis (yaw), in rad
Initial yaw rate	`r_o`	Initial vehicle angular velocity about the vehicle-fixed z-axis (yaw rate), in rad/s
Air temperature	`AirTemp`	Ambient air temperature. Considering this option if you want to vary the temperature during run-time.

Theory

The Vehicle Body 3DOF block implements a rigid two-axle vehicle body model to calculate longitudinal, lateral, and yaw motion. The block accounts for body mass, aerodynamic drag, and weight distribution between the axles due to acceleration and steering. To determine the vehicle motion, the block implements these equations for the single track, dual track, and drag calculations.

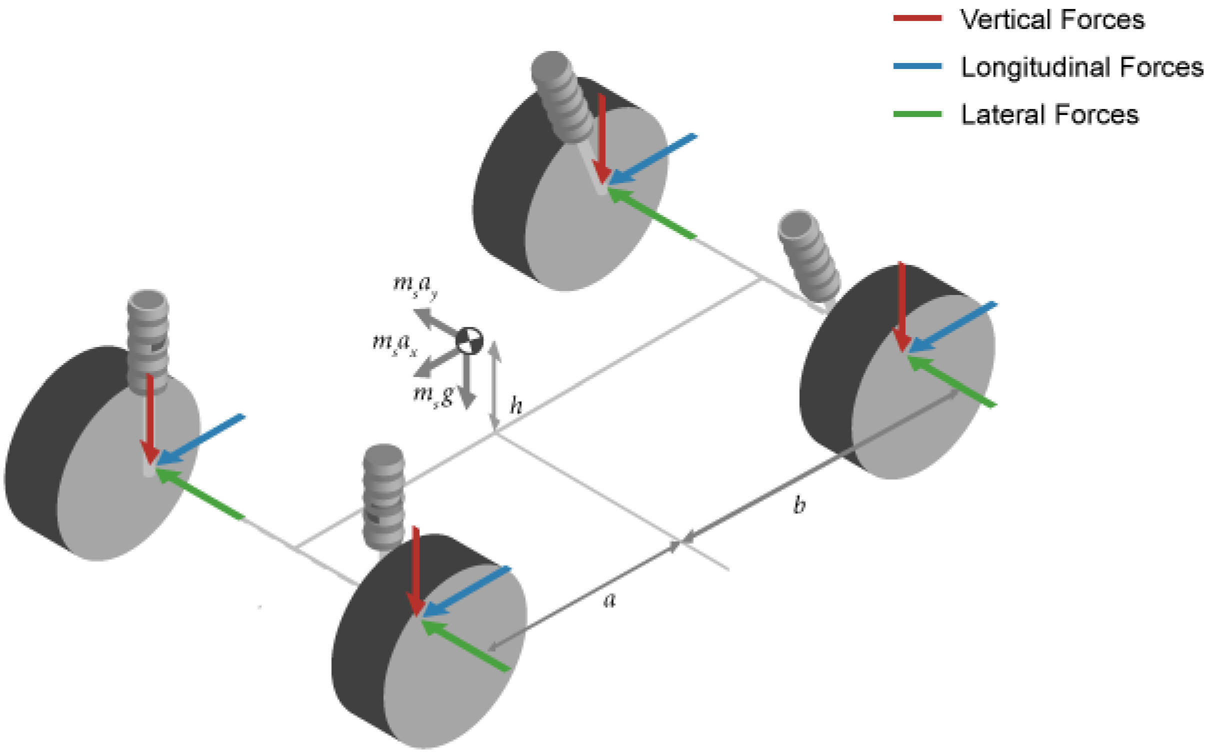
Single Track

Calculation	Description
Dynamics	The block uses these equations to calculate the rigid body planar dynamics. $\ddot{y} = -\dot{x}r + \frac{F_{yf} + F_{yr} + F_{yext}}{m}$ $\dot{r} = \frac{aF_{yf} - bF_{yr} + M_{zext}}{I_{zz}}$ $r = \dot{\psi}$ If you set **Axle forces** to either `External longitudinal forces` or `External forces`, the block uses this equation for the longitudinal acceleration. $\ddot{x} = \dot{y}r + \frac{F_{xf} + F_{xr} + F_{xext}}{m}$ If you set **Axle forces** to `External longitudinal velocity`, the block assumes a quasi-steady state for the longitudinal acceleration. $\ddot{x} = 0$

Calculation	Description
External forces	External forces include both drag and external force inputs. The forces act on the vehicle CG. $F_{x,y,z\,ext} = F_{d\,x,y,z} + F_{x,y,z\,input}$ $M_{x,y,z\,ext} = M_{d\,x,y,z} + M_{x,y,z\,input}$ If you set **Axle forces** to `External longitudinal forces`, the block uses these equations. $F_{xft} = F_{xfinput}$ $F_{yft} = -C_{yf}\alpha_f\mu_f\frac{F_{zf}}{F_{znom}}$ $F_{xrt} = F_{xrinput}$ $F_{yrt} = -C_{yr}\alpha_r\mu_r\frac{F_{zr}}{F_{znom}}$ If you set **Axle forces** to `External longitudinal velocity`, the block uses these equations. $F_{xft} = 0$ $F_{yft} = -C_{yf}\alpha_f\mu_f\frac{F_{zf}}{F_{znom}}$ $F_{xrt} = 0$ $F_{yrt} = -C_{yr}\alpha_r\mu_r\frac{F_{zr}}{F_{znom}}$ The block divides the normal forces by the nominal normal load to vary the effective friction parameters during weight and load transfer. The block uses these equations to maintain pitch and roll equilibrium. $F_{zf} = \frac{bmg - (\ddot{x} - \dot{y}r)mh + hF_{xext} + bF_{zext} - M_{yext}}{a + b}$ $F_{zr} = \frac{amg + (\ddot{x} - \dot{y}r)mh - hF_{xext} + aF_{zext} + M_{yext}}{a + b}$

Calculation	Description
Tire forces	The block uses the ratio of the local and longitudinal and lateral velocities to determine the slip angles. $\alpha_f = atan\left(\frac{\dot{y} + ar}{\dot{x}}\right) - \delta_f$ $\alpha_r = atan\left(\frac{\dot{y} - br}{\dot{x}}\right) - \delta_r$ To determine the tire forces, the block uses the slip angles. $F_{xf} = F_{xft}\cos\left(\delta_f\right) - F_{yft}\sin\left(\delta_f\right)$ $F_{yf} = -F_{xft}\sin\left(\delta_f\right) + F_{yft}\cos\left(\delta_f\right)$ $F_{xr} = F_{xrt}\cos(\delta_r) - F_{yrt}\sin(\delta_r)$ $F_{yr} = -F_{xrt}\sin(\delta_r) + F_{yrt}\cos(\delta_r)$ If you set **Axle forces** to `External forces`, the block sets the tire forces equal to the external input force. $F_{xf} = F_{xft} = F_{xfinput}$ $F_{yf} = F_{yft} = F_{yfinput}$ $F_{xr} = F_{xrt} = F_{xrinput}$ $F_{yr} = F_{yrt} = F_{yrinput}$

Dual Track



Calculation	Description
Dynamics	The block uses these equations to calculate the rigid body planar dynamics. $\ddot{x} = \dot{y}r + \frac{F_{xfl} + F_{xfr} + F_{xrl} + F_{xrr} + F_{xext}}{m}$ $\ddot{y} = -\dot{x}r + \frac{F_{yfl} + F_{yfr} + F_{yrl} + F_{yrr} + F_{yext}}{m}$ $\dot{r} = \frac{a(F_{yfl} + F_{yfr}) - b\left(F_{yrl} + F_{yrr}\right) + \frac{w_f(F_{xfl} - F_{xfr})}{2} + \frac{w_r(F_{xrl} - F_{xrr})}{2} + M_{zext}}{I_{zz}}$ $r = \dot{\psi}$ If you set **Axle forces** to `External longitudinal velocity`, the block assumes a quasi-steady state for the longitudinal acceleration. $\ddot{x} = 0$

Calculation	Description
External forces	External forces include both drag and external force inputs. The forces act on the vehicle CG. $F_{x,y,z\,ext} = F_{d\,x,y,z} + F_{x,y,z\,input}$ $M_{x,y,z\,ext} = M_{d\,x,y,z} + M_{x,y,z\,input}$ If you set **Axle forces** to `External longitudinal forces`, the block uses these equations. $F_{xflt} = F_{xflinput}$ $F_{yflt} = -C_{yfl}\alpha_{fl}\mu_{fl}\frac{F_{zfl}}{2F_{znom}}$ $F_{xfrt} = F_{xlrinput}$ $F_{yfrt} = -C_{yfr}\alpha_{fr}\mu_{fr}\frac{F_{zfr}}{2F_{znom}}$ $F_{xrlt} = F_{xrlinput}$ $F_{yrlt} = -C_{yrl}\alpha_{rl}\mu_{rl}\frac{F_{zrl}}{2F_{znom}}$ $F_{xrrt} = F_{xrrinput}$ $F_{yrrt} = -C_{yrr}\alpha_{rr}\mu_{rr}\frac{F_{zrr}}{2F_{znom}}$ If you set **Axle forces** to `External longitudinal velocity`, the block uses these equations. $F_{xflt} = 0$ $F_{yflt} = -C_{yfl}\alpha_{fl}\mu_{fl}\frac{F_{zfl}}{2F_{znom}}$ $F_{xfrt} = 0$ $F_{yfrt} = -C_{yfr}\alpha_{fr}\mu_{fr}\frac{F_{zfr}}{2F_{znom}}$ $F_{xrlt} = 0$ $F_{yrlt} = -C_{yrl}\alpha_{rl}\mu_{rl}\frac{F_{zrl}}{2F_{znom}}$ $F_{xrrt} = 0$ $F_{yrrt} = -C_{yrr}\alpha_{rr}\mu_{rr}\frac{F_{zrr}}{2F_{znom}}$ The block divides the normal forces by the nominal normal load to vary the effective friction parameters during weight and load transfer. The block uses these equations to maintain pitch and roll equilibrium.

Calculation	Description
	$F_{zf} = \frac{bmg - (\ddot{x} - \dot{y}r)mh + hF_{xext} + bF_{zext} - M_{yext}}{a + b}$ $F_{zr} = \frac{amg + (\ddot{x} - \dot{y}r)mh - hF_{xext} + aF_{zext} + M_{yext}}{(a + b)}$ $F_{zfl} = F_{zf} + (mh(\ddot{y} + \dot{x}r) - hF_{yext} - M_{xext})\frac{2}{w_f}$ $F_{zfr} = F_{zf} + (-mh(\ddot{y} + \dot{x}r) + hF_{yext} + M_{xext})\frac{2}{w_f}$ $F_{zrl} = F_{zr} + (mh(\ddot{y} + \dot{x}r) - hF_{yext} - M_{xext})\frac{2}{w_r}$ $F_{zrr} = F_{zr} + (-mh(\ddot{y} + \dot{x}r) + hF_{yext} + M_{xext})\frac{2}{w_r}$
Tire forces	The block uses the ratio of the local and longitudinal and lateral velocities to determine the slip angles. $\alpha_{fl} = atan\left(\frac{\dot{y} + ar}{\dot{x} + r\frac{w_f}{2}}\right) - \delta_{fl}$ $\alpha_{fr} = atan\left(\frac{\dot{y} + ar}{\dot{x} - r\frac{w_f}{2}}\right) - \delta_{fr}$ $\alpha_{rl} = atan\left(\frac{\dot{y} - ar}{\dot{x} + r\frac{w_r}{2}}\right) - \delta_{rl}$ $\alpha_{rr} = atan\left(\frac{\dot{y} - ar}{\dot{x} - r\frac{w_r}{2}}\right) - \delta_{rr}$ The block uses the steering angles to transform the tire forces to the vehicle-fixed frame. $F_{xf} = F_{xft}\cos(\delta_f) - F_{yft}\sin(\delta_f)$ $F_{yf} = -F_{xft}\sin(\delta_f) + F_{yft}\cos(\delta_f)$ $F_{xr} = F_{xrt}\cos(\delta_r) - F_{yrt}\sin(\delta_r)$ $F_{yr} = -F_{xrt}\sin(\delta_r) + F_{yrt}\cos(\delta_r)$ If you set **Axle forces** to `External forces`, the block uses these equations. The blocks assumes that the externally provided forces are in the vehicle-fixed frame at the axle-wheel location. $F_{xf} = F_{xft} = F_{xfinput}$ $F_{yf} = F_{yft} = F_{yfinput}$ $F_{xr} = F_{xrt} = F_{xrinput}$ $F_{yr} = F_{yrt} = F_{yrinput}$

Drag

Calculation	Description
Coordinate transformation	The block transforms the wind speeds from the inertial frame to the vehicle-fixed frame. $w_x = W_x\cos(\psi) + W_y\sin(\psi)$ $w_y = W_y\cos(\psi) - W_x\sin(\psi)$ $w_z = W_z$
Drag forces	To determine a relative airspeed, the block subtracts the wind speed from the CG vehicle velocity. Using the relative airspeed, the block determines the drag forces. $\overline{w} = \sqrt{(\dot{x} - w_x)^2 + (\dot{x} - w_x)^2 + (w_z)^2}$ $F_{dx} = -\frac{1}{2TR}C_dA_fP_{abs}(^{\overline{w}}$ $F_{dy} = -\frac{1}{2TR}C_sA_fP_{abs}(^{\overline{w}}$ $F_{dz} = -\frac{1}{2TR}C_lA_fP_{abs}(^{\overline{w}}$
Drag moments	Using the relative airspeed, the block determines the drag moments. $M_{dr} = -\frac{1}{2TR}C_{rm}A_fP_{abs}(^{\overline{w}}(a + b)$ $M_{dp} = -\frac{1}{2TR}C_{pm}A_fP_{abs}(^{\overline{w}}(a + b)$ $M_{dy} = -\frac{1}{2TR}C_{ym}A_fP_{abs}(^{\overline{w}}(a + b)$

Lateral Corner Stiffness and Relaxation Dynamics

Description	Implementation
Constant values.	The block uses constant stiffness values for Cy_f and Cy_r.
Lookup tables as a function of corner stiffness data and slip angles.	The block uses lookup tables that are functions of the corner stiffness data and slip angles. $Cy_f = f(\alpha_f, Cy_{fdata})$ $Cy_r = f(\alpha_r, Cy_{rdata})$

Description	Implementation
Lookup tables as a function of corner stiffness data and slip angles. *Slip angles include the relaxation length dynamic settings.*	The block uses lookup tables that are functions of the corner stiffness data and slip angles. The slip angles include the relaxation length dynamic settings. The relaxation length approximates an effective corner stiffness force that is a function of wheel travel. $Cy_f = f(\alpha_{f\sigma}, Cy_{fdata})$ $Cy_r = f(\alpha_{r\sigma}, Cy_{rdata})$ $\alpha_{f\sigma} = \frac{1}{s}\left[\frac{(\alpha_f - \alpha_{f\sigma})v_{wf}}{\alpha_f}\right]$ $\alpha_{r\sigma} = \frac{1}{s}\left[\frac{(\alpha_r - \alpha_{r\sigma})v_{wr}}{\alpha_r}\right]$

The equations use these variables.

$x, \dot{x}, \ddot{x}$	Vehicle CG displacement, velocity, and acceleration, along the vehicle-fixed *x*-axis
$y, \dot{y}, \ddot{y}$	Vehicle CG displacement, velocity, and acceleration, along the vehicle-fixed *y*-axis
ψ	Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)
$r, \dot{\Psi}$	Vehicle angular velocity, about the vehicle-fixed *z*-axis (yaw rate)
F_{xf}, F_{xr}	Longitudinal forces applied to front and rear wheels, along the vehicle-fixed *x*-axis
F_{yf}, F_{yr}	Lateral forces applied to front and rear wheels, along vehicle-fixed *y*-axis
F_{xext}, F_{yext}, F_{zext}	External forces applied to vehicle CG, along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{dx}, F_{dy}, F_{dz}	Drag forces applied to vehicle CG, along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{xinput}, F_{yinput}, F_{zinput}	Input forces applied to vehicle CG, along the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{xext}, M_{yext}, M_{zext}	External moment about vehicle CG, about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{dx}, M_{dy}, M_{dz}	Drag moment about vehicle CG, about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{xinput}, M_{yinput}, M_{zinput}	Input moment about vehicle CG, about the vehicle-fixed *x*-, *y*-, and *z*-axes
I_{zz}	Vehicle body moment of inertia about the vehicle-fixed *z*-axis
F_{xft}, F_{xrt}	Longitudinal tire force applied to front and rear wheels, along the vehicle-fixed *x*-axis
F_{yft}, F_{yft}	Lateral tire force applied to front and rear wheels, along vehicle-fixed *y*-axis
F_{xfl}, F_{xfr}	Longitudinal force applied to front left and front right wheels, along the vehicle-fixed *x*-axis
F_{yfl}, F_{yfr}	Lateral force applied to front left and front right wheels, along the vehicle-fixed *y*-axis
F_{xrl}, F_{xrr}	Longitudinal force applied to rear left and rear right wheels, along the vehicle-fixed *x*-axis

F_{yrl}, F_{yrr}	Lateral force applied to rear left and rear right wheels, along the vehicle-fixed y-axis
F_{xflt}, F_{xfrt}	Longitudinal tire force applied to front left and front right wheels, along the vehicle-fixed x-axis
F_{yflt}, F_{yfrt}	Lateral force tire applied to front left and front right wheels, along the vehicle-fixed y-axis
F_{xrlt}, F_{xrrt}	Longitudinal tire force applied to rear left and rear right wheels, along the vehicle-fixed x-axis
F_{yrlt}, F_{yrrt}	Lateral force applied to rear left and rear right wheels, along the vehicle-fixed y-axis
F_{zf},F_{zr}	Normal force applied to front and rear wheels, along vehicle-fixed z-axis
F_{znom}	Nominal normal force applied to axles, along the vehicle-fixed z-axis
F_{zfl},F_{zfr}	Normal force applied to front left and right wheels, along vehicle-fixed z-axis
F_{zrl},F_{zrr}	Normal force applied to rear left and right wheels, along vehicle-fixed z-axis
m	Vehicle body mass
a, b	Distance of front and rear wheels, respectively, from the normal projection point of vehicle CG onto the common axle plane
h	Height of vehicle CG above the axle plane
d	Lateral distance from the geometric centerline to the center of mass along the vehicle-fixed y-axis
hh	Height of the hitch above the axle plane along the vehicle-fixed z-axis
dh	Longitudinal distance of the hitch from the normal projection point of tractor CG onto the common axle plane
hl	Lateral distance from center of mass to hitch along the vehicle-fixed y-axis.
α_f, α_r	Front and rear wheel slip angles
α_{fl}, α_{fr}	Front left and right wheel slip angles
α_{rl}, α_{rr}	Rear left and right wheel slip angles
δ_f, δ_r	Front and rear wheel steering angles
δ_{rl}, δ_{rr}	Rear left and right wheel steering angles
δ_{fl}, δ_{fr}	Front left and right wheel steering angles
w_f, w_r	Front and rear track widths
Cy_f, Cy_r	Front and rear wheel cornering stiffness
Cy_{fdata}, Cy_{rdata}	Front and rear wheel cornering stiffness data
σ_f, σ_r	Front and rear wheel relaxation length
$\alpha_{f\sigma}$, $\alpha_{r\sigma}$	Front and rear wheel slip angles that include relaxation length
v_{wf}, v_{wr}	Magnitude of front and rear wheel hardpoint velocity
μ_f, μ_r	Front and rear wheel friction coefficient
μ_{fl}, μ_{fr}	Front left and right wheel friction coefficient
μ_{rl}, μ_{rr}	Rear left and right wheel friction coefficient

C_d	Air drag coefficient acting along vehicle-fixed *x*-axis
C_s	Air drag coefficient acting along vehicle-fixed *y*-axis
C_l	Air drag coefficient acting along vehicle-fixed *z*-axis
C_{rm}	Air drag roll moment acting about the vehicle-fixed *x*-axis
C_{pm}	Air drag pitch moment acting about the vehicle-fixed *y*-axis
C_{ym}	Air drag yaw moment acting about the vehicle-fixed *z*-axis
A_f	Frontal area
R	Atmospheric specific gas constant
T	Environmental air temperature
P_{abs}	Environmental absolute pressure
w_x, w_y, w_z	Wind speed, along the vehicle-fixed *x*-, *y*-, and *z*-axes
W_x, W_y, W_z	Wind speed, along inertial *X*-, *Y*-, and *Z*-axes

Ports

Input

`WhlAngF` — Front wheel steering angles

`scalar` | `array`

Front wheel steering angles, δ_F, in rad.

Vehicle Track Setting	Variable	Signal Dimension
`Single (bicycle)`	δ_F	Scalar – 1
`Dual`	$\delta_F = [\delta_{fl}\ \delta_{fr}]$ or $\begin{bmatrix}\delta_{fl}\\ \delta_{fr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port, on the **Input signals** pane, select **Front wheel steering**.

`WhlAngR` — Rear wheel steering angles

`scalar` | `array`

Rear wheel steering angles, δ_R, in rad.

Vehicle Track Setting	Variable	Signal Dimension
`Single (bicycle)`	δ_R	Scalar – 1
`Dual`	$\delta_R = [\delta_{rl}\ \delta_{rr}]$ or $\begin{bmatrix}\delta_{rl}\\ \delta_{rr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port, on the **Input signals** pane, select **Rear wheel steering**.

`xdotin` — Longitudinal velocity

`scalar`

Vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this port, set **Axle forces** to `External longitudinal velocity`.

FwF — Total force on the front wheels
`scalar` | `array`

Force on the front wheels, Fw_F, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	`External longitudinal forces`	Longitudinal force on the front wheel	$FwF = Fx_f$	Scalar – 1
	`External forces`	Longitudinal and lateral forces on the front wheel	$FwF = \begin{bmatrix} Fx_f & Fy_f \end{bmatrix}$ or $\begin{bmatrix} Fx_f \\ Fy_f \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
`Dual`	`External longitudinal forces`	Longitudinal force on the front wheels	$FwF = \begin{bmatrix} F_{xfl} & F_{xfr} \end{bmatrix}$ or $\begin{bmatrix} F_{xfl} \\ F_{xfr} \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
	`External forces`	Longitudinal and lateral forces on the front wheels	$FwF = \begin{bmatrix} F_{xfl} & F_{xfr} \\ F_{yfl} & F_{yfr} \end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

FwR — Total force on the rear wheels
`scalar` | `array`

Force on the rear wheels, Fw_R, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	`External longitudinal forces`	Longitudinal force on the rear wheel	$FwR = Fx_r$	Scalar – 1
	`External forces`	Longitudinal and lateral forces on the rear wheel	$FwR = \begin{bmatrix} Fx_r & Fy_r \end{bmatrix}$ or $\begin{bmatrix} Fx_r \\ Fy_r \end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Dual`	`External longitudinal forces`	Longitudinal force on the rear wheels	$FwR = [F_{xrl}\ F_{xrr}]$ or $\begin{bmatrix} F_{xrl} \\ F_{xrr} \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
	`External forces`	Longitudinal and lateral forces on the rear wheels	$FwR = \begin{bmatrix} F_{xrl} & F_{xrr} \\ F_{yrl} & F_{yrr} \end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

`FExt` — External force on vehicle CG

`array`

External forces applied to vehicle CG, F_{xext}, F_{yext}, F_{zext}, in vehicle-fixed frame, in N. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, on the **Input signals** pane, select **External forces**.

`MExt` — External moment about vehicle CG

`array`

External moment about vehicle CG, M_x, M_y, M_z, in the vehicle-fixed frame, in N·m. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, on the **Input signals** pane, select **External moments**.

`Fh` — Hitch force on the body

`array`

Hitch force applied to the body at the hitch location, Fh_x, Fh_y, Fh_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch forces**.

`Mh` — Hitch moment about body

`array`

Hitch moment at the hitch location, Mh_x, Mh_y, Mh_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch moments**.

`WindXYZ` — Wind speed

`array`

Wind speed, W_x, W_y, W_z along inertial X-, Y-, and Z-axes, in m/s. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, on the **Input signals** pane, select **External wind**.

`Mu` — Tire friction coefficient

`scalar`

Tire friction coefficient, μ. The value is dimensionless.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	Longitudinal force on the front wheel	$Mu = \begin{bmatrix}\mu_f & \mu_r\end{bmatrix}$ or $\begin{bmatrix}\mu_f \\ \mu_r\end{bmatrix}$	Array – `[1x2]` or `[2x1]`
`Dual`	Longitudinal force on the front wheels	$Mu = \begin{bmatrix}\mu_{fl} & \mu_{fr} \\ \mu_{rl} & \mu_{rr}\end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, on the **Input signals** pane, select **External friction**.

`AirTemp` — Ambient air temperature

`scalar`

Ambient air temperature, in K.

Dependencies

To enable this port, on the **Input signals** pane, select **Air temperature**.

`X_o` — Initial longitudinal position

`scalar`

Initial vehicle CG displacement along the earth-fixed X-axis, in m.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial longitudinal position**.

`Y_o` — Initial lateral position

`scalar`

Initial vehicle CG displacement along the earth-fixed Y-axis, in m.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial lateral position**.

`xdot_o` — Initial longitudinal position

`scalar`

Initial vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this port:

1. Set **Axle forces** to one of these options:
   - `External longitudinal forces`
   - `External forces`
2. On the **Input signals** pane, select **Initial longitudinal velocity**

`ydot_o` — Initial lateral position

`scalar`

Initial vehicle CG velocity along the vehicle-fixed *y*-axis, in m/s.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial lateral velocity**.

`psi_o` — Initial yaw angle

`scalar`

Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw), in rad.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial yaw angle**.

`r_o` — Initial yaw rate

`scalar`

Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial yaw rate**.

Output

`Info` — Bus signal

bus

Bus signal containing these block values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CG displacement along the earth-fixed *X*-axis	Computed	m

Signal					Description	Value	Units
			`Y`		Vehicle CG displacement along the earth-fixed *Y*-axis	Computed	m
			`Z`		Vehicle CG displacement along the earth-fixed *Z*-axis	`0`	m
		`Vel`	`Xdot`		Vehicle CG velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Vehicle CG velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`		Vehicle CG velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Ang`	`phi`		Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	`0`	rad
			`theta`		Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	`0`	rad
			`psi`		Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad
	`FrntAxl`	`Lft`	`Disp`	`X`	Front left wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front left wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front left wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Front left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front left wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Rght`	`Disp`	`X`	Front right wheel displacement along the earth-fixed *X*-axis	Computed	m

Signal					Description	Value	Units
				`Y`	Front right wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front right wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Front right wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front right wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
	`RearAxl`	`Lft`	`Disp`	`X`	Rear left wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear left wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear left wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Rear left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear left wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Rght`	`Disp`	`X`	Rear right wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear right wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear right wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Rear right wheel velocity along the earth-fixed *X*-axis	Computed	m/s

Signal					**Description**	**Value**	**Units**
				`Ydot`	Rear right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear right wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
	`Hitch`	`Disp`	`X`		Hitch offset from axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`		Hitch offset from center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`		Hitch offset from axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`		Hitch offset velocity from axle plane along the earth-fixed *X*-axis	Computed	m
			`Ydot`		Hitch offset velocity from center plane along the earth-fixed *Y*-axis	Computed	m
			`Zdot`		Hitch offset velocity from axle plane along the earth-fixed *Z*-axis	Computed	m
	`Geom`	`Disp`	`X`		Vehicle chassis offset from axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`		Vehicle chassis offset from center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`		Vehicle chassis offset from axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`		Vehicle chassis offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Vehicle chassis offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`		Vehicle chassis offset velocity along the earth-fixed *Z*-axis	Computed	m/s
`BdyFrm`	`Cg`	`Vel`	`xdot`		Vehicle CG velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal				Description	Value	Units
			`ydot`	Vehicle CG velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle CG velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	`0`	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	`0`	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s
		`Acc`	`ax`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	gn
			`xddot`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2
			`zddot`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	m/s^2
		`AngAcc`	`pdot`	Vehicle angular acceleration about the vehicle-fixed *x*-axis	`0`	rad/s
			`qdot`	Vehicle angular acceleration about the vehicle-fixed *y*-axis	`0`	rad/s
			`rdot`	Vehicle angular acceleration about the vehicle-fixed *z*-axis	Computed	rad/s

Signal					Description	Value	Units
		`DCM`			Direction cosine matrix	Computed	rad
	`Forces`	`Body`	`Fx`		Net force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Net force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Net force on vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`Ext`	`Fx`		External force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		External force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		External force on vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`Hitch`	`Fx`		Hitch force applied to body at the hitch location along the vehicle-fixed *x*-axis	Input	N
			`Fy`		Hitch force applied to body at the hitch location along the vehicle-fixed *y*-axis	Input	N
			`Fz`		Hitch force applied to body at the hitch location along the vehicle-fixed *z*-axis	Input	N
		`FrntAxl`	`Lft`	`Fx`	Longitudinal force on left front wheel, along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on left front wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on left front wheel, along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on right front wheel, along the vehicle-fixed *x*-axis	Computed	N

Signal						Description	Value	Units
				`Fy`		Lateral force on right front wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`		Normal force on right front wheel, along the vehicle-fixed *z*-axis	Computed	N
		`RearAxl`	`Lft`	`Fx`		Longitudinal force on left rear wheel, along the vehicle-fixed *x*-axis	Computed	N
				`Fy`		Lateral force on left rear wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`		Normal force on left rear wheel, along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`		Longitudinal force on right rear wheel, along the vehicle-fixed *x*-axis	Computed	N
				`Fy`		Lateral force on right rear wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`		Normal force on right rear wheel, along the vehicle-fixed *z*-axis	Computed	N
		`Tires`	`FrntTires`	`Lft`	`Fx`	Front left tire force, along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front left tire force, along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front left tire force, along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Front right tire force, along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front right tire force, along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front right tire force, along the vehicle-fixed *z*-axis	Computed	N
			`RearTires`	`Lft`	`Fx`	Rear left tire force, along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear left tire force, along the vehicle-fixed *y*-axis	Computed	N

Signal						Description	Value	Units
					Fz	Rear left tire force, along the vehicle-fixed *z*-axis	Computed	N
				Rght	Fx	Rear right tire force, along the vehicle-fixed *x*-axis	Computed	N
					Fy	Rear right tire force, along the vehicle-fixed *y*-axis	Computed	N
					Fz	Rear right tire force, along the vehicle-fixed *z*-axis	Computed	
		Drag	Fx			Drag force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			Fy			Drag force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			Fz			Drag force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
		Grvty	Fx			Gravity force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			Fy			Gravity force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			Fz			Gravity force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
	Moments	Body	Mx			Body moment on vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My			Body moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz			Body moment on vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		Drag	Mx			Drag moment on vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My			Drag moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m

Signal					Description	Value	Units
			Mz		Drag moment on vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		Ext	Mx		External moment on vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My		External moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz		External moment on vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		Hitch	Mx		Hitch moment at the hitch location about vehicle-fixed *x*-axis	0	N·m
			My		Hitch moment at the hitch location about vehicle-fixed *y*-axis	Computed	N·m
			Mz		Hitch moment at the hitch location about vehicle-fixed *z*-axis	0	N·m
	FrntAxl	Lft	Disp	x	Front left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				y	Front left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				z	Front left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			Vel	xdot	Front left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				ydot	Front left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				zdot	Front left wheel velocity along the vehicle-fixed *z*-axis	0	m/s
		Rght	Disp	x	Front right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				y	Front right wheel displacement along the vehicle-fixed *y*-axis	Computed	m

Signal					Description	Value	Units
				`z`	Front right wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front right wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngFL`		Front left wheel steering angle	Computed	rad
			`WhlAngFR`		Front right wheel steering angle	Computed	rad
	`RearAxl`	`Lft`	`Disp`	`x`	Rear left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear left wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Rght`	`Disp`	`x`	Rear right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear right wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear right wheel displacement along the vehicle-fixed *z*-axis	Computed	m

Signal					Description	Value	Units
			Vel	xdot	Rear right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				ydot	Rear right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				zdot	Rear right wheel velocity along the vehicle-fixed *z*-axis	0	m/s
		Steer	WhlAngRL		Rear left wheel steering angle	Computed	rad
			WhlAngRR		Rear right wheel steering angle	Computed	rad
	Hitch	Disp		x	Hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	m
				y	Hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
				z	Hitch offset from axle plane along the earth-fixed *z*-axis	Input	m
		Vel		xdot	Hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
				ydot	Hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
				zdot	Hitch offset velocity along the vehicle-fixed *z*-axis	Computed	m/s
	Pwr	Ext			Applied external power	Computed	W
		Hitch			Power loss due to hitch	Computed	W
		Drag			Power loss due to drag	Computed	W
	Geom	Disp		x	Vehicle chassis offset from axle plane along the vehicle-fixed *x*-axis	Input	m
				y	Vehicle chassis offset from center plane along the vehicle-fixed *y*-axis	Input	m
				z	Vehicle chassis offset from axle plane along the earth-fixed *z*-axis	Input	m
		Vel		xdot	Vehicle chassis offset velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal				Description	Value	Units
			ydot	Vehicle chassis offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			zdot	Vehicle chassis offset velocity along the vehicle-fixed *z*-axis	0	m/s
		Beta	Beta	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad

Signal			Description	Value	Units
PwrInfo	PwrTrnsfrd	PwrFxExt	Externally applied longitudinal force power	Computed	W
		PwrFyExt	Externally applied lateral force power	Computed	W
		PwrMzExt	Externally applied roll moment power	Computed	W
		PwrFwFLx	Longitudinal force applied at the front left axle power	Computed	W
		PwrFwFLy	Lateral force applied at the front left axle power	Computed	W
		PwrFwFRx	Longitudinal force applied at the front right axle power	Computed	W
		PwrFwFRy	Lateral force applied at the front right axle power	Computed	W
		PwrFwRLx	Longitudinal force applied at the rear left axle power	Computed	W
		PwrFwRLy	Lateral force applied at the rear left axle power	Computed	W
		PwrFwRRx	Longitudinal force applied at the rear right axle power	Computed	W
		PwrFwRRy	Lateral force applied at the rear right axle power	Computed	W
	PwrNotTrnsfrd	PwrFxDrag	Longitudinal drag force power	Computed	W
		PwrFyDrag	Lateral drag force power	Computed	W
		PwrMzDrag	Drag pitch moment power	Computed	W
	PwrStored	PwrStoredGrvty	Rate change in gravitational potential energy	Computed	W

Signal			Description	Value	Units
		`PwrStoredxdot`	Rate of change of longitudinal kinetic energy	Computed	W
		`PwrStoredydot`	Rate of change of lateral kinetic energy	Computed	W
		`PwrStoredr`	Rate of change of rotational yaw kinetic energy	Computed	W

`xdot` — Vehicle longitudinal velocity

`scalar`

Vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

`ydot` — Vehicle lateral velocity

`scalar`

Vehicle CG velocity along the vehicle-fixed *y*-axis, in m/s.

`psi` — Yaw

`scalar`

Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw), in rad.

`r` — Yaw rate

`scalar`

Vehicle angular velocity, `r`, about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

`FzF` — Normal force on front wheels

`scalar` | `array`

Normal force on front wheels, Fz_F, along the vehicle-fixed *z*-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	Normal force on front axle	$FzF = Fz_f$	Scalar – 1
`Dual`	Normal force on the front wheels	$FzF = [Fz_{fl}\ Fz_{fr}]$	Array – `[1x2]`

`FzR` — Normal force on rear wheels

`scalar` | `array`

Normal force on rear wheels, Fz_R, along the vehicle-fixed *z*-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	Normal force on rear wheel	$FzR = Fz_r$	Scalar – 1

Vehicle Track Setting	Description	Variable	Signal Dimension
`Dual`	Normal force on the rear wheels	$FzR = \left[Fz_{rl}\ Fz_{rr}\right]$	Array - `[1x2]`

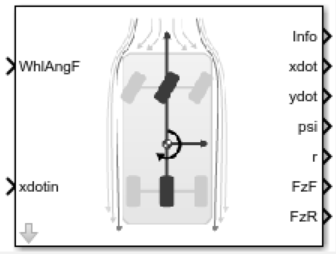
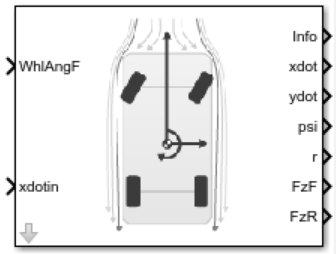
Parameters

Options

`Vehicle track` — Number of wheels

`Single (bicycle)` | `Dual`

In the Vehicle Dynamics Blockset library, there are two types of Vehicle Body 3DOF blocks that model longitudinal, lateral, and yaw motion.

Block	Vehicle Track Setting	Implementation
Vehicle Body 3DOF Single Track 	`Single (bicycle)`	• Forces act along the center line at the front and rear axles. • No lateral load transfer.
Vehicle Body 3DOF Dual Track 	`Dual`	Forces act at the four vehicle corners or *hard points*.

`Axle forces` — Type of axle force

`External longitudinal velocity` | `External longitudinal forces` | `External forces`

Use the **Axle forces** parameter to specify the type of force.

Axle Forces Setting	Implementation

`External longitudinal velocity`	- The block assumes that the external longitudinal velocity is in a quasi-steady state, so the longitudinal acceleration is approximately zero.
	- Because the motion is quasi-steady, the block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	- Consider this setting when you want to:
	  - Generate virtual sensor signal data.
	  - Conduct high-level software studies that are not impacted by driveline or nonlinear tire responses.

`External longitudinal forces`	- The block uses the external longitudinal force to accelerate or brake the vehicle.
	- The block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	- Consider this setting when you want to:
	  - Account for changes in the longitudinal velocity on the lateral and yaw motion.
	  - Specify the external longitudinal motion through a force instead of an external longitudinal velocity.
	  - Connect the block to tractive actuators, wheels, brakes, and hitches.

`External forces`	- The block uses the external lateral and longitudinal forces to steer, accelerate, or brake the vehicle. - The block does not use the steering input to calculate vehicle motion. - Consider this setting when you need tire models with more accurate nonlinear combined lateral and longitudinal slip.

Input Signals

`Front wheel steering` — WhlAngF input port

`on` (default) | `off`

Specify to create input port `WhlAngF`.

`External wind` — WindXYZ input port

`off` (default) | `on`

Specify to create input port `WindXYZ`.

`External forces` — FExt input port

`off` (default) | `on`

Specify to create input port `FExt`.

`External moments` — MExt input port

`off` (default) | `on`

Specify to create input port `MExt`.

`Rear wheel steering` — WhlAngR input port
`off` (default) | `on`

Specify to create input port `WhlAngR`.

`External friction` — Mu input port
`off` (default) | `on`

Specify to create input port `Mu`.

`Hitch forces` — Fh input port
`on` (default) | `off`

Select to create input port `Fh`.

`Hitch moments` — Mh input port
`on` (default) | `off`

Specify to create input port `Mh`.

`Initial longitudinal position` — X_o input port
`off` (default) | `on`

Specify to create input port `X_o`.

`Initial lateral position` — Y_o input port
`off` (default) | `on`

Specify to create input port `Y_o`.

`Initial longitudinal velocity` — xdot_o input port
`off` (default) | `on`

Specify to create input port `xdot_o`.

`Initial lateral velocity` — ydot_o input port
`off` (default) | `on`

Specify to create input port `ydot_o`.

`Initial yaw angle` — psi_o input port
`off` (default) | `on`

Specify to create input port `psi_o`.

`Initial yaw rate` — r_o input port
`off` (default) | `on`

Specify to create input port `r_o`.

`Air temperature` — AirTemp input port
`off` (default) | `on`

Specify to create input port `AirTemp`.

Longitudinal

`Number of wheels on front axle, NF` — Front wheel count
`2` (default) | `scalar`

Number of wheels on front axle, N_F. The value is dimensionless.

`Number of wheels on rear axle, NR` — Rear wheel count
`2` (default) | `scalar`

Number of wheels on rear axle, N_R. The value is dimensionless.

`Vehicle mass, m` — Vehicle mass
`2000` (default) | `scalar`

Vehicle mass, m, in kg.

`Longitudinal distance from center of mass to front axle, a` — Front axle distance
`1.4` (default) | `scalar`

Horizontal distance a from the vehicle CG to the front wheel axle, in m.

`Longitudinal distance from center of mass to rear axle, b` — Rear axle distance
`1.6` (default) | `scalar`

Horizontal distance b from the vehicle CG to the rear wheel axle, in m.

`Vertical distance from center of mass to axle plane, h` — Height
`0.35` (default) | `scalar`

Height of vehicle CG above the axles, h, in m.

`Longitudinal distance from center of mass to hitch, dh` — Distance from CM to hitch
`1` (default) | `scalar`

Longitudinal distance from center of mass to hitch, dh, in m.

Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Vertical distance from hitch to axle plane, hh` — Distance from hitch to axle plane
`0.2` (default) | `scalar`

Vertical distance from hitch to axle plane, hh, in m.

Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Initial inertial frame longitudinal position, X_o` — Position
`0` (default) | `scalar`

Initial vehicle CG displacement along earth-fixed X-axis, in m.

`Initial longitudinal velocity, xdot_o` — Velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along vehicle-fixed *x*-axis, in m/s.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

Lateral

`Front tire corner stiffness, Cy_f` — Stiffness

`12e3` (default) | `scalar`

Front tire corner stiffness, Cy_f, in N/rad.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Rear tire corner stiffness, Cy_r` — Stiffness

`11e3` (default) | `scalar`

Rear tire corner stiffness, Cy_r, in N/rad.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Initial inertial frame lateral displacement, Y_o` — Position

`0` (default) | `scalar`

Initial vehicle CG displacement along earth-fixed *Y*-axis, in m.

`Initial lateral velocity, ydot_o` — Velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along vehicle-fixed *y*-axis, in m/s.

`Mapped corner stiffness` — Selection

`off` (default) | `on`

Enables mapped corner stiffness calculation.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

`Include relaxation length dynamics` — Enable relaxation length dynamics

`on` (default) | `off`

Enables relaxation length dynamics.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Lateral distance from geometric centerline to center of mass, d` — Distance

`0` (default) | `scalar`

Lateral distance from geometric centerline to center of mass, *d*, in m, along the vehicle-fixed *y*. Positive values indicate that the vehicle CM is to the right of the geometric centerline. Negative values indicate that the vehicle CM is to the left of the geometric centerline.

`Lateral distance from geometric centerline to hitch, hl` — Distance

`0` (default) | `scalar`

Lateral distance from geometric centerline to the hitch, *hl*, in m, along the vehicle-fixed *y*. Positive values indicate that the hitch is to the right of the geometric centerline. Negative values indicate that the hitch is to the left of the geometric centerline.

Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Track width` — Width

`[1.4,1.4]` (default) | 1-by-2 `vector`

Track width, *w*, in m.

Dependencies

To enable this parameter, set **Vehicle track** to `Dual`.

`Front tire(s) relaxation length, sigma_f` — Relaxation length

`.1` (default) | `scalar`

Front tire relaxation length, σ_f, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Rear tire(s) relaxation length, sigma_r` — Relaxation length

`.1` (default) | `scalar`

Rear tire relaxation length, σ_r, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Front axle slip angle breakpoints, alpha_f_brk` — Breakpoints

`[-.1 .1]` (default) | `vector`

Front axle slip angle breakpoints, α_{fbrk}, in rad.

Dependencies

To enable this parameter:

1 Set **Axle forces** to one of these options:

   - `External longitudinal velocity`
   - `External longitudinal forces`

2 Select **Mapped corner stiffness**.

`Front axle corner data, Cy_f_data` — Breakpoints

`[-9e3 9e3]` (default) | `vector`

Front axle corner data, Cy_{fdata}, in N/rad.

Dependencies

To enable this parameter:

1 Set **Axle forces** to one of these options:

   - `External longitudinal velocity`
   - `External longitudinal forces`

2 Select **Mapped corner stiffness**.

`Rear axle slip angle breakpoints, alpha_r_brk` — Breakpoints

`[-.1 .1]` (default) | `vector`

Rear axle slip angle breakpoints, α_{rbrk}, in rad.

Dependencies

To enable this parameter:

1 Set **Axle forces** to one of these options:

   - `External longitudinal velocity`
   - `External longitudinal forces`

2 Select **Mapped corner stiffness**.

`Rear axle corner data, Cy_r_data` — Data

`[-9e3 9e3]` (default) | `vector`

Rear axle corner data, Cy_{rdata}, in N/rad.

Dependencies

To enable this parameter:

1 Set **Axle forces** to one of these options:

   - `External longitudinal velocity`
   - `External longitudinal forces`

2 Select **Mapped corner stiffness**.

Yaw

`Yaw polar inertia, Izz` — Inertia

`4000` (default) | `scalar`

Yaw polar inertia, in kg*m^2.

`Initial yaw angle, psi_o` — Psi rotation
`0` (default) | `scalar`

Rotation of the vehicle-fixed frame about earth-fixed *Z*-axis (yaw), in rad.

`Initial yaw rate, r_o` — Yaw rate
`0` (default) | `scalar`

Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

Aerodynamic

`Longitudinal drag area, Af` — Effective vehicle cross-sectional area
`2` (default) | `scalar`

Effective vehicle cross-sectional area, A_f, to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Air drag coefficient
`.3` (default) | `scalar`

Air drag coefficient, C_d. The value is dimensionless.

`Longitudinal lift coefficient, Cl` — Air lift coefficient
`.1` (default) | `scalar`

Air lift coefficient, C_l. The value is dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}. The value is dimensionless.

`Relative wind angle vector, beta_w` — Wind angle
`[0:0.01:0.3]` (default) | `vector`

Relative wind angle vector, β_w, in rad.

`Side force coefficient vector, Cs` — Side force coefficient
`[0:0.03:0.9]` (default) | `vector`

Side force coefficient vector coefficient, C_s. The value is dimensionless.

`Yaw moment coefficient vector, Cym` — Yaw moment drag
`[0:0.01:0.3]` (default) | `vector`

Yaw moment coefficient vector coefficient, C_{ym}. The value is dimensionless.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar` | `scalar`

Environmental absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Temperature

`273` (default) | `scalar`

Environmental absolute temperature, *T*, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity

`9.81` (default) | `scalar`

Gravitational acceleration, *g*, in m/s^2.

`Nominal friction scaling factor, mu` — Friction scale factor

`1` (default) | `scalar`

Nominal friction scale factor, μ. The value is dimensionless.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **External Friction**.

Simulation

`Longitudinal velocity tolerance, xdot_tol` — Tolerance

`.01` (default) | `scalar`

Longitudinal velocity tolerance, in m/s.

`Nominal normal force, Fznom` — Normal force

`5000` (default) | `scalar`

Nominal normal force, in N.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

`Geometric longitudinal offset from axle plane, longOff` — Longitudinal offset

`0` (default) | `scalar`

Vehicle chassis offset from axle plane along body-fixed *x*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Geometric lateral offset from center plane, latOff` — Lateral offset
`0` (default) | `scalar`

Vehicle chassis offset from center plane along body-fixed *y*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Geometric vertical offset from axle plane, vertOff` — Vertical offset
`0` (default) | `scalar`

Vehicle chassis offset from axle plane along body-fixed *z*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Wrap Euler angles, wrapAng` — Selection
`off` (default) | `on`

Wrap the Euler angles to the interval `[-pi, pi]`. For vehicle maneuvers that might undergo vehicle yaw rotations that are outside of the interval, consider deselecting the parameter if you want to:

- Track the total vehicle yaw rotation.
- Avoid discontinuities in the vehicle state estimators.

Version History

Introduced in R2018a

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

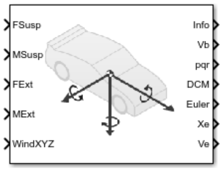
Vehicle Body 3DOF Longitudinal | Vehicle Body 6DOF | Vector Concatenate, Matrix Concatenate

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Vehicle Body 6DOF

Two-axle vehicle body with translational and rotational motion
Library: Vehicle Dynamics Blockset / Vehicle Body



Description

The Vehicle Body 6DOF block implements a six degrees-of-freedom (DOF) rigid two-axle vehicle body model to calculate longitudinal, lateral, vertical, pitch, roll, and yaw motion. The block accounts for body mass, inertia, aerodynamic drag, road incline, and weight distribution between the axles due to suspension and external forces and moments. Use the **Inertial Loads** parameters to analyze the vehicle dynamics under different loading conditions.

You can connect the block to virtual sensors, suspension system, or external systems like body control actuators. Use the Vehicle Body 6DOF block in ride and handling studies to model the effects of drag forces, passenger loading, and suspension hardpoint locations.

To create additional input ports, under **Input signals**, select these block parameters.

Parameter	Input Port	Description
Front hitch forces	`FhF`	Hitch force applied to the body at the front hitch location, FhF_x, FhF_y, and FhF_z, in the vehicle-fixed frame
Front hitch moments	`MhF`	Hitch moment at the front hitch location, MhF_x, MhF_y, and MhF_z, about the vehicle-fixed frame
Rear hitch forces	`FhR`	Hitch force applied to the body at the rear hitch location, FhR_x, FhR_y, and FhR_z, in the vehicle-fixed frame
Rear hitch moments	`MhR`	Hitch moment at the rear hitch location, MhR_x, MhR_y, and MhR_z, about the vehicle-fixed frame

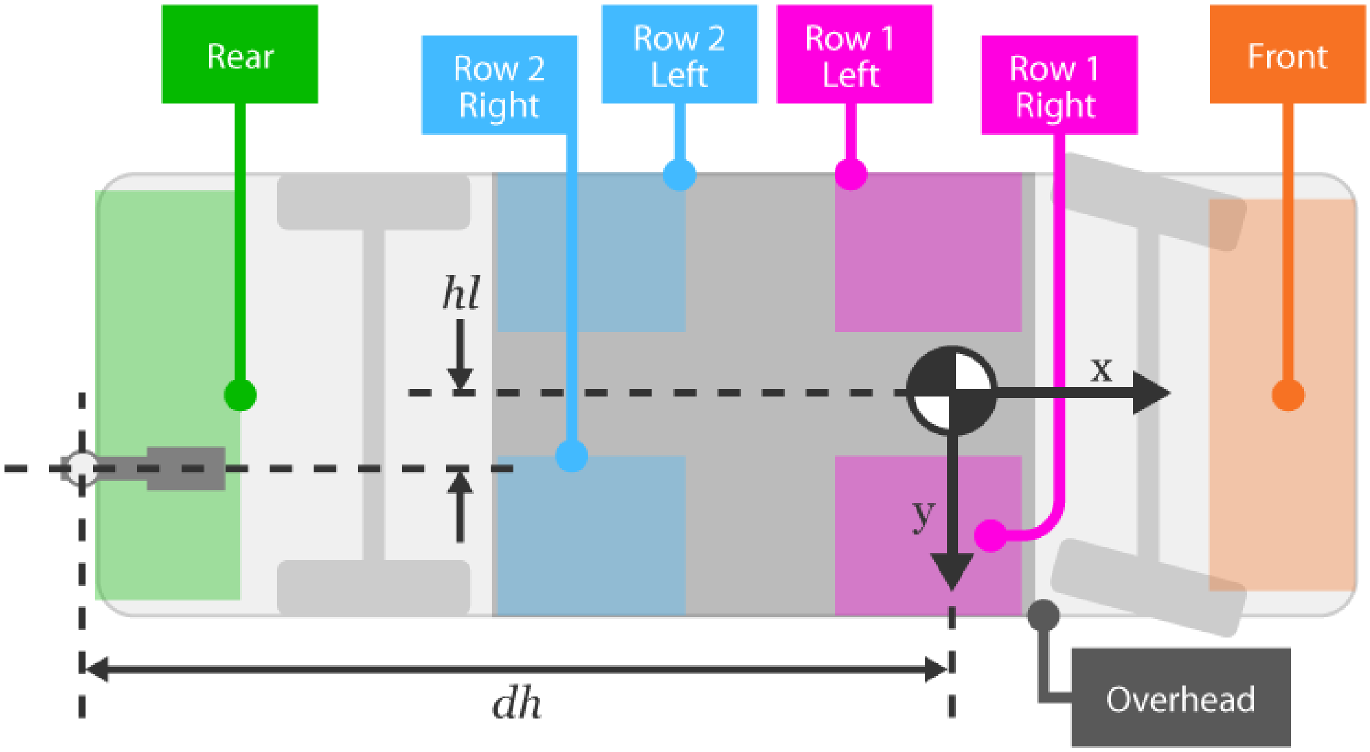
Inertial Loads

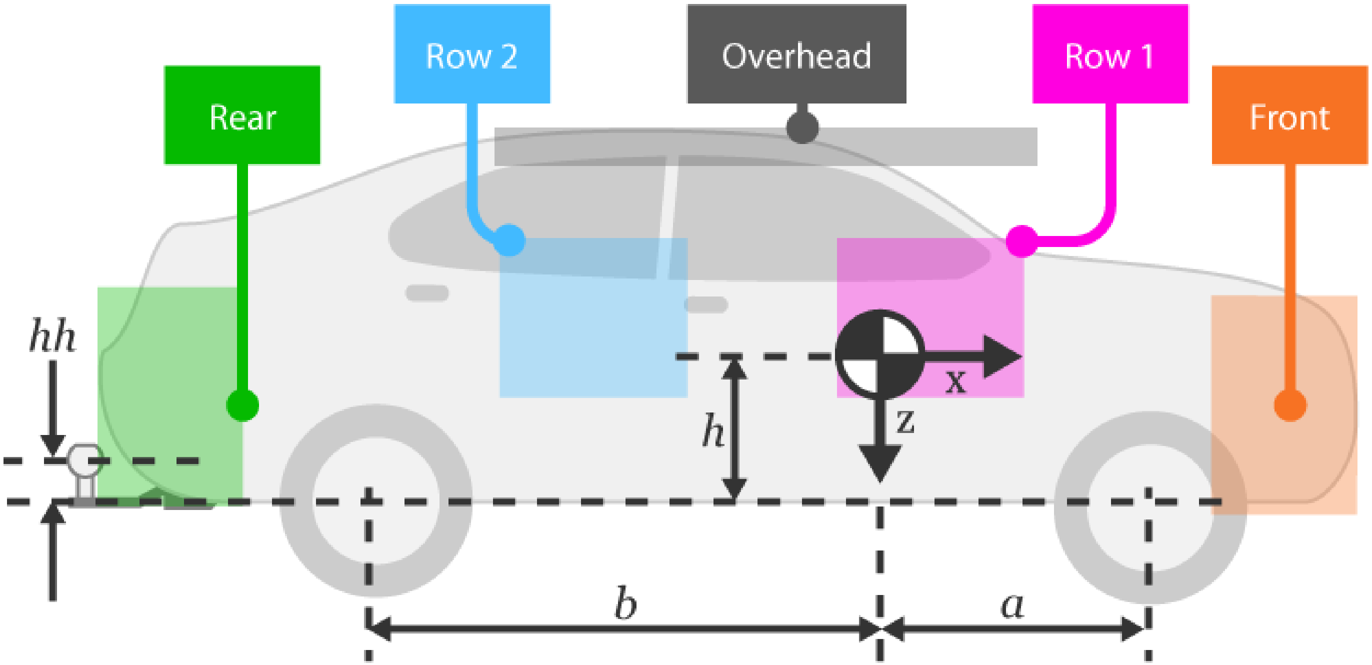
To analyze the vehicle dynamics under different loading conditions, use the **Inertial Loads** parameters. Specifically, you can specify these loads:

- Front powertrain
- Front and rear row passengers
- Overhead cargo
- Rear cargo

For each of the loads, you can specify the mass, location, and inertia.

The illustrations provide the load locations and vehicle parameter dimensions. The table provides the corresponding location parameter sign settings.





This table summarizes the parameter settings that specify the load locations indicated by the dots. For the location, the block uses this distance vector:

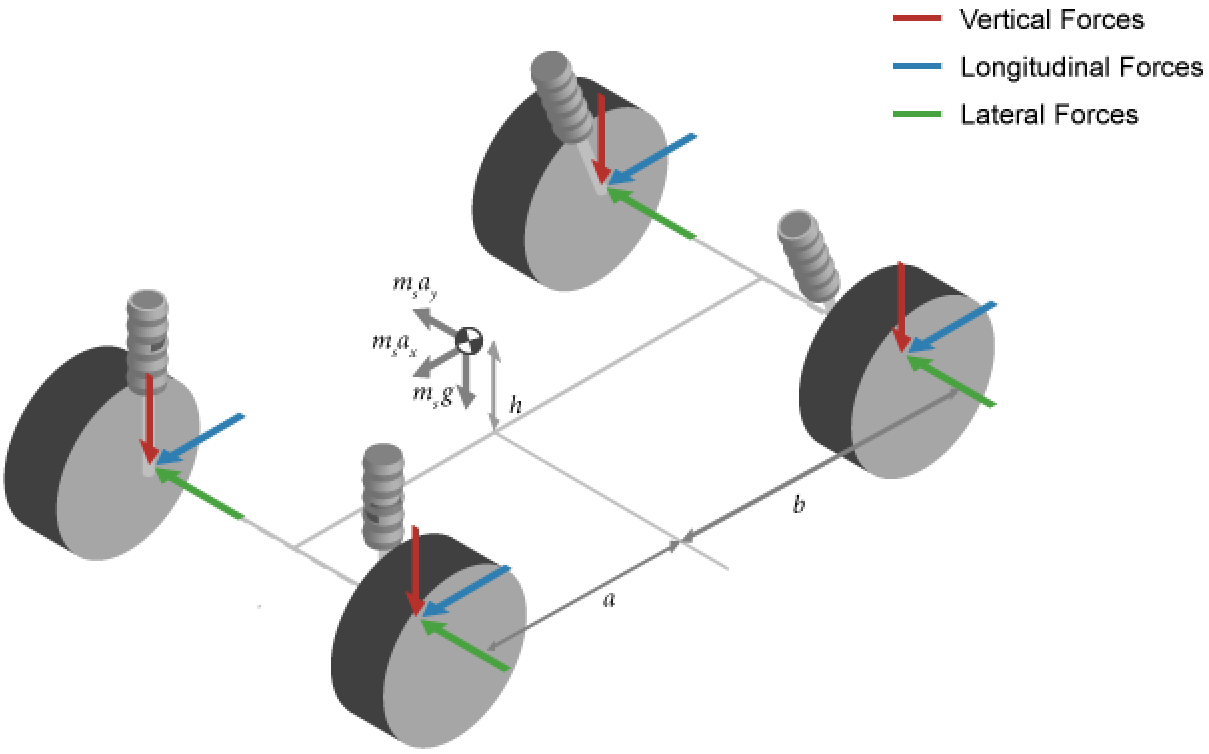
- Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
- Vehicle centerline to load, along the vehicle-fixed *y*-axis
- Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

Load	Parameter	Example Location
Front	**Distance vector from front axle, z1R**	• `z1R(1,1)<0` — Forward of the front axle • `z1R(1,2)>0` — Right of the vehicle centerline • `z1R(1,3)>0` — Above the front axle suspension hardpoint
Overhead	**Distance vector from front axle, z2R**	• `z2R(1,1)>0` — Rear of the front axle • `z2R(1,2)<0` — Left of the vehicle centerline • `z2R(1,3)>0` — Above the front axle suspension hardpoint
Row 1, left side	**Distance vector from front axle, z3R**	• `z3R(1,1)>0` — Rear of the front axle • `z3R(1,2)<0` — Left of the vehicle centerline • `z3R(1,3)>0` — Above the front axle suspension hardpoint
Row 1, right side	**Distance vector from front axle, z4R**	• `z4R(1,1)>0` — Rear of the front axle • `z4R(1,2)>0` — Right of the vehicle centerline • `z4R(1,3)>0` — Above the front axle suspension hardpoint
Row 2, left side	**Distance vector from front axle, z5R**	• `z5R(1,1)>0` — Rear of the front axle • `z5R(1,2)<0` — Left of the vehicle centerline • `z5R(1,3)>0` — Above the front axle suspension hardpoint
Row 2, right side	**Distance vector from front axle, z6R**	• `z6R(1,1)>0` — Rear of the front axle • `z6R(1,2)>0` — Right of the vehicle centerline • `z6R(1,3)>0` — Above the front axle suspension hardpoint
Rear	**Distance vector from front axle, z7R**	• `z7R(1,1)>0` — Rear of the front axle • `z7R(1,2)>0` — Right of the vehicle centerline • `z7R(1,3)>0` — Above the front axle suspension hardpoint

Equations of Motion

To determine the vehicle motion, the block implements calculations for the rigid body vehicle dynamics, wind drag, inertial loads, and coordinate transformations. The body-fixed and the vehicle-fixed are the same coordinate systems.

The Vehicle Body 6DOF block considers the rotation of a body-fixed coordinate frame about a flat earth-fixed inertial reference frame. The origin of the body-fixed coordinate frame is the vehicle center of gravity of the body.



The block uses this equation to calculate the translational motion of the body-fixed coordinate frame, where the applied forces $[F_x \; F_y \; F_z]^T$ are in the body-fixed frame, and the mass of the body, m, is assumed constant.

$$\bar{F}_b = \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = m\left(\dot{\bar{V}}_b + \bar{\omega} \times \bar{V}_b\right)$$

$$\bar{M}_b = \begin{bmatrix} L \\ M \\ N \end{bmatrix} = I\dot{\bar{\omega}} + \bar{\omega} \times (I\bar{\omega})$$

$$I = \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix}$$

To determine the relationship between the body-fixed angular velocity vector, $[p \; q \; r]^T$, and the rate of change of the Euler angles, $\begin{bmatrix} \dot{\phi} & \dot{\theta} & \dot{\psi} \end{bmatrix}^T$, the block resolves the Euler rates into the body-fixed frame.

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \dot{\phi} \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} 0 \\ \dot{\theta} \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \dot{\psi} \end{bmatrix} \equiv J^{-1} \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

Inverting J gives the required relationship to determine the Euler rate vector.

$$\begin{bmatrix}\dot{\phi}\\ \dot{\theta}\\ \dot{\psi}\end{bmatrix} = J\begin{bmatrix}p\\ q\\ r\end{bmatrix} = \begin{bmatrix}1 & (\sin\phi\tan\theta) & (\cos\phi\tan\theta)\\ 0 & \cos\phi & -\sin\phi\\ 0 & \dfrac{\sin\phi}{\cos\theta} & \dfrac{\cos\phi}{\cos\theta}\end{bmatrix}\begin{bmatrix}p\\ q\\ r\end{bmatrix}$$

The applied forces and moments are the sum of the drag, gravitational, external, and suspension forces.

$$\bar{F}_b = \begin{bmatrix}F_x\\ F_y\\ F_z\end{bmatrix} = \begin{bmatrix}F_{d_x}\\ F_{d_y}\\ F_{d_z}\end{bmatrix} + \begin{bmatrix}F_{g_x}\\ F_{g_y}\\ F_{g_z}\end{bmatrix} + \begin{bmatrix}F_{ext_x}\\ F_{ext_y}\\ F_{ext_z}\end{bmatrix} + \begin{bmatrix}F_{FL_x}\\ F_{FL_y}\\ F_{FL_z}\end{bmatrix} + \begin{bmatrix}F_{FR_x}\\ F_{FR_y}\\ F_{FR_z}\end{bmatrix} + \begin{bmatrix}F_{RL_x}\\ F_{RL_y}\\ F_{RL_z}\end{bmatrix} + \begin{bmatrix}F_{RR_x}\\ F_{RR_y}\\ F_{RR_z}\end{bmatrix}$$

$$\overline{M}_b = \begin{bmatrix}M_x\\ M_y\\ M_z\end{bmatrix} = \begin{bmatrix}M_{d_x}\\ M_{d_y}\\ M_{d_z}\end{bmatrix} + \begin{bmatrix}M_{ext_x}\\ M_{ext_y}\\ M_{ext_z}\end{bmatrix} + \begin{bmatrix}M_{FL_x}\\ M_{FL_y}\\ M_{FL_z}\end{bmatrix} + \begin{bmatrix}M_{FR_x}\\ M_{FR_y}\\ M_{FR_z}\end{bmatrix} + \begin{bmatrix}M_{RL_x}\\ M_{RL_y}\\ M_{RL_z}\end{bmatrix} + \begin{bmatrix}M_{RR_x}\\ M_{RR_y}\\ M_{RR_z}\end{bmatrix} + \overline{M}_F$$

Calculation	**Implementation**
Load masses and inertias	Block uses parallel axis theorem to resolve the individual load masses and inertias with the vehicle mass and inertia. $J_{ij} = I_{ij} + m(\lvert R\rvert^2\delta_{ij} - R_iR_j)$
Gravitational forces, F_g	Block uses direction cosine matrix (DCM) to transform the gravitational vector in the inertial-fixed frame to the body-fixed frame.
Drag forces, F_d, and moments, M_d	To determine a relative airspeed, the block subtracts the wind speed from the vehicle center of mass (CM) velocity. Using the relative airspeed, the block determines the drag forces. $\overline{w} = \sqrt{(\dot{x} - w_x)^2 + (\dot{x} - w_x)^2 + (w_z)^2}$ $F_{dx} = -\frac{1}{2TR}C_dA_fP_{abs}(^{\overline{w}}$ $F_{dy} = -\frac{1}{2TR}C_sA_fP_{abs}(^{\overline{w}}$ $F_{dz} = -\frac{1}{2TR}C_lA_fP_{abs}(^{\overline{w}}$ Using the relative airspeed, the block determines the drag moments. $M_{dr} = -\frac{1}{2TR}C_{rm}A_fP_{abs}(^{\overline{w}}(a+b)$ $M_{dp} = -\frac{1}{2TR}C_{pm}A_fP_{abs}(^{\overline{w}}(a+b)$ $M_{dy} = -\frac{1}{2TR}C_{ym}A_fP_{abs}(^{\overline{w}}(a+b)$
External forces, F_{in}, and moments, M_{in}	External forces and moments are input via ports `FExt` and `MExt`.

Calculation	Implementation
Suspension forces and moments	Block assumes that the suspension forces and moments act on these hardpoint locations: • F_{FL}, M_{FL} — Front left • F_{FR}, M_{FR} — Front right • F_{RL}, M_{RL} — Rear left • F_{RR}, M_{RR} — Rear right

The equations use these variables.

$x, \dot{x}, \ddot{x}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *x*-axis
$y, \dot{y}, \ddot{y}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *y*-axis
$z, \dot{z}, \ddot{z}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *z*-axis
φ	Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)
θ	Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)
ψ	Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)
F_{FLx}, F_{FLy}, F_{FLz}	Suspension forces applied to front left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{FRx}, F_{FRy}, F_{FRz}	Suspension forces applied to front right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{RLx}, F_{RLy}, F_{RLz}	Suspension forces applied to rear left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{RRx}, F_{RRy}, F_{RRz}	Suspension forces applied to rear right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{Fx}, F_{Fy}, F_{Fz}	Suspension moments applied to vehicle CM about the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{extx}, F_{exty}, F_{extz}	External forces applied to vehicle CM along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{dx}, F_{dy}, F_{dz}	Drag forces applied to vehicle CM along the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{extx}, M_{exty}, M_{extz}	External moment about vehicle CM about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{dx}, M_{dy}, M_{dz}	Drag moment about vehicle CM about the vehicle-fixed *x*-, *y*-, and *z*-axes
I	Vehicle body moments of inertia
a, b	Distance of front and rear wheels, respectively, from the normal projection point of vehicle CM onto the common axle plane
d	Lateral distance from the geometric centerline to the center of mass along the vehicle-fixed *y*-axis
h	Height of vehicle CM above the axle plane
hh	Height of the hitch above the axle plane along the vehicle-fixed *z*-axis
dh	Longitudinal distance of the hitch from the normal projection point of tractor CG onto the common axle plane

hl	Lateral distance from center of mass to hitch along the vehicle-fixed y-axis.
w_F, w_R	Front and rear track widths
C_d	Air drag coefficient acting along the vehicle-fixed x-axis
C_s	Air drag coefficient acting along the vehicle-fixed y-axis
C_l	Air drag coefficient acting along the vehicle-fixed z-axis
C_{rm}	Air drag roll moment acting about vehicle-fixed x-axis
C_{pm}	Air drag pitch moment acting about the vehicle-fixed y-axis
C_{ym}	Air drag yaw moment acting about vehicle-fixed z-axis
A_f	Frontal area
R	Atmospheric specific gas constant
T	Environmental air temperature
P_{abs}	Environmental absolute pressure
w_x, w_y, w_z	Wind speed along the vehicle-fixed x-, y-, and z-axes
W_x, W_y, W_z	Wind speed along inertial X-, Y-, and Z-axes

Ports

Input

`FSusp` — Suspension forces on vehicle

`array`

Suspension longitudinal, lateral, and vertical suspension forces applied to the vehicle at the hardpoint location, in N. Signal dimensions are `[3x4]`.

$$FSusp = \begin{bmatrix} F_{FLx} & F_{FRx} & F_{RLx} & F_{RRx} \\ F_{FLy} & F_{FRy} & F_{RLy} & F_{RRy} \\ F_{FLz} & F_{FRz} & F_{RLz} & F_{RRz} \end{bmatrix}$$

Array Element	Axle	Wheel	Force Axis
`FSusp(1,1)`	Front	Left	Vehicle-fixed x-axis (longitudinal)
`FSusp(1,2)`	Front	Right	
`FSusp(1,3)`	Rear	Left	
`FSusp(1,4)`	Rear	Right	
`FSusp(2,1)`	Front	Left	Vehicle-fixed y-axis (lateral)
`FSusp(2,2)`	Front	Right	
`FSusp(2,3)`	Rear	Left	
`FSusp(2,4)`	Rear	Right	
`FSusp(3,1)`	Front	Left	Vehicle-fixed z-axis (vertical)
`FSusp(3,2)`	Front	Right	
`FSusp(3,3)`	Rear	Left	
`FSusp(3,4)`	Rear	Right	

`MSusp` — Suspension moment on vehicle

`array`

Suspension longitudinal, lateral, and vertical suspension moments applied about the vehicle at the hardpoint location, in N·m. Signal dimensions are `[3x4]`.

$$MSusp = \begin{bmatrix} M_{FLx} & M_{FRx} & M_{RLx} & M_{RRx} \\ M_{FLy} & M_{FRy} & M_{RLy} & M_{RRy} \\ M_{FLz} & M_{FRz} & M_{RLz} & M_{RRz} \end{bmatrix}$$

Array Element	**Axle**	**Wheel**	**Moment Axis**
`MSusp(1,1)`	Front	Left	Vehicle-fixed *x*-axis (longitudinal)
`MSusp(1,2)`	Front	Right	
`MSusp(1,3)`	Rear	Left	
`MSusp(1,4)`	Rear	Right	
`MSusp(2,1)`	Front	Left	Vehicle-fixed *y*-axis (lateral)
`MSusp(2,2)`	Front	Right	
`MSusp(2,3)`	Rear	Left	
`MSusp(2,4)`	Rear	Right	
`MSusp(3,1)`	Front	Left	Vehicle-fixed *z*-axis (vertical)
`MSusp(3,2)`	Front	Right	
`MSusp(3,3)`	Rear	Left	
`MSusp(3,4)`	Rear	Right	

`FExt` — External forces acting on vehicle

`vector`

External forces on the vehicle, in N, specified as a `1-by-3` or `3-by-1` vector.

$$\text{FExt} = F_{ext} = \begin{bmatrix} F_{ext_x} & F_{ext_y} & F_{ext_z} \end{bmatrix} or \begin{bmatrix} F_{ext_x} \\ F_{ext_y} \\ F_{ext_z} \end{bmatrix}$$

Array Element	**Force Axis**
`FExt(1,1)`	Vehicle-fixed *x*-axis (longitudinal)
`FExt(1,2)` or `FExt(2,1)`	Vehicle-fixed *y*-axis (lateral)
`FExt(1,3)` or `FExt(3,1)`	Vehicle-fixed *z*-axis (vertical)

`MExt` — External moments acting on vehicle

`vector`

External moments acting on the vehicle, in N·m, specified as a `1-by-3` or `3-by-1` vector.

$$\text{MExt} = M_{ext} = \begin{bmatrix} M_{ext_x} & M_{ext_y} & M_{ext_z} \end{bmatrix} or \begin{bmatrix} M_{ext_x} \\ M_{ext_y} \\ M_{ext_z} \end{bmatrix}$$

Array Element	Force Axis
`MExt(1,1)`	Vehicle-fixed *x*-axis (longitudinal)
`MExt(1,2)` or `MExt(2,1)`	Vehicle-fixed *y*-axis (lateral)
`MExt(1,3)` or `MExt(3,1)`	Vehicle-fixed *z*-axis (vertical)

`Fh` — Hitch force on the body
`array`

Hitch force applied to the body at the hitch location, Fh_x, Fh_y, Fh_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch forces**.

`Mh` — Hitch moment about body
`array`

Hitch moment at the hitch location, Mh_x, Mh_y, Mh_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch moments**.

`WindXYZ` — Wind speed
`array`

Wind speed, W_x, W_y, W_z along inertial *X*-, *Y*-, and *Z*-axes, in m/s, specified as a `1-by-3` or `3-by-1` array.

`AirTemp` — Ambient air temperature
`scalar`

Ambient air temperature, T_{air}, in K, specified as a scalar.

Dependencies

To enable this port, under **Environment**, select **Air temperature**.

Output

`Info` — Bus signal
bus

Bus signal containing these block values.

Signal					Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`		Vehicle CM displacement along the earth-fixed *X*-axis	Computed	m
			`Y`		Vehicle CM displacement along the earth-fixed *Y*-axis	Computed	m
			`Z`		Vehicle CM displacement along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`		Vehicle CM velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Vehicle CM velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`		Vehicle CM velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Ang`	`phi`		Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	Computed	rad
			`theta`		Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	Computed	rad
			`psi`		Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad
	`FrntAxl`	`Lft`	`Disp`	`X`	Front left axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front left axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front left axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Front left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front left axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front left axle velocity along the earth-fixed *Z*-axis	Computed	m/s

Signal					Description	Value	Units
		`Rght`	`Disp`	`X`	Front right axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front right axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Front right axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`RearAxl`	`Lft`	`Disp`	`X`	Rear left axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear left axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear left axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Rear left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear left axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear left axle velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Rght`	`Disp`	`X`	Rear right axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear right axle displacement along the earth-fixed *Z*-axis	Computed	m

Signal					Description	Value	Units
			Vel	Xdot	Rear right axle velocity along the earth-fixed *X*-axis	Computed	m/s
				Ydot	Rear right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				Zdot	Rear right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	Hitch	Disp	X		Hitch offset from axle plane along the earth-fixed *X*-axis	Computed	m
			Y		Hitch offset from axle plane along the earth-fixed *Y*-axis	Computed	m
			Z		Hitch offset from axle plane along the earth-fixed *Z*-axis	Computed	m
		Vel	Xdot		Hitch velocity along the earth-fixed *X*-axis	Computed	m/s
			Ydot		Hitch velocity along the earth-fixed *Y*-axis	Computed	m/s
			Zdot		Hitch velocity along the earth-fixed *Z*-axis	Computed	m/s
	Geom	Disp	X		Vehicle chassis offset from axle plane along the earth-fixed *X*-axis	Computed	m
			Y		Vehicle chassis offset from center plane along the earth-fixed *Y*-axis	Computed	m
			Z		Vehicle chassis offset from axle plane along the earth-fixed *Z*-axis	Computed	m
		Vel	Xdot		Vehicle chassis offset velocity along the earth-fixed *X*-axis	Computed	m/s
			Ydot		Vehicle chassis offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			Zdot		Vehicle chassis offset velocity along the earth-fixed *Z*-axis	Computed	m/s
BdyFrm	Cg	Vel	xdot		Vehicle CM velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal				Description	Value	Units
			`ydot`	Vehicle CM velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle CM velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	Computed	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	Computed	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s
		`Acc`	`ax`	Vehicle CM acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CM acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CM acceleration along the vehicle-fixed *z*-axis	Computed	gn
			`xddot`	Vehicle CM acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CM acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2
			`zddot`	Vehicle CM acceleration along the vehicle-fixed *z*-axis	Computed	m/s^2
		`DCM`	Direction cosine matrix		Computed	rad
	`Forces`	`Body`	`Fx`	Net force on vehicle CM along the vehicle-fixed *x*-axis	Computed	N
			`Fy`	Net force on vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`	Net force on vehicle CM along the vehicle-fixed *z*-axis	Computed	N
		`Ext`	`Fx`	External force on vehicle CM along the vehicle-fixed *x*-axis	Input	N

Signal					Description	Value	Units
			`Fy`		External force on vehicle CM along the vehicle-fixed *x*-axis	Input	N
			`Fz`		External force on vehicle CM along the vehicle-fixed *x*-axis	Input	N
		`FrntAxl`	`Lft`	`Fx`	Longitudinal force on front left axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on front axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on front axle left along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on front right axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on front axle right along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on front axle right along the vehicle-fixed *z*-axis	Computed	N
		`RearAxl`	`Lft`	`Fx`	Longitudinal force on rear left axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on rear left axle along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on rear left axle along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on rear right axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on rear right axle along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on rear right axle along the vehicle-fixed *z*-axis	Computed	N

Signal						Description	Value	Units
		`Hitch`	`Fx`			Hitch force applied to body at the hitch location along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Hitch force applied to body at the hitch location along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Hitch force applied to body at the hitch location along the vehicle-fixed *z*-axis	Computed	N
		`Tires`	`FrntTires`	`Lft`	`Fx`	Front left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Front right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front right tire force along the vehicle-fixed *z*-axis	Computed	N
			`RearTires`	`Lft`	`Fx`	Rear left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Rear right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear right tire force along the vehicle-fixed *z*-axis	Computed	N
		`Drag`	`Fx`			Drag force on vehicle CM along the vehicle-fixed *x*-axis	Computed	N

Signal				**Description**	**Value**	**Units**
			`Fy`	Drag force on vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`	Drag force on vehicle CM along the vehicle-fixed *z*-axis	Computed	N
		`Grvty`	`Fx`	Gravity force on vehicle CM along the vehicle-fixed *x*-axis	Computed	N
			`Fy`	Gravity force on vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`	Gravity force on vehicle CM along the vehicle-fixed *z*-axis	Computed	N
	`Moments`	`Body`	`Mx`	Body moment on vehicle CM about the vehicle-fixed *x*-axis	Computed	N·m
			`My`	Body moment on vehicle CM about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`	Body moment on vehicle CM about the vehicle-fixed *z*-axis	Computed	N·m
		`Drag`	`Mx`	Drag moment on vehicle CM about the vehicle-fixed *x*-axis	Computed	N·m
			`My`	Drag moment on vehicle CM about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`	Drag moment on vehicle CM about the vehicle-fixed *z*-axis	Computed	N·m
		`Ext`	`Mx`	External moment on vehicle CG about the vehicle-fixed *x*-axis	Computed	N·m
			`My`	External moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`	External moment on vehicle CG about the vehicle-fixed *z*-axis	Computed	N·m
		`Hitch`	`Mx`	Hitch moment at the hitch location about vehicle-fixed *x*-axis	Computed	N·m

Signal					Description	Value	Units
			`My`		Hitch moment at the hitch location about vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		Hitch moment at the hitch location about vehicle-fixed *z*-axis	Computed	N·m
	`FrntAxl`	`Lft`	`Disp`	`x`	Front left axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Front left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Rght`	`Disp`	`x`	Front right axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Front right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`RearAxl`	`Lft`	`Disp`	`x`	Rear left axle displacement along the vehicle-fixed *x*-axis	Computed	m

Signal					Description	Value	Units
				`y`	Rear left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Rght`	`Disp`	`x`	Rear right axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`Hitch`	`Disp`		`x`	Hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	m
				`y`	Hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
				`z`	Hitch offset from axle plane along the vehicle-fixed *z*-axis	Input	m
		`Vel`		`xdot`	Hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal				Description	Value	Units
			`ydot`	Hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Hitch offset velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`Pwr`	`PwrExt`		Applied external power	Computed	W
		`Drag`		Power loss due to drag	Computed	W
	`Geom`	`Disp`	`x`	Vehicle chassis offset from axle plane along the vehicle-fixed *x*-axis	Input	m
			`y`	Vehicle chassis offset from center plane along the vehicle-fixed *y*-axis	Input	m
			`z`	Vehicle chassis offset from axle plane along the vehicle-fixed *z*-axis	Input	m
		`Vel`	`xdot`	Vehicle chassis offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle chassis offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle chassis offset velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad

`Vb` — Vehicle velocity along vehicle-fixed frame
`vector`

Vehicle CM velocity along the vehicle-fixed *x*-, *y*-, *z*-axes, respectively, in m/s, returned as a vector.

`pqr` — Vehicle angular velocity about vehicle-fixed frame
`vector`

Vehicle CM angular velocity about the vehicle-fixed *x*- (roll rate), *y*- (pitch rate), *z*-axes (yaw rate), respectively, in rad/s, returned as a vector.

`DCM` — Direction cosine matrix
`array`

Direction cosine matrix, in rad, returned as an array.

`Euler` — Euler angles
`array`

Euler angles, φ, θ, and ψ, respectively, in rad, returned as an array.

Xe — Vehicle position in inertial reference frame
`vector`

Vehicle CM position along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively, in m, returned as a vector.

Ve — Vehicle velocity in inertial reference frame
`vector`

Vehicle CM velocity along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively, in m/s, returned as a vector.

Parameters

Block Options

Input Signals

`Hitch forces` — Create input port
`off` (default) | `on`

Select to create an input port, `Fh`, for the hitch forces.

`Hitch moments` — Create input port
`off` (default) | `on`

Select to create an input port, `Mh`, for the hitch moments.

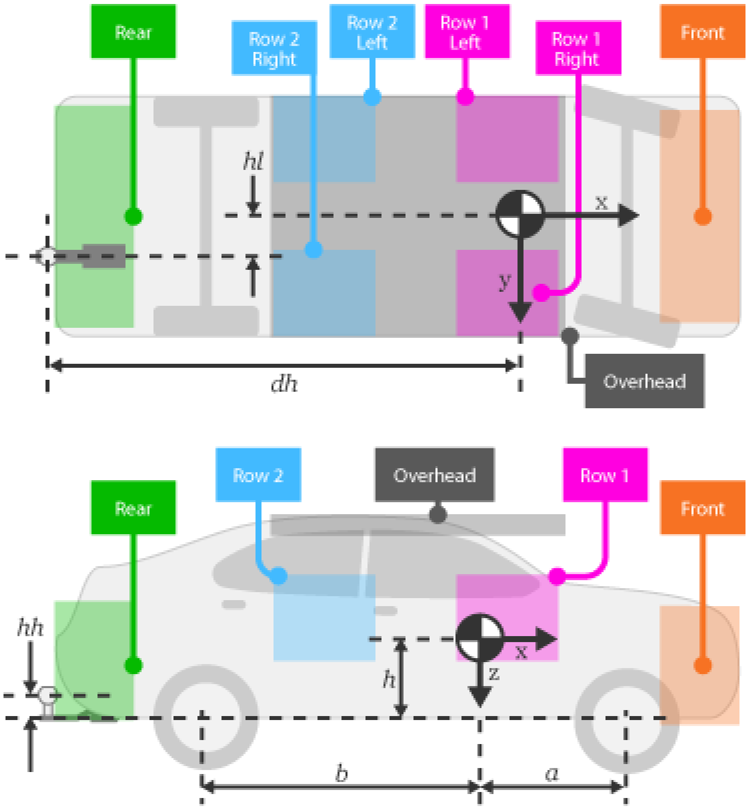
Chassis

`Vehicle mass, m` — Mass
`2000` (default) | `scalar`

Vehicle mass, *m*, in kg.

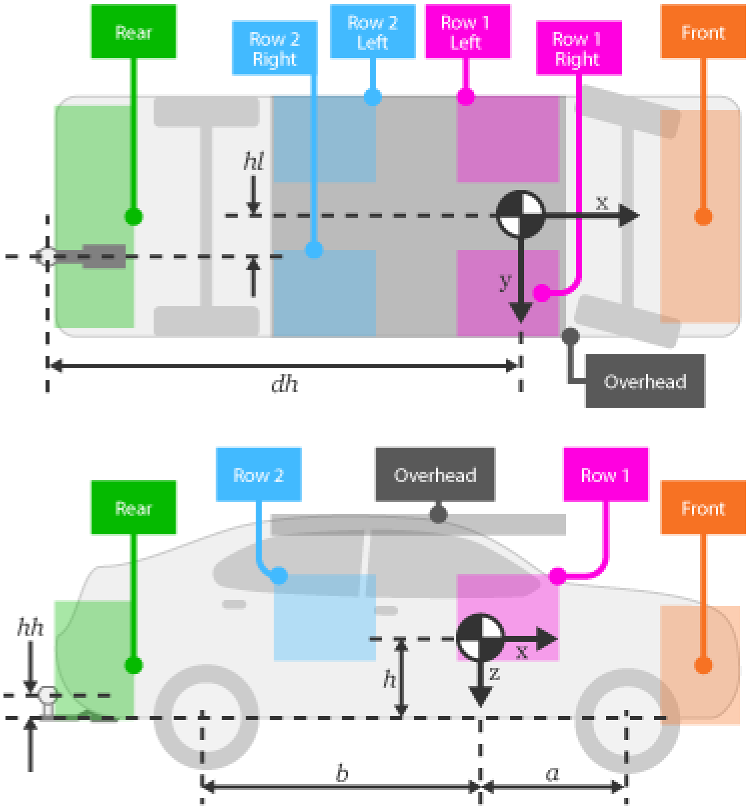
`Longitudinal distance from center of mass to front axle, a` — Distance
`1.4` (default) | `scalar`

Distance from vehicle CM to front axle, *a*, in m.



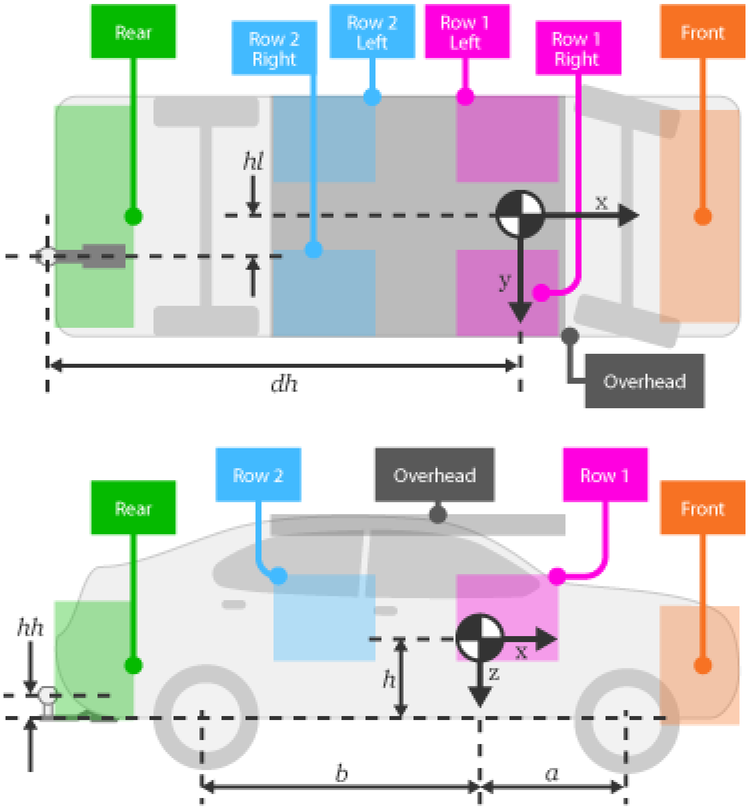
Longitudinal distance from center of mass to rear axle, b — Distance
`1.6` (default) | `scalar`

Distance from vehicle CM to front axle, *b*, in m.



`Lateral distance from geometric centerline to center of mass, d` — Distance
`0` (default) | `scalar`

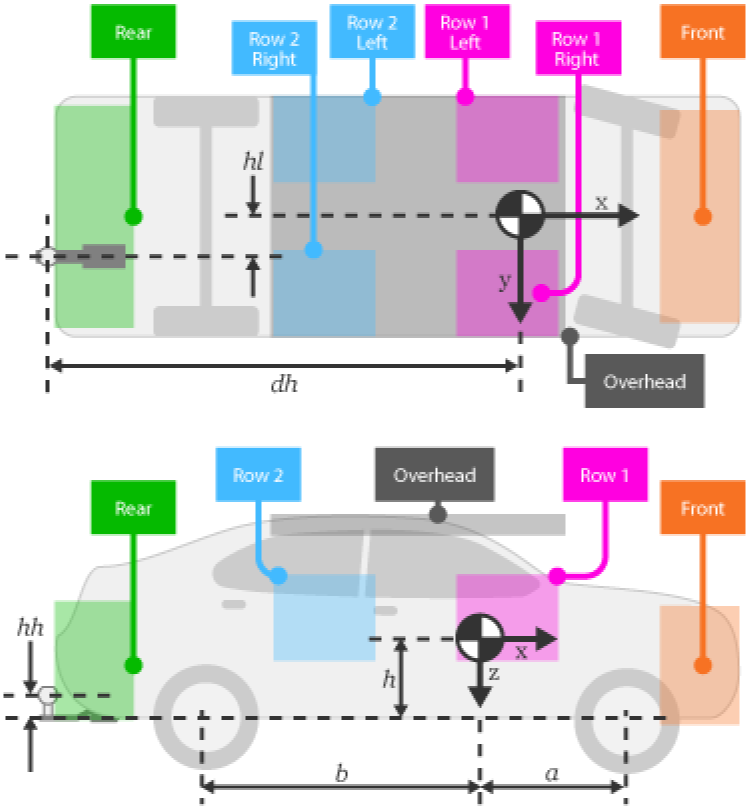
Lateral distance from geometric centerline to center of mass, *d*, in m, along the vehicle-fixed *y*. Positive values indicate that the vehicle CM is to the right of the geometric centerline. Negative values indicate that the vehicle CM is to the left of the geometric centerline.



`Vertical distance from center of mass to axle plane, h` — Distance

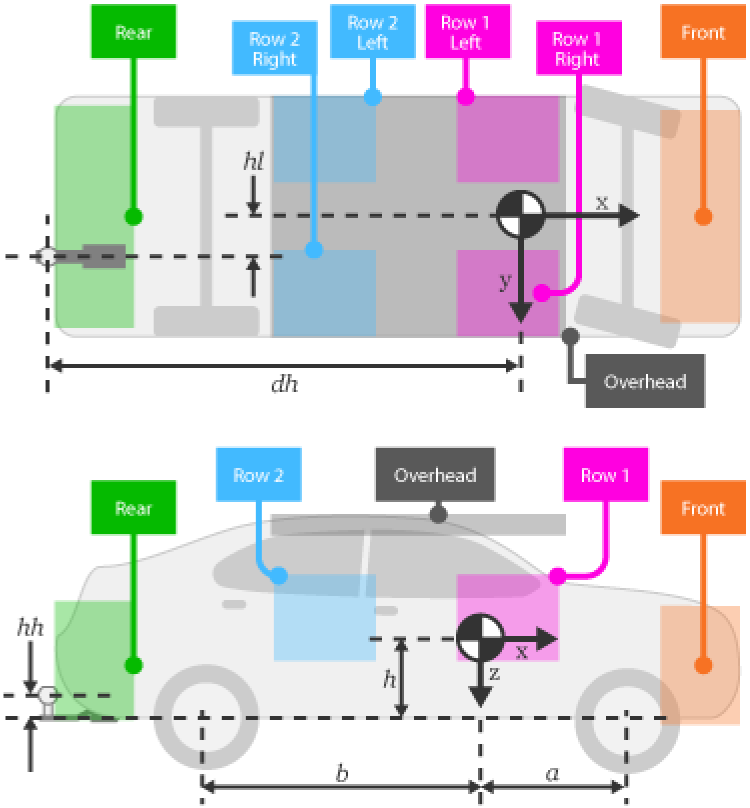
`.35` (default) | `scalar`

Vertical distance from vehicle CM to axle plane, *h*, in m.



`Longitudinal distance from center of mass to hitch, dh` — Longitudinal distance from CM to hitch
1 (default) | `scalar`

Longitudinal distance from center of mass to hitch, *dh*, in m.



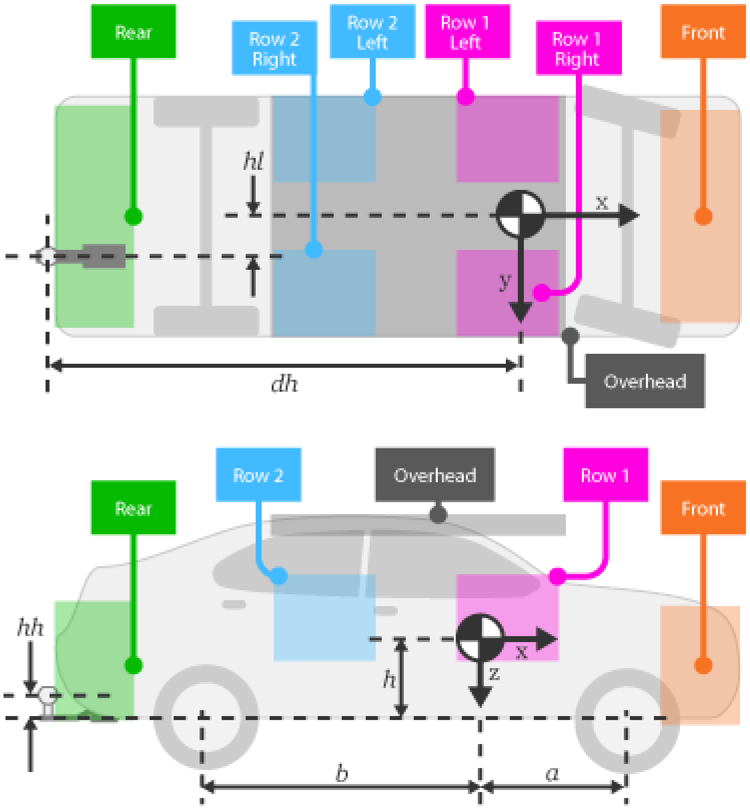
Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Longitudinal distance from center of mass to hitch, hl` — Lateral distance from CM to hitch

`0` (default) | `scalar`

Lateral distance from center of mass to hitch, *hl*, in m.

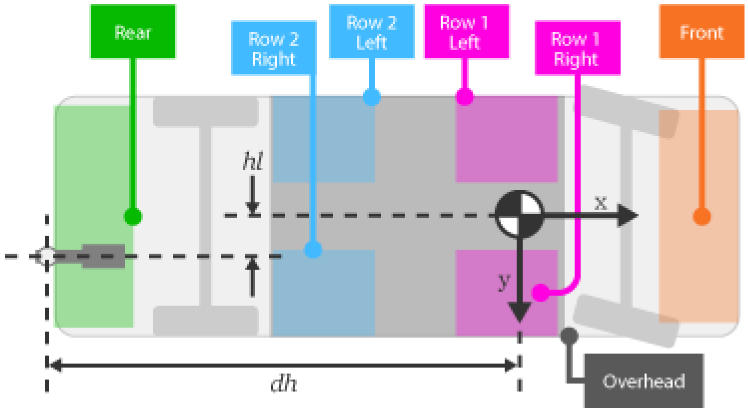


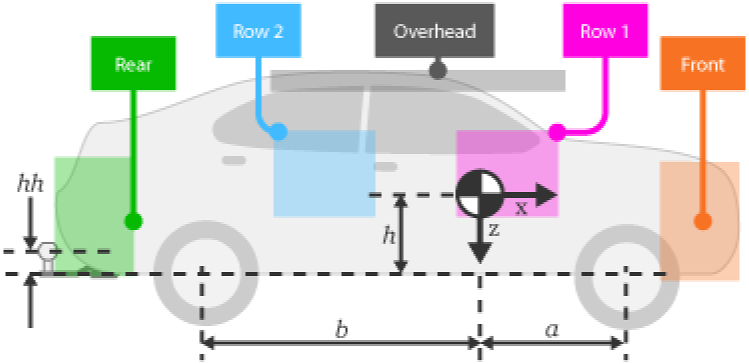
Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Vertical distance from hitch to axle plane, hh` — Distance from hitch to axle plane
`0.1` (default) | `scalar`

Vertical distance from hitch to axle plane, *hh*, in m.





Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Initial position in the inertial frame [Xeo,Yeo,Zeo], Xe_o` — Position

`[0,0,0]` (default) | `vector`

Initial position of vehicle in the inertial frame, Xe_o, in m.

`Initial velocity in body axes [xdot_o,ydot_o,zdot_o], xbdot_o` — Velocity

`[0,0,0]` (default) | `vector`

Initial vehicle CM velocity along the vehicle-fixed *x*, *y*-, and *z*- axes, respectively, in m/s.

`Initial Euler orientation [roll, pitch, yaw], eul_o` — Rotation

`[0,0,0]` (default) | `vector`

Initial Euler rotation of the vehicle-fixed frame about the earth-fixed *X*(roll)-, *Y*(pitch)-, *Z*(yaw)- axes, respectively, in rad.

`Initial body rotation rates [p,q,r], p_o` — Rotation rate

`[0,0,0]` (default) | `vector`

Initial vehicle CM angular velocity about the vehicle-fixed *x*(roll rate)-, *y*(pitch rate)-, *z*(yaw rate)- axes, respectively, in rad/s.

`Chassis inertia tensor, Iveh` — Inertia

`[430 0 0; 0 1900 0; 0 0 2100]` (default) | `array`

Vehicle inertia tensor, I_{veh}, in kg*m^2. Dimensions are `[3-by-3]`.

`Track widths [front,rear], w` — Widths

`[1.9,1.9]` (default) | `vector`

Front and rear track width, in m. Dimensions are `[1-by-2]`.

Inertial Loads

Front

`Mass, z1m` — Mass

`0` (default) | `scalar`

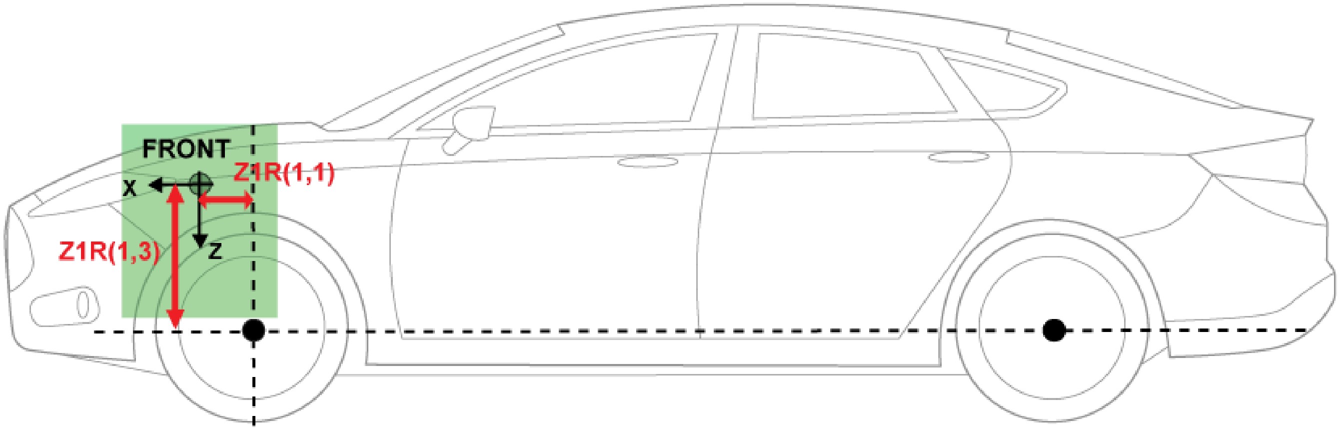
Mass, *z1m*, in kg.

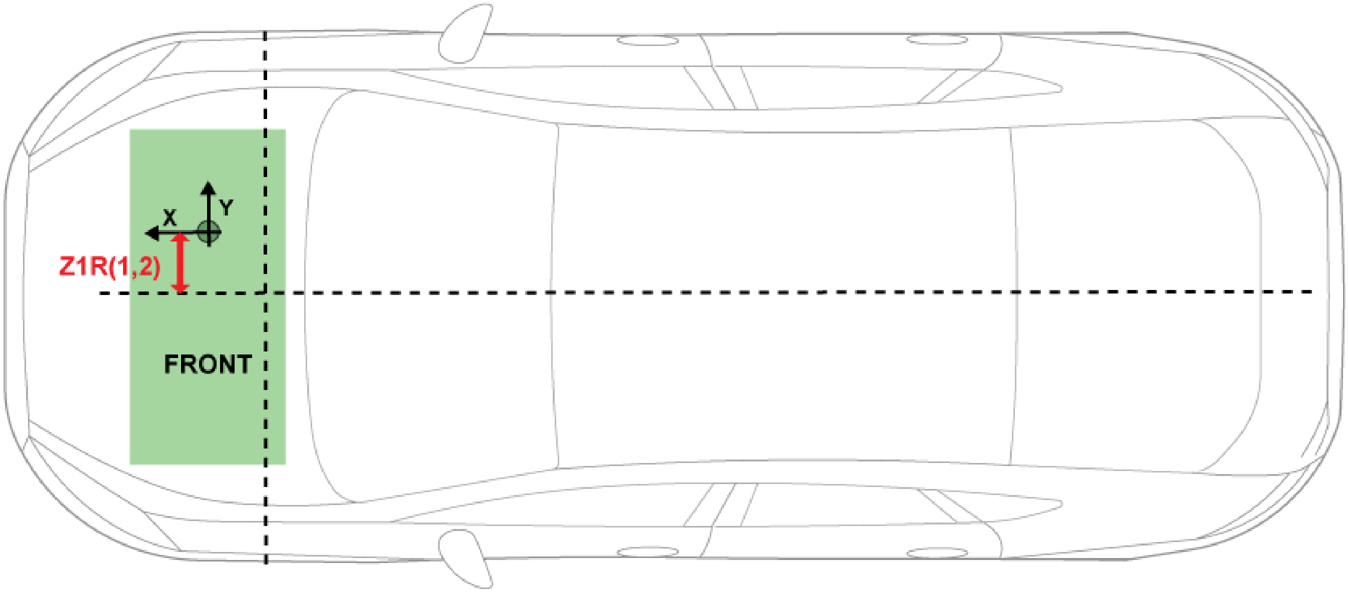
`Distance vector from front axle, z1R` — Distance

`[-.25,.125,.15]` (default) | `vector`

Distance vector from front axle to load, *z1R*, in m. Dimensions are `[1-by-3]`.

Array Element	Description
`z1R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z1R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z1R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis





For example, this table summarizes the parameter settings that specify the load location indicated by the dots.

Example Location	Sign
• Forward of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z1R(1,1)` < 0 • `z1R(1,2)` > 0 • `z1R(1,3)` > 0

`Inertia tensor, z1I` — Inertia

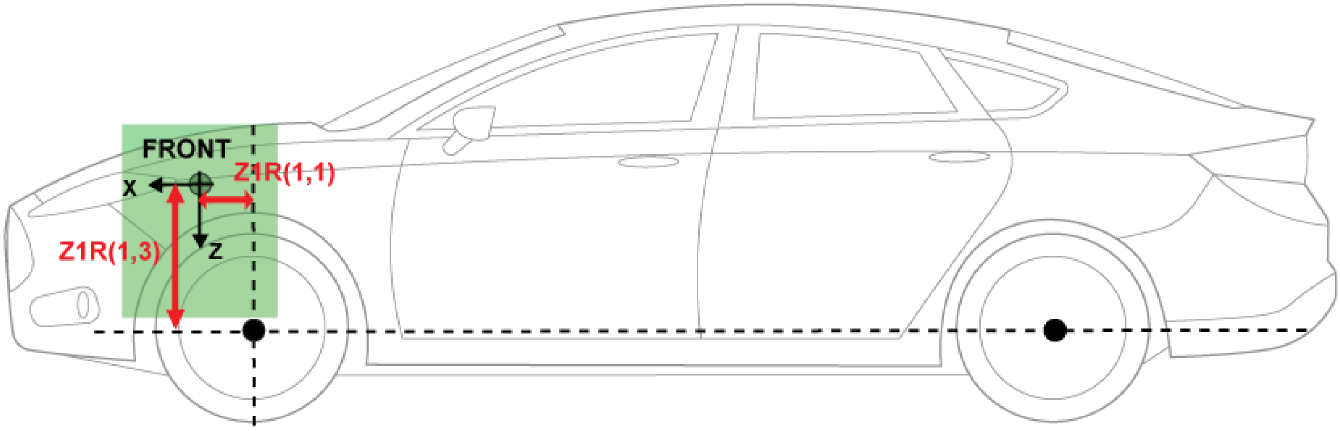
`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

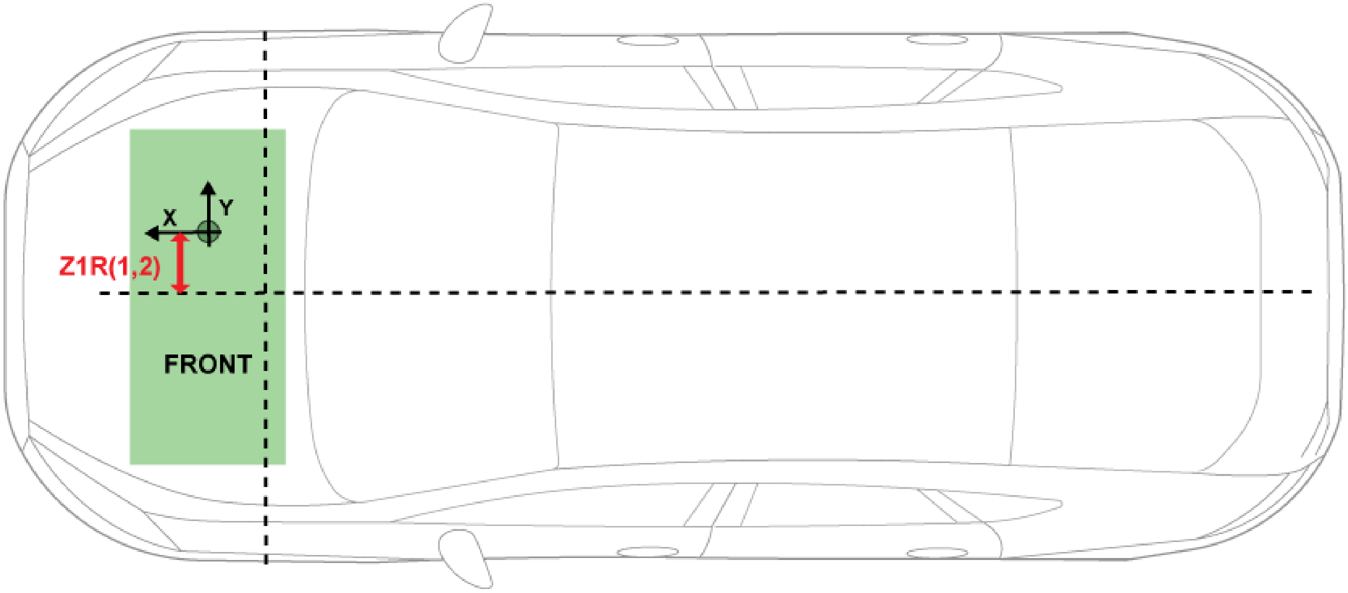
Inertia tensor, *z1I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z1I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis





Overhead

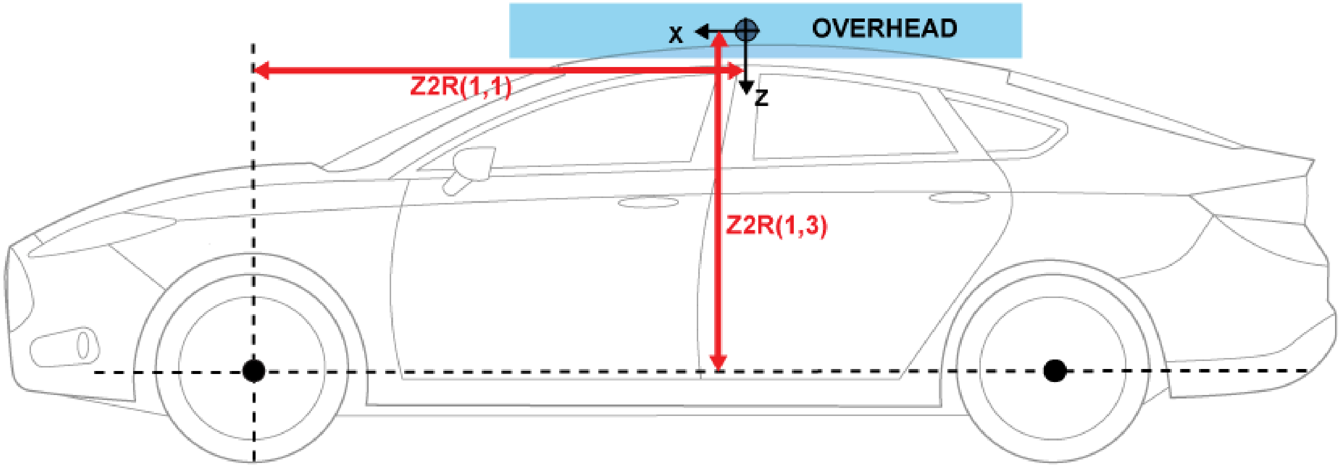
`Mass, z2m` — Mass
`0` (default) | `scalar`

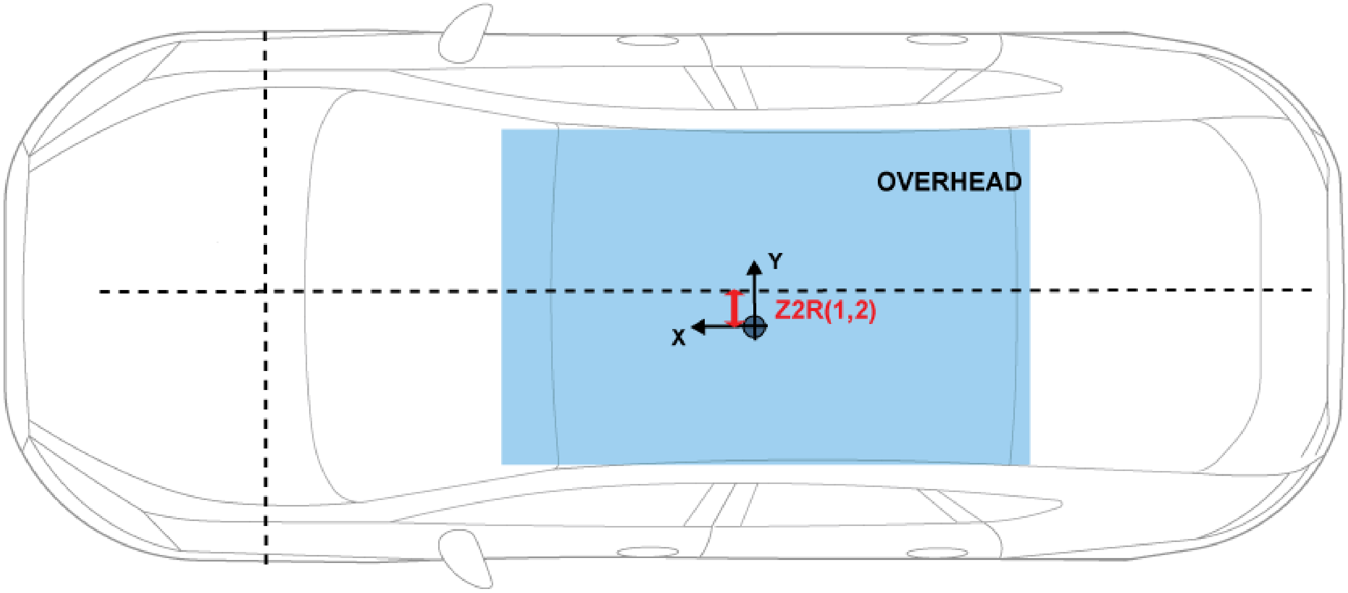
Mass, *z2m*, in kg.

`Distance vector from front axle, z2R` — Distance
`[1.4,0,.8]` (default) | `vector`

Distance vector from front axle to load, *z2R*, in m. Dimensions are `[1-by-3]`.

Array Element	Description
`z2R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z2R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z2R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis





For example, this table summarizes the parameter settings that specify the load location indicated by the dot.

Example Location	Sign
• Rear of the front axle	• `z2R(1,1)` > 0
• Left of the vehicle centerline	• `z2R(1,2)` < 0
• Above the front axle suspension hardpoint	• `z2R(1,3)` > 0

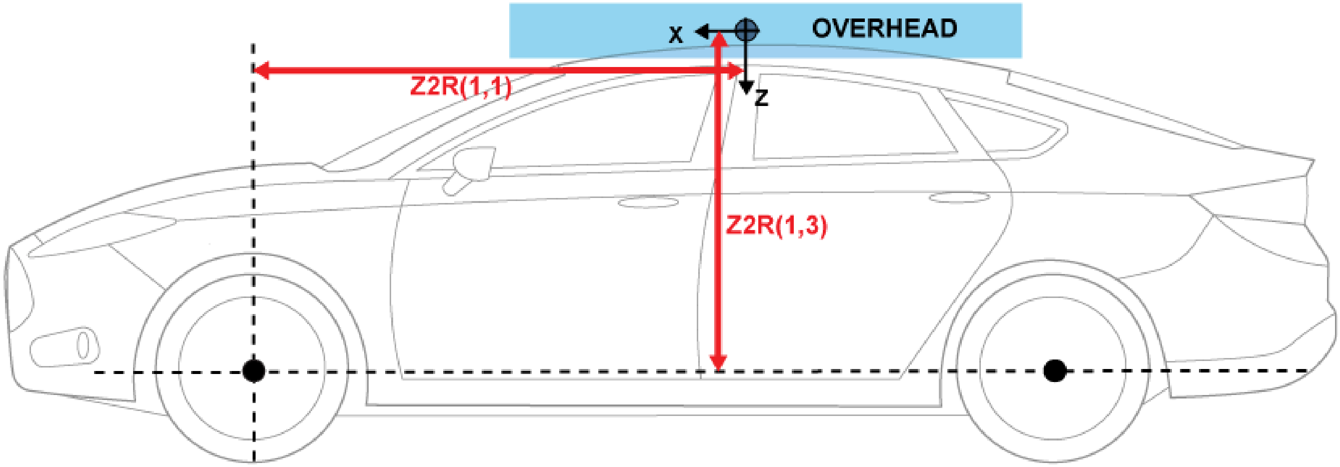
`Inertia tensor, z2I` — Inertia
`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

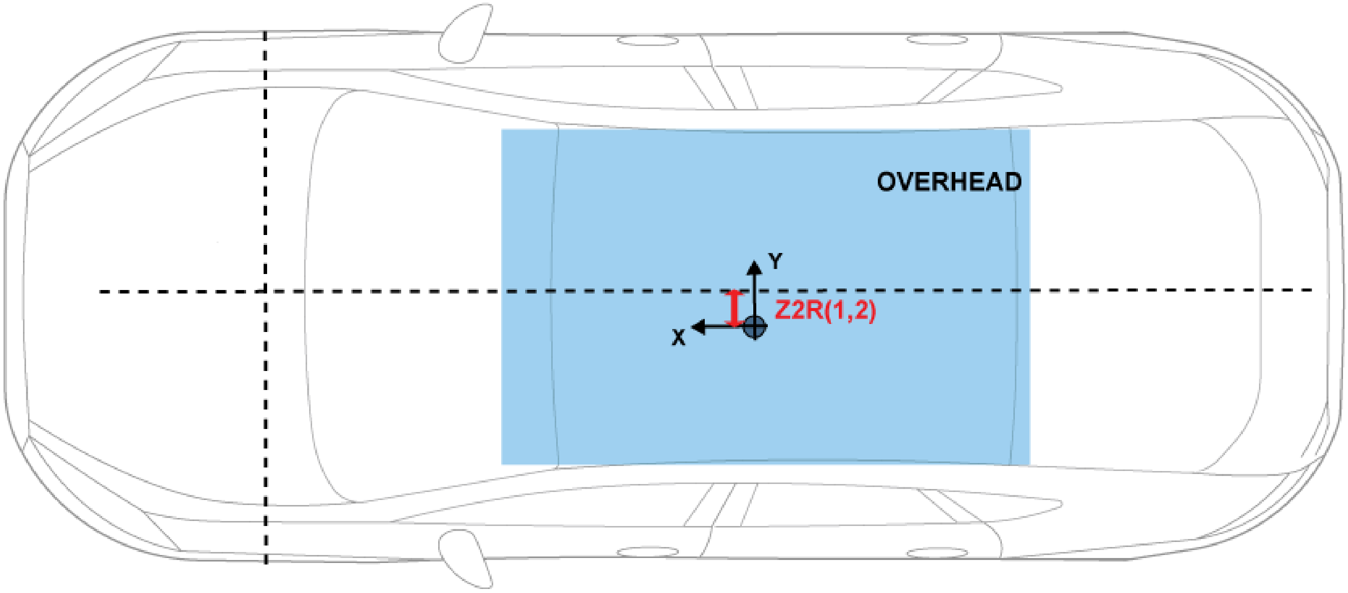
Inertia tensor, *z2I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z2I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- x-axis along the vehicle-fixed x-axis
- y-axis along the vehicle-fixed y-axis
- z-axis along the vehicle-fixed z-axis





Row 1, left side

`Mass, z3m` — Mass

`0` (default) | `scalar`

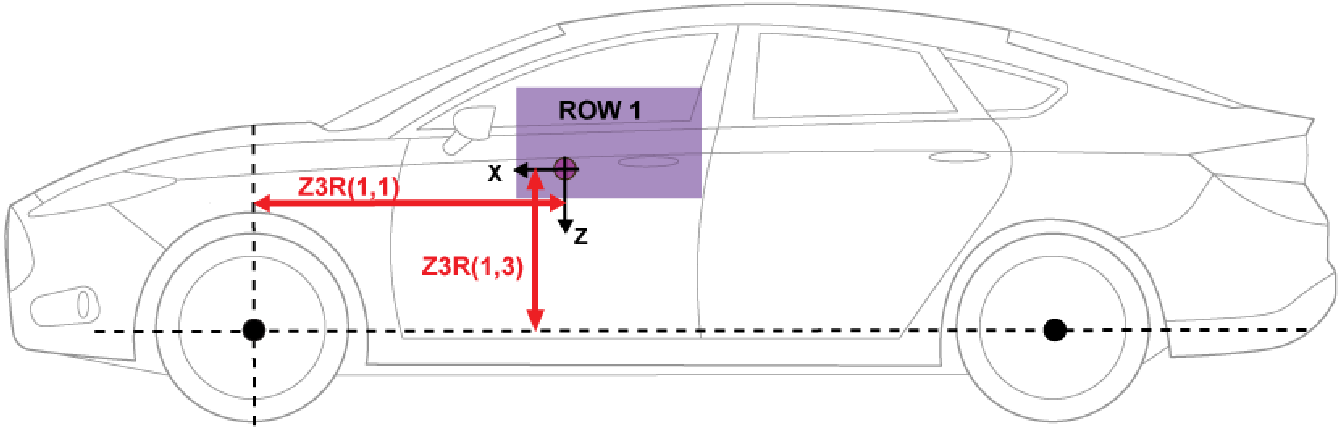
Mass, *z3m*, in kg.

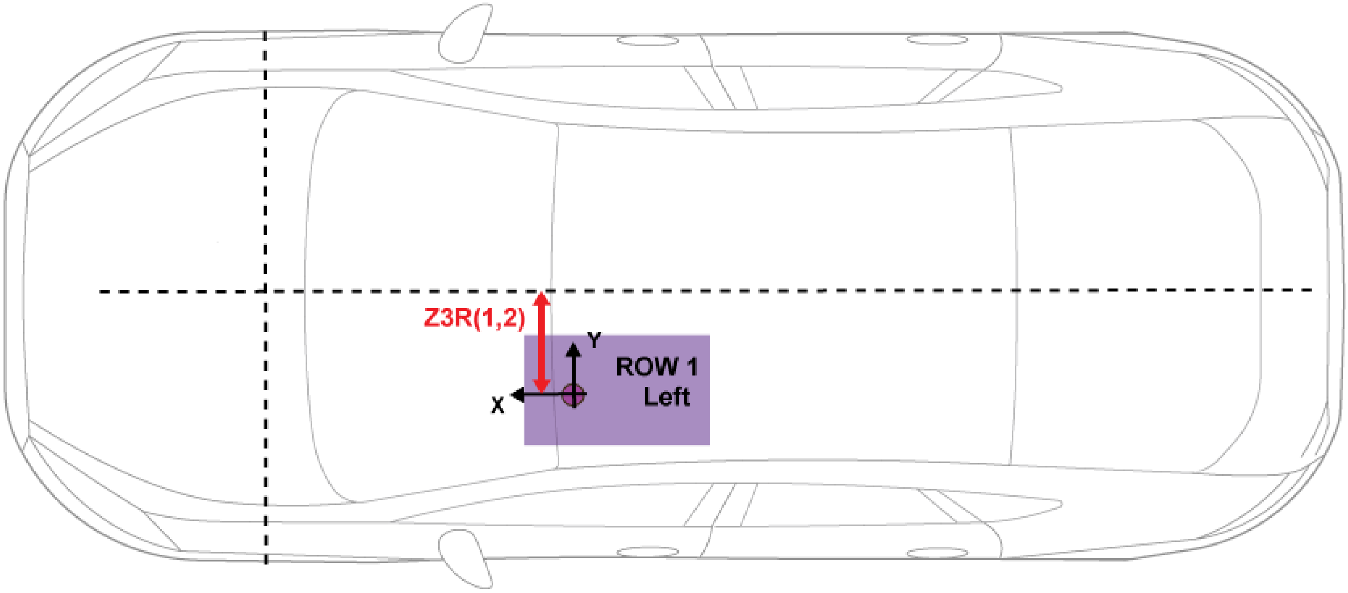
`Distance vector from front axle, z3R` — Distance

`[.75,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z3R*, in m. Dimensions are `[1-by-3]`.

Array Element	Description
`z3R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z3R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z3R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis





For example, this table summarizes the parameter settings that specify the load location indicated by the dot.

Example Location	Sign
• Rear of the front axle • Left of the vehicle centerline • Above the front axle suspension hardpoint	• `z3R(1,1)` > 0 • `z3R(1,2)` < 0 • `z3R(1,3)` > 0

`Inertia tensor, z3I` — Inertia

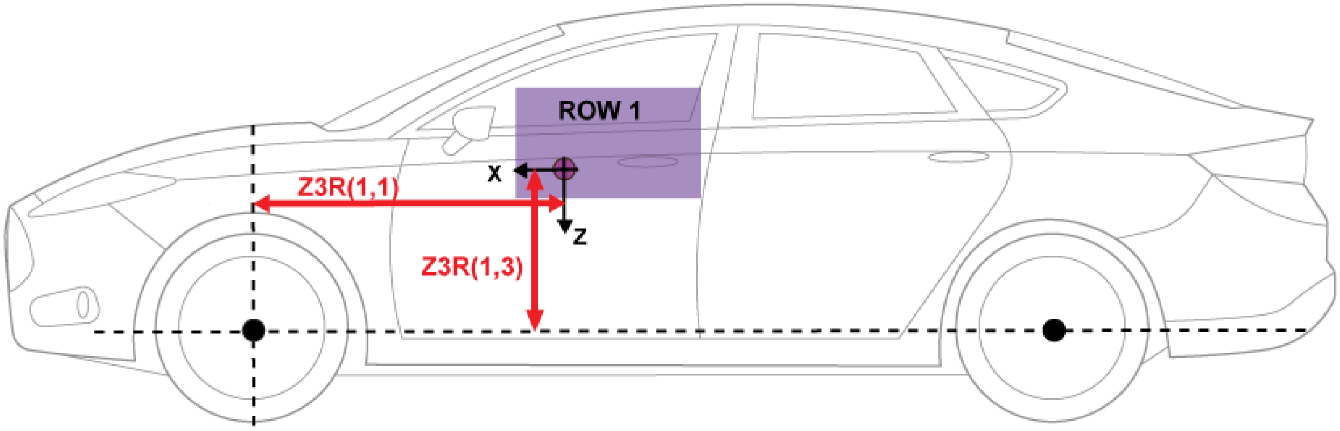
`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

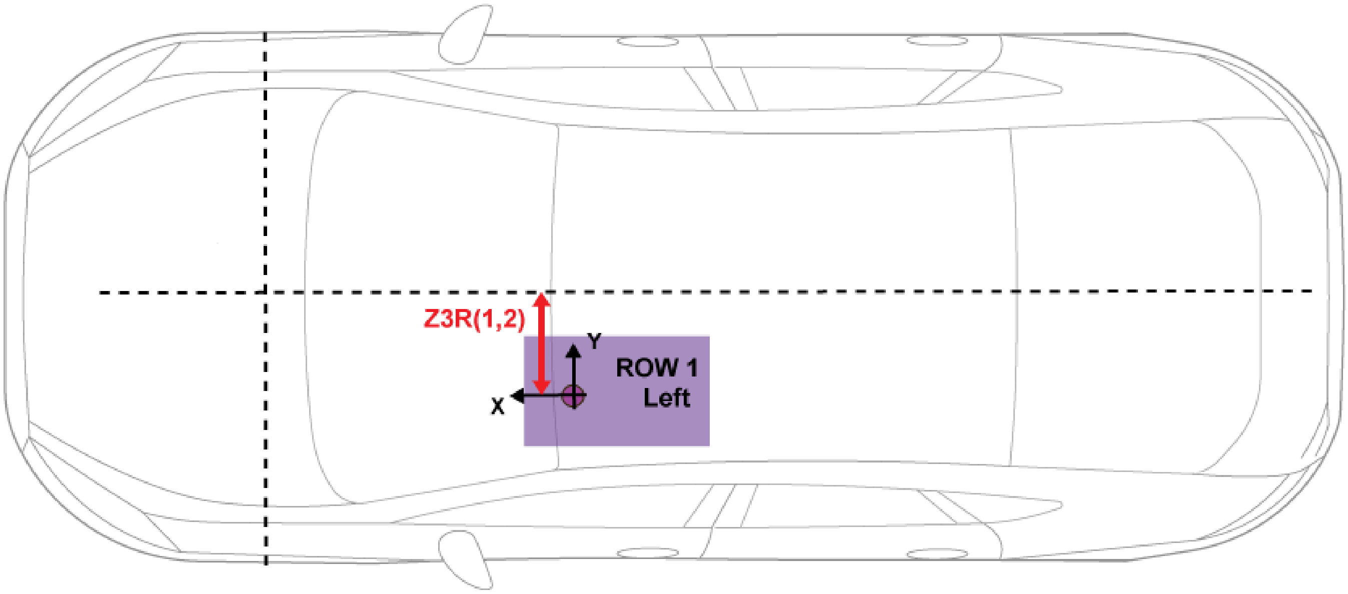
Inertia tensor, *z3I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z3I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- x-axis along the vehicle-fixed x-axis
- y-axis along the vehicle-fixed y-axis
- z-axis along the vehicle-fixed z-axis





Row 1, right side

`Mass, z4m` — Mass

`0` (default) | `scalar`

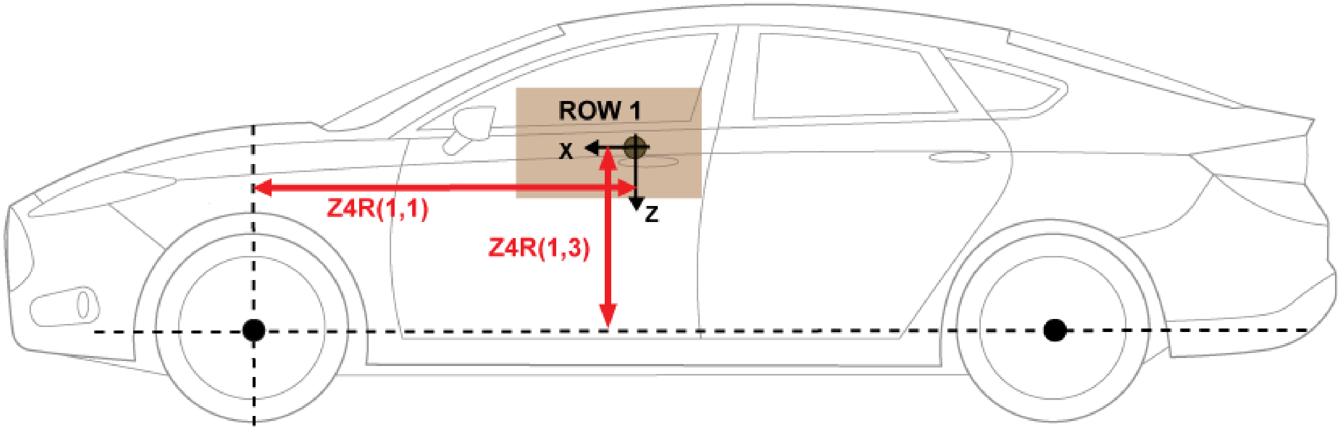
Mass, *z4m*, in kg.

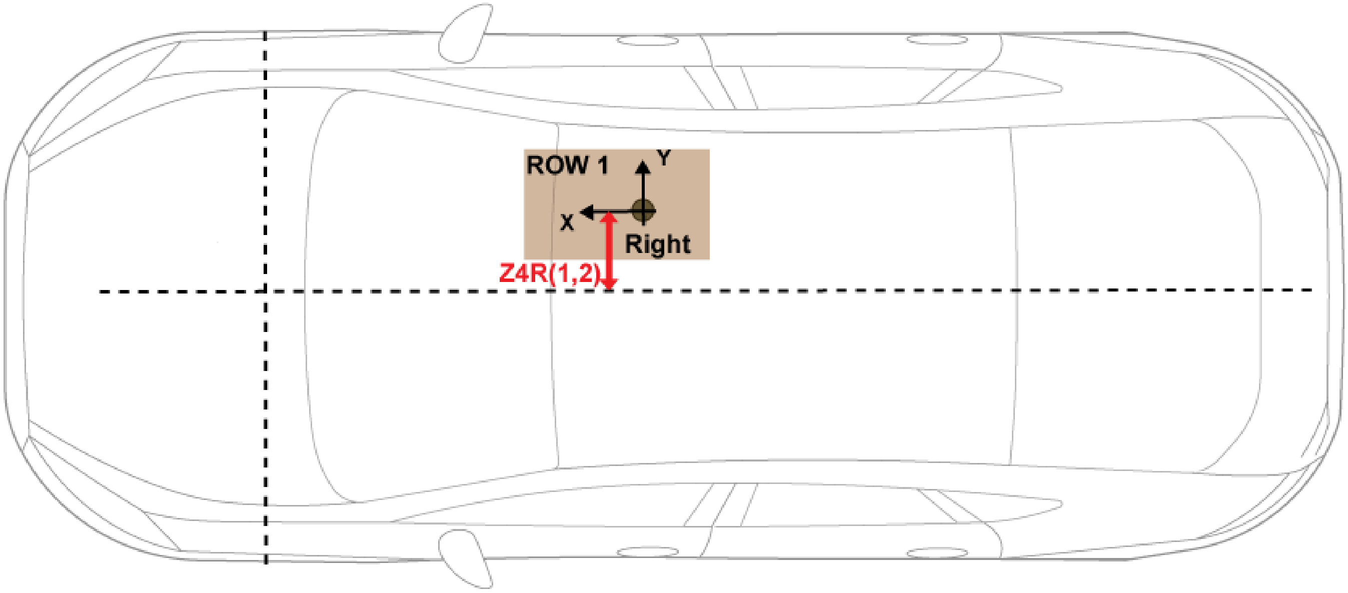
`Distance vector from front axle, z4R` — Distance

`[.75,.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z4R*, in m. Dimensions are `[1-by-3]`.

Array Element	Description
`z4R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z4R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z4R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis





For example, this table summarizes the parameter settings that specify the load location indicated by the dot.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z4R(1,1)` > 0 • `z4R(1,2)` > 0 • `z4R(1,3)` > 0

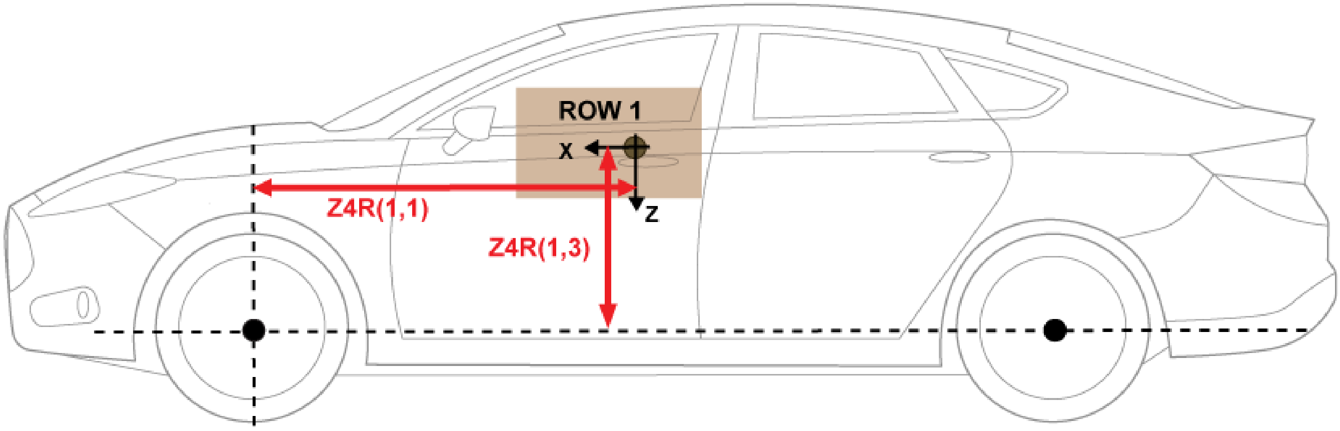
`Inertia tensor, z4I` — Inertia
`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

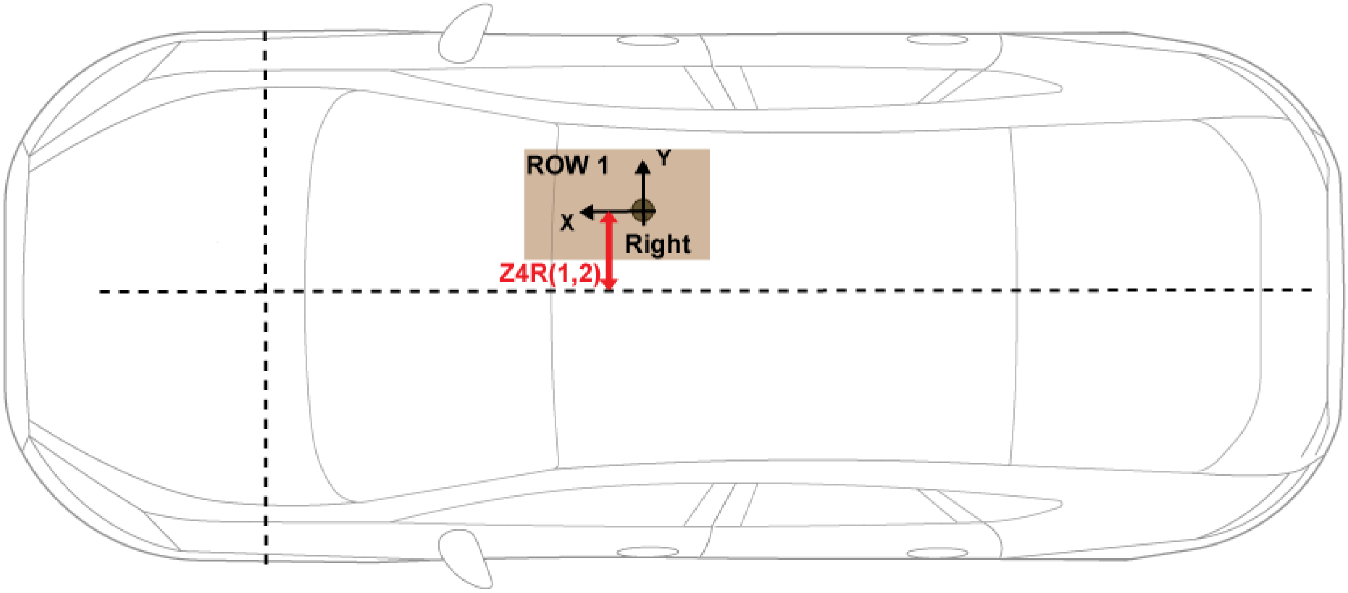
Inertia tensor, *z4I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z4I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- x-axis along the vehicle-fixed x-axis
- y-axis along the vehicle-fixed y-axis
- z-axis along the vehicle-fixed z-axis





Row 2, left side

`Mass, z5m` — Mass

`0` (default) | `scalar`

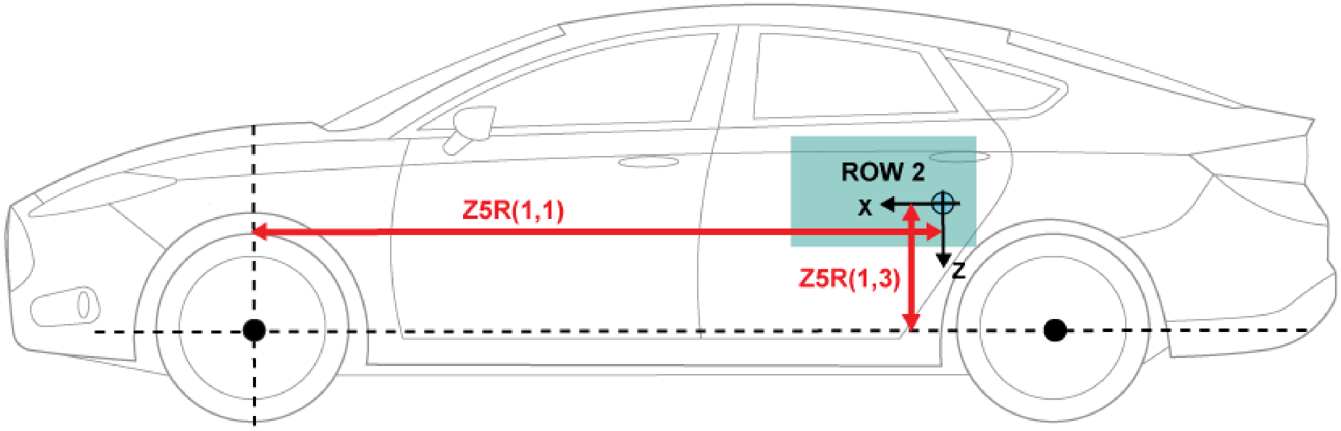
Mass, z5m, in kg.

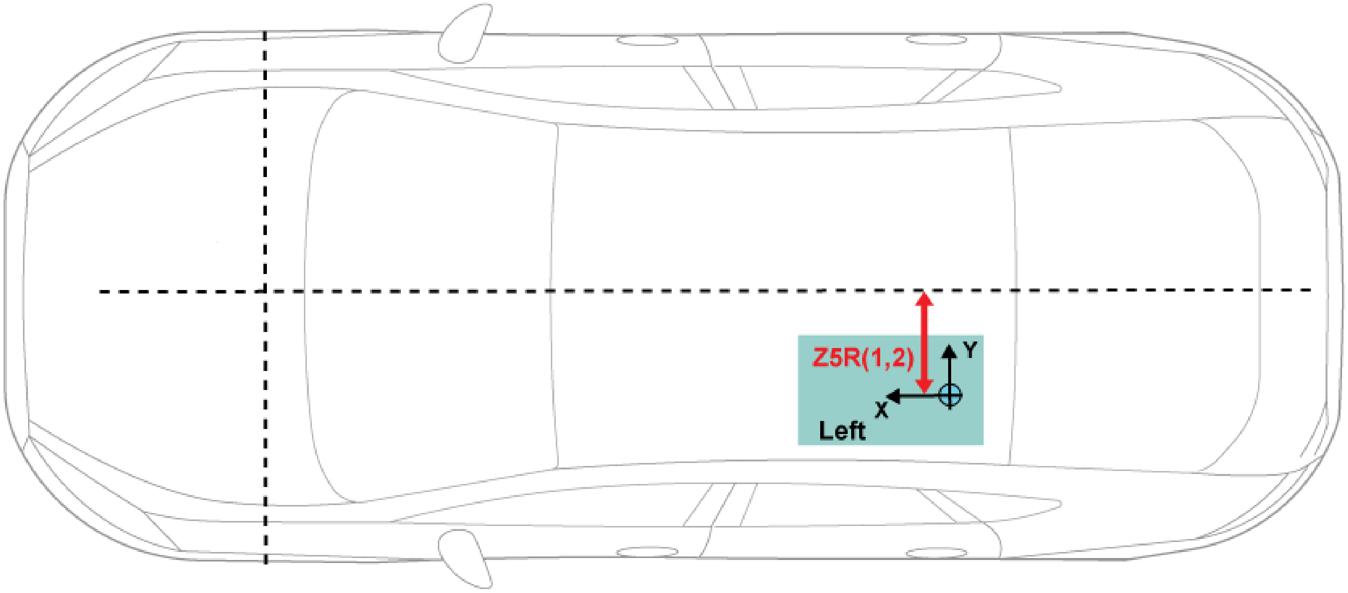
`Distance vector from front axle, z5R` — Distance

`[1.25,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z5R*, in m. Dimensions are `[1-by-3]`.

Array Element	Description
`z5R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z5R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z5R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis





For example, this table summarizes the parameter settings that specify the load location indicated by the dot.

Example Location	Sign
• Rear of the front axle	• `z5R(1,1)` > 0
• Left of the vehicle centerline	• `z5R(1,2)` < 0
• Above the front axle suspension hardpoint	• `z5R(1,3)` > 0

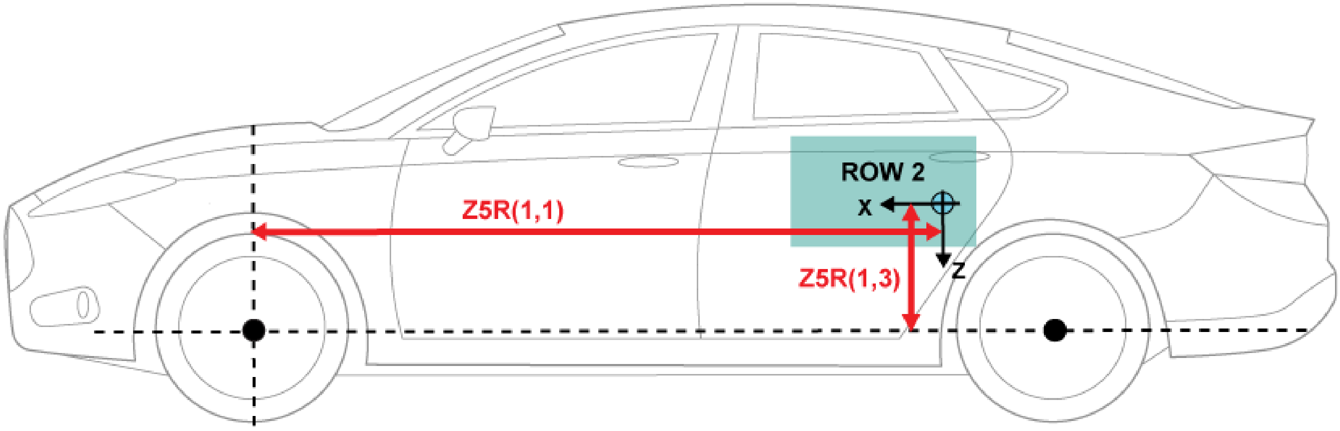
`Inertia tensor, z5I` — Inertia
`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

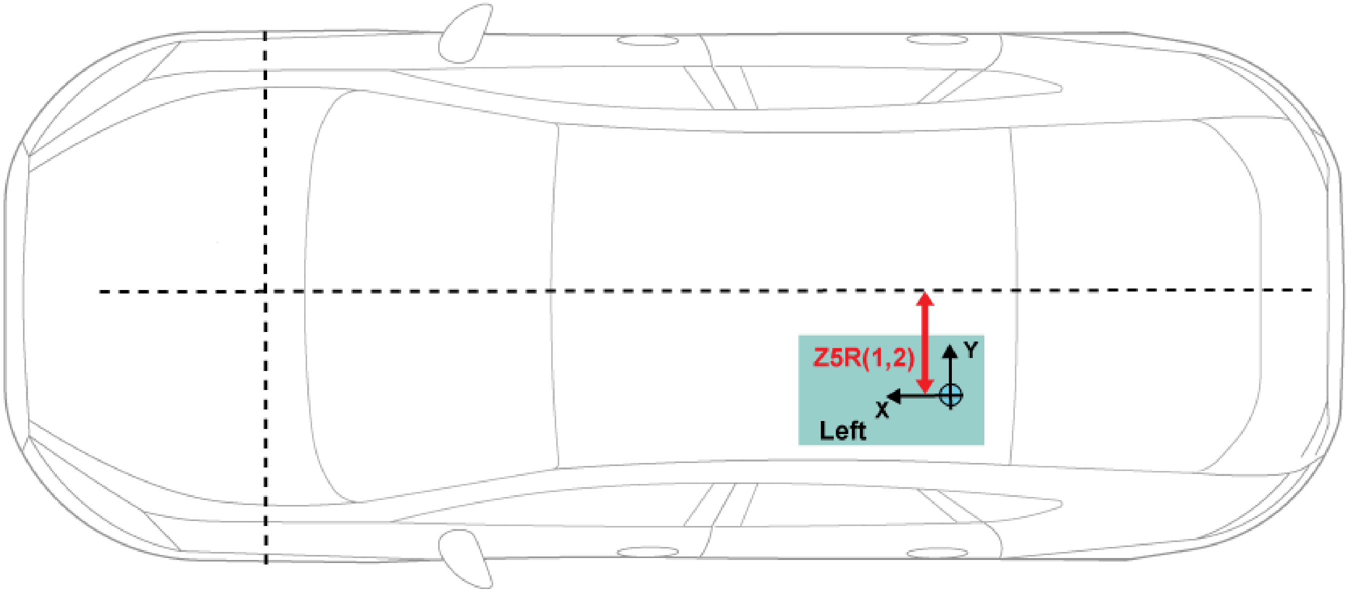
Inertia tensor, *z5I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z5I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- x-axis along the vehicle-fixed x-axis
- y-axis along the vehicle-fixed y-axis
- z-axis along the vehicle-fixed z-axis





Row 2, right side

`Mass, z6m` — Mass

`0` (default) | `scalar`

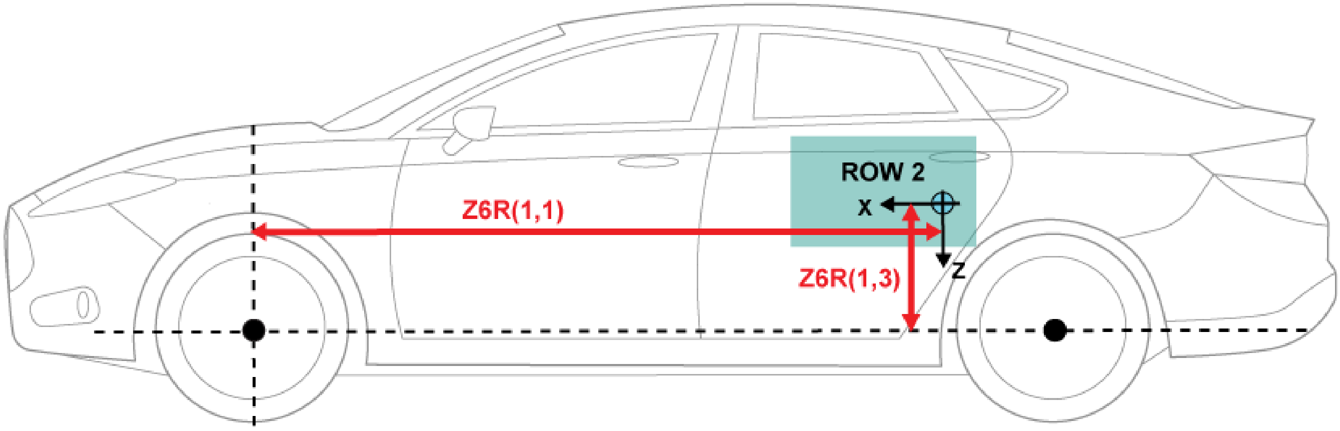
Mass, *z6m*, in kg.

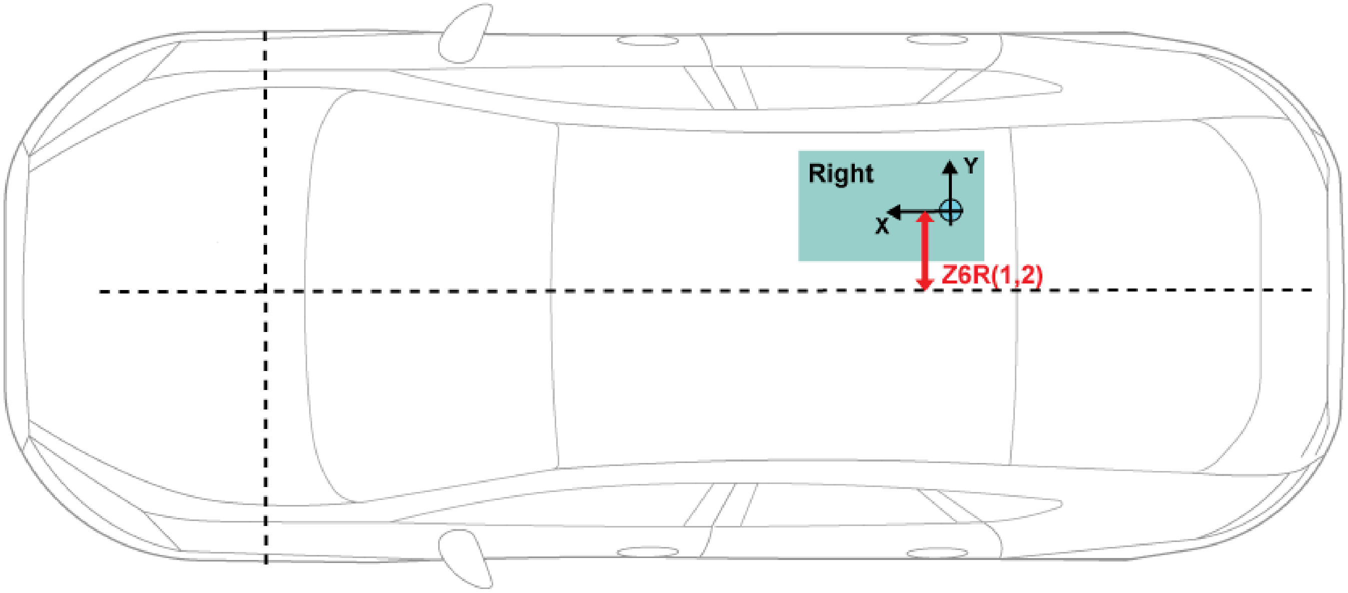
`Distance vector from front axle, z6R` — Distance

`[1.25,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z6R*, in m. Dimensions are `[1-by-3]`.

Array Element	Description
`z6R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z6R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z6R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis





For example, this table summarizes the parameter settings that specify the load location indicated by the dot.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z6R(1,1)` > 0 • `z6R(1,2)` > 0 • `z6R(1,3)` > 0

`Inertia tensor, z6I` — Inertia

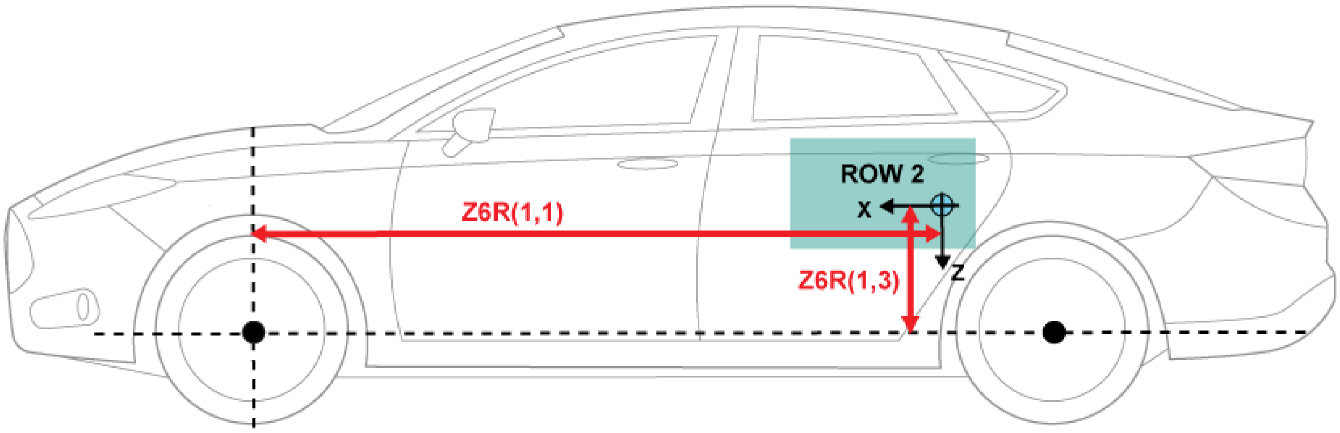
`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

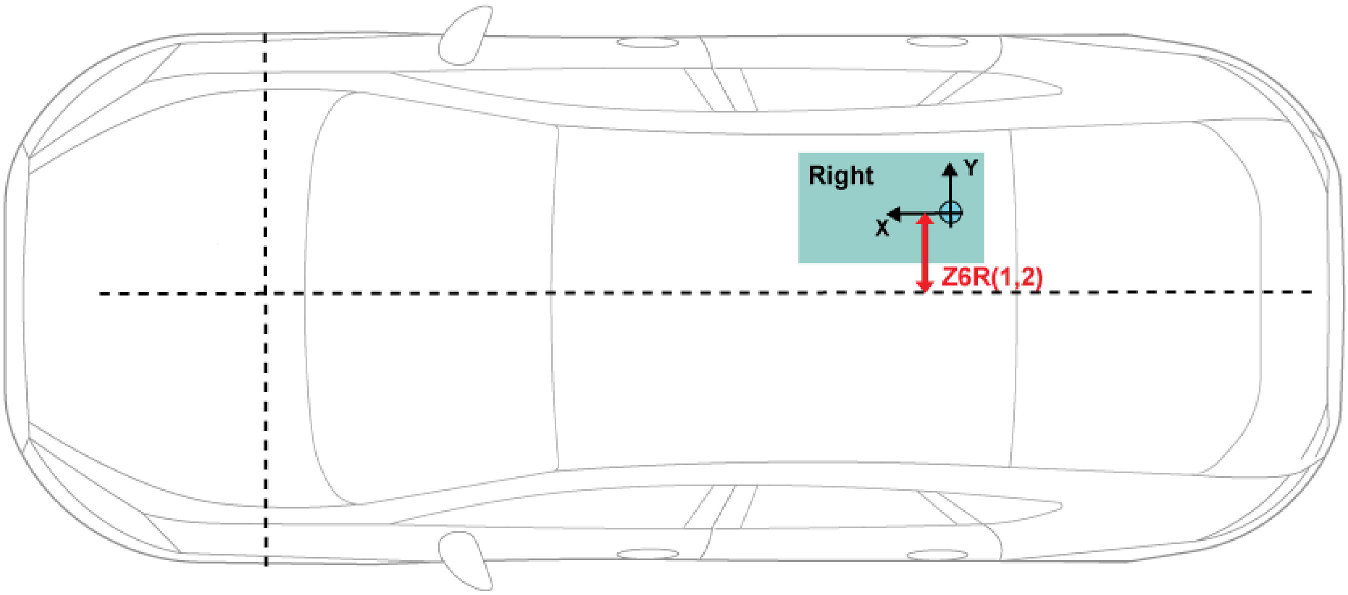
Inertia tensor, *z6I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z6I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- x-axis along the vehicle-fixed x-axis
- y-axis along the vehicle-fixed y-axis
- z-axis along the vehicle-fixed z-axis





Rear

`Mass, z7m` — Mass

`0` (default) | `scalar`

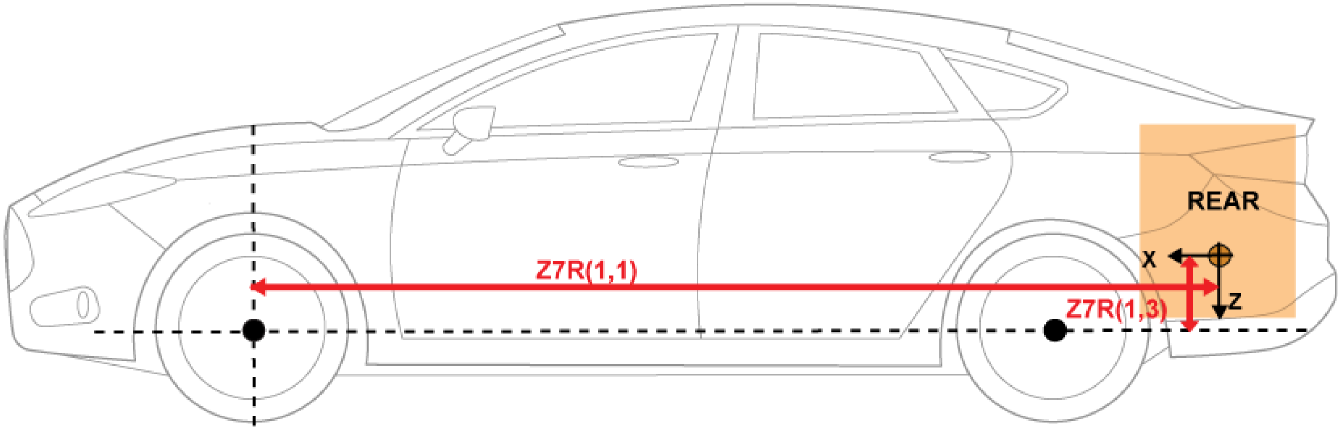
Mass, *z7m*, in kg.

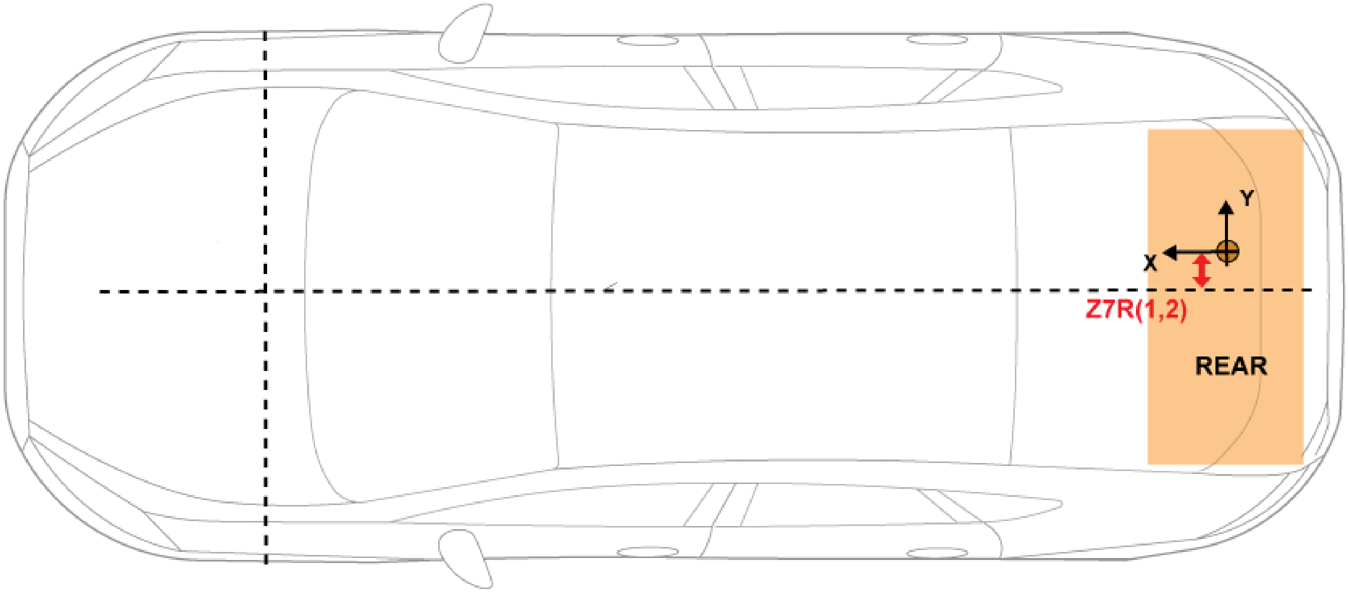
`Distance vector from front axle, z7R` — Distance

`[2,0,.25]` (default) | `vector`

Distance vector from front axle to load, *z7R*, in m. Dimensions are `[1-by-3]`.

Array Element	Description
`z7R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z7R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z7R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis





For example, this table summarizes the parameter settings that specify the load location indicated by the dot.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z7R(1,1)` > 0 • `z7R(1,2)` > 0 • `z7R(1,3)` > 0

`Inertia tensor, z7I` — Inertia

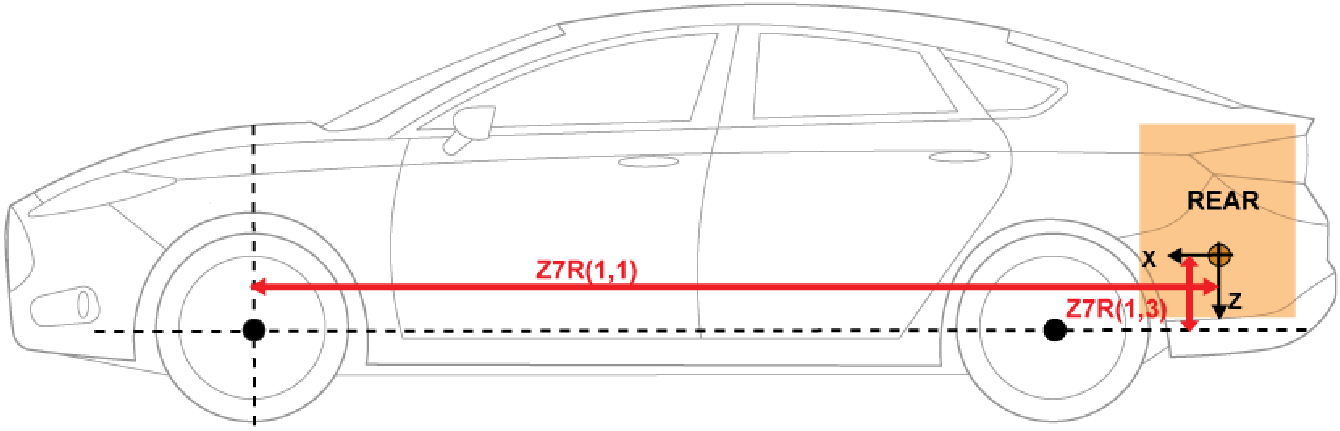
`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

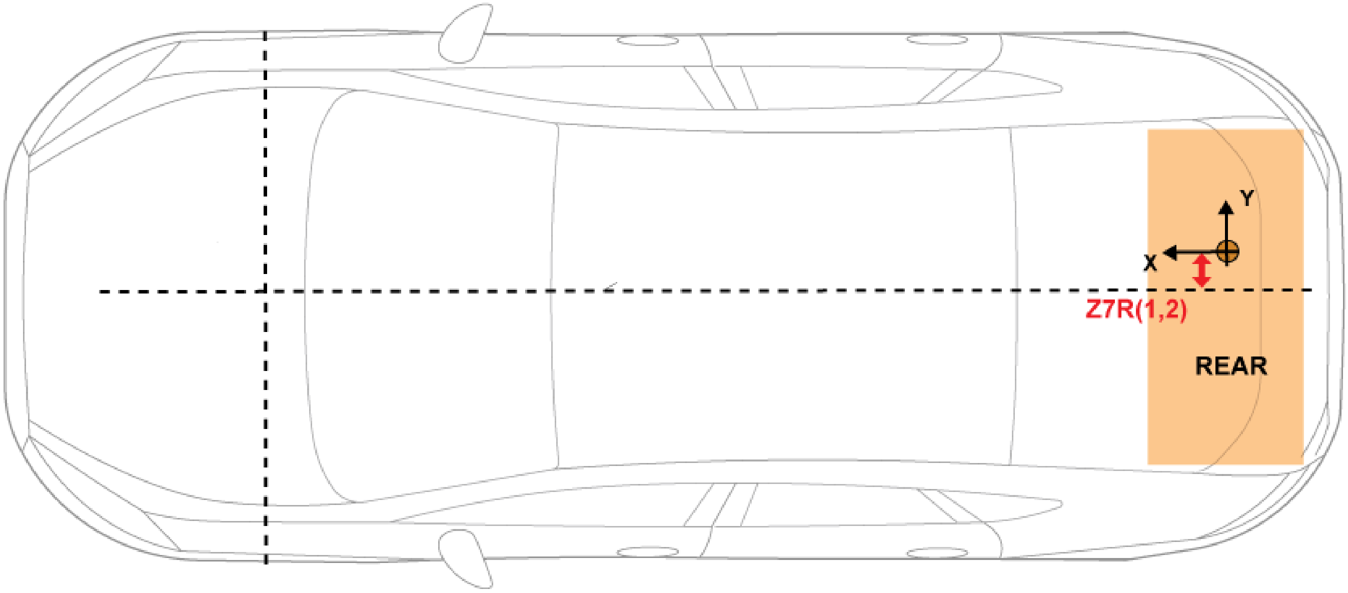
Inertia tensor, *z7I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z7I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- x-axis along the vehicle-fixed x-axis
- y-axis along the vehicle-fixed y-axis
- z-axis along the vehicle-fixed z-axis





Aerodynamic

`Longitudinal drag area, Af` — Area
`2` (default) | `scalar`

Effective vehicle cross-sectional area, A_f to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Drag
`.3` (default) | `scalar`

Air drag coefficient, C_d, dimensionless.

`Longitudinal lift coefficient, Cl` — Lift
`.1` (default) | `scalar`

Air lift coefficient, C_l, dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}, dimensionless.

`Relative wind angle vector, beta_w` — Wind angle
`[0:0.001:0.01]` (default) | `vector`

Relative wind angle vector, β_w, in rad.

`Side force coefficient vector, Cs` — Side force drag
`[0:0.01:0.1]` (default) | `vector`

Side force coefficient vector coefficient, C_s, dimensionless.

`Yaw moment coefficient vector, Cym` — Yaw moment drag
`[0:0.001:0.01]` (default) | `vector`

Yaw moment coefficient vector coefficient, C_{ym}, dimensionless.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar`

Environmental air absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Ambient air temperature
`273` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity
`9.81` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

Simulation

`Longitudinal velocity tolerance, xdot_tol` — Tolerance
`.1` (default) | `scalar`

Longitudinal velocity tolerance, $xdot_{tol}$, in m/s.

The block uses this parameter to avoid a division by zero when it calculates the body slip angle, β.

`Geometric longitudinal offset from axle plane, longOff` — Longitudinal offset
`0` (default) | `scalar`

Vehicle chassis offset from axle plane along body-fixed x-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Geometric lateral offset from center plane, latOff` — Lateral offset
`0` (default) | `scalar`

Vehicle chassis offset from center plane along body-fixed y-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Geometric vertical offset from axle plane, vertOff` — Vertical offset
`0` (default) | `scalar`

Vehicle chassis offset from axle plane along body-fixed z-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Wrap Euler angles, wrapAng` — Selection
`on` (default) | `off`

Wrap the Euler angles to the interval `[-pi, pi]`. For vehicle maneuvers that might undergo vehicle yaw rotations that are outside of the interval, consider deselecting the parameter if you want to:

- Track the total vehicle yaw rotation.
- Avoid discontinuities in the vehicle state estimators.

Version History

Introduced in R2018a

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

See Also

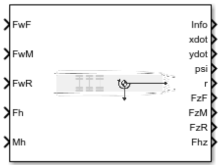
6DOF (Euler Angles) | Vehicle Body 3DOF | Vector Concatenate, Matrix Concatenate

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Trailer Body 3DOF

Trailer body with longitudinal, lateral, and yaw motion
Library: Vehicle Dynamics Blockset / Vehicle Body



Description

The Trailer Body 3DOF block implements a rigid one-axle, two-axle or three-axle trailer body model to calculate longitudinal, lateral, and yaw motion. Configure the block for a single or dual track. The block accounts for axle and hitch reaction forces due to the trailer acceleration, aerodynamic drag, and steering.

Use this block in vehicle dynamics and automated driving studies to model nonholonomic vehicle motion when vehicle pitch, roll, and vertical motion are not significant.

Use the **Vehicle track** parameter to specify the number of wheels.

Vehicle Track Setting	Implementation
`Single 1-axle`	Trailer with a single track and one axle. • Forces act along the center line of the axle. • No lateral load transfer.
`Dual 1-axle`	Trailer with a dual track and one axle. Forces act at the axle hard-point locations.
`Single 2-axle`	Trailer with a single track and two axles. • Forces act along the center line of the axles. • No lateral load transfer.
`Dual 2-axle`(default)	Trailer with a dual track and two axles. Forces act at the axle hard-point locations.
`Single 3-axle`	Trailer with a single track and three axles. • Forces act along the center line of the axles. • No lateral load transfer.
`Dual 3-axle`	Trailer with a dual track and three axles. Forces act at the axle hard-point locations.

Use the **Axle forces** parameter to specify the type of force.

Axle Forces Setting	Implementation

`External longitudinal velocity`	• The block assumes that the external longitudinal velocity is in a quasi-steady state, and the longitudinal acceleration is approximately zero.
	• Because the motion is quasi-steady, the block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Generate virtual sensor signal data.
	  • Conduct high-level software studies that are not impacted by driveline or nonlinear tire responses.

`External longitudinal forces`	• The block uses the external longitudinal force to accelerate or brake the vehicle.
	• The block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Account for changes in the longitudinal velocity on the lateral and yaw motion.
	  • Specify the external longitudinal motion through a force instead of an external longitudinal velocity.
	  • Connect the block to tractive actuators, wheels, brakes, and hitches.

`External forces`	• The block uses the external lateral and longitudinal forces to steer, accelerate, or brake the vehicle. • The block does not use the steering input to calculate vehicle motion. • Consider this setting when you need tire models with more accurate nonlinear combined lateral and longitudinal slip.

To create additional input ports, under **Input signals**, select these block parameters.

Input Signals Pane Parameter	Input Port	Description
Front wheel steering	`WhlAngF`	Front wheel angle, δ_F
Middle wheel steering	`WhlAngM`	Middle wheel angle, δ_M
Rear wheel steering	`WhlAngR`	Rear wheel angle, δ_R
External wind	`WindXYZ`	Wind speed, W_X, W_Y, and W_Z, in an inertial reference frame
External friction	`Mu`	Friction coefficient
External forces	`FExt`	External force on the vehicle center of gravity (CG), F_x, F_y, and F_z, in the vehicle-fixed frame
External moments	`MExt`	External moment about the vehicle CG, M_x, M_y, and M_z, in the vehicle-fixed frame
Front hitch forces	`FhF`	Hitch force applied to the body at the front hitch location, FhF_x, FhF_y, and FhF_z, in the vehicle-fixed frame

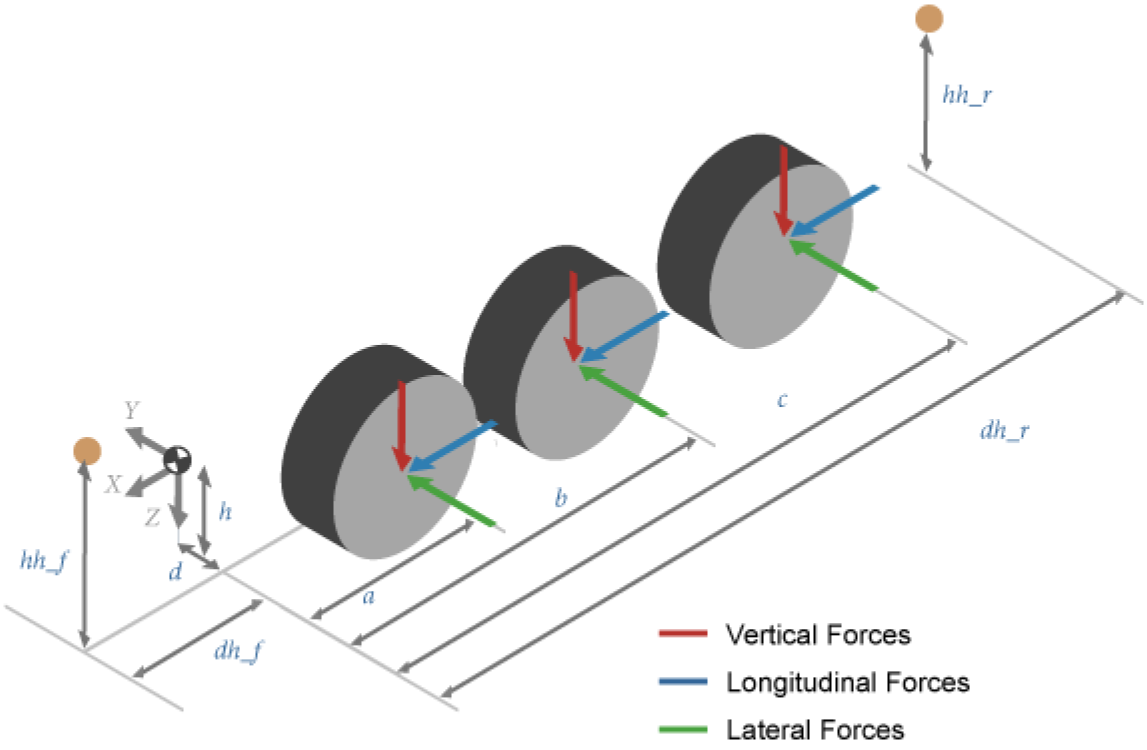
Input Signals Pane Parameter	Input Port	Description
Front hitch moments	`MhF`	Hitch moment at the front hitch location, MhF_x, MhF_y, and MhF_z, about the vehicle-fixed frame
Rear hitch forces	`FhR`	Hitch force applied to the body at the rear hitch location, FhR_x, FhR_y, and FhR_z, in the vehicle-fixed frame
Rear hitch moments	`MhR`	Hitch moment at the rear hitch location, MhR_x, MhR_y, and MhR_z, about the vehicle-fixed frame
Initial longitudinal position	`X_o`	Initial vehicle CG displacement along the earth-fixed *X*-axis
Initial yaw angle	`psi_o`	Initial rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)
Initial longitudinal velocity	`xdot_o`	Initial vehicle CG velocity along the vehicle-fixed *x*-axis
Initial yaw rate	`r_o`	Initial vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)
Initial lateral position	`Y_o`	Initial vehicle CG displacement along the earth-fixed *Y*-axis
Air temperature	`AirTemp`	Ambient air temperature. Consider this option if you want to vary the temperature during run time.
Initial lateral velocity	`ydot_o`	Initial vehicle CG velocity along the vehicle-fixed *y*-axis

Theory

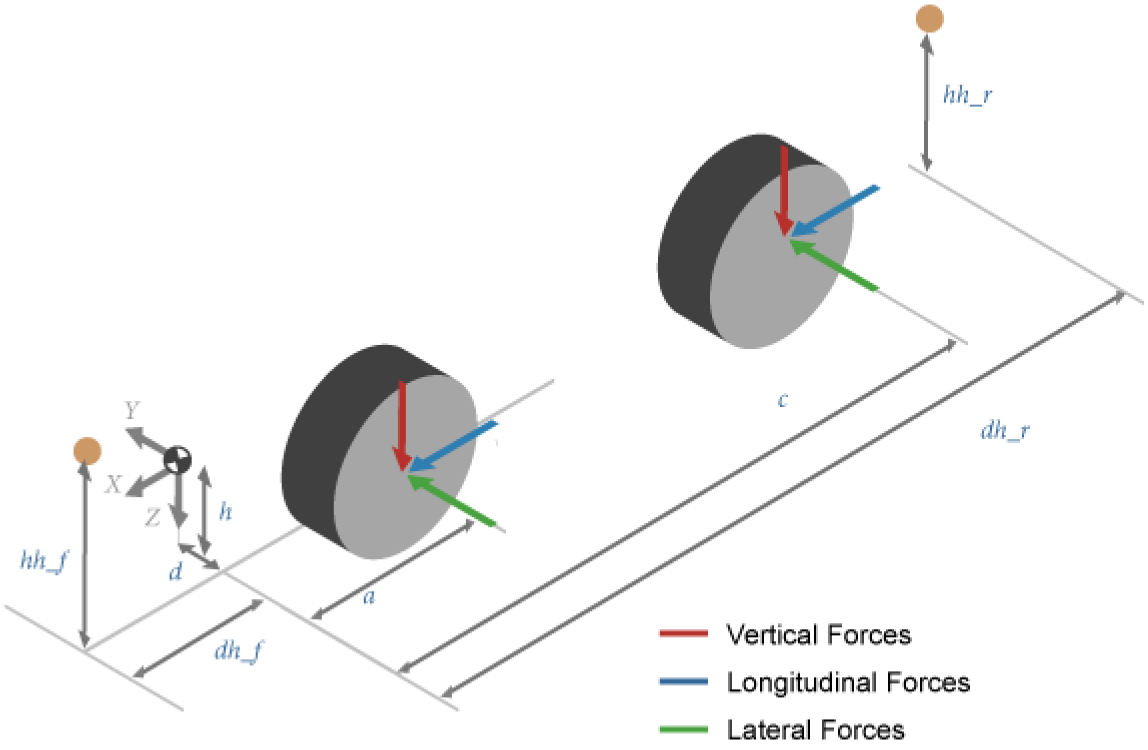
To determine the vehicle motion, the block solves the rigid body planar dynamics equations of motion.

Calculation	Description
Dynamics	The block solves the rigid-body planar dynamics equations to determine the vehicle longitudinal motion. If you set **Axle forces** to `External longitudinal velocity`, the block assumes a quasi-steady state for the longitudinal acceleration.
External forces	External forces include both drag and external force inputs. The forces act on the vehicle CG. The block divides the normal forces by the nominal normal load to vary the effective friction parameters during weight and load transfer. The block maintains pitch and roll equilibrium.
Tire forces	The block uses the ratio of the local, longitudinal, and lateral velocities to determine the slip angles. The block uses the steering angles to transform the tire forces to the vehicle-fixed frame. If you set **Axle forces** to `External forces`, the block assumes that the externally provided forces are in the vehicle-fixed frame at the axle-wheel location.

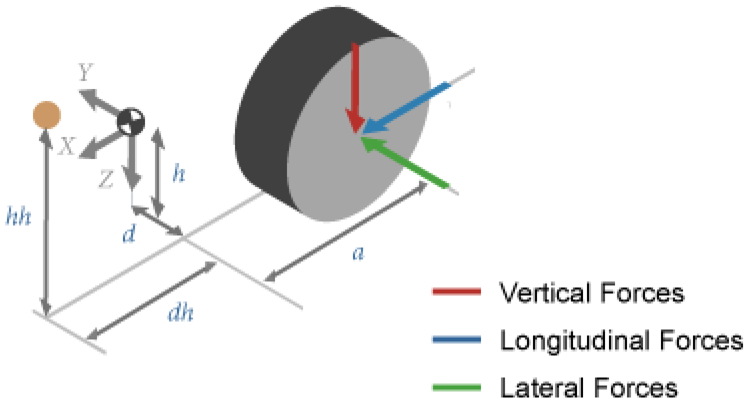
Single Track — Three Axles



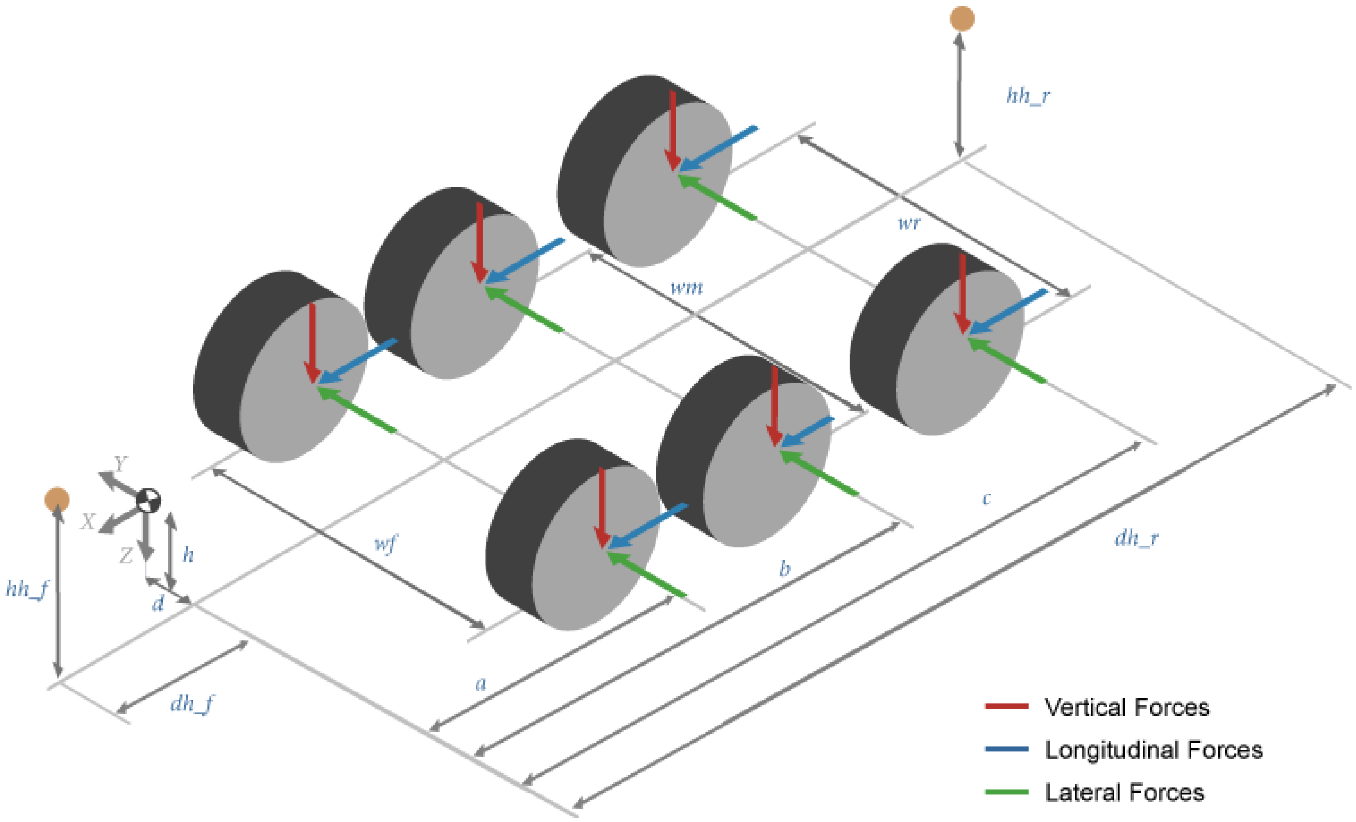
Single Track — Two Axles



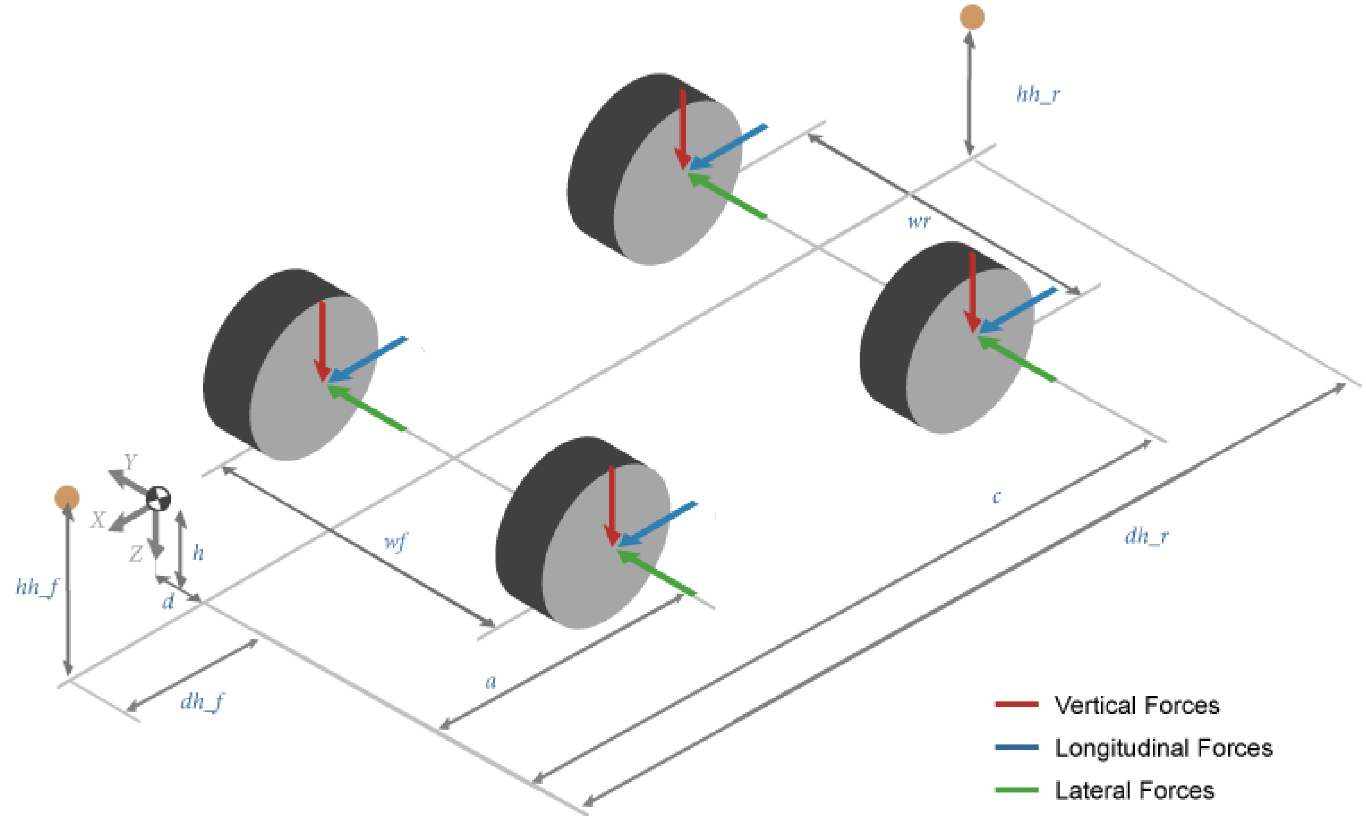
Single Track — One Axle



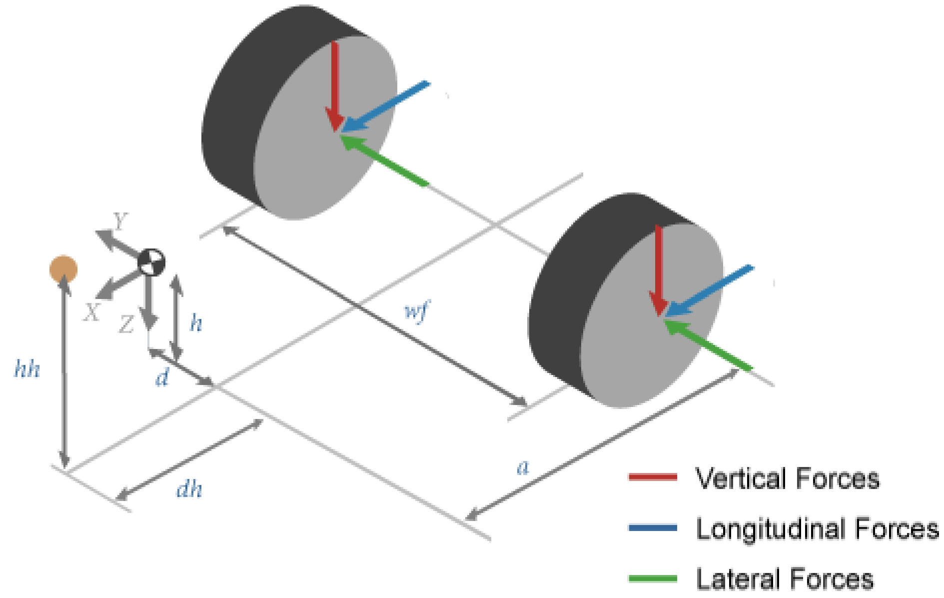
Dual Track — Three Axles



Dual Track — Two Axles



Dual Track — One Axle



The illustrations use these variables.

a, *b*, *c*	Longitudinal distance of the front, middle, and rear axles, respectively, from the normal projection point of the vehicle CG onto the common axle plane
h	Height of the tractor CG above the axle plane along the vehicle-fixed *z*-axis
d	Lateral distance from the geometric centerline to the center of mass along the vehicle-fixed *y*-axis
hh_f, *hh_r*	Height of the front and rear hitch, respectively, above the axle plane along the vehicle-fixed *z*-axis
dh_f, *dh_r*	Longitudinal distance of the front and rear hitch, respectively, from the normal projection point of tractor CG onto the common axle plane
wf, *wm*, *wr*	Front, middle, and rear track width, respectively

Drag

This table summarizes the block implementation for the drag calculation.

Calculation	Description
Coordinate transformation	The block transforms the wind speeds from the inertial frame to the vehicle-fixed frame.
Drag forces	To determine a relative airspeed, the block subtracts the wind speed from the CG vehicle velocity. Using the relative airspeed, the block determines the drag forces.
Drag moments	Using the relative airspeed, the block determines the drag moments.

Lateral Corner Stiffness and Relaxation Dynamics

To enable the mapped corner stiffness and relaxation length dynamic parameters, set **Axle forces** to `External longitudinal forces` or `External longitudinal velocity`.

Parameter Settings		Description
Mapped Corner Stiffness	Include Relaxation Length Dynamics	
`Off` (default)	`On` (default)	The block uses constant corner stiffness values. The slip angles include the relaxation length dynamic settings. The relaxation length approximates an effective corner stiffness force that is a function of wheel travel.
`On`	`On` (default)	The block uses lookup tables that are functions of the corner stiffness data and slip angles. The slip angles include the relaxation length dynamic settings. The relaxation length approximates an effective corner stiffness force that is a function of wheel travel.
`Off` (default)	`Off`	The block uses constant corner stiffness values.

Ports

Input

`WhlAngF` — Front wheel steering angles

`scalar` | `array`

Front wheel steering angles, δ_F, in rad.

Vehicle Track Setting	Variable	Signal Dimension

`Single 1-axle`
`Single 2-axle`
`Single 3-axle`
	δ_F	Scalar – 1

`Dual 1-axle`
`Dual 2-axle`
`Dual 3-axle`
	$\delta_F = [\delta_{fl}\ \delta_{fr}]$ or $\begin{bmatrix}\delta_{fl}\\ \delta_{fr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port, under **Input signals**, select **Front wheel steering**.

`WhlAngM` — Middle wheel steering angles

`scalar` | `array`

Middle wheel steering angles, δ_M, in rad.

Vehicle Track Setting	Variable	Signal Dimension
`Single 3-axle`	δ_M	Scalar – 1
`Dual 3-axle`	$\delta_M = [\delta_{ml}\ \delta_{mr}]$ or $\begin{bmatrix}\delta_{ml}\\ \delta_{mr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port:

- Set **Vehicle track** to `Single 3-axle` or `Dual 3-axle`.
- To enable this port, under **Input signals**, select **Middle wheel steering**.

`WhlAngR` — Rear wheel steering angles

`scalar` | `array`

Rear wheel steering angles, δ_R, in rad.

Vehicle Track Setting	Variable	Signal Dimension

`Single 1-axle`
`Single 2-axle`
`Single 3-axle`
	δ_R	Scalar – 1

`Dual 1-axle`
`Dual 2-axle`
`Dual 3-axle`
	$\delta_R = [\delta_{rl}\ \delta_{rr}]$ or $\begin{bmatrix}\delta_{rl}\\ \delta_{rr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port, under **Input signals**, select **Rear wheel steering**.

`xdotin` — Longitudinal velocity

scalar

Vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this port, set **Axle forces** to `External longitudinal velocity`.

FwF — Total force on the front wheels

scalar | array

Force on the front wheels, Fw_F, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension

`Single 1-axle`
`Single 2-axle`
`Single 3-axle`
	`External longitudinal forces`	Longitudinal force on the front wheel	$FwF = Fx_f$	Scalar – 1

	`External forces`	Longitudinal and lateral forces on the front wheel	$FwF = [Fx_f\ Fy_f]$ or $\begin{bmatrix}Fx_f\\ Fy_f\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

`Dual 1-axle`
`Dual 2-axle`
`Dual 3-axle`
	`External longitudinal forces`	Longitudinal force on the front wheels	$FwF = [F_{xfl}\ F_{xfr}]$ or $\begin{bmatrix}F_{xfl}\\ F_{xfr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

	`External forces`	Longitudinal and lateral forces on the front wheels	$FwF = \begin{bmatrix}F_{xfl} & F_{xfr}\\ F_{yfl} & F_{yfr}\end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

`FwM` — Total force on the middle wheels

scalar | array

Force on the middle wheels, Fw_M, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Single 3-axle`	`External longitudinal forces`	Longitudinal force on the middle wheel	$FwM = Fx_r$	Scalar – 1
	`External forces`	Longitudinal and lateral forces on the middle wheel	$FwM = [Fx_m \ Fy_m]$ or $\begin{bmatrix} Fx_m \\ Fy_m \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
`Dual 3-axle`	`External longitudinal forces`	Longitudinal force on the middle wheels	$FwM = [F_{xml} \ F_{xmr}]$ or $\begin{bmatrix} F_{xml} \\ F_{xmr} \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
	`External forces`	Longitudinal and lateral forces on the middle wheels	$FwM = \begin{bmatrix} F_{xml} & F_{xmr} \\ F_{yml} & F_{ymr} \end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set:

- **Vehicle track** to `Single 3-axle` or `Dual 3-axle`.
- **Axle forces** to `External longitudinal forces` or `External forces`.

`FwR` — Total force on the rear wheels

scalar | array

Force on the rear wheels, Fw_R, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Single 2-axle` `Single 3-axle`	`External longitudinal forces`	Longitudinal force on the rear wheel	$FwR = Fx_r$	Scalar – 1
	`External forces`	Longitudinal and lateral forces on the rear wheel	$FwR = [Fx_r \ Fy_r]$ or $\begin{bmatrix} Fx_r \\ Fy_r \end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Dual 2-axle` `Dual 3-axle`	`External longitudinal forces`	Longitudinal force on the rear wheels	$FwR = [F_{xrl}\ F_{xrr}]$ or $\begin{bmatrix} F_{xrl} \\ F_{xrr} \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
	`External forces`	Longitudinal and lateral forces on the rear wheels	$FwR = \begin{bmatrix} F_{xrl} & F_{xrr} \\ F_{yrl} & F_{yrr} \end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set:

- **Vehicle track** to `Single 3-axle`, `Single 2-axle`, `Dual 3-axle` or `Dual 2-axle`.
- **Axle forces** to `External longitudinal forces` or `External forces`.

`FExt` — External force on the vehicle CG

`array`

External forces applied to the vehicle CG, F_{xext}, F_{yext}, F_{zext}, in vehicle-fixed frame, in N. The signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, under **Input signals**, select **External forces**.

`MExt` — External moment about vehicle CG

`array`

External moment about the vehicle CG, M_x, M_y, M_z, in the vehicle-fixed frame, in N·m. The signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, under **Input signals**, select **External moments**.

`FhF` — Front hitch force on the body

`array`

Hitch force applied to the body at the front hitch location, FhF_x, FhF_y, FhF_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Front hitch forces**.

`MhF` — Front hitch moment about body

`array`

Hitch moment at the front hitch location, MhF_x, MhF_y, MhF_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Front hitch moments**.

`FhR` — Rear hitch force on the body

`array`

Hitch force applied to the body at the rear hitch location, FhR_x, FhR_y, FhR_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Rear hitch forces**.

`MhR` — Rear hitch moment about body

`array`

Hitch moment at the rear hitch location, MhR_x, MhR_y, MhR_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Rear hitch moments**.

`WindXYZ` — Wind speed

`array`

Wind speed, W_x, W_y, W_z, along the inertial X-, Y-, and Z-axes, in m/s. The signal vector dimensions are `1-by-3` or `3-by-1`.

Dependencies

To enable this port, under **Input signals**, select **External wind**.

`Mu` — Tire friction coefficient

`array`

Tire friction coefficient, μ. The value is dimensionless.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single 1-axle`	Friction coefficient on the wheels	$Mu = \mu_f$	Array – `[1x1]`
`Dual 1-axle`	Friction coefficient on the wheels	$Mu = \begin{bmatrix}\mu_{fl} & \mu_{fr}\end{bmatrix}$ or $\begin{bmatrix}\mu_{fl} \\ \mu_{fr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`
`Single 2-axle`	Friction coefficient on the wheels	$Mu = \begin{bmatrix}\mu_f & \mu_r\end{bmatrix}$ or $\begin{bmatrix}\mu_f \\ \mu_r\end{bmatrix}$	Array – `[1x2]` or `[2x1]`
`Dual 2-axle`	Friction coefficient on the wheels	$Mu = \begin{bmatrix}\mu_{fl} & \mu_{fr} \\ \mu_{rl} & \mu_{rr}\end{bmatrix}$	Array – `[2x2]`

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single 3-axle`	Friction coefficient on the wheels	$Mu = \begin{bmatrix} \mu_f & \mu_m & \mu_r \end{bmatrix}$ or $\begin{bmatrix} \mu_f \\ \mu_m \\ \mu_r \end{bmatrix}$	Array – `[1x3]` or `[3x1]`
`Dual 3-axle`	Friction coefficient on the wheels	$Mu = \begin{bmatrix} \mu_{fl} & \mu_{fr} \\ \mu_{ml} & \mu_{mr} \\ \mu_{rl} & \mu_{rr} \end{bmatrix}$	Array – `[3x2]`

Dependencies

To enable this port, under **Input signals**, select **External friction**.

`AirTemp` — Ambient air temperature

`scalar`

Ambient air temperature, in K.

Dependencies

To enable this port, under **Input signals**, select **Air temperature**.

`X_o` — Initial longitudinal position

`scalar`

Initial vehicle CG displacement along the earth-fixed *X*-axis, in m.

Dependencies

To enable this port, under **Input signals**, select **Initial longitudinal position**.

`Y_o` — Initial lateral position

`scalar`

Initial vehicle CG displacement along the earth-fixed *Y*-axis, in m.

Dependencies

To enable this port, under **Input signals**, select **Initial lateral position**.

`xdot_o` — Initial longitudinal position

`scalar`

Initial vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this port:

1. Set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

2. Under **Input signals**, select **Initial longitudinal velocity**

`ydot_o` — Initial lateral position

scalar

Initial vehicle CG velocity along the vehicle-fixed *y*-axis, in m/s.

Dependencies

To enable this port, under **Input signals**, select **Initial lateral velocity**.

`psi_o` — Initial yaw angle

scalar

Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw), in rad.

Dependencies

To enable this port, under **Input signals**, select **Initial yaw angle**.

`r_o` — Initial yaw rate

scalar

Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

Dependencies

To enable this port, under **Input signals**, select **Initial yaw rate**.

Output

`Info` — Trailer data

bus

Trailer data, returned as a bus signal containing these block values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CG displacement along the earth-fixed *X*-axis	Computed	m
			`Y`	Vehicle CG displacement along the earth-fixed *Y*-axis	Computed	m
			`Z`	Vehicle CG displacement along the earth-fixed *Z*-axis	`0`	m
		`Vel`	`Xdot`	Vehicle CG velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Vehicle CG velocity along the earth-fixed *Y*-axis	Computed	m/s

Signal					Description	Value	Units
			`Zdot`		Vehicle CG velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Ang`	`phi`		Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	`0`	rad
			`theta`		Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	`0`	rad
			`psi`		Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad
	`FrntAxl`	`Lft`	`Disp`	`X`	Front left wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front left wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front left wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Front left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front left wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Rght`	`Disp`	`X`	Front right wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front right wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front right wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Front right wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s

Signal					Description	Value	Units
				`Zdot`	Front right wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
	`MidlAxl`	`Lft`	`Disp`	`X`	Middle left wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Middle left wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Middle left wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Middle left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Middle left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Middle left wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Rght`	`Disp`	`X`	Middle right wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Middle right wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Middle right wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Middle right wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Middle right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Middle right wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
	`RearAxl`	`Lft`	`Disp`	`X`	Rear left wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear left wheel displacement along the earth-fixed *Y*-axis	Computed	m

Signal					Description	Value	Units
				`Z`	Rear left wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Rear left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear left wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Rght`	`Disp`	`X`	Rear right wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear right wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear right wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Rear right wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear right wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
	`Geom`	`Disp`	`X`		Trailer body offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`		Trailer body offset from the center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`		Trailer body offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`		Trailer body offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Trailer body offset velocity along the earth-fixed *Y*-axis	Computed	m/s

Signal				Description	Value	Units
			`Zdot`	Trailer body offset velocity along the earth-fixed *Z*-axis	Computed	m/s
	`HitchF`	`Disp`	`X`	Trailer front hitch offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`	Trailer front hitch offset from the center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`	Trailer front hitch offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Trailer front hitch offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Trailer front hitch offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Trailer front hitch offset velocity along the earth-fixed *Z*-axis	Computed	m/s
	`HitchR`	`Disp`	`X`	Trailer rear hitch offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`	Trailer rear hitch offset from the center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`	Trailer rear hitch offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Trailer rear hitch offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Trailer rear hitch offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Trailer rear hitch offset velocity along the earth-fixed *Z*-axis	Computed	m/s
`BdyFrm`	`Cg`	`Vel`	`xdot`	Vehicle CG velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle CG velocity along the vehicle-fixed *y*-axis	Computed	m/s

Signal				Description	Value	Units
			`zdot`	Vehicle CG velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	`0`	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	`0`	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s
		`Acc`	`ax`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	gn
			`xddot`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2
			`zddot`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	m/s^2
		`AngAcc`	`pdot`	Vehicle angular acceleration about the vehicle-fixed *x*-axis	`0`	rad/s
			`qdot`	Vehicle angular acceleration about the vehicle-fixed *y*-axis	`0`	rad/s
			`rdot`	Vehicle angular acceleration about the vehicle-fixed *z*-axis	Computed	rad/s
	`Forces`	`Body`	`Fx`	Net force on the vehicle CG along the vehicle-fixed *x*-axis	Computed	N

Signal					**Description**	**Value**	**Units**
			`Fy`		Net force on the vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Net force on the vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`Ext`	`Fx`		External force on the vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		External force on the vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		External force on the vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`HitchF`	`Fx`		Hitch front force applied to the body at the hitch location along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Hitch front force applied to the body at the hitch location along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Hitch front force applied to the body at the hitch location along the vehicle-fixed *z*-axis	Computed	N
		`HitchR`	`Fx`		Hitch rear force applied to the body at the hitch location along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Hitch rear force applied to the body at the hitch location along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Hitch rear force applied to the body at the hitch location along the vehicle-fixed *z*-axis	Computed	N
		`FrntAxl`	`Lft`	`Fx`	Longitudinal force on the left front wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the left front wheel along the vehicle-fixed *y*-axis	Computed	N

Signal					Description	Value	Units
				`Fz`	Normal force on the left front wheel along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right front wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right front wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right front wheel along the vehicle-fixed *z*-axis	Computed	N
		`MidlAxl`	`Lft`	`Fx`	Longitudinal force on the left middle wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the left middle wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the left middle wheel along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right middle wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right middle wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right middle wheel along the vehicle-fixed *z*-axis	Computed	N
		`RearAxl`	`Lft`	`Fx`	Longitudinal force on the left rear wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the left rear wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the left rear wheel along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right rear wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right rear wheel along the vehicle-fixed *y*-axis	Computed	N

Signal						**Description**	**Value**	**Units**
				`Fz`		Normal force on the right rear wheel along the vehicle-fixed *z*-axis	Computed	N
		`Tires`	`FrntTires`	`Lft`	`Fx`	Front left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Front right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front right tire force along the vehicle-fixed *z*-axis	Computed	N
			`RearTires`	`Lft`	`Fx`	Rear left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Rear right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear right tire force along the vehicle-fixed *z*-axis	Computed	
		`Drag`	`Fx`			Drag force on the vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Drag force on the vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Drag force on the vehicle CG along the vehicle-fixed *z*-axis	Computed	N
		`Grvty`	`Fx`			Gravity force on the vehicle CG along the vehicle-fixed *x*-axis	Computed	N

Signal				Description	Value	Units
			Fy	Gravity force on the vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			Fz	Gravity force on the vehicle CG along the vehicle-fixed *z*-axis	Computed	N
	Moments	Body	Mx	Body moment on the vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My	Body moment on the vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz	Body moment on the vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		Drag	Mx	Drag moment on the vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My	Drag moment on the vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz	Drag moment on the vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		Ext	Mx	External moment on the vehicle CG about the vehicle-fixed *x*-axis	0	N·m
			My	External moment on the vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz	External moment on the vehicle CG about the vehicle-fixed *z*-axis	0	N·m
		HitchF	Mx	Hitch moment at the front hitch location about vehicle-fixed *x*-axis	0	N·m
			My	Hitch moment at the front hitch location about vehicle-fixed *y*-axis	Computed	N·m
			Mz	Hitch moment at the front hitch location about vehicle-fixed *z*-axis	0	N·m
		HitchR	Mx	Hitch moment at the rear hitch location about vehicle-fixed *x*-axis	0	N·m

Signal					Description	Value	Units
			`My`		Hitch moment at the rear hitch location about vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		Hitch moment at the rear hitch location about vehicle-fixed *z*-axis	`0`	N·m
	`FrntAxl`	`Lft`	`Disp`	`x`	Front left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Front left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front left wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Rght`	`Disp`	`x`	Front right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Front right wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front right wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front right wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngFL`		Front left wheel steering angle	Computed	rad

Signal					Description	Value	Units
			WhlAngFR		Front right wheel steering angle	Computed	rad
	MidlAxl	Lft	Disp	x	Middle left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				y	Middle left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				z	Middle left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			Vel	xdot	Middle left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				ydot	Middle left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				zdot	Middle left wheel velocity along the vehicle-fixed *z*-axis	0	m/s
		Rght	Disp	x	Middle right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				y	Middle right wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				z	Middle right wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			Vel	xdot	Middle right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				ydot	Middle right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				zdot	Middle right wheel velocity along the vehicle-fixed *z*-axis	0	m/s
		Steer	WhlAngRL		Middle left wheel steering angle	Computed	rad
			WhlAngRR		Middle right wheel steering angle	Computed	rad

Signal					Description	Value	Units
	`RearAxl`	`Lft`	`Disp`	`x`	Rear left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear left wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Rght`	`Disp`	`x`	Rear right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear right wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear right wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear right wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngRL`		Rear left wheel steering angle	Computed	rad
			`WhlAngRR`		Rear right wheel steering angle	Computed	rad
	`HitchF`	`Disp`		`x`	Front hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	m

Signal				Description	Value	Units
			`y`	Front hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
			`z`	Front hitch offset from axle plane along the earth-fixed *z*-axis	Input	m
		`Vel`	`xdot`	Front hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Front hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Front hitch offset velocity along the vehicle-fixed *z*-axis	`0`	m/s
	`HitchR`	`Disp`	`x`	Rear hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	m
			`y`	Rear hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
			`z`	Rear hitch offset from axle plane along the earth-fixed *z*-axis	Input	m
		`Vel`	`xdot`	Rear hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Rear hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Rear hitch offset velocity along the vehicle-fixed *z*-axis	`0`	m/s
	`Pwr`	`Ext`		Applied external power	Computed	W
		`HitchF`		Front hitch power	Computed	W
		`HitchR`		Rear hitch power	Computed	W
		`Drag`		Power loss due to drag	Computed	W
	`Geom`	`Disp`	`x`	Trailer offset from axle plane along the vehicle-fixed *x*-axis	Input	m
			`y`	Trailer offset from center plane along the vehicle-fixed *y*-axis	Input	m

Signal				Description	Value	Units
			`z`	Trailer offset from axle plane along the vehicle-fixed z-axis	Input	m
		`Vel`	`xdot`	Trailer offset velocity along the vehicle-fixed x-axis	Computed	m/s
			`ydot`	Trailer offset velocity along the vehicle-fixed y-axis	Computed	m/s
			`zdot`	Trailer offset velocity along the vehicle-fixed z-axis	`0`	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad

Signal			Description	Value	Units
`PwrInfo`	`PwrTrnsfrd`	`PwrFxExt`	Externally applied longitudinal force power	Computed	W
		`PwrFyExt`	Externally applied lateral force power	Computed	W
		`PwrMzExt`	Externally applied yaw moment power	Computed	W
		`PwrFwFLx`	Longitudinal force applied at the front left axle power	Computed	W
		`PwrFwFLy`	Lateral force applied at the front left axle power	Computed	W
		`PwrFwFRx`	Longitudinal force applied at the front right axle power	Computed	W
		`PwrFwFRy`	Lateral force applied at the front right axle power	Computed	W
		`PwrFwMLx`	Longitudinal force applied at the middle left axle power	Computed	W
		`PwrFwMLy`	Lateral force applied at the middle left axle power	Computed	W
		`PwrFwMRx`	Longitudinal force applied at the middle right axle power	Computed	W
		`PwrFwMRy`	Lateral force applied at the middle right axle power	Computed	W
		`PwrFwRLx`	Longitudinal force applied at the rear left axle power	Computed	W

Signal			Description	Value	Units
		`PwrFwRLy`	Lateral force applied at the rear left axle power	Computed	W
		`PwrFwRRx`	Longitudinal force applied at the rear right axle power	Computed	W
		`PwrFwRRy`	Lateral force applied at the rear right axle power	Computed	W
	`PwrNotTrnsfrd`	`PwrFxDrag`	Longitudinal drag force power	Computed	W
		`PwrFyDrag`	Lateral drag force power	Computed	W
		`PwrMzDrag`	Drag pitch moment power	Computed	W
	`PwrStored`	`PwrStoredGrvty`	Rate change in gravitational potential energy	Computed	W
		`PwrStoredxdot`	Rate of change of longitudinal kinetic energy	Computed	W
		`PwrStoredydot`	Rate of change of lateral kinetic energy	Computed	W
		`PwrStoredr`	Rate of change of rotational yaw kinetic energy	Computed	W

`xdot` — Trailer longitudinal velocity
`scalar`

Trailer CG velocity along the vehicle-fixed x-axis, in m/s.

`ydot` — Trailer lateral velocity
`scalar`

Trailer CG velocity along the vehicle-fixed y-axis, in m/s.

`psi` — Yaw
`scalar`

Rotation of the vehicle-fixed frame about the earth-fixed Z-axis (yaw), in rad.

`r` — Yaw rate
`scalar`

Vehicle angular velocity, r, about the vehicle-fixed z-axis (yaw rate), in rad/s.

`FzF` — Normal force on the front wheels
`scalar` | `array`

Normal force on the front wheels, Fz_F, along the vehicle-fixed z-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single 2-axle` `Single 3-axle`	Normal force on the front axle	$FzF = Fz_f$	Scalar – 1
`Dual 2-axle` `Dual 3-axle`	Normal force on the front wheels	$FzF = \left[Fz_{fl}\ Fz_{fr}\right]$	Array – `[1x2]`

`FzM` — Normal force on the middle wheels

`scalar` | `array`

Normal force on the middle wheels, Fz_M, along the vehicle-fixed z-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single 3-axle`	Normal force on the middle axle	$FzM = Fz_m$	Scalar – 1
`Dual 3-axle`	Normal force on the right and left middle wheels	$FzM = \left[Fz_{ml}\ Fz_{rl}\right]$	Array – `[1x2]`

Dependencies

To enable this port, set **Vehicle track** to `Single 3-axle` or `Dual 3-axle`.

`FzR` — Normal force on the rear wheels

`scalar` | `array`

Normal force on the rear wheels, Fz_R, along the vehicle-fixed z-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single 2-axle` `Single 3-axle`	Normal force on the rear wheel	$FzR = Fz_r$	Scalar – 1
`Dual 2-axle` `Dual 3-axle`	Normal force on the rear wheels	$FzR = \left[Fz_{rl}\ Fz_{rr}\right]$	Array – `[1x2]`

`Fhz` — Normal component of hitch force on the body

`scalar`

Normal hitch force applied to the body at the hitch location, Fh_z, in the vehicle-fixed frame z-axis, in N.

If you enable the **Hitch forces** parameter, the block offsets the normal hitch force, Fh_z, with the value of the Fh input port component along the vehicle-fixed z-axis.

Parameters

Options

`Vehicle track` — Type of vehicle track

`Dual 2-axle` (default) | `Single 1-axle` | `Dual 1-axle` | `Single 2-axle` | `Dual 3-axle`

Use the **Vehicle track** parameter to specify the number of wheels.

Vehicle Track Setting	Implementation
`Single 1-axle`	Trailer with a single track and one axle. • Forces act along the center line of the axle. • No lateral load transfer.
`Dual 1-axle`	Trailer with a dual track and one axle. Forces act at the axle hard-point locations.
`Single 2-axle`	Trailer with a single track and two axles. • Forces act along the center line of the axles. • No lateral load transfer.
`Dual 2-axle`(default)	Trailer with a dual track and two axles. Forces act at the axle hard-point locations.
`Single 3-axle`	Trailer with a single track and three axles. • Forces act along the center line of the axles. • No lateral load transfer.
`Dual 3-axle`	Trailer with a dual track and three axles. Forces act at the axle hard-point locations.

`Axle forces` — Type of axle force

`External forces` (default) | `External longitudinal velocity` | `External longitudinal forces`

Use the **Axle forces** parameter to specify the type of force.

Axle Forces Setting	Implementation

`External longitudinal velocity`	• The block assumes that the external longitudinal velocity is in a quasi-steady state, and the longitudinal acceleration is approximately zero.
	• Because the motion is quasi-steady, the block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Generate virtual sensor signal data.
	  • Conduct high-level software studies that are not impacted by driveline or nonlinear tire responses.

Axle Forces Setting	Implementation

`External longitudinal forces`	• The block uses the external longitudinal force to accelerate or brake the vehicle.
	• The block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Account for changes in the longitudinal velocity on the lateral and yaw motion.
	  • Specify the external longitudinal motion through a force instead of an external longitudinal velocity.
	  • Connect the block to tractive actuators, wheels, brakes, and hitches.

`External forces`	• The block uses the external lateral and longitudinal forces to steer, accelerate, or brake the vehicle. • The block does not use the steering input to calculate vehicle motion. • Consider this setting when you need tire models with more accurate nonlinear combined lateral and longitudinal slip.

Input Signals

`Front wheel steering` — WhlAngF input port
`off` (default) | `on`

Select to create input port `WhlAngF`.

`Middle wheel steering` — WhlAngM input port
`off` (default) | `on`

Select to create input port `WhlAngM`.

Dependencies

To enable this parameter, set **Vehicle track** to `Single 3-axle` or `Dual 3-axle`.

`Rear wheel steering` — WhlAngR input port
`off` (default) | `on`

Select to create input port `WhlAngR`.

Dependencies

To enable this parameter, set **Vehicle track** to `Single 2-axle`, `Dual 2-axle`, `Single 3-axle`, or `Dual 3-axle`.

`External wind` — WindXYZ input port
`off` (default) | `on`

Select to create input port `WindXYZ`.

`External friction` — Mu input port
`off` (default) | `on`

Select to create input port `Mu`.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

`External forces` — FExt input port
`off` (default) | `on`

Select to create input port `FExt`.

`External moments` — MExt input port
`off` (default) | `on`

Select to create input port `MExt`.

`Front hitch forces` — FhF input port
`on` (default) | `off`

Select to create input port `Fh`.

`Front hitch moments` — MhF input port
`on` (default) | `off`

Select to create input port `Mh`.

`Rear hitch forces` — FhR input port
`off` (default) | `on`

Select to create input port `Fh`.

`Rear hitch moments` — MhR input port
`off` (default) | `on`

Select to create input port `Mh`.

`Initial longitudinal position` — X_o input port
`off` (default) | `on`

Select to create input port `X_o`.

`Initial yaw angle` — psi_o input port
`off` (default) | `on`

Select to create input port `psi_o`.

`Initial longitudinal velocity` — xdot_o input port
`off` (default) | `on`

Select to create input port `xdot_o`.

Dependencies

To enable this parameter, set **Axle forces** to `External longitudinal forces` or `External forces`.

`Initial yaw rate` — r_o input port

`off` (default) | `on`

Select to create input port `r_o`.

`Initial lateral position` — Y_o input port

`off` (default) | `on`

Select to create input port `Y_o`.

`Air temperature` — AirTemp input port

`off` (default) | `on`

Select to create input port `AirTemp`.

`Initial lateral velocity` — ydot_o input port

`off` (default) | `on`

Select to create input port `ydot_o`.

Longitudinal

`Number of wheels on front axle, NF` — Front wheel count

`2` (default) | `scalar`

Number of wheels on the front axle, N_F. The value is dimensionless.

`Number of wheels on middle axle, NM` — Middle wheel count

`2` (default) | `scalar`

Number of wheels on the middle axle, N_M. The value is dimensionless.

Dependencies

To enable this parameter, set **Vehicle track** to `Single 3-axle` or `Dual 3-axle`.

`Number of wheels on rear axle, NR` — Rear wheel count

`2` (default) | `scalar`

Number of wheels on the rear axle, N_R. The value is dimensionless.

To enable this parameter, set **Vehicle track** to `Single 2-axle`, `Single 3-axle`, `Dual 2-axle`, or `Dual 3-axle`.

`Vehicle mass, m` — Vehicle mass

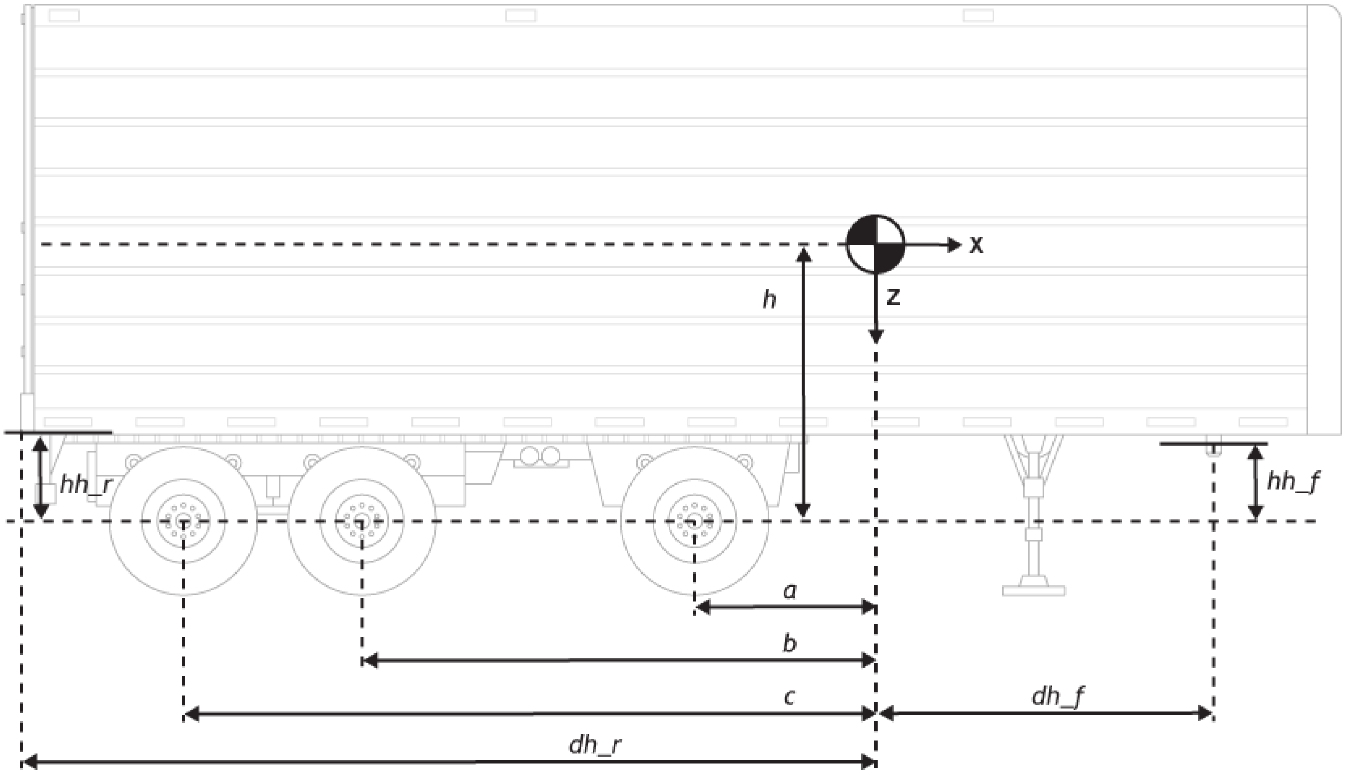
`26000` (default) | `scalar`

Vehicle mass, m, in kg.

`Longitudinal distance from center of mass to front axle, a` — Distance from CM to front axle

`4` (default) | `scalar`

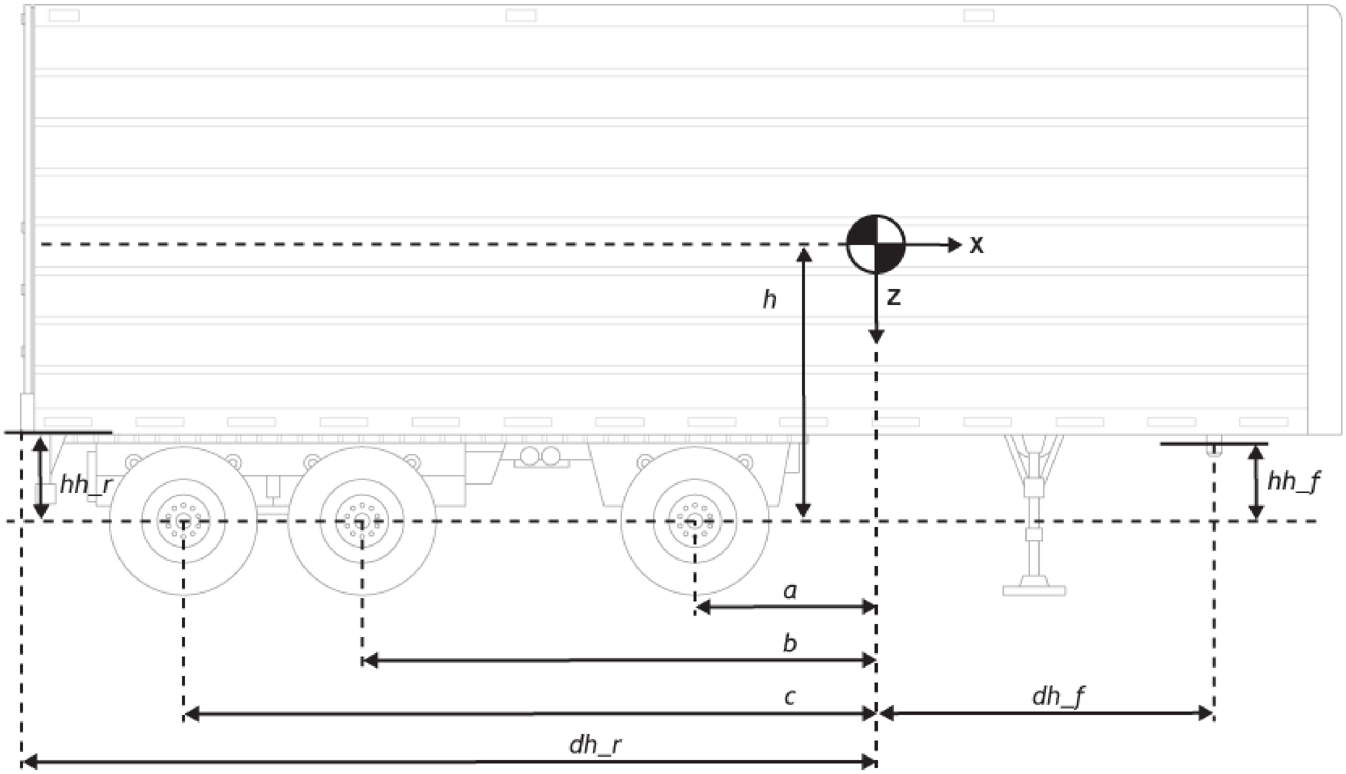
Distance from the vehicle CM to the front axle, *a*, in m.



`Longitudinal distance from center of mass to middle axle, b` — Distance from CM to middle axle

`4.5` (default) | `scalar`

Distance from vehicle CM to middle axle, *b*, in m.



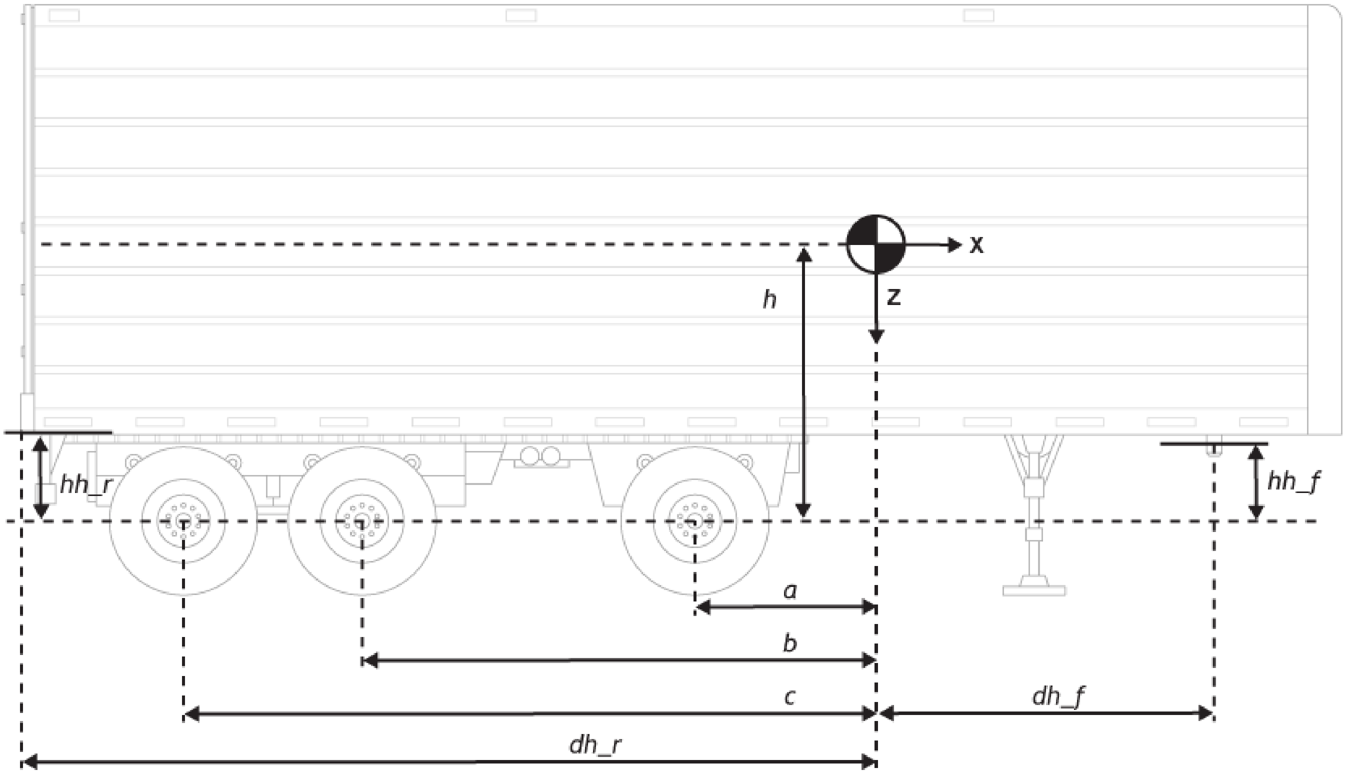
Dependencies

To enable this parameter, set **Vehicle track** to `Single 3-axle` or `Dual 3-axle`.

`Longitudinal distance from center of mass to rear axle, c` — Distance from CM to rear axle

5 (default) | `scalar`

Distance from vehicle CM to the front axle, *c*, in m.



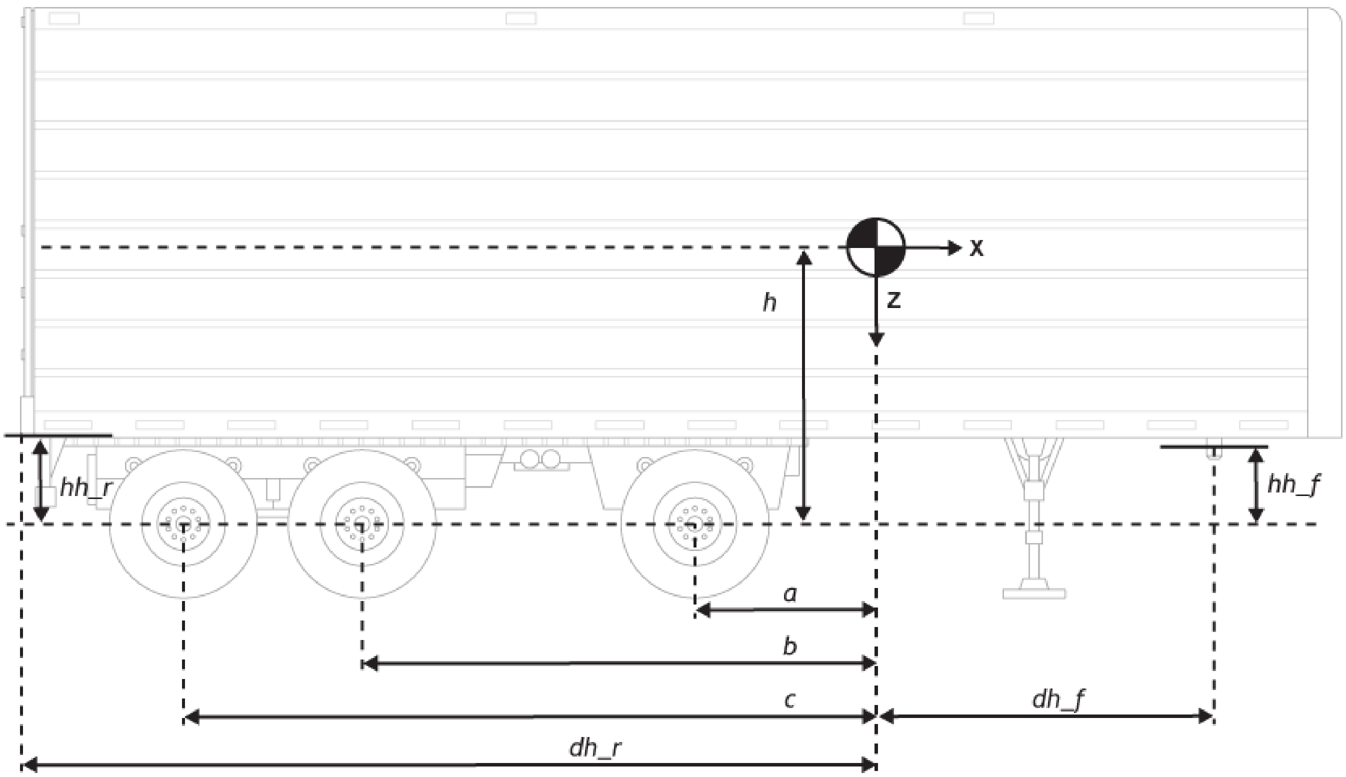
Dependencies

To enable this parameter, set **Vehicle track** to `Single 2-axle`, `Single 3-axle`, `Single 3-axle`, or `Dual 3-axle`.

`Vertical distance from center of mass to axle plane, h` — Distance from CM to axle plane

2 (default) | `scalar`

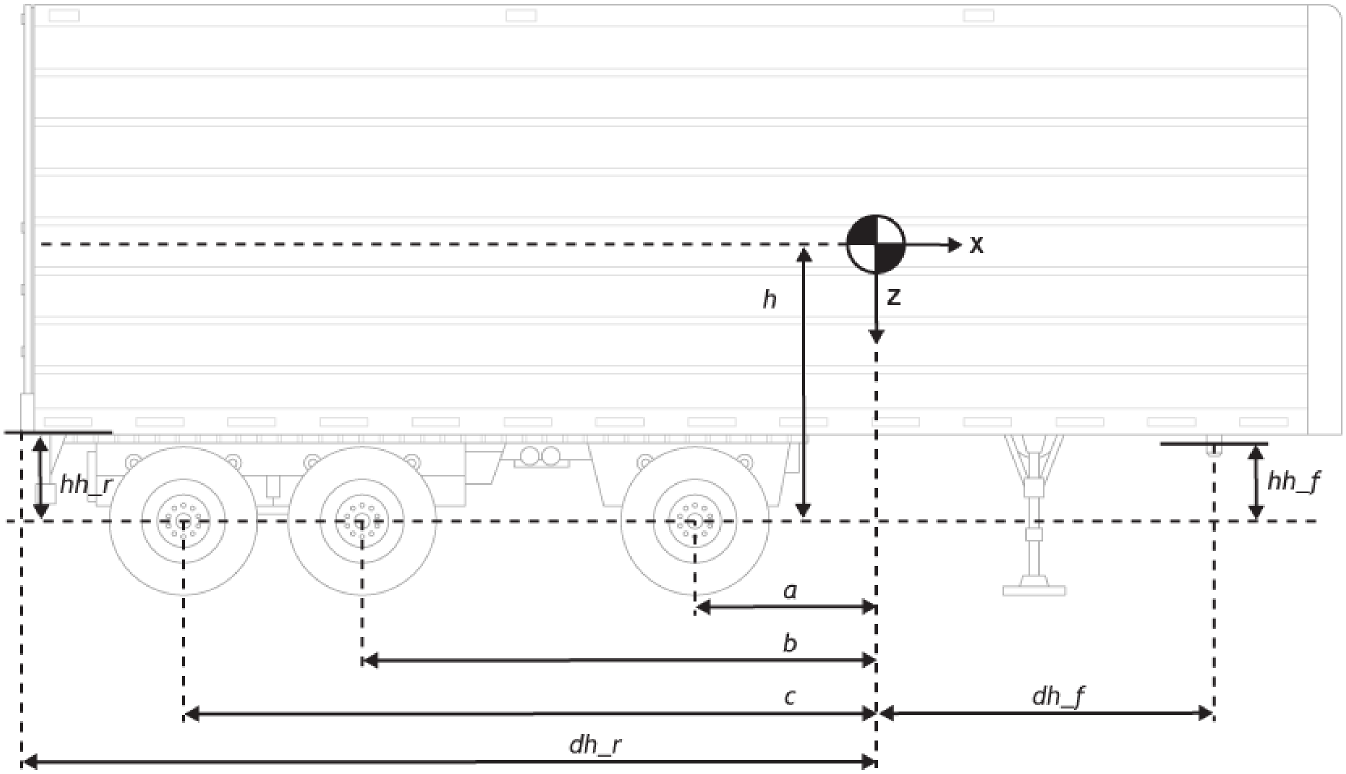
Vertical distance from vehicle CM to the axle plane, *h*, in m.



`Longitudinal distance from center of mass to front hitch, dh_f` — Distance to front hitch

`7.5` (default) | `scalar`

Longitudinal distance from the center of mass to the front hitch, *dh_f*, in m.



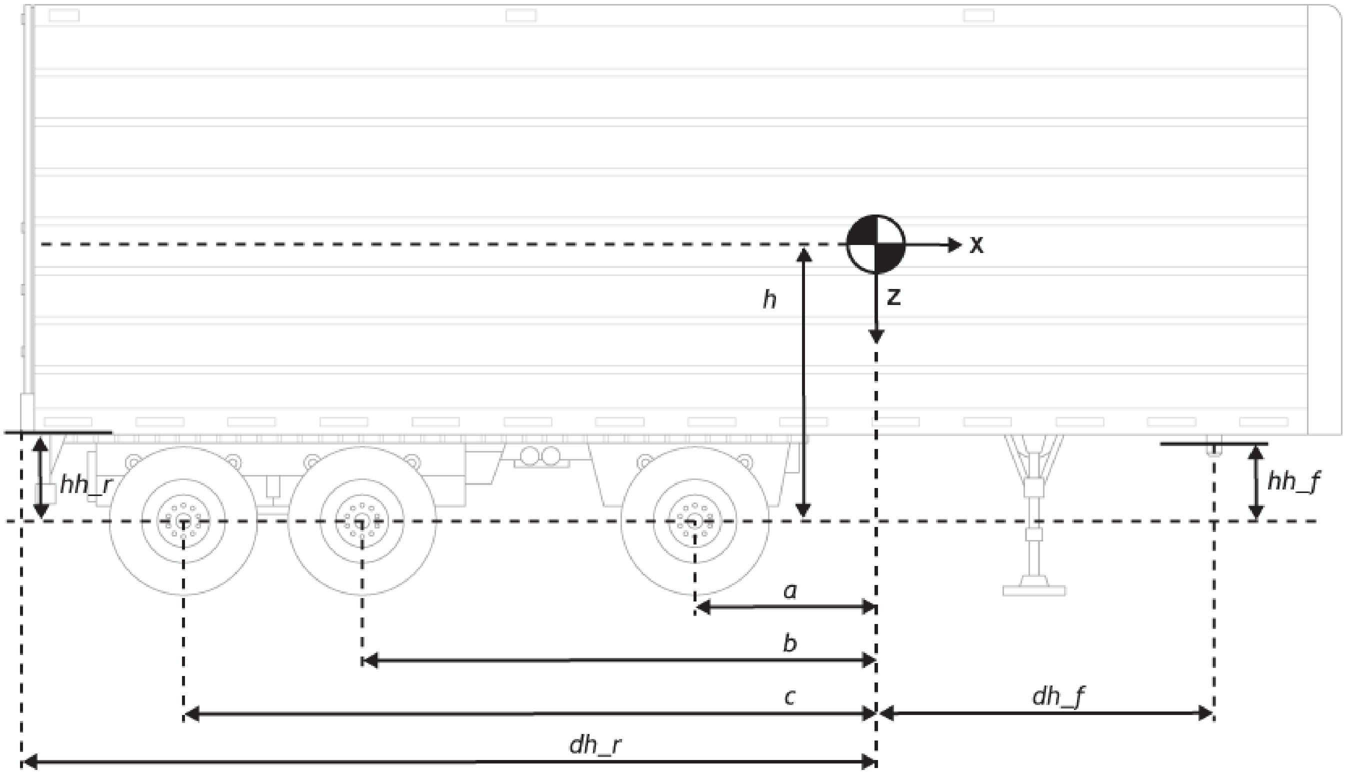
Dependencies

To enable this parameter, on the **Input signals** pane, select **Front hitch forces** or **Front hitch moments**.

`Vertical distance from front hitch to axle plane, hh_f` — Distance from front hitch to axle plane

`0.6` (default) | `scalar`

Vertical distance from the front hitch to the axle plane, *hh_f*, in m.



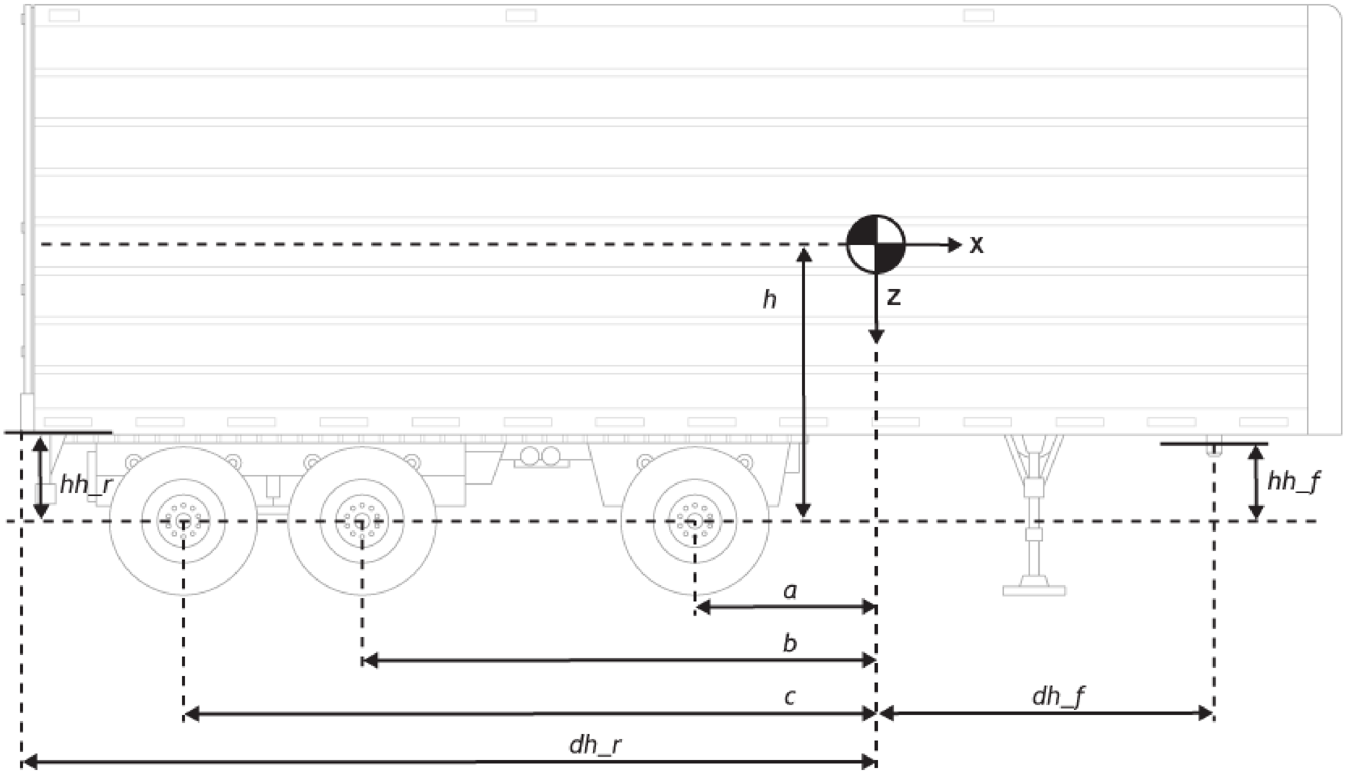
Dependencies

To enable this parameter, on the **Input signals** pane, select **Front hitch forces** or **Front hitch moments**.

`Longitudinal distance from center of mass to rear hitch, dh_r` — Distance to front hitch

`7.5` (default) | `scalar`

Longitudinal distance from the center of mass to the rear hitch, *dh_r*, in m.

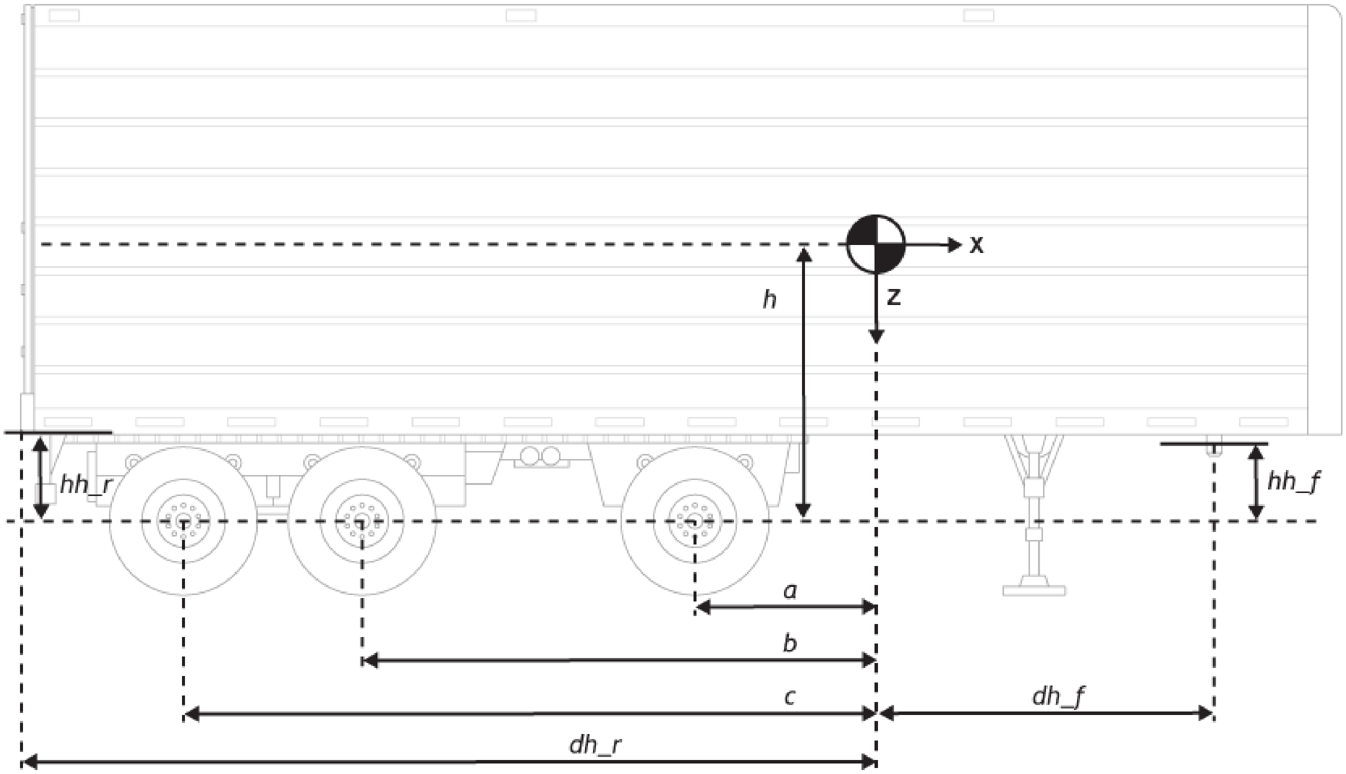


Dependencies

To enable this parameter, on the **Input signals** pane, select **Rear hitch forces** or **Rear hitch moments**.

`Vertical distance from front hitch to axle plane, hh_r` — Distance from rear hitch to axle plane
`0.6` (default) | `scalar`

Vertical distance from the rear hitch to the axle plane, *hh_r*, in m.



Dependencies

To enable this parameter, on the **Input signals** pane, select **Rear hitch forces** or **Rear hitch moments**.

`Initial inertial frame longitudinal position, X_o` — Initial inertial X location

`0` (default) | `scalar`

Initial vehicle CG displacement along the earth-fixed *X*-axis, in m.

`Initial longitudinal velocity, xdot_o` — Initial velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

Lateral

`Mapped corner stiffness` — Selection

`off` (default) | `on`

Enables mapped corner stiffness calculation.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

`Include relaxation length dynamics` — Enable relaxation length dynamics

`on` (default) | `off`

Enables relaxation length dynamics.

Dependencies

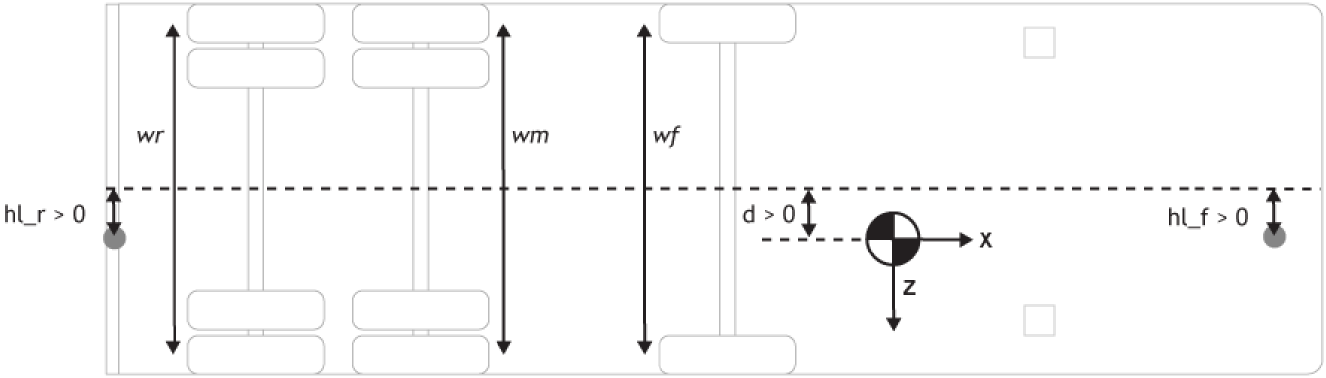
To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Lateral distance from geometric centerline to center of mass, d` — Distance from centerline to CM

`0` (default) | `scalar`

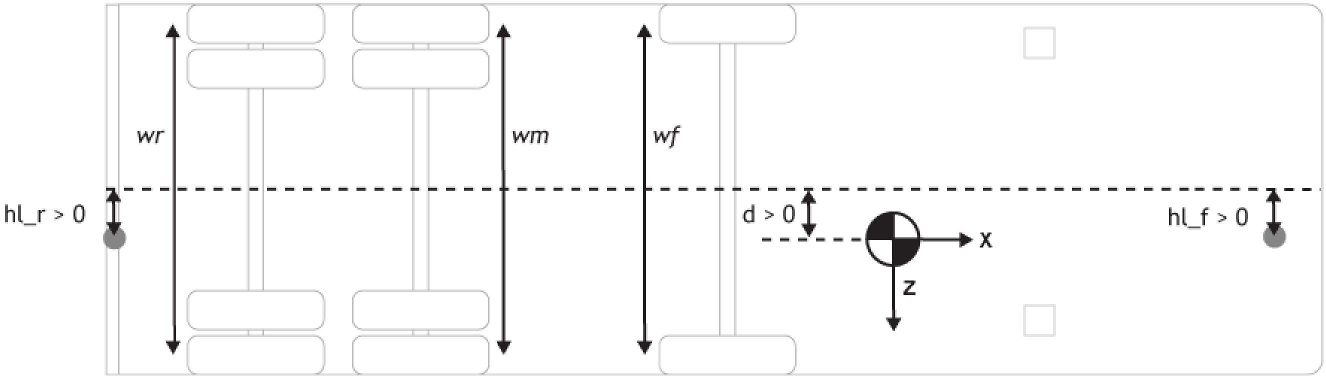
Lateral distance from the geometric centerline to the center of mass, *d*, in m, along the vehicle-fixed *y*. Positive values indicate that the trailer CM is to the right of the geometric centerline. Negative values indicate that the trailer CM is to the left of the geometric centerline.



`Lateral distance from geometric centerline to front hitch, hl_f` — Distance from centerline to front hitch

`0` (default) | `scalar`

Lateral distance from the geometric centerline to the front hitch, *hl_f*, in m, along the vehicle-fixed *y*. Positive values indicate that the trailer hitch is to the right of the geometric centerline. Negative values indicate that the trailer hitch is to the left of the geometric centerline.



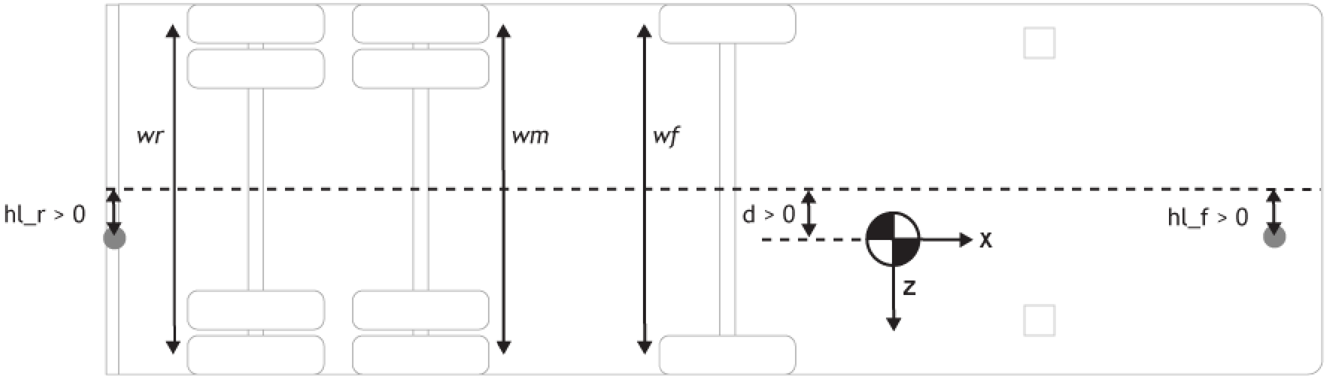
Dependencies

To enable this parameter, on the **Input signals** pane, select **Front hitch forces** or **Front hitch moments**.

`Lateral distance from geometric centerline to rear hitch, hl_r` — Distance from centerline to rear hitch

`0` (default) | `scalar`

Lateral distance from the geometric centerline to the rear hitch, *hl_r*, in m, along the vehicle-fixed *y*. Positive values indicate that the trailer hitch is to the right of the geometric centerline. Negative values indicate that the trailer hitch is to the left of the geometric centerline.



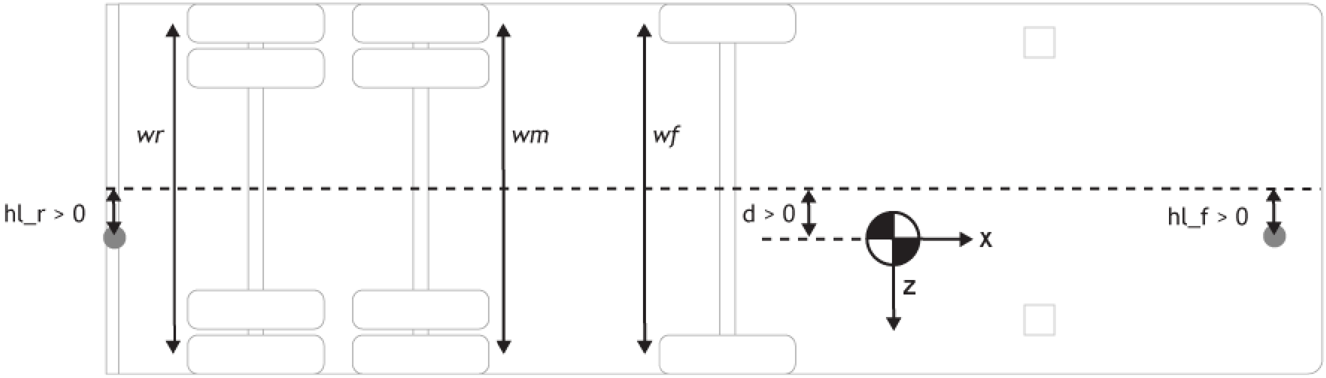
Dependencies

To enable this parameter, on the **Input signals** pane, select **Rear hitch forces** or **Rear hitch moments**.

`Front track width, w_f` — Front track width

`1.82` (default) | `scalar`

Front track width, *wf*, in m.

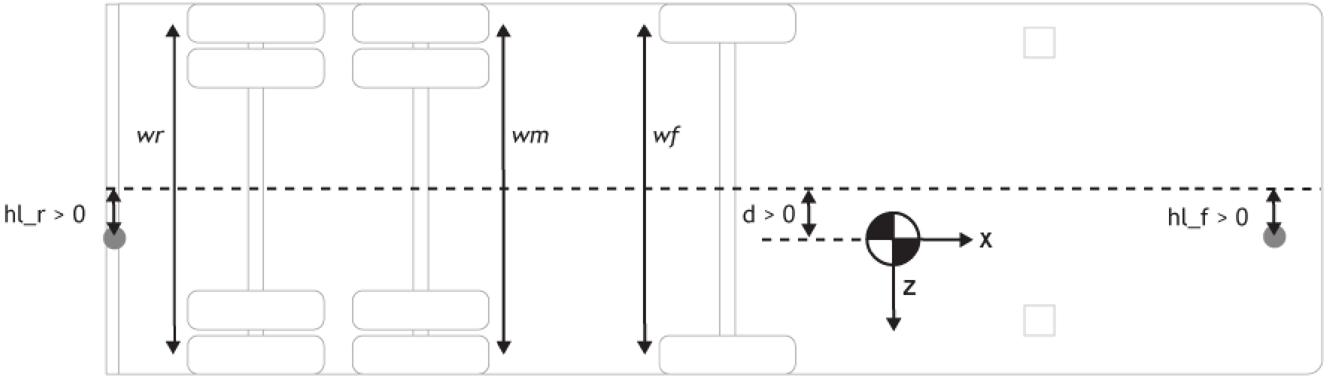


Dependencies

To enable this parameter, set **Vehicle track** to `Dual 2-axle`, `Dual 2-axle`, or `Dual 3-axle`.

`Middle track width, w_m` — Middle track width
`1.82` (default) | `scalar`

Middle track width, *wm*, in m.

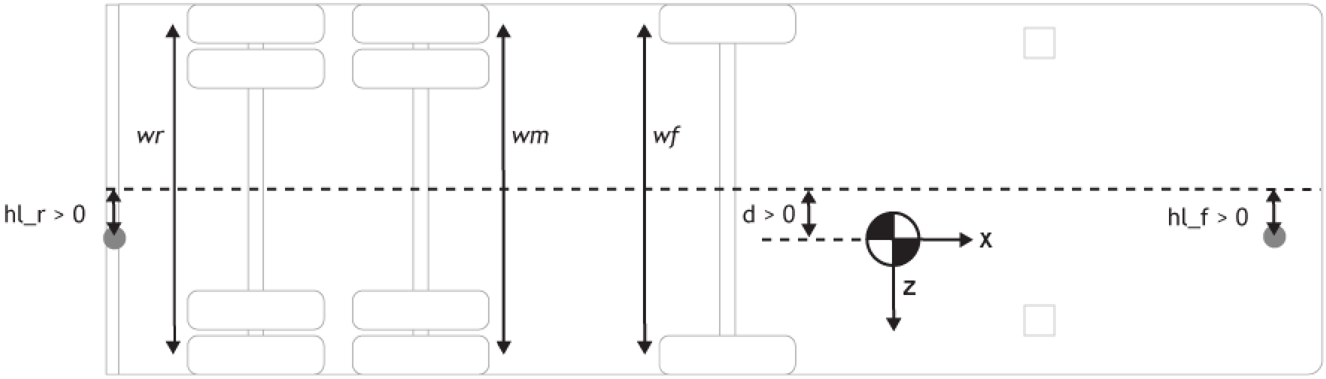


Dependencies

To enable this parameter, set **Vehicle track** to `Dual 3-axle`.

`Rear track width, w_r` — Rear track width
`1.82` (default) | `scalar`

Rear track width, *wr*, in m.



Dependencies

To enable this parameter, set **Vehicle track** to `Dual 2-axle` or `Dual 3-axle`.

`Front axle tire corner stiffness, Cy_f` — Front axle tire stiffness

`12.3` (default) | `scalar`

Front tire corner stiffness, Cy_f, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Middle axle tire corner stiffness, Cy_m` — Middle axle tire stiffness

`11.3` (default) | `scalar`

Middle tire corner stiffness, Cy_m, in N/rad.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Clear **Mapped corner stiffness**.

`Rear axle tire corner stiffness, Cy_r` — Rear axle tire stiffness

`11.3` (default) | `scalar`

Rear tire corner stiffness, Cy_r, in N/rad.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Clear **Mapped corner stiffness**.

`Front tire(s) relaxation length, sigma_f` — Relaxation length

`.1` (default) | `scalar`

Front tire relaxation length, σ_f, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Middle tire(s) relaxation length, sigma_m` — Relaxation length

`.1` (default) | `scalar`

Middle tire relaxation length, σ_m, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Rear tire(s) relaxation length, sigma_r` — Relaxation length
`.1` (default) | `scalar`

Rear tire relaxation length, σ_r, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Front axle slip angle breakpoints, alpha_f_brk` — Breakpoints
`[-.1 .1]` (default) | `vector`

Front axle slip angle breakpoints, α_{fbrk}, in rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Front axle corner data, Cy_f_data` — Breakpoints
`[-9e3 9e3]` (default) | `vector`

Front axle corner data, Cy_{fdata}, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Middle axle slip angle breakpoints, alpha_m_brk` — Breakpoints
`[-.1 .1]` (default) | `vector`

Middle axle slip angle breakpoints, α_{mbrk}, in rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Middle axle corner data, Cy_m_data` — Breakpoints
`[-9e3 9e3]` (default) | `vector`

Middle axle corner data, Cy_{mdata}, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Rear axle slip angle breakpoints, alpha_r_brk` — Breakpoints
`[-.1 .1]` (default) | `vector`

Rear axle slip angle breakpoints, α_{rbrk}, in rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:

   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Rear axle corner data, Cy_r_data` — Data

`[-9e3 9e3]` (default) | `vector`

Rear axle corner data, Cy_{rdata}, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Initial inertial frame lateral displacement, Y_o` — Position

`0` (default) | `scalar`

Initial vehicle CG displacement along the earth-fixed Y-axis, in m.

`Initial lateral velocity, ydot_o` — Velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along the vehicle-fixed y-axis, in m/s.

Yaw

`Yaw polar inertia, Izz` — Inertia

`4000` (default) | `scalar`

Yaw polar inertia, in kg*m^2.

`Initial yaw angle, psi_o` — Psi rotation

`0` (default) | `scalar`

Rotation of the vehicle-fixed frame about earth-fixed Z-axis (yaw), in rad.

`Initial yaw rate, r_o` — Yaw rate

`0` (default) | `scalar`

Vehicle angular velocity about the vehicle-fixed z-axis (yaw rate), in rad/s.

Aerodynamic

`Longitudinal drag area, Af` — Effective vehicle cross-sectional area

`2` (default) | `scalar`

Effective vehicle cross-sectional area, A_f, to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Air drag coefficient

`.3` (default) | `scalar`

Air drag coefficient, C_d. The value is dimensionless.

`Longitudinal lift coefficient, Cl` — Air lift coefficient
`.1` (default) | `scalar`

Air lift coefficient, C_l. The value is dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}. The value is dimensionless.

`Relative wind angle vector, beta_w` — Wind angle
`[0:0.01:0.3]` (default) | `vector`

Relative wind angle vector, β_w, in rad.

`Side force coefficient vector, Cs` — Side force coefficient
`[0:0.03:0.9]` (default) | `vector`

Side force coefficient vector coefficient, C_s. The value is dimensionless.

`Yaw moment coefficient vector, Cym` — Yaw moment drag
`[0:0.01:0.3]` (default) | `vector`

Yaw moment coefficient vector coefficient, C_{ym}. The value is dimensionless.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar`

Environmental absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Temperature
`273` (default) | `scalar`

Environmental absolute temperature, T, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity
`9.81` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

`Nominal friction scaling factor, mu` — Friction scale factor
`1` (default) | `scalar`

Nominal friction scale factor, μ. The value is dimensionless.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **External Friction**.

Simulation

`Longitudinal velocity tolerance, xdot_tol` — Tolerance
`.01` (default) | `scalar`

Longitudinal velocity tolerance, in m/s.

`Nominal normal force, Fznom` — Normal force
`5000` (default) | `scalar`

Nominal normal force, in N.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

`Geometric longitudinal offset from axle plane, longOff` — Longitudinal offset
`0` (default) | `scalar`

Vehicle chassis offset from the axle plane along the vehicle-fixed *x*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric lateral offset from center plane, latOff` — Lateral offset
`0` (default) | `scalar`

Vehicle chassis offset from the center plane along the vehicle-fixed *y*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric vertical offset from axle plane, vertOff` — Vertical offset
`0` (default) | `scalar`

Vehicle chassis offset from the axle plane along the vehicle-fixed *z*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Wrap Euler angles, wrapAng` — Wrap the Euler angles to the interval `[-pi, pi]`
`off` (default) | `on`

Wrap the Euler angles to the interval `[-pi, pi]`. For vehicle maneuvers that might undergo vehicle yaw rotations that are outside of this interval, consider clearing the parameter if you want to:

- Track the total vehicle yaw rotation.
- Avoid discontinuities in the vehicle state estimators.

Version History

Introduced in R2020a

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

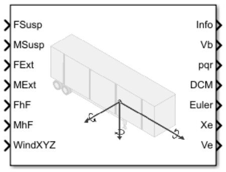
Vehicle Body 3DOF Three Axles | Vehicle Body 3DOF | Trailer Body 6DOF

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"

Trailer Body 6DOF

Trailer body with translational and rotational motion
Library: Vehicle Dynamics Blockset / Vehicle Body



Description

The Trailer Body 6DOF block implements a rigid one-axle, two-axle or three-axle trailer body model that calculates longitudinal, lateral, vertical, pitch, roll, and yaw motion. The block accounts for body mass, inertia, aerodynamic drag, road incline, and weight distribution between the axle hard-point locations due to suspension and external forces and moments.

Use the **Inertial Loads** parameters to analyze the trailer dynamics under different loading conditions. To specify the number of trailer axles, use the **Number of axles** parameter.

To create additional input ports, under **Input signals**, select these block parameters.

Parameter	Input Port	Description
Front hitch forces	`FhF`	Hitch force applied to the body at the front hitch location, FhF_x, FhF_y, and FhF_z, in the vehicle-fixed frame
Front hitch moments	`MhF`	Hitch moment at the front hitch location, MhF_x, MhF_y, and MhF_z, about the vehicle-fixed frame
Rear hitch forces	`FhR`	Hitch force applied to the body at the rear hitch location, FhR_x, FhR_y, and FhR_z, in the vehicle-fixed frame
Rear hitch moments	`MhR`	Hitch moment at the rear hitch location, MhR_x, MhR_y, and MhR_z, about the vehicle-fixed frame

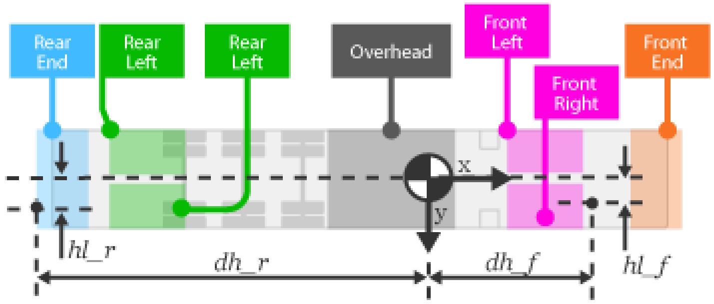
Inertial Loads

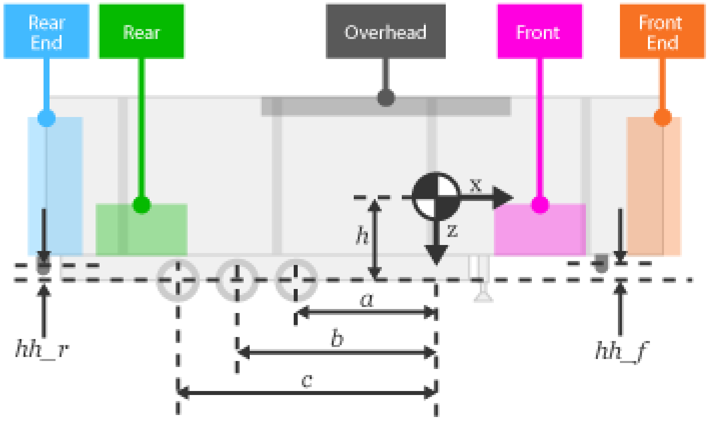
To analyze the vehicle dynamics under different loading conditions, use the **Inertial Loads** parameters. You can specify these loads:

- Front end
- Overhead
- Front left and front right
- Rear left and rear right
- Rear end

For each of the loads, you can specify the mass, location, and inertia.

The illustrations provide the load locations and vehicle parameter dimensions. The table provides the corresponding location parameter sign settings.





This table summarizes the parameter settings that specify the load locations indicated by the dots. For the location, the block uses this distance vector:

- Front axle to load, along the vehicle-fixed *x*-axis
- Vehicle centerline to load, along the vehicle-fixed *y*-axis
- Front axle to load, along the vehicle-fixed *z*-axis

Load	Parameter	Example Location
Front end	**Distance vector from front axle, z1R**	• `z1R(1,1)<0` — Forward of the front axle • `z1R(1,2)>0` — Right of the vehicle centerline • `z1R(1,3)>0` — Above the front axle suspension hardpoint
Overhead	**Distance vector from front axle, z2R**	• `z2R(1,1)>0` — Rear of the front axle • `z2R(1,2)<0` — Left of the vehicle centerline • `z2R(1,3)>0` — Above the front axle suspension hardpoint
Front left	**Distance vector from front axle, z3R**	• `z3R(1,1)>0` — Rear of the front axle • `z3R(1,2)<0` — Left of the vehicle centerline • `z3R(1,3)>0` — Above the front axle suspension hardpoint

Load	Parameter	Example Location
Front right	**Distance vector from front axle, z4R**	• `z4R(1,1)>0` — Rear of the front axle • `z4R(1,2)>0` — Right of the vehicle centerline • `z4R(1,3)>0` — Above the front axle suspension hardpoint
Rear left	**Distance vector from front axle, z5R**	• `z5R(1,1)>0` — Rear of the front axle • `z5R(1,2)<0` — Left of the vehicle centerline • `z5R(1,3)>0` — Above the front axle suspension hardpoint
Rear right	**Distance vector from front axle, z6R**	• `z6R(1,1)>0` — Rear of the front axle • `z6R(1,2)>0` — Right of the vehicle centerline • `z6R(1,3)>0` — Above the front axle suspension hardpoint
Rear end	**Distance vector from front axle, z7R**	• `z7R(1,1)>0` — Rear of the front axle • `z7R(1,2)>0` — Right of the vehicle centerline • `z7R(1,3)>0` — Above the front axle suspension hardpoint

Equations of Motion

To determine the vehicle motion, the block implements calculations for the rigid body vehicle dynamics, wind drag, inertial loads, and coordinate transformations. The body-fixed and vehicle-fixed coordinate systems are the same.

The block considers the rotation of a body-fixed coordinate frame about a flat earth-fixed inertial reference frame. The origin of the body-fixed coordinate frame is the vehicle center of gravity of the body.

The block uses this equation to calculate the translational motion of the body-fixed coordinate frame, where the applied forces $[F_x\ F_y\ F_z]^T$ are in the body-fixed frame, and the mass of the body, m, is assumed to be constant.

$$\bar{F}_b = \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = m\left(\dot{\bar{V}}_b + \bar{\omega} \times \bar{V}_b\right)$$

$$\overline{M}_b = \begin{bmatrix} L \\ M \\ N \end{bmatrix} = I\dot{\bar{\omega}} + \bar{\omega} \times (I\bar{\omega})$$

$$I = \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix}$$

To determine the relationship between the body-fixed angular velocity vector, $[p\ q\ r]^T$, and the rate of change of the Euler angles, $\left[\dot{\phi}\ \ \dot{\theta}\ \ \dot{\psi}\right]^T$, the block resolves the Euler rates into the body-fixed frame.

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \dot{\phi} \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} 0 \\ \dot{\theta} \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \dot{\psi} \end{bmatrix} \equiv J^{-1} \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

Inverting J gives the required relationship to determine the Euler rate vector.

$$\begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = J \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} 1 & (\sin\phi\tan\theta) & (\cos\phi\tan\theta) \\ 0 & \cos\phi & -\sin\phi \\ 0 & \dfrac{\sin\phi}{\cos\theta} & \dfrac{\cos\phi}{\cos\theta} \end{bmatrix} \begin{bmatrix} p \\ q \\ r \end{bmatrix}$$

The applied forces and moments are the sum of the drag, gravitational, external, and suspension forces.

$$\bar{F}_b = \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \begin{bmatrix} F_{d_x} \\ F_{d_y} \\ F_{d_z} \end{bmatrix} + \begin{bmatrix} F_{g_x} \\ F_{g_y} \\ F_{g_z} \end{bmatrix} + \begin{bmatrix} F_{ext_x} \\ F_{ext_y} \\ F_{ext_z} \end{bmatrix} + \begin{bmatrix} F_{FL_x} \\ F_{FL_y} \\ F_{FL_z} \end{bmatrix} + \begin{bmatrix} F_{FR_x} \\ F_{FR_y} \\ F_{FR_z} \end{bmatrix} + \begin{bmatrix} F_{ML_x} \\ F_{ML_y} \\ F_{ML_z} \end{bmatrix} + \begin{bmatrix} F_{MR_x} \\ F_{MR_y} \\ F_{MR_z} \end{bmatrix} + \begin{bmatrix} F_{RL_x} \\ F_{RL_y} \\ F_{RL_z} \end{bmatrix} + \begin{bmatrix} F_{RR_x} \\ F_{RR_y} \\ F_{RR_z} \end{bmatrix}$$

$$\overline{M}_b = \begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} M_{d_x} \\ M_{d_y} \\ M_{d_z} \end{bmatrix} + \begin{bmatrix} M_{ext_x} \\ M_{ext_y} \\ M_{ext_z} \end{bmatrix} + \begin{bmatrix} M_{FL_x} \\ M_{FL_y} \\ M_{FL_z} \end{bmatrix} + \begin{bmatrix} M_{FR_x} \\ M_{FR_y} \\ M_{FR_z} \end{bmatrix} + \begin{bmatrix} M_{ML_x} \\ M_{ML_y} \\ M_{ML_z} \end{bmatrix} + \begin{bmatrix} M_{MR_x} \\ M_{MR_y} \\ M_{MR_z} \end{bmatrix} + \begin{bmatrix} M_{RL_x} \\ M_{RL_y} \\ M_{RL_z} \end{bmatrix} + \begin{bmatrix} M_{RR_x} \\ M_{RR_y} \\ M_{RR_z} \end{bmatrix} + \overline{M}_F$$

Calculation	**Implementation**
Load masses and inertias	The block uses the parallel axis theorem to resolve the individual load masses and inertias with the vehicle mass and inertia. $J_{ij} = I_{ij} + m(\lvert R\rvert^2\delta_{ij} - R_iR_j)$
Gravitational forces, F_g	The block uses the direction cosine matrix (DCM) to transform the gravitational vector in the inertial-fixed frame to the body-fixed frame.

Calculation	Implementation
Drag forces, F_d, and moments, M_d	To determine a relative airspeed, the block subtracts the wind speed from the vehicle center of mass (CM) velocity. Using the relative airspeed, the block determines the drag forces. $\overline{w} = \sqrt{(\dot{x} - w_x)^2 + (\dot{x} - w_x)^2 + (w_z)^2}$ $F_{dx} = -\frac{1}{2TR} C_d A_f P_{abs} ({}^{\overline{w}}$ $F_{dy} = -\frac{1}{2TR} C_s A_f P_{abs} ({}^{\overline{w}}$ $F_{dz} = -\frac{1}{2TR} C_l A_f P_{abs} ({}^{\overline{w}}$ Using the relative airspeed, the block determines the drag moments. $M_{dr} = -\frac{1}{2TR} C_{rm} A_f P_{abs} ({}^{\overline{w}}(a + c)$ $M_{dp} = -\frac{1}{2TR} C_{pm} A_f P_{abs} ({}^{\overline{w}}(a + c)$ $M_{dy} = -\frac{1}{2TR} C_{ym} A_f P_{abs} ({}^{\overline{w}}(a + c)$
External forces, F_{in}, and moments, M_{in}	The external forces and moments are input via ports **FExt** and **MExt**.
Suspension forces and moments	The block assumes that the suspension forces and moments act on these hardpoint locations: • F_{FL}, M_{FL} — Front left • F_{FR}, M_{FR} — Front right • F_{ML}, M_{ML} — Middle left • F_{MR}, M_{MR} — Middle right • F_{RL}, M_{RL} — Rear left • F_{RR}, M_{RR} — Rear right

The equations use these variables.

$x, \dot{x}, \ddot{x}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *x*-axis
$y, \dot{y}, \ddot{y}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *y*-axis
$z, \dot{z}, \ddot{z}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *z*-axis
φ	Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)
θ	Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)
ψ	Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)

F_{FLx}, F_{FLy}, F_{FLz}	Suspension forces applied to the front left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{FRx}, F_{FRy}, F_{FRz}	Suspension forces applied to the front right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{MLx}, F_{MLy}, F_{MLz}	Suspension forces applied to the middle left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{MRx}, F_{MRy}, F_{MRz}	Suspension forces applied to the middle right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{RLx}, F_{RLy}, F_{RLz}	Suspension forces applied to the rear left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{RRx}, F_{RRy}, F_{RRz}	Suspension forces applied to the rear right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{FLx}, M_{FLy}, M_{FLz}	Suspension moment applied to the front left hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{FRx}, M_{FRy}, M_{FRz}	Suspension moment applied to the front right hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{MLx}, M_{MLy}, M_{MLz}	Suspension moment applied to the middle left hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{MRx}, M_{MRy}, M_{MRz}	Suspension moment applied to the middle right hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{RLx}, M_{RLy}, M_{RLz}	Suspension moment applied to the rear left hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{RRx}, M_{RRy}, M_{RRz}	Suspension moment applied to the rear right hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{extx}, F_{exty}, F_{extz}	External forces applied to the vehicle CM along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{dx}, F_{dy}, F_{dz}	Drag forces applied to the vehicle CM along the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{extx}, M_{exty}, M_{extz}	External moment about the vehicle CM about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{dx}, M_{dy}, M_{dz}	Drag moment about the vehicle CM about the vehicle-fixed *x*-, *y*-, and *z*-axes
I	Vehicle body moments of inertia
a, b, c	Distance of the front, middle, and rear axles, respectively, from the normal projection point of the vehicle CM onto the common axle plane
h	Height of the vehicle CM above the axle plane
d	Lateral distance from the geometric centerline to the center of mass along the vehicle-fixed *y*-axis
hh_f, *hh_r*	Height of the front and rear hitches, respectively, above the axle plane along the vehicle-fixed *z*-axis
dh_f, *dh_r*	Longitudinal distance of the front and rear hitches, respectively, from the normal projection point of the vehicle CM onto the common axle plane
hl_f, *hl_r*	Lateral distance from center of mass to the front and rear hitches, respectively, along the vehicle-fixed *y*-axis
w_F, w_M, w_R	Front, middle, and rear track widths, respectively

C_d	Air drag coefficient acting along the vehicle-fixed *x*-axis
C_s	Air drag coefficient acting along the vehicle-fixed *y*-axis
C_l	Air drag coefficient acting along the vehicle-fixed *z*-axis
C_{rm}	Air drag roll moment acting about the vehicle-fixed *x*-axis
C_{pm}	Air drag pitch moment acting about the vehicle-fixed *y*-axis
C_{ym}	Air drag yaw moment acting about the vehicle-fixed *z*-axis
A_f	Frontal area
R	Atmospheric specific gas constant
T	Environmental air temperature
P_{abs}	Environmental absolute pressure
w_x, w_y, w_z	Wind speed along the vehicle-fixed *x*-, *y*-, and *z*-axes
W_x, W_y, W_z	Wind speed along inertial *X*-, *Y*-, and *Z*-axes

Ports

Input

`FSusp` — Suspension forces on trailer

`3-by-4` array (default) | `3-by-2` array | `3-by-6` array

Suspension longitudinal, lateral, and vertical suspension forces, `FSusp`, applied to the trailer at the hardpoint location, in N, specified as a `3-by-2`, `3-by-4`, or `3-by-6` array, depending on the **Number of axles** parameter.

Number of axles Setting	Variable	Signal Dimension
1	$FSusp = \begin{bmatrix} F_{FLx} & F_{FRx} \\ F_{FLy} & F_{FRy} \\ F_{FLz} & F_{FRz} \end{bmatrix}$	Array – `3-by-2`
2	$FSusp = \begin{bmatrix} F_{FLx} & F_{FRx} & F_{RLx} & F_{RRx} \\ F_{FLy} & F_{FRy} & F_{RLy} & F_{RRy} \\ F_{FLz} & F_{FRz} & F_{RLz} & F_{RRz} \end{bmatrix}$	Array – `3-by-4`
3	$FSusp =$ $\begin{bmatrix} F_{FLx} & F_{FRx} & F_{MLx} & F_{MRx} & F_{RLx} & F_{RRx} \\ F_{FLy} & F_{FRy} & F_{MLy} & F_{MRy} & F_{RLy} & F_{RRy} \\ F_{FLz} & F_{FRz} & F_{MLz} & F_{MRz} & F_{RLz} & F_{RRz} \end{bmatrix}$	Array – `3-by-6`

The arrays use these variables.

F_{FLx}, F_{FLy}, F_{FLz}	Suspension forces applied to front left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes

F_{FRx}, F_{FRy}, F_{FRz}	Suspension forces applied to front right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{MLx}, F_{MLy}, F_{MLz}	Suspension forces applied to middle left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{MRx}, F_{MRy}, F_{MRz}	Suspension forces applied to middle right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{RLx}, F_{RLy}, F_{RLz}	Suspension forces applied to rear left hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes
F_{RRx}, F_{RRy}, F_{RRz}	Suspension forces applied to rear right hardpoint along the vehicle-fixed *x*-, *y*-, and *z*-axes

`MSusp` — Suspension moments on trailer

`3-by-4 array` (default) | `3-by-2 array` | `3-by-6 array`

Suspension longitudinal, lateral, and vertical suspension moments, `MSusp`, applied about the vehicle at the hardpoint location, in N·m, specified as a `3-by-2`, `3-by-4`, or `3-by-6` array, depending on the **Number of axles** parameter.

Number of axles Setting	Variable	Signal Dimension
1	$MSusp = \begin{bmatrix} M_{FLx} & M_{FRx} \\ M_{FLy} & M_{FRy} \\ M_{FLz} & M_{FRz} \end{bmatrix}$	Array – `3-by-2`
2	$MSusp = \begin{bmatrix} M_{FLx} & M_{FRx} & M_{RLx} & M_{RRx} \\ M_{FLy} & M_{FRy} & M_{RLy} & M_{RRy} \\ M_{FLz} & M_{FRz} & M_{RLz} & M_{RRz} \end{bmatrix}$	Array – `3-by-4`
3	$MSusp =$ $\begin{bmatrix} M_{FLx} & M_{FRx} & M_{MLx} & M_{MRx} & M_{RLx} & M_{RRx} \\ M_{FLy} & M_{FRz} & M_{MLy} & M_{MRy} & M_{RLy} & M_{RRy} \\ M_{FLz} & M_{FRz} & M_{MLz} & M_{MRz} & M_{RLz} & M_{RRz} \end{bmatrix}$	Array – `3-by-6`

The arrays use these variables.

M_{FLx}, M_{FLy}, M_{FLz}	Suspension moment applied to front left hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{FRx}, M_{FRy}, M_{FRz}	Suspension moment applied to front right hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{MLx}, M_{MLy}, M_{MLz}	Suspension moment applied to middle left hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{MRx}, M_{MRy}, M_{MRz}	Suspension moment applied to middle right hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes

M_{RLx}, M_{RLy}, M_{RLz}	Suspension moment applied to rear left hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes
M_{RRx}, M_{RRy}, M_{RRz}	Suspension moment applied to rear right hardpoint about the vehicle-fixed *x*-, *y*-, and *z*-axes

`FExt` — External forces acting on vehicle

`vector`

External forces on the vehicle, in N, specified as a `1-by-3` or `3-by-1` vector.

$$\text{FExt} = F_{ext} = \left[F_{ext_x}\ F_{ext_y}\ F_{ext_z}\right] or \begin{bmatrix} F_{ext_x} \\ F_{ext_y} \\ F_{ext_z} \end{bmatrix}$$

Array Element	Force Axis
`FExt(1,1)`	Vehicle-fixed *x*-axis (longitudinal)
`FExt(1,2)` or `FExt(2,1)`	Vehicle-fixed *y*-axis (lateral)
`FExt(1,3)` or `FExt(3,1)`	Vehicle-fixed *z*-axis (vertical)

`MExt` — External moments acting on vehicle

`vector`

External moments acting on the vehicle, in N·m, specified as a `1-by-3` or `3-by-1` vector.

$$\text{MExt} = M_{ext} = \left[M_{ext_x}\ M_{ext_y}\ M_{ext_z}\right] or \begin{bmatrix} M_{ext_x} \\ M_{ext_y} \\ M_{ext_z} \end{bmatrix}$$

Array Element	Force Axis
`MExt(1,1)`	Vehicle-fixed *x*-axis (longitudinal)
`MExt(1,2)` or `MExt(2,1)`	Vehicle-fixed *y*-axis (lateral)
`MExt(1,3)` or `MExt(3,1)`	Vehicle-fixed *z*-axis (vertical)

`FhF` — Front hitch force on the body

`array`

Hitch force applied to the body at the front hitch location, FhF_x, FhF_y, FhF_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Front hitch forces**.

`MhF` — Front hitch moment about body

`array`

Hitch moment at the front hitch location, MhF_x, MhF_y, MhF_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Front hitch moments**.

`FhR` — Rear hitch force on the body

`array`

Hitch force applied to the body at the rear hitch location, FhR_x, FhR_y, FhR_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Rear hitch forces**.

`MhR` — Rear hitch moment about body

`array`

Hitch moment at the rear hitch location, MhR_x, MhR_y, MhR_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Rear hitch moments**.

`WindXYZ` — Wind speed

`array`

Wind speed, W_x, W_y, W_z along inertial *X*-, *Y*-, and *Z*-axes, in m/s, specified as a `1-by-3` or `3-by-1` array.

`AirTemp` — Ambient air temperature

`scalar`

Ambient air temperature, T_{air}, in K, specified as a scalar.

Dependencies

To enable this port, under **Environment**, select **Air temperature**.

Output

`Info` — Trailer body information

bus

Trailer body information, returned as a bug signal containing the following values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CM displacement along the earth-fixed *X*-axis	Computed	m

Signal					Description	Value	Units
			Y		Vehicle CM displacement along the earth-fixed *Y*-axis	Computed	m
			Z		Vehicle CM displacement along the earth-fixed *Z*-axis	Computed	m
		Vel	Xdot		Vehicle CM velocity along the earth-fixed *X*-axis	Computed	m/s
			Ydot		Vehicle CM velocity along the earth-fixed *Y*-axis	Computed	m/s
			Zdot		Vehicle CM velocity along the earth-fixed *Z*-axis	Computed	m/s
		Ang	phi		Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	Computed	rad
			theta		Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	Computed	rad
			psi		Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad
	FrntAxl	Lft	Disp	X	Front left axle displacement along the earth-fixed *X*-axis	Computed	m
				Y	Front left axle displacement along the earth-fixed *Y*-axis	Computed	m
				Z	Front left axle displacement along the earth-fixed *Z*-axis	Computed	m
			Vel	Xdot	Front left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				Ydot	Front left axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				Zdot	Front left axle velocity along the earth-fixed *Z*-axis	Computed	m/s
		Rght	Disp	X	Front right axle displacement along the earth-fixed *X*-axis	Computed	m

Signal					Description	Value	Units
				`Y`	Front right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front right axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Front right axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`MidlAxl`	`Lft`	`Disp`	`X`	Middle left axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Middle left axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Middle left axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Middle left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Middle left axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Middle left axle velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Rght`	`Disp`	`X`	Middle right axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Middle right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Middle right axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Middle right axle velocity along the earth-fixed *X*-axis	Computed	m/s

Signal					**Description**	**Value**	**Units**
				`Ydot`	Middle right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Middle right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`RearAxl`	`Lft`	`Disp`	`X`	Rear left axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear left axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear left axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Rear left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear left axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear left axle velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Rght`	`Disp`	`X`	Rear right axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear right axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Rear right axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`HitchF`	`Disp`	`X`		Trailer front hitch offset from the axle plane along the earth-fixed *X*-axis	Computed	m

Signal				Description	Value	Units
			Y	Trailer front hitch offset from the center plane along the earth-fixed *Y*-axis	Computed	m
			Z	Trailer front hitch offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		Vel	Xdot	Trailer front hitch offset velocity along the earth-fixed *X*-axis	Computed	m/s
			Ydot	Trailer front hitch offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			Zdot	Trailer front hitch offset velocity along the earth-fixed *Z*-axis	Computed	m/s
	HitchR	Disp	X	Trailer rear hitch offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			Y	Trailer rear hitch offset from the center plane along the earth-fixed *Y*-axis	Computed	m
			Z	Trailer rear hitch offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		Vel	Xdot	Hitch velocity along the earth-fixed *X*-axis	Computed	m/s
			Ydot	Hitch velocity along the earth-fixed *Y*-axis	Computed	m/s
			Zdot	Hitch velocity along the earth-fixed *Z*-axis	Computed	m/s
	Geom	Disp	X	Trailer offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			Y	Trailer offset from the center plane along the earth-fixed *Y*-axis	Computed	m
			Z	Trailer offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		Vel	Xdot	Trailer offset velocity along the earth-fixed *X*-axis	Computed	m/s

Signal				Description	Value	Units
			`Ydot`	Trailer offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Trailer offset velocity along the earth-fixed *Z*-axis	Computed	m/s
`BdyFrm`	`Cg`	`Vel`	`xdot`	Vehicle CM velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle CM velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle CM velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	Computed	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	Computed	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s
		`Acc`	`ax`	Vehicle CM acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CM acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CM acceleration along the vehicle-fixed *z*-axis	Computed	gn
			`xddot`	Vehicle CM acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CM acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2
			`zddot`	Vehicle CM acceleration along the vehicle-fixed *z*-axis	Computed	m/s^2
		`DCM`	Direction cosine matrix		Computed	rad
	`Forces`	`Body`	`Fx`	Net force on the vehicle CM along the vehicle-fixed *x*-axis	Computed	N

Signal					Description	Value	Units
			`Fy`		Net force on the vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Net force on the vehicle CM along the vehicle-fixed *z*-axis	Computed	N
		`Ext`	`Fx`		External force on the vehicle CM along the vehicle-fixed *x*-axis	Input	N
			`Fy`		External force on the vehicle CM along the vehicle-fixed *x*-axis	Input	N
			`Fz`		External force on the vehicle CM along the vehicle-fixed *x*-axis	Input	N
		`FrntAxl`	`Lft`	`Fx`	Front left axle velocity along the earth-fixed *Y*-axis	Computed	N
				`Fy`	Lateral force on the left side of the front axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the left side of the front axle along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right side of the front axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right side of the front axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right side of the front axle along the vehicle-fixed *z*-axis	Computed	N
		`MidlAxl`	`Lft`	`Fx`	Longitudinal force on the left side of the middle axle along the vehicle-fixed *x*-axis	Computed	N

Signal					Description	Value	Units
				`Fy`	Longitudinal force on the left side of the middle axle along the vehicle-fixed *x*-axis	Computed	N
				`Fz`	Normal force on the left side of the middle axle along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right side of the middle axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right side of the middle axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right side of the middle axle along the vehicle-fixed *z*-axis	Computed	N
		`RearAxl`	`Lft`	`Fx`	Longitudinal force on the left side of the rear axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the left side of the rear axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the left side of the rear axle along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right side of the rear axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right side of the rear axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right side of the rear axle along the vehicle-fixed *z*-axis	Computed	N
		`HitchF`	`Fx`		Hitch front force applied to the body at the hitch location along the vehicle-fixed *x*-axis	Computed	N

Signal						Description	Value	Units
			`Fy`			Hitch front force applied to the body at the hitch location along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Hitch front force applied to the body at the hitch location along the vehicle-fixed *z*-axis	Computed	N
		`HitchR`	`Fx`			Hitch rear force applied to the body at the hitch location along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Hitch rear force applied to the body at the hitch location along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Hitch rear force applied to the body at the hitch location along the vehicle-fixed *z*-axis	Computed	N
		`Tires`	`FrntTires`	`Lft`	`Fx`	Front left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Front right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front right tire force along the vehicle-fixed *z*-axis	Computed	N
			`MidlTires`	`Lft`	`Fx`	Middle left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Middle left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Middle left tire force along the vehicle-fixed *z*-axis	Computed	N

Signal						Description	Value	Units
				`Rght`	`Fx`	Middle right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Middle right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Middle right tire force along the vehicle-fixed *z*-axis	Computed	N
			`RearTires`	`Lft`	`Fx`	Rear left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Rear right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear right tire force along the vehicle-fixed *z*-axis	Computed	N
		`Drag`	`Fx`			Drag force on the vehicle CM along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Drag force on the vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Drag force on the vehicle CM along the vehicle-fixed *z*-axis	Computed	N
		`Grvty`	`Fx`			Gravity force on the vehicle CM along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Gravity force on the vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Gravity force on the vehicle CM along the vehicle-fixed *z*-axis	Computed	N
	`Moments`	`Body`	`Mx`			Body moment on the vehicle CM about the vehicle-fixed *x*-axis	Computed	N·m

Signal					Description	Value	Units
			My		Body moment on the vehicle CM about the vehicle-fixed *y*-axis	Computed	N·m
			Mz		Body moment on the vehicle CM about the vehicle-fixed *z*-axis	Computed	N·m
		Drag	Mx		Drag moment on the vehicle CM about the vehicle-fixed *x*-axis	Computed	N·m
			My		Drag moment on the vehicle CM about the vehicle-fixed *y*-axis	Computed	N·m
			Mz		Drag moment on the vehicle CM about the vehicle-fixed *z*-axis	Computed	N·m
		Ext	Mx		External moment on the vehicle CG about the vehicle-fixed *x*-axis	Computed	N·m
			My		External moment on the vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz		External moment on the vehicle CG about the vehicle-fixed *z*-axis	Computed	N·m
		HitchF	Mx		Hitch moment at the front hitch location about vehicle-fixed *x*-axis	Computed	N·m
			My		Hitch moment at the front hitch location about vehicle-fixed *y*-axis	Computed	N·m
			Mz		Hitch moment at the front hitch location about vehicle-fixed *z*-axis	Computed	N·m
		HitchR	Mx		Hitch moment at the rear hitch location about vehicle-fixed *x*-axis	Computed	N·m
			My		Hitch moment at the rear hitch location about vehicle-fixed *y*-axis	Computed	N·m
			Mz		Hitch moment at the rear hitch location about vehicle-fixed *z*-axis	Computed	N·m
	FrntAxl	Lft	Disp	x	Front left axle displacement along the vehicle-fixed *x*-axis	Computed	m

Signal					Description	Value	Units
				`y`	Front left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Rght`	`Disp`	`x`	Front right axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Front right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`MidlAxl`	`Lft`	`Disp`	`x`	Middle left axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Middle left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Middle left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Middle left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal					Description	Value	Units
				`ydot`	Middle left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Middle left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Rght`	`Disp`	`x`	Middle right axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Middle right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Middle right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Middle right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Middle right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Middle right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`RearAxl`	`Lft`	`Disp`	`x`	Rear left axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Rght`	`Disp`	`x`	Rear right axle displacement along the vehicle-fixed *x*-axis	Computed	m

Signal					**Description**	**Value**	**Units**
				`y`	Rear right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`HitchF`	`Disp`		`x`	Front hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	
				`y`	Front hitch offset from center plane along the vehicle-fixed *y*-axis	Input	
				`z`	Front hitch offset from axle plane along the earth-fixed *z*-axis	Input	
		`Vel`		`xdot`	Front hitch offset velocity along the vehicle-fixed *x*-axis	Computed	
				`ydot`	Front hitch offset velocity along the vehicle-fixed *y*-axis	Computed	
				`zdot`	Front hitch offset velocity along the vehicle-fixed *z*-axis	`0`	
	`HitchR`	`Disp`		`x`	Rear hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	m
				`y`	Rear hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
				`z`	Rear hitch offset from axle plane along the earth-fixed *z*-axis	Input	m
		`Vel`		`xdot`	Rear hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal				**Description**	**Value**	**Units**
			`ydot`	Rear hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Rear hitch offset velocity along the vehicle-fixed *z*-axis	`0`	m/s
	`Pwr`	`PwrExt`		Applied external power	Computed	W
		`Drag`		Power loss due to drag	Computed	W
	`Geom`	`Disp`	`x`	Trailer offset from axle plane along the vehicle-fixed *x*-axis	Input	m
			`y`	Trailer offset from center plane along the vehicle-fixed *y*-axis	Input	m
			`z`	Trailer offset from axle plane along the vehicle-fixed *z*-axis	Input	m
		`Vel`	`xdot`	Trailer chassis offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Trailer chassis offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Trailer chassis offset velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad

`Vb` — Vehicle velocity along vehicle-fixed frame
`vector`

Vehicle CM velocity along the vehicle-fixed *x*-, *y*-, *z*-axes, respectively, in m/s, returned as a vector.

`pqr` — Vehicle angular velocity about vehicle-fixed frame
`vector`

Vehicle CM angular velocity about the vehicle-fixed *x*- (roll rate), *y*- (pitch rate), *z*-axes (yaw rate), respectively, in rad/s, returned as a vector.

`DCM` — Direction cosine matrix
`array`

Direction cosine matrix, in rad, returned as an array.

`Euler` — Euler angles
`array`

Euler angles, φ, θ, and ψ, respectively, in rad, returned as an array.

Xe — Vehicle position in inertial reference frame
`vector`

Vehicle CM position along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively, in m, returned as a vector.

Ve — Vehicle velocity in inertial reference frame
`vector`

Vehicle CM velocity along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively, in m/s, returned as a vector.

Parameters

Block Options

`Number of axles` — Create hitch force input port
2 (default) | 1 | 3

Specify the number of axles on the trailer.

Input Signals

`Front hitch forces` — FhF input port
on (default) | `off`

Select to create input port `Fh`.

`Front hitch moments` — MhF input port
on (default) | `off`

Select to create input port `Mh`.

`Rear hitch forces` — FhR input port
`off` (default) | on

Select to create input port `Fh`.

`Rear hitch moments` — MhR input port
`off` (default) | on

Select to create input port `Mh`.

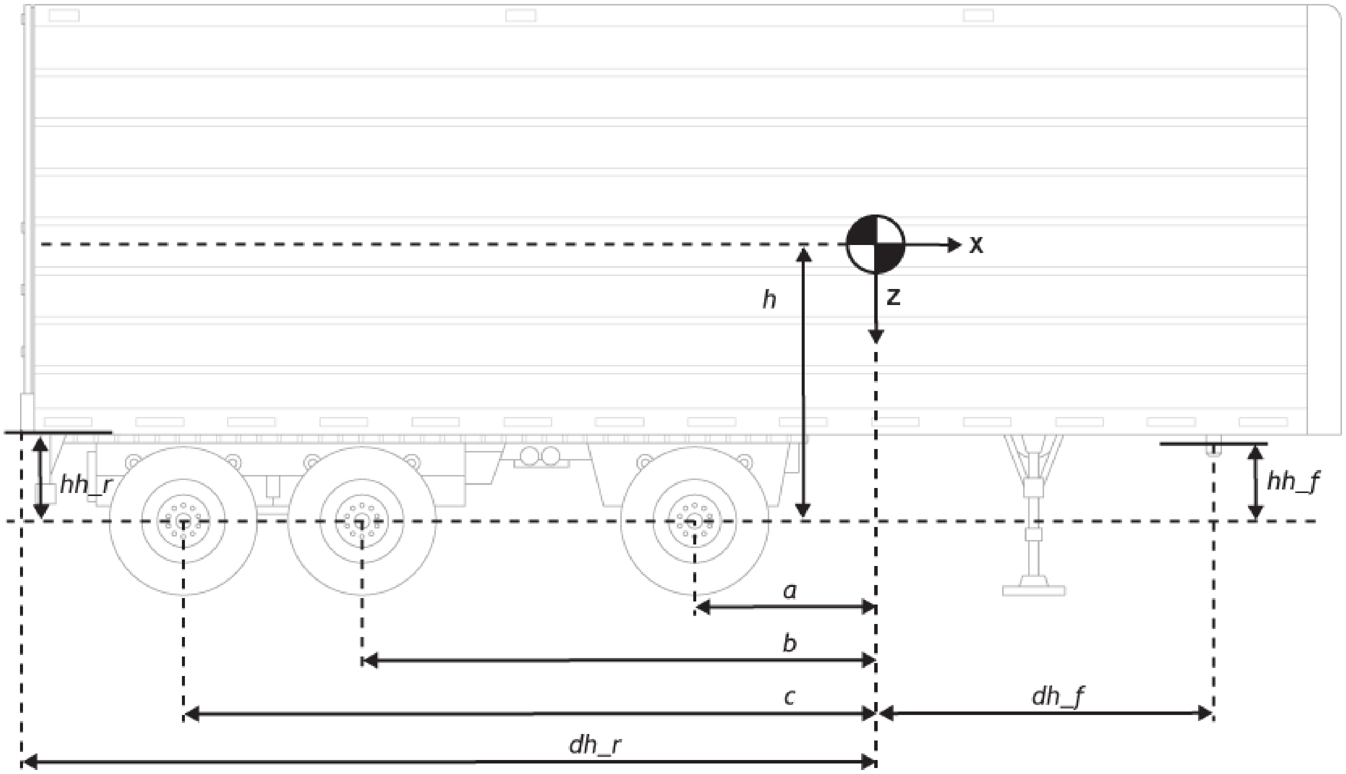
Chassis

`Vehicle mass, m` — Mass
`2000` (default) | `scalar`

Vehicle mass, *m*, in kg.

`Longitudinal distance from center of mass to front axle, a` — Distance from center of mass to front axle
`1.4` (default) | `scalar`

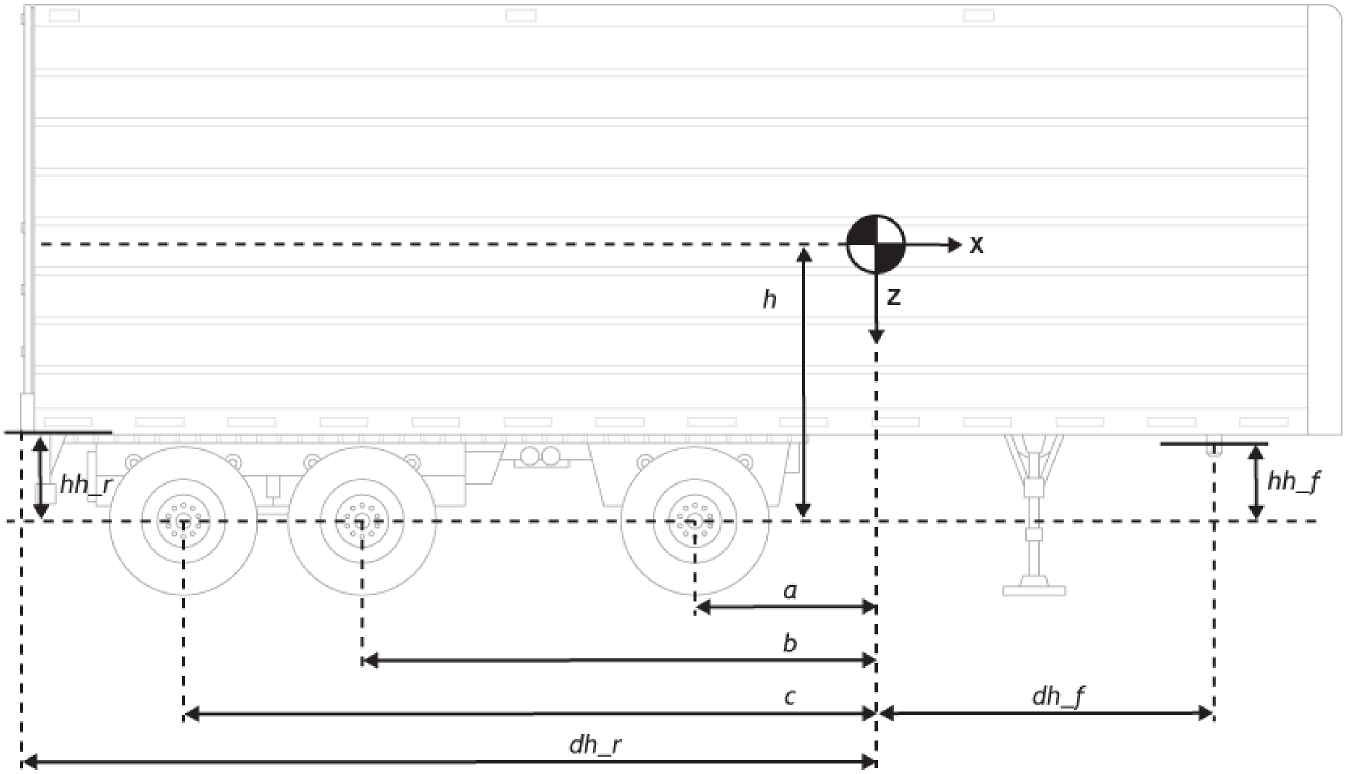
Distance from the vehicle CM to the front axle, *a*, in m.



`Longitudinal distance from center of mass to middle axle, b` — Distance from center of mass to middle axle

`1.6` (default) | `scalar`

Distance from the vehicle CM to the middle axle, *b*, in m.

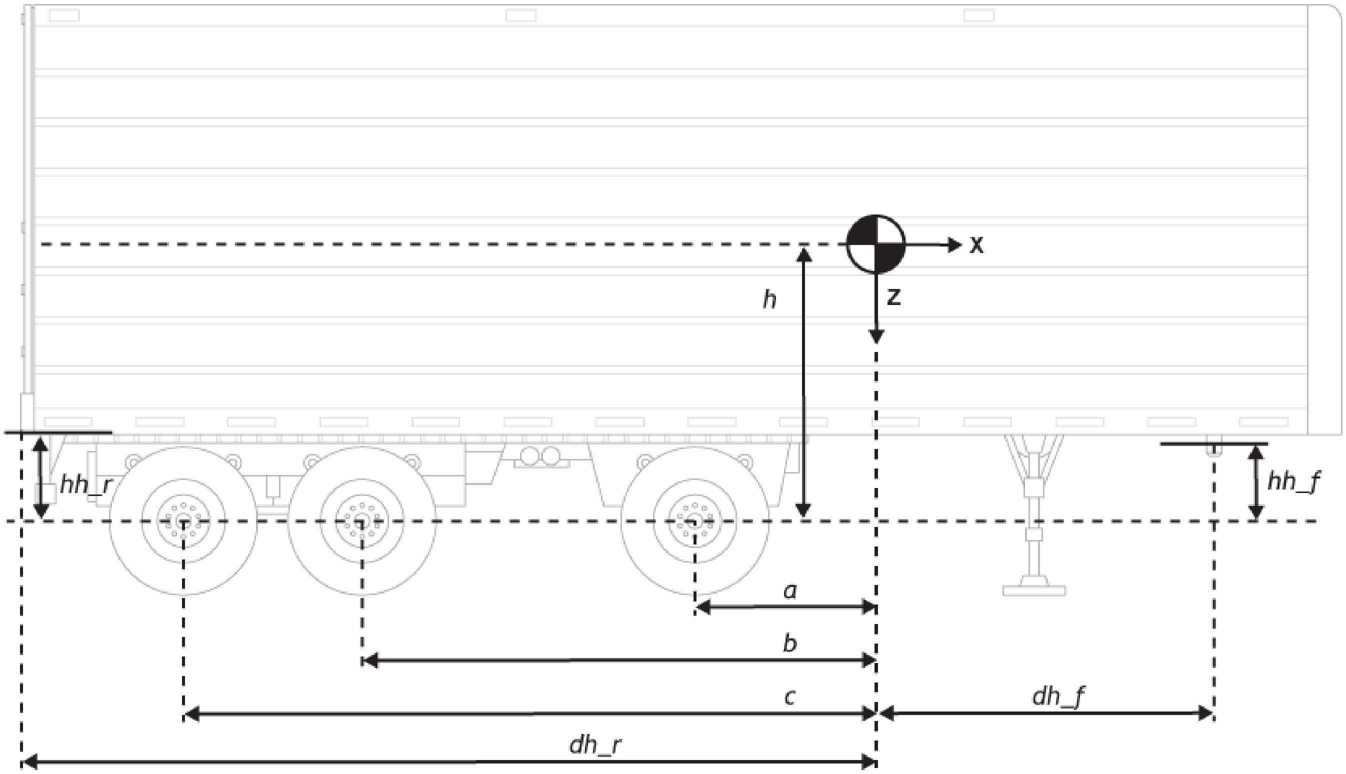


Dependencies

To enable this parameter, set **Number of axles** to 3.

`Longitudinal distance from center of mass to rear axle, c` — Distance from center of mass to rear axle
`1.9` (default) | `scalar`

Distance from the vehicle CM to the rear axle, *c*, in m.



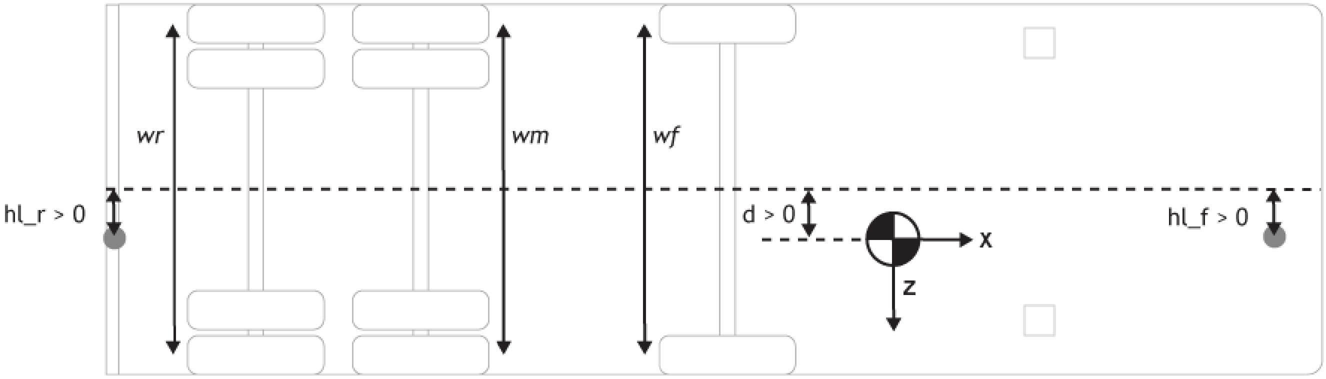
Dependencies

To enable this parameter, set **Number of axles** to 2 or 3.

`Lateral distance from geometric centerline to center of mass, d` — Distance from geometric centerline to center of mass

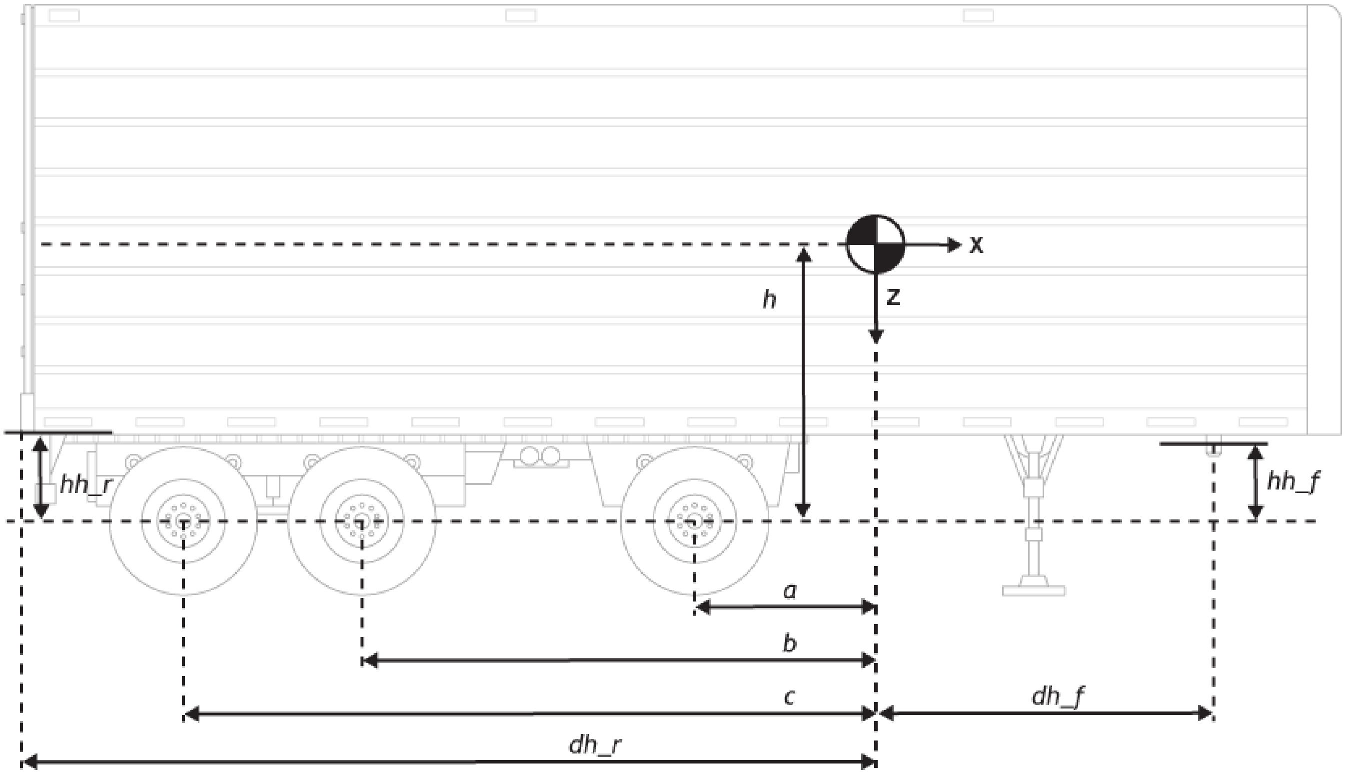
`0` (default) | `scalar`

Lateral distance from the geometric centerline to the CM, *d*, in m, along the vehicle-fixed *y*-axis. Positive values indicate that the vehicle CM is to the right of the geometric centerline. Negative values indicate that the vehicle CM is to the left of the geometric centerline.



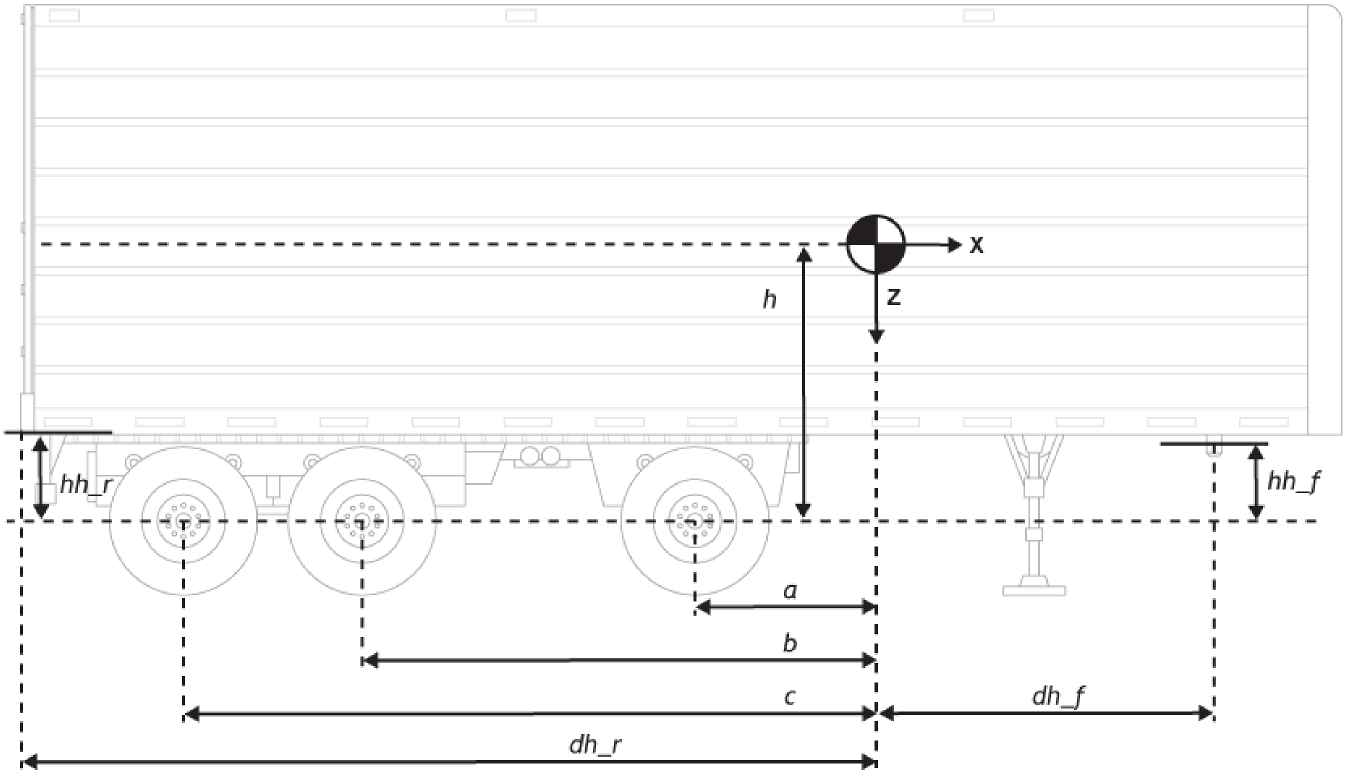
`Vertical distance from center of mass to axle plane, h` — Distance from center of mass to axle plane
`.35` (default) | `scalar`

Vertical distance from the vehicle CM to the axle plane, *h*, in m.



`Longitudinal distance from center of mass to front hitch, dh_f` — Longitudinal distance from CM to hitch
1 (default) | `scalar`

Longitudinal distance from center of mass to front hitch, *dh_f*, in m.



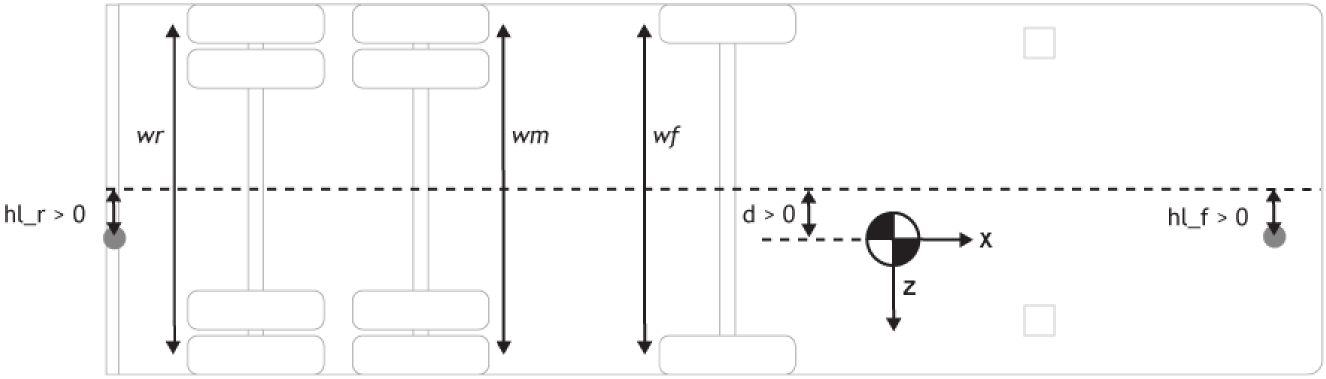
Dependencies

To enable this parameter, on the **Input signals** pane, select **Front hitch forces** or **Front hitch moments**.

`Lateral distance from geometric centerline to front hitch, hl_f` — Distance from centerline to front hitch

`0` (default) | `scalar`

Lateral distance from the geometric centerline to the front hitch, *hl_f*, in m, along the vehicle-fixed *y*. Positive values indicate that the trailer hitch is to the right of the geometric centerline. Negative values indicate that the trailer hitch is to the left of the geometric centerline.



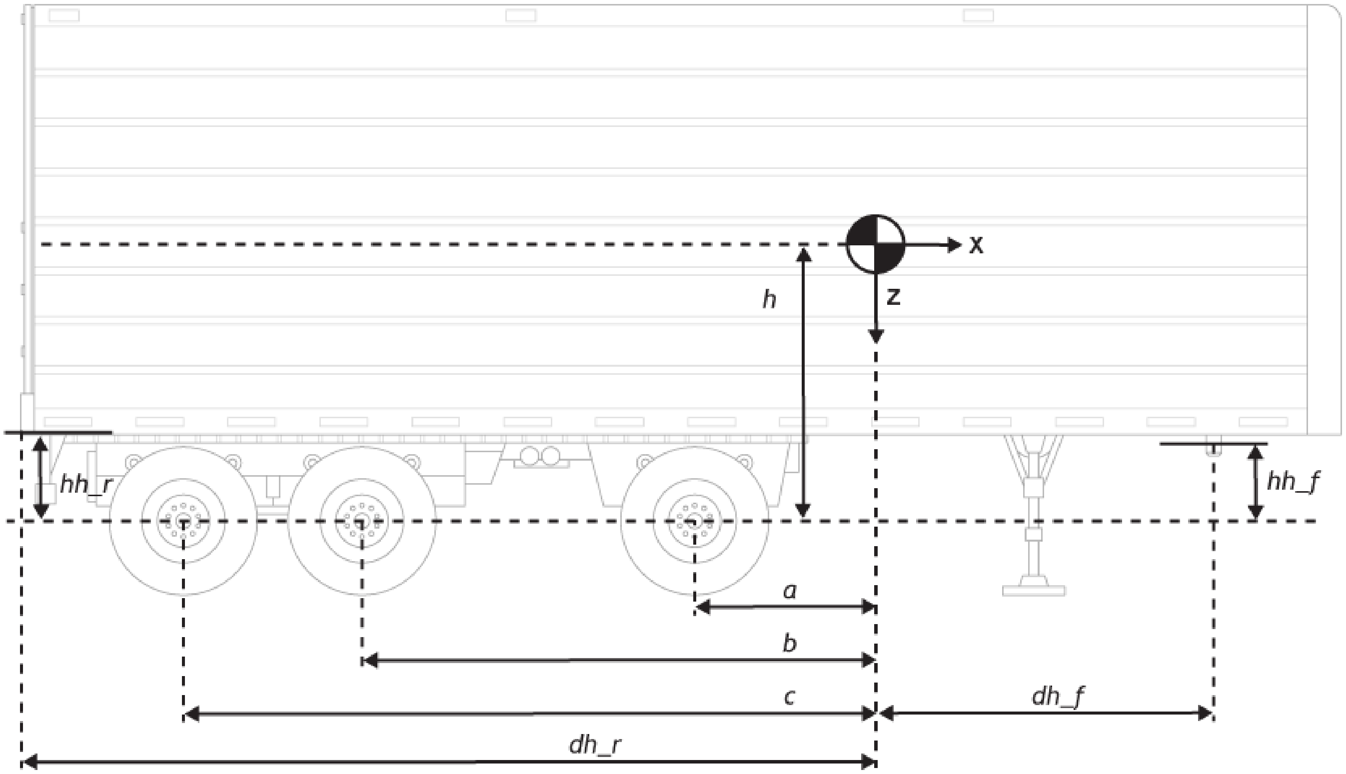
Dependencies

To enable this parameter, on the **Input signals** pane, select **Front hitch forces** or **Front hitch moments**.

`Vertical distance from front hitch to axle plane, hh_f` — Distance from front hitch to axle plane

`0.1` (default) | `scalar`

Vertical distance from front hitch to axle plane, *hh_f*, in m.



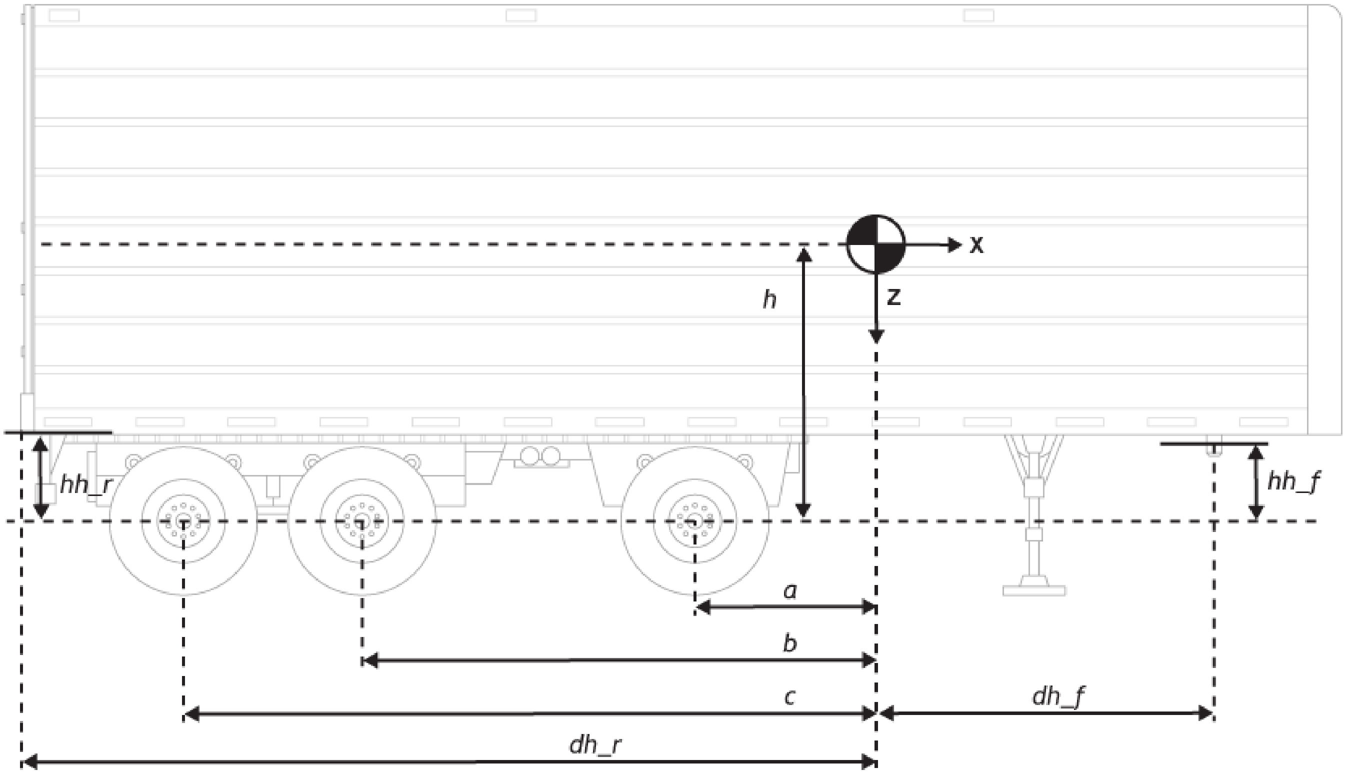
Dependencies

To enable this parameter, on the **Input signals** pane, select **Front hitch forces** or **Front hitch moments**.

`Longitudinal distance from center of mass to rear hitch, dh_r` — Distance to front hitch

`1` (default) | `scalar`

Longitudinal distance from the center of mass to the rear hitch, *dh_r*, in m.



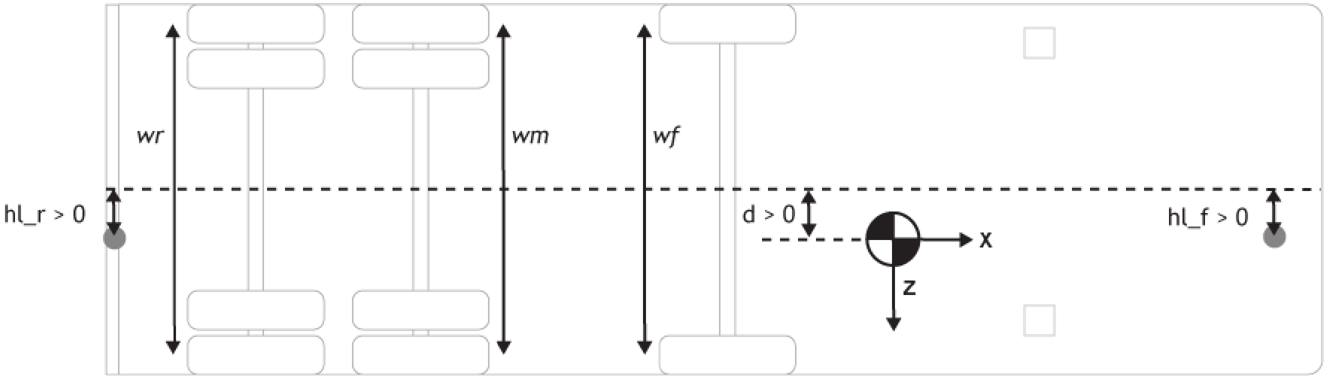
Dependencies

To enable this parameter, on the **Input signals** pane, select **Rear hitch forces** or **Rear hitch moments**.

`Lateral distance from geometric centerline to rear hitch, hl_r` — Distance from centerline to rear hitch

`0` (default) | `scalar`

Lateral distance from the geometric centerline to the rear hitch, *hl_r*, in m, along the vehicle-fixed *y*. Positive values indicate that the trailer hitch is to the right of the geometric centerline. Negative values indicate that the trailer hitch is to the left of the geometric centerline.



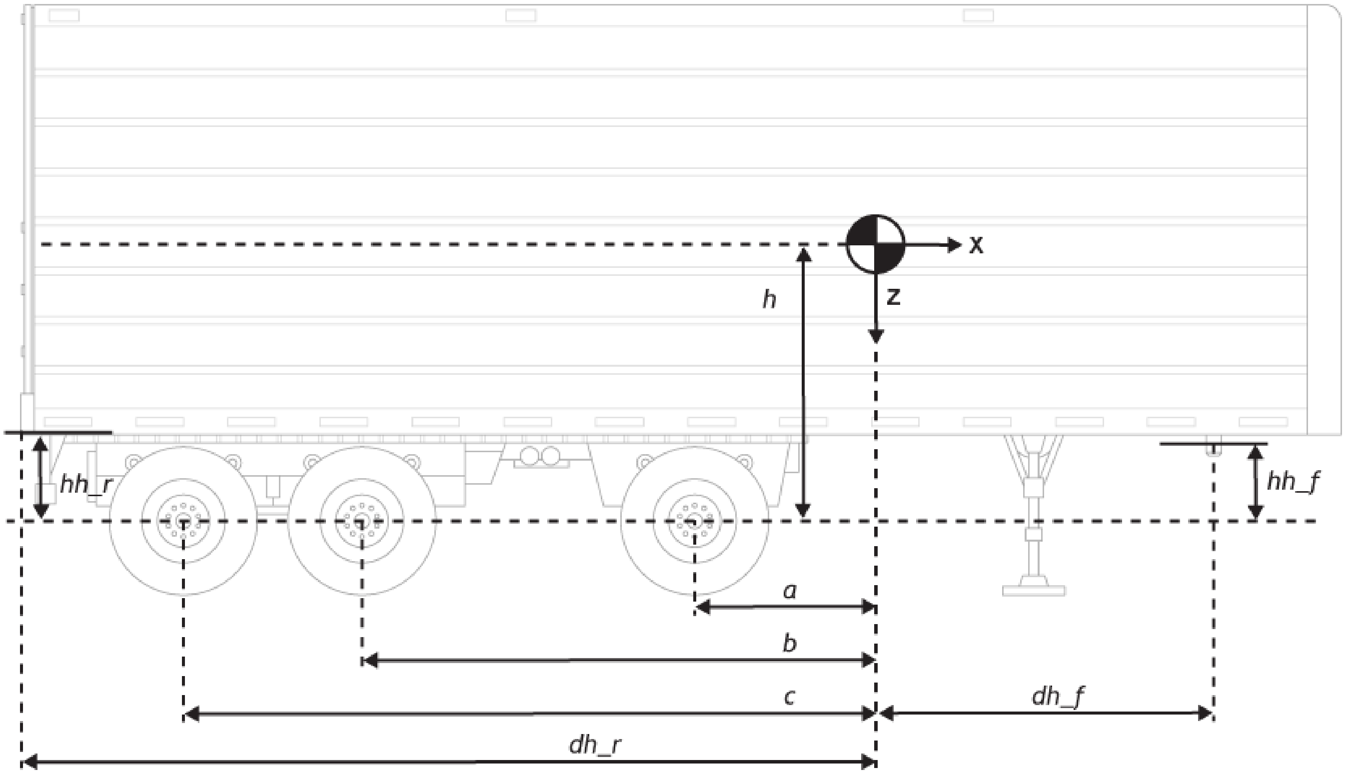
Dependencies

To enable this parameter, on the **Input signals** pane, select **Rear hitch forces** or **Rear hitch moments**.

`Vertical distance from rear hitch to axle plane, hh_r` — Distance from rear hitch to axle plane

`0.1` (default) | `scalar`

Vertical distance from the rear hitch to the axle plane, *hh_r*, in m.



Dependencies

To enable this parameter, on the **Input signals** pane, select **Rear hitch forces** or **Rear hitch moments**.

`Initial position in the inertial frame [Xeo,Yeo,Zeo], Xe_o` — Initial position

`[0,0,0]` (default) | `vector`

Initial position of the vehicle in the inertial frame, Xe_o, in m.

`Initial velocity in body axes [xdot_o,ydot_o,zdot_o], xbdot_o` — Initial velocity

`[0,0,0]` (default) | `vector`

Initial vehicle CM velocity along the vehicle-fixed *x*, *y*-, and *z*-axes, respectively, in m/s.

`Initial Euler orientation [roll, pitch, yaw], eul_o` — Rotation

`[0,0,0]` (default) | `vector`

Initial Euler rotation of the vehicle-fixed frame about the earth-fixed *X*- (roll), *Y*- (pitch), *Z*-axes (yaw), respectively, in rad.

`Initial body rotation rates [p,q,r], p_o` — Initial rotation rate

`[0,0,0]` (default) | `vector`

Initial vehicle CM angular velocity about the vehicle-fixed *x*- (roll rate), *y*- (pitch rate), *z*-axes (yaw rate), respectively, in rad/s.

`Chassis inertia tensor, Iveh` — Inertia

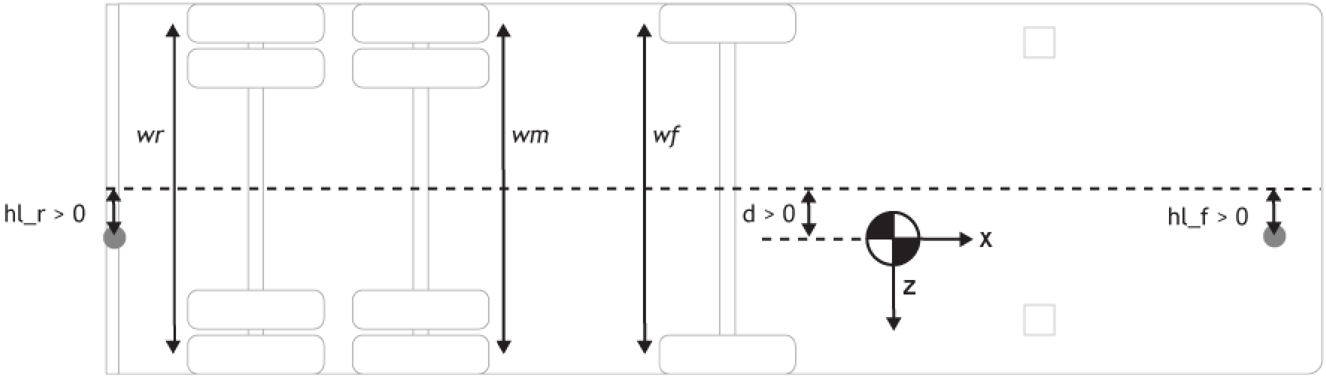
`[430 0 0; 0 1900 0; 0 0 2100]` (default) | `array`

Vehicle inertia tensor, I_{veh}, in kg*m^2. Dimensions are `[3-by-3]`.

`Front track width, w_f` — Front track width

`1.9` (default) | `scalar`

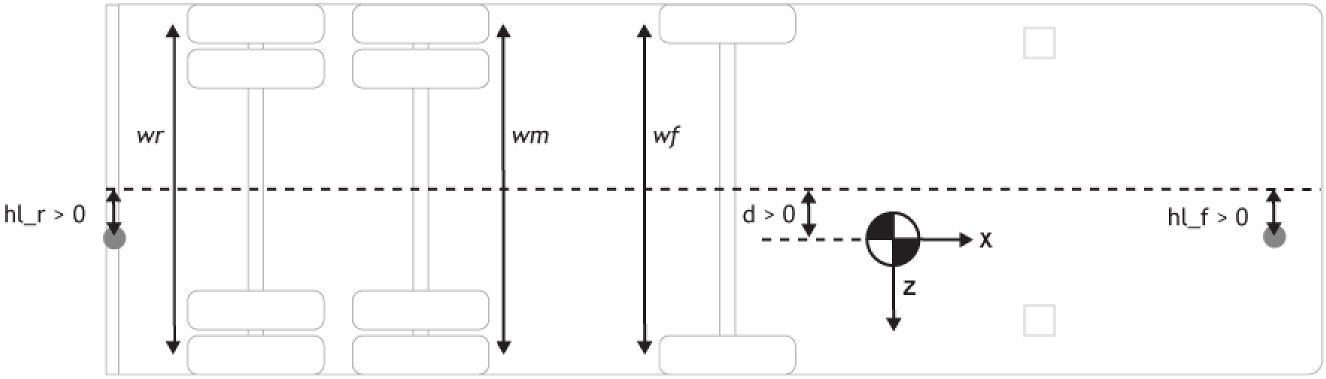
Front track width, in m.



`Middle track width, w_m` — Middle track width

`1.9` (default) | `scalar`

Middle track width, in m.



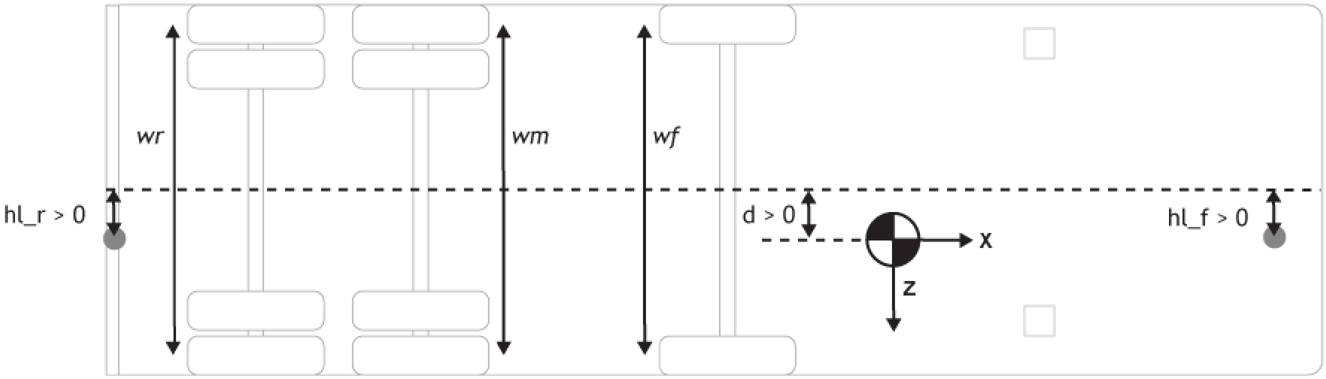
Dependencies

To enable this parameter, set **Number of axles** to 3.

`Rear track width, w_r` — Rear track width

`1.9` (default) | `scalar`

Rear track width, in m.



Dependencies

To enable this parameter, set **Number of axles** to 2 or 3.

Inertial Loads

Front End

`Mass, z1m` — Mass

`0` (default) | `scalar`

Mass, *z1m*, in kg.

`Distance vector from front axle, z1R` — Distance

`[-.25,.125,.15]` (default) | `vector`

Distance vector from front axle to load, *z1R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z1R(1,1)`	Front suspension hardpoint to load, along vehicle-fixed *x*-axis
`z1R(1,2)`	Vehicle centerline to load, along vehicle-fixed *y*-axis
`z1R(1,3)`	Front suspension hardpoint to load, along vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Forward of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z1R(1,1)` < 0 • `z1R(1,2)` > 0 • `z1R(1,3)` > 0

`Inertia tensor, z1I` — Inertia

`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

Inertia tensor, *z1I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z1I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Overhead

`Mass, z2m` — Mass

`0` (default) | `scalar`

Mass, *z2m*, in kg.

`Distance vector from front axle, z2R` — Distance

`[1.4,0,.8]` (default) | `vector`

Distance vector from front axle to load, *z2R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z2R(1,1)`	Front suspension hardpoint to load, along vehicle-fixed *x*-axis

Array Element	Description
`z2R(1,2)`	Vehicle centerline to load, along vehicle-fixed *y*-axis
`z2R(1,3)`	Front suspension hardpoint to load, along vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Left of the vehicle centerline • Above the front axle suspension hardpoint	• `z2R(1,1)` > 0 • `z2R(1,2)` < 0 • `z2R(1,3)` > 0

`Inertia tensor, z2I` — Inertia

`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

Inertia tensor, *z2I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z2I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Front Left

`Mass, z3m` — Mass

`0` (default) | `scalar`

Mass, *z3m*, in kg.

`Distance vector from front axle, z3R` — Distance

`[.75,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z3R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z3R(1,1)`	Front suspension hardpoint to load, along vehicle-fixed *x*-axis
`z3R(1,2)`	Vehicle centerline to load, along vehicle-fixed *y*-axis
`z3R(1,3)`	Front suspension hardpoint to load, along vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Left of the vehicle centerline • Above the front axle suspension hardpoint	• `z3R(1,1)` > 0 • `z3R(1,2)` < 0 • `z3R(1,3)` > 0

`Inertia tensor, z3I` — Inertia
`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z3I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z3I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Front Right

`Mass, z4m` — Mass
`0` (default) | `scalar`

Mass, *z4m*, in kg.

`Distance vector from front axle, z4R` — Distance
`[.75,.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z4R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z4R(1,1)`	Front suspension hardpoint to load, along vehicle-fixed *x*-axis
`z4R(1,2)`	Vehicle centerline to load, along vehicle-fixed *y*-axis
`z4R(1,3)`	Front suspension hardpoint to load, along vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z4R(1,1)` > 0 • `z4R(1,2)` > 0 • `z4R(1,3)` > 0

`Inertia tensor, z4I` — Inertia
`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z4I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z4I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Rear Left

`Mass, z5m` — Mass

`0` (default) | `scalar`

Mass, z5m, in kg.

`Distance vector from front axle, z5R` — Distance

`[1.25,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z5R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z5R(1,1)`	Front suspension hardpoint to load, along vehicle-fixed *x*-axis
`z5R(1,2)`	Vehicle centerline to load, along vehicle-fixed *y*-axis
`z5R(1,3)`	Front suspension hardpoint to load, along vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Left of the vehicle centerline • Above the front axle suspension hardpoint	• `z5R(1,1)` > 0 • `z5R(1,2)` < 0 • `z5R(1,3)` > 0

`Inertia tensor, z5I` — Inertia

`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z5I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z5I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis

- *z*-axis along the vehicle-fixed *z*-axis

Rear Right

`Mass, z6m` — Mass

`0` (default) | `scalar`

Mass, *z6m*, in kg.

`Distance vector from front axle, z6R` — Distance

`[1.25,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z6R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z6R(1,1)`	Front suspension hardpoint to load, along vehicle-fixed *x*-axis
`z6R(1,2)`	Vehicle centerline to load, along vehicle-fixed *y*-axis
`z6R(1,3)`	Front suspension hardpoint to load, along vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z6R(1,1)` > 0 • `z6R(1,2)` > 0 • `z6R(1,3)` > 0

`Inertia tensor, z6I` — Inertia

`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z6I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z6I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Rear End

`Mass, z7m` — Mass

`0` (default) | `scalar`

Mass, *z7m*, in kg.

`Distance vector from front axle, z7R` — Distance

`[2,0,.25]` (default) | `vector`

Distance vector from front axle to load, *z7R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z7R(1,1)`	Front suspension hardpoint to load, along vehicle-fixed *x*-axis
`z7R(1,2)`	Vehicle centerline to load, along vehicle-fixed *y*-axis
`z7R(1,3)`	Front suspension hardpoint to load, along vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z7R(1,1)` > 0 • `z7R(1,2)` > 0 • `z7R(1,3)` > 0

`Inertia tensor, z7I` — Inertia
`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

Inertia tensor, *z7I*, in kg·m^2. Dimensions are `[3-by-3]`.

$$z7I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Aerodynamic

`Longitudinal drag area, Af` — Drag area
2 (default) | `scalar`

Effective vehicle cross-sectional area, A_f to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Drag coefficient
`.3` (default) | `scalar`

Air drag coefficient, C_d, dimensionless.

`Longitudinal lift coefficient, Cl` — Lift
`.1` (default) | `scalar`

Air lift coefficient, C_l, dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}, dimensionless.

`Relative wind angle vector, beta_w` — Wind angle
`[0:0.001:0.01]` (default) | `vector`

Relative wind angle vector, β_w, in rad.

`Side force coefficient vector, Cs` — Side force drag
`[0:0.01:0.1]` (default) | `vector`

Side force coefficient vector coefficient, C_s, dimensionless.

`Yaw moment coefficient vector, Cym` — Yaw moment drag
`[0:0.001:0.01]` (default) | `vector`

Yaw moment coefficient vector coefficient, C_{ym}, dimensionless.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar`

Environmental air absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Ambient air temperature
`273` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity
`9.81` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

Simulation

`Longitudinal velocity tolerance, xdot_tol` — Tolerance
`.1` (default) | `scalar`

Longitudinal velocity tolerance, $xdot_{tol}$, in m/s.

The block uses this parameter to avoid a division by zero when it calculates the body slip angle, β.

`Geometric longitudinal offset from axle plane, longOff` — Longitudinal offset
`0` (default) | `scalar`

Trailer offset from axle plane along body-fixed *x*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric lateral offset from center plane, latOff` — Lateral offset
`0` (default) | `scalar`

Trailer offset from center plane along body-fixed *y*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric vertical offset from axle plane, vertOff` — Vertical offset
`0` (default) | `scalar`

Trailer offset from axle plane along body-fixed *z*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Wrap Euler angles, wrapAng` — Selection
`on` (default) | `off`

Wrap the Euler angles to the interval `[-pi, pi]`. For vehicle maneuvers that might undergo vehicle yaw rotations that are outside of the interval, consider clearing the parameter if you want to:

- Track the total vehicle yaw rotation.
- Avoid discontinuities in the vehicle state estimators.

Version History

Introduced in R2020b

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Vehicle Body 3DOF Longitudinal | Vehicle Body 6DOF | Trailer Body 3DOF

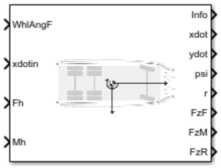
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Vehicle Body 3DOF Three Axles

Three-axle vehicle body with longitudinal, lateral, and yaw motion

Library: Vehicle Dynamics Blockset / Vehicle Body



Description

The Vehicle Body 3DOF Three Axles block implements a rigid, three-axle vehicle body model to calculate longitudinal, lateral, and yaw motion. The block accounts for the axle and hitch reaction forces due to the vehicle body mass acceleration, aerodynamic drag, and steering.

Use this block in vehicle dynamics and automated driving studies to model nonholonomic vehicle motion when vehicle pitch, roll, and vertical motion are not significant.

Use the **Vehicle track** parameter to specify the number of wheels.

Vehicle Track Setting	Implementation
`Single (bicycle)`	• Forces act along the center line of the axles. • No lateral load transfer.
`Dual`	Forces act at the axle hard-point locations.

Use the **Axle forces** parameter to specify the type of force.

Axle Forces Setting	Implementation

`External longitudinal velocity`	• The block assumes that the external longitudinal velocity is in a quasi-steady state, so the longitudinal acceleration is approximately zero.
	• Because the motion is quasi-steady, the block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Generate virtual sensor signal data.
	  • Conduct high-level software studies that are not impacted by driveline or nonlinear tire responses.

Axle Forces Setting	Implementation

`External longitudinal forces`	• The block uses the external longitudinal force to accelerate or brake the vehicle.
	• The block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Account for changes in the longitudinal velocity on the lateral and yaw motion.
	  • Specify the external longitudinal motion through a force instead of an external longitudinal velocity.
	  • Connect the block to tractive actuators, wheels, brakes, and hitches.

`External forces`	• The block uses the external lateral and longitudinal forces to steer, accelerate, or brake the vehicle. • The block does not use the steering input to calculate vehicle motion. • Consider this setting when you need tire models with more accurate nonlinear combined lateral and longitudinal slip.

To create additional input ports, under **Input signals**, select these block parameters.

Input Signals Pane Parameter	Input Port	Description
Front wheel steering	`WhlAngF`	Front wheel angle, δ_F
Middle wheel steering	`WhlAngM`	Middle wheel angle, δ_M
Rear wheel steering	`WhlAngR`	Rear wheel angle, δ_R
External wind	`WindXYZ`	Wind speed, W_X, W_Y, and W_Z, in an inertial reference frame
External friction	`Mu`	Friction coefficient
External forces	`FExt`	External force on the vehicle center of gravity (CG), F_x, F_y, and F_z, in the vehicle-fixed frame
External moments	`MExt`	External moment about the vehicle CG, M_x, M_y, and M_z, in the vehicle-fixed frame
Front hitch forces	`FhF`	Hitch force applied to the body at the front hitch location, FhF_x, FhF_y, and FhF_z, in the vehicle-fixed frame
Front hitch moments	`MhF`	Hitch moment at the front hitch location, MhF_x, MhF_y, and MhF_z, about the vehicle-fixed frame
Rear hitch forces	`FhR`	Hitch force applied to the body at the rear hitch location, FhR_x, FhR_y, and FhR_z, in the vehicle-fixed frame
Rear hitch moments	`MhR`	Hitch moment at the rear hitch location, MhR_x, MhR_y, and MhR_z, about the vehicle-fixed frame
Initial longitudinal position	`X_o`	Initial vehicle CG displacement along the earth-fixed *X*-axis

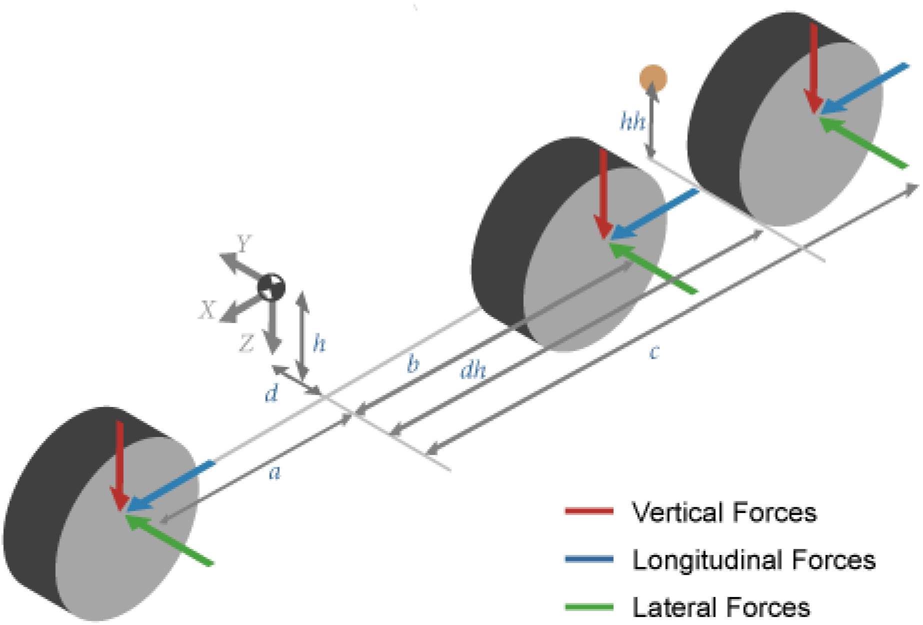
Input Signals Pane Parameter	Input Port	Description
Initial yaw angle	`psi_o`	Initial rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)
Initial longitudinal velocity	`xdot_o`	Initial vehicle CG velocity along the vehicle-fixed *x*-axis
Initial yaw rate	`r_o`	Initial vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)
Initial lateral position	`Y_o`	Initial vehicle CG displacement along the earth-fixed *Y*-axis
Air temperature	`AirTemp`	Ambient air temperature. Consider this option if you want to vary the temperature during run time.
Initial lateral velocity	`ydot_o`	Initial vehicle CG velocity along the vehicle-fixed *y*-axis

Theory

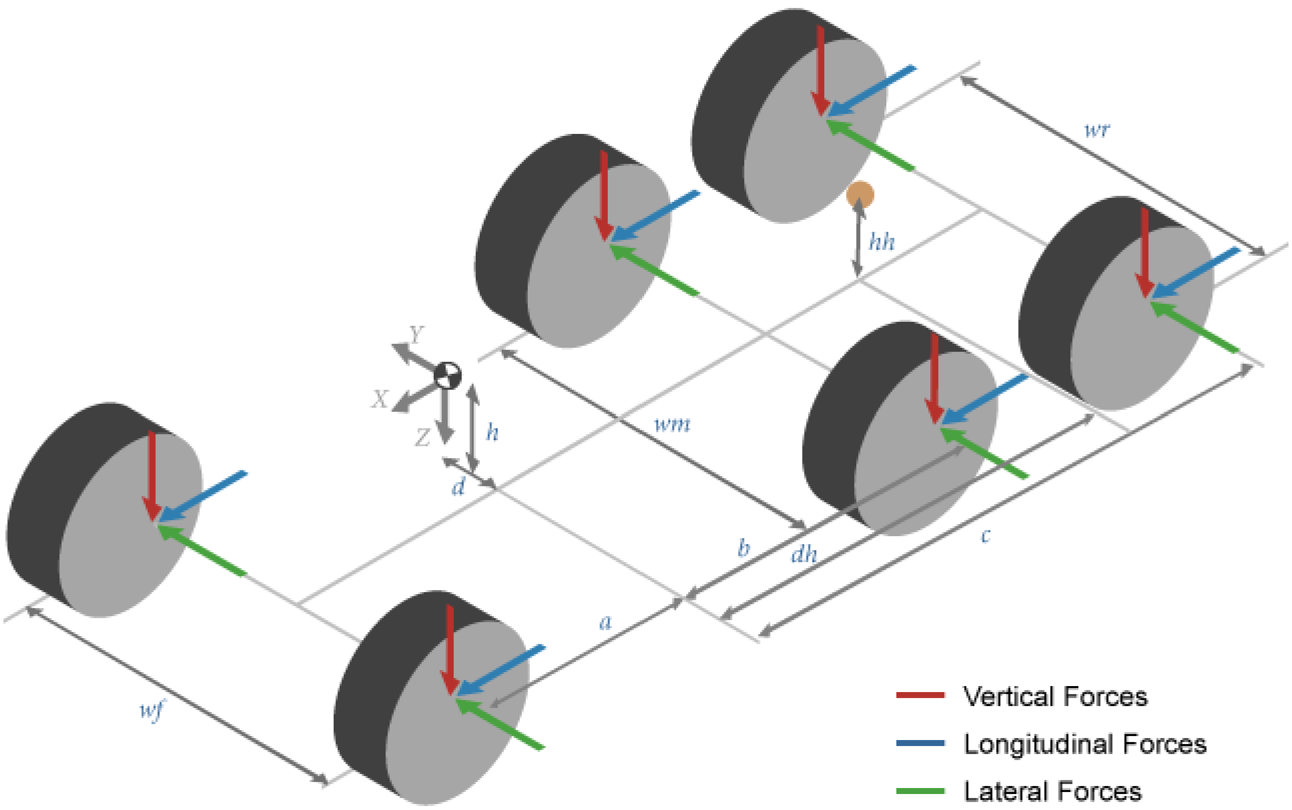
To determine the vehicle motion, the block solves the rigid body planar dynamics equations of motion.

Calculation	Description
Dynamics	The block solves the rigid-body planar dynamics equations to determine the vehicle longitudinal motion. If you set **Axle forces** to `External longitudinal velocity`, the block assumes a quasi-steady state for the longitudinal acceleration.
External forces	External forces include both drag and external force inputs. The forces act on the vehicle CG. The block divides the normal forces by the nominal normal load to vary the effective friction parameters during weight and load transfer. The block maintains pitch and roll equilibrium.
Tire forces	The block uses the ratio of the local, longitudinal, and lateral velocities to determine the slip angles. The block uses the steering angles to transform the tire forces to the vehicle-fixed frame. If you set **Axle forces** to `External forces`, the block assumes that the externally provided forces are in the vehicle-fixed frame at the axle-wheel location.

Single Track



Dual Track



The illustrations use these variables.

a, *b*, *c*	Longitudinal distance of the front, middle, and rear axles, respectively, from the normal projection point of the vehicle CG onto the common axle plane
h	Height of vehicle CG above the axle plane along the vehicle-fixed *z*-axis
d	Lateral distance from geometric centerline to center of mass along the vehicle-fixed *y*-axis
hh	Height of the hitch above the axle plane along the vehicle-fixed *z*-axis
dh	Longitudinal distance of the hitch from normal projection point of the vehicle CG onto the common axle plane
hl	Lateral distance from center of mass to hitch along the vehicle-fixed *y*-axis.
wf, *wm*, *wr*	Front, middle, and rear track width, respectively

Drag

This table summarizes the block implementation for the drag calculation.

Calculation	Description
Coordinate transformation	The block transforms the wind speeds from the inertial frame to the vehicle-fixed frame.

Calculation	Description
Drag forces	To determine a relative airspeed, the block subtracts the wind speed from the CG vehicle velocity. Using the relative airspeed, the block determines the drag forces.
Drag moments	Using the relative airspeed, the block determines the drag moments.

Lateral Corner Stiffness and Relaxation Dynamics

To enable the mapped corner stiffness and relaxation length dynamic parameters, set **Axle forces** to `External longitudinal force` or `External longitudinal velocity`.

Parameter Settings		Description
Mapped Corner Stiffness	**Include Relaxation Length Dynamics**	
`Off` (default)	`On` (default)	The block uses constant corner stiffness values. The slip angles include the relaxation length dynamic settings. The relaxation length approximates an effective corner stiffness force that is a function of wheel travel.
`On`	`On` (default)	The block uses lookup tables that are functions of the corner stiffness data and slip angles. The slip angles include the relaxation length dynamic settings. The relaxation length approximates an effective corner stiffness force that is a function of wheel travel.
`Off` (default)	`Off`	The block uses constant corner stiffness values.

Ports

Input

`WhlAngF` — Front wheel steering angles
`scalar` | `array`

Front wheel steering angles, δ_F, in rad.

Vehicle Track Setting	Variable	Signal Dimension
`Single (bicycle)`	δ_F	Scalar – `1`
`Dual`	$\delta_F = [\delta_{fl}\ \delta_{fr}]$ or $\begin{bmatrix}\delta_{fl}\\ \delta_{fr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port, on the **Input signals** pane, select **Front wheel steering**.

`WhlAngM` — Middle wheel steering angles
`scalar` | `array`

Middle wheel steering angles, δ_M, in rad.

Vehicle Track Setting	Variable	Signal Dimension
`Single (bicycle)`	δ_M	Scalar – 1
`Dual`	$\delta_M = [\delta_{ml}\ \delta_{mr}]$ or $\begin{bmatrix}\delta_{ml}\\ \delta_{mr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port, on the **Input signals** pane, select **Middle wheel steering**.

`WhlAngR` — Rear wheel steering angles

scalar | array

Rear wheel steering angles, δ_R, in rad.

Vehicle Track Setting	Variable	Signal Dimension
`Single (bicycle)`	δ_R	Scalar – 1
`Dual`	$\delta_R = [\delta_{rl}\ \delta_{rr}]$ or $\begin{bmatrix}\delta_{rl}\\ \delta_{rr}\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Dependencies

To enable this port, on the **Input signals** pane, select **Rear wheel steering**.

`xdotin` — Longitudinal velocity

scalar

Vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this port, set **Axle forces** to `External longitudinal velocity`.

`FwF` — Total force on the front wheels

scalar | array

Force on the front wheels, Fw_F, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	`External longitudinal forces`	Longitudinal force on the front wheel	$FwF = Fx_f$	Scalar – 1
	`External forces`	Longitudinal and lateral forces on the front wheel	$FwF = [Fx_f\ Fy_f]$ or $\begin{bmatrix}Fx_f\\ Fy_f\end{bmatrix}$	Array – `[1x2]` or `[2x1]`

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Dual`	`External longitudinal forces`	Longitudinal force on the front wheels	$FwF = \begin{bmatrix} F_{xfl} & F_{xfr} \end{bmatrix}$ or $\begin{bmatrix} F_{xfl} \\ F_{xfr} \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
	`External forces`	Longitudinal and lateral forces on the front wheels	$FwF = \begin{bmatrix} F_{xfl} & F_{xfr} \\ F_{yfl} & F_{yfr} \end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

`FwM` — Total force on the middle wheels

`scalar` | `array`

Force on the middle wheels, Fw_M, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	`External longitudinal forces`	Longitudinal force on the middle wheel	$FwM = Fx_r$	Scalar – `1`
	`External forces`	Longitudinal and lateral forces on the middle wheel	$FwM = \begin{bmatrix} Fx_m & Fy_m \end{bmatrix}$ or $\begin{bmatrix} Fx_m \\ Fy_m \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
`Dual`	`External longitudinal forces`	Longitudinal force on the middle wheels	$FwM = \begin{bmatrix} F_{xml} & F_{xmr} \end{bmatrix}$ or $\begin{bmatrix} F_{xml} \\ F_{xmr} \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
	`External forces`	Longitudinal and lateral forces on the middle wheels	$FwM = \begin{bmatrix} F_{xml} & F_{xmr} \\ F_{yml} & F_{ymr} \end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set **Axle forces** to one of these options:

- `External longitudinal forces`

- `External forces`

`FwR` — Total force on the rear wheels

`scalar` | `array`

Force on the rear wheels, Fw_R, along the vehicle-fixed axis, in N.

Vehicle Track Setting	Axle Forces Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	`External longitudinal forces`	Longitudinal force on the rear wheel	$FwR = Fx_r$	Scalar – `1`
	`External forces`	Longitudinal and lateral forces on the rear wheel	$FwR = \begin{bmatrix} Fx_r & Fy_r \end{bmatrix}$ or $\begin{bmatrix} Fx_r \\ Fy_r \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
`Dual`	`External longitudinal forces`	Longitudinal force on the rear wheels	$FwR = \begin{bmatrix} F_{xrl} & F_{xrr} \end{bmatrix}$ or $\begin{bmatrix} F_{xrl} \\ F_{xrr} \end{bmatrix}$	Array – `[1x2]` or `[2x1]`
	`External forces`	Longitudinal and lateral forces on the rear wheels	$FwR = \begin{bmatrix} F_{xrl} & F_{xrr} \\ F_{yrl} & F_{yrr} \end{bmatrix}$	Array – `[2x2]`

Dependencies

To enable this port, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

`FExt` — External force on vehicle CG

`array`

External forces applied to the vehicle CG, F_{xext}, F_{yext}, F_{zext}, in vehicle-fixed frame, in N. The signal array dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, on the **Input signals** pane, select **External forces**.

`MExt` — External moment about vehicle CG

`array`

External moment about the vehicle CG, M_x, M_y, M_z, in the vehicle-fixed frame, in N·m. The signal array dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, on the **Input signals** pane, select **External moments**.

`Fh` — Hitch force on the body

`array`

Hitch force applied to the body at the hitch location, Fh_x, Fh_y, Fh_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch forces**.

`Mh` — Hitch moment about body

`array`

Hitch moment at the hitch location, Mh_x, Mh_y, Mh_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch moments**.

`WindXYZ` — Wind speed

`array`

Wind speed, W_x, W_y, W_z along the inertial X-, Y-, and Z-axes, in m/s. The signal array dimensions are `[1x3]` or `[3x1]`.

Dependencies

To enable this port, on the **Input signals** pane, select **External wind**.

`Mu` — Tire friction coefficient

`array`

Tire friction coefficient, μ, dimensionless.

Vehicle Track Setting	Variable	Signal Dimension
`Single (bicycle)`	$Mu = \begin{bmatrix}\mu_f & \mu_m & \mu_r\end{bmatrix} \text{ or } \begin{bmatrix}\mu_f \\ \mu_m \\ \mu_r\end{bmatrix}$	Array – `[1x3]` or `[3x1]`
`Dual`	$Mu = \begin{bmatrix}\mu_{fl} & \mu_{fr} \\ \mu_{ml} & \mu_{mr} \\ \mu_{rl} & \mu_{rr}\end{bmatrix}$	Array – `[3x2]`

Dependencies

To enable this port, on the **Input signals** pane, select **External friction**.

`AirTemp` — Ambient air temperature

`scalar`

Ambient air temperature, in K.

Dependencies

To enable this port, on the **Input signals** pane, select **Air temperature**.

`X_o` — Initial longitudinal position

`scalar`

Initial vehicle CG displacement along the earth-fixed *X*-axis, in m.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial longitudinal position**.

`Y_o` — Initial lateral position

`scalar`

Initial vehicle CG displacement along the earth-fixed *Y*-axis, in m.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial lateral position**.

`xdot_o` — Initial longitudinal position

`scalar`

Initial vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this port:

1. Set **Axle forces** to one of these options:
   - `External longitudinal forces`
   - `External forces`
2. On the **Input signals** pane, select **Initial longitudinal velocity**

`ydot_o` — Initial lateral position

`scalar`

Initial vehicle CG velocity along the vehicle-fixed *y*-axis, in m/s.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial lateral velocity**.

`psi_o` — Initial yaw angle

`scalar`

Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw), in rad.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial yaw angle**.

`r_o` — Initial yaw rate

`scalar`

Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

Dependencies

To enable this port, on the **Input signals** pane, select **Initial yaw rate**.

Output

`Info` — Vehicle data

bus

Vehicle data, returned as a bus signal containing these block values.

Signal					Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`		Vehicle CG displacement along the earth-fixed *X*-axis	Computed	m
			`Y`		Vehicle CG displacement along the earth-fixed *Y*-axis	Computed	m
			`Z`		Vehicle CG displacement along the earth-fixed *Z*-axis	`0`	m
		`Vel`	`Xdot`		Vehicle CG velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Vehicle CG velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`		Vehicle CG velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Ang`	`phi`		Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	`0`	rad
			`theta`		Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	`0`	rad
			`psi`		Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad
	`FrntAxl`	`Lft`	`Disp`	`X`	Front left wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front left wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front left wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Front left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s

Signal					Description	Value	Units
				Zdot	Front left wheel velocity along the earth-fixed *Z*-axis	0	m/s
		Rght	Disp	X	Front right wheel displacement along the earth-fixed *X*-axis	Computed	m
				Y	Front right wheel displacement along the earth-fixed *Y*-axis	Computed	m
				Z	Front right wheel displacement along the earth-fixed *Z*-axis	0	m
			Vel	Xdot	Front right wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				Ydot	Front right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				Zdot	Front right wheel velocity along the earth-fixed *Z*-axis	0	m/s
	MidlAxl	Lft	Disp	X	Middle left wheel displacement along the earth-fixed *X*-axis	Computed	m
				Y	Middle left wheel displacement along the earth-fixed *Y*-axis	Computed	m
				Z	Middle left wheel displacement along the earth-fixed *Z*-axis	0	m
			Vel	Xdot	Middle left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				Ydot	Middle left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				Zdot	Middle left wheel velocity along the earth-fixed *Z*-axis	0	m/s
		Rght	Disp	X	Middle right wheel displacement along the earth-fixed *X*-axis	Computed	m
				Y	Middle right wheel displacement along the earth-fixed *Y*-axis	Computed	m

Signal					Description	Value	Units
				`Z`	Middle right wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Middle right wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Middle right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Middle right wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
	`RearAxl`	`Lft`	`Disp`	`X`	Rear left wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear left wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear left wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Rear left wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear left wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear left wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Rght`	`Disp`	`X`	Rear right wheel displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear right wheel displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear right wheel displacement along the earth-fixed *Z*-axis	`0`	m
			`Vel`	`Xdot`	Rear right wheel velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear right wheel velocity along the earth-fixed *Y*-axis	Computed	m/s

Signal					Description	Value	Units
				`Zdot`	Rear right wheel velocity along the earth-fixed *Z*-axis	`0`	m/s
	`Hitch`	`Disp`	`X`		Trailer hitch offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`		Trailer hitch offset from the center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`		Trailer hitch offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`		Trailer hitch offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Trailer hitch offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`		Trailer hitch offset velocity along the earth-fixed *Z*-axis	Computed	m/s
	`Geom`	`Disp`	`X`		Vehicle chassis offset from axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`		Vehicle chassis offset from center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`		Vehicle chassis offset from axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`		Vehicle chassis offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Vehicle chassis offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`		Vehicle chassis offset velocity along the earth-fixed *Z*-axis	Computed	m/s
`BdyFrm`	`Cg`	`Vel`	`xdot`		Vehicle CG velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`		Vehicle CG velocity along the vehicle-fixed *y*-axis	Computed	m/s

Signal				**Description**	**Value**	**Units**
			`zdot`	Vehicle CG velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	`0`	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	`0`	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s
		`Acc`	`ax`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	gn
			`xddot`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2
			`zddot`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	m/s^2
		`AngAcc`	`pdot`	Vehicle angular acceleration about the vehicle-fixed *x*-axis	`0`	rad/s
			`qdot`	Vehicle angular acceleration about the vehicle-fixed *y*-axis	`0`	rad/s
			`rdot`	Vehicle angular acceleration about the vehicle-fixed *z*-axis	Computed	rad/s
	`Forces`	`Body`	`Fx`	Net force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N

Signal					Description	Value	Units
			`Fy`		Net force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Net force on vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`Ext`	`Fx`		External force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		External force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		External force on vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`Hitch`	`Fx`		Hitch force applied to body at the hitch location along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Hitch force applied to body at the hitch location along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Hitch force applied to body at the hitch location along the vehicle-fixed *z*-axis	Computed	N
		`FrntAxl`	`Lft`	`Fx`	Longitudinal force on left front wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on left front wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on left front wheel along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on right front wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on right front wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on right front wheel along the vehicle-fixed *z*-axis	Computed	N

Signal						Description	Value	Units
		`MidlAxl`	`Lft`	`Fx`		Longitudinal force on left middle wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`		Lateral force on left middle wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`		Normal force on left middle wheel along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`		Longitudinal force on right middle wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`		Lateral force on right middle wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`		Normal force on right middle wheel along the vehicle-fixed *z*-axis	Computed	N
		`RearAxl`	`Lft`	`Fx`		Longitudinal force on left rear wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`		Lateral force on left rear wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`		Normal force on left rear wheel along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`		Longitudinal force on right rear wheel along the vehicle-fixed *x*-axis	Computed	N
				`Fy`		Lateral force on right rear wheel along the vehicle-fixed *y*-axis	Computed	N
				`Fz`		Normal force on right rear wheel along the vehicle-fixed *z*-axis	Computed	N
		`Tires`	`FrntTires`	`Lft`	`Fx`	Front left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front left tire force along the vehicle-fixed *z*-axis	Computed	N

Signal						Description	Value	Units
				`Rght`	`Fx`	Front right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front right tire force along the vehicle-fixed *z*-axis	Computed	N
			`RearTires`	`Lft`	`Fx`	Rear left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Rear right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear right tire force along the vehicle-fixed *z*-axis	Computed	
		`Drag`	`Fx`			Drag force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Drag force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Drag force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
		`Grvty`	`Fx`			Gravity force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Gravity force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Gravity force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
	`Moments`	`Body`	`Mx`			Body moment on vehicle CG about the vehicle-fixed *x*-axis	`0`	N·m

Signal					Description	Value	Units
			`My`		Body moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		Body moment on vehicle CG about the vehicle-fixed *z*-axis	`0`	N·m
		`Drag`	`Mx`		Drag moment on vehicle CG about the vehicle-fixed *x*-axis	`0`	N·m
			`My`		Drag moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		Drag moment on vehicle CG about the vehicle-fixed *z*-axis	`0`	N·m
		`Ext`	`Mx`		External moment on vehicle CG about the vehicle-fixed *x*-axis	`0`	N·m
			`My`		External moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		External moment on vehicle CG about the vehicle-fixed *z*-axis	`0`	N·m
		`Hitch`	`Mx`		Hitch moment at the hitch location about vehicle-fixed *x*-axis	`0`	N·m
			`My`		Hitch moment at the hitch location about vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		Hitch moment at the hitch location about vehicle-fixed *z*-axis	`0`	N·m
	`FrntAxl`	`Lft`	`Disp`	`x`	Front left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Front left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal					**Description**	**Value**	**Units**
				`ydot`	Front left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front left wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Rght`	`Disp`	`x`	Front right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Front right wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front right wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front right wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngFL`		Front left wheel steering angle	Computed	rad
			`WhlAngFR`		Front right wheel steering angle	Computed	rad
	`MidlAxl`	`Lft`	`Disp`	`x`	Middle left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Middle left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Middle left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Middle left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Middle left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s

Signal					**Description**	**Value**	**Units**
				`zdot`	Middle left wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Rght`	`Disp`	`x`	Middle right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Middle right wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Middle right wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Middle right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Middle right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Middle right wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngRL`		Middle left wheel steering angle	Computed	rad
			`WhlAngRR`		Middle right wheel steering angle	Computed	rad
	`RearAxl`	`Lft`	`Disp`	`x`	Rear left wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear left wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear left wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear left wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear left wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear left wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s

Signal					**Description**	**Value**	**Units**
		`Rght`	`Disp`	`x`	Rear right wheel displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear right wheel displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear right wheel displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear right wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear right wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear right wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngRL`		Rear left wheel steering angle	Computed	rad
			`WhlAngRR`		Rear right wheel steering angle	Computed	rad
	`Hitch`	`Disp`		`x`	Hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	m
				`y`	Hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
				`z`	Hitch offset from axle plane along the earth-fixed *z*-axis	Input	m
		`Vel`		`xdot`	Hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Hitch offset velocity along the vehicle-fixed *z*-axis	`0`	m/s
	`Pwr`	`Ext`			Applied external power	Computed	W
		`Hitch`			Power loss due to hitch	Computed	W
		`Drag`			Power loss due to drag	Computed	W
	`Geom`	`Disp`		`x`	Vehicle chassis offset from axle plane along the vehicle-fixed *x*-axis	Input	m

Signal				Description	Value	Units
			`y`	Vehicle chassis offset from center plane along the vehicle-fixed *y*-axis	Input	m
			`z`	Vehicle chassis offset from axle plane along the earth-fixed *z*-axis	Input	m
		`Vel`	`xdot`	Vehicle chassis offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle chassis offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle chassis offset velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad

Signal			Description	Value	Units
`PwrInfo`	`PwrTrnsfrd`	`PwrFxExt`	Externally applied longitudinal force power	Computed	W
		`PwrFyExt`	Externally applied lateral force power	Computed	W
		`PwrMzExt`	Externally applied yaw moment power	Computed	W
		`PwrFwFLx`	Longitudinal force applied at the front left axle power	Computed	W
		`PwrFwFLy`	Lateral force applied at the front left axle power	Computed	W
		`PwrFwFRx`	Longitudinal force applied at the front right axle power	Computed	W
		`PwrFwFRy`	Lateral force applied at the front right axle power	Computed	W
		`PwrFwMLx`	Longitudinal force applied at the middle left axle power	Computed	W
		`PwrFwMLy`	Lateral force applied at the middle left axle power	Computed	W
		`PwrFwMRx`	Longitudinal force applied at the middle right axle power	Computed	W
		`PwrFwMRy`	Lateral force applied at the middle right axle power	Computed	W

Signal			Description	Value	Units
		`PwrFwRLx`	Longitudinal force applied at the rear left axle power	Computed	W
		`PwrFwRLy`	Lateral force applied at the rear left axle power	Computed	W
		`PwrFwRRx`	Longitudinal force applied at the rear right axle power	Computed	W
		`PwrFwRRy`	Lateral force applied at the rear right axle power	Computed	W
	`PwrNotTrnsfrd`	`PwrFxDrag`	Longitudinal drag force power	Computed	W
		`PwrFyDrag`	Lateral drag force power	Computed	W
		`PwrMzDrag`	Drag pitch moment power	Computed	W
	`PwrStored`	`PwrStoredGrvty`	Rate change in gravitational potential energy	Computed	W
		`PwrStoredxdot`	Rate of change of longitudinal kinetic energy	Computed	W
		`PwrStoredydot`	Rate of change of lateral kinetic energy	Computed	W
		`PwrStoredr`	Rate of change of rotational yaw kinetic energy	Computed	W

`xdot` — Vehicle longitudinal velocity
`scalar`

Vehicle CG velocity along the vehicle-fixed x-axis, in m/s.

`ydot` — Vehicle lateral velocity
`scalar`

Vehicle CG velocity along the vehicle-fixed y-axis, in m/s.

`psi` — Yaw
`scalar`

Rotation of the vehicle-fixed frame about the earth-fixed Z-axis (yaw), in rad.

`r` — Yaw rate
`scalar`

Vehicle angular velocity, `r`, about the vehicle-fixed z-axis (yaw rate), in rad/s.

`FzF` — Normal force on front wheels
`scalar` | `array`

Normal force on the front wheels, Fz_F, along the vehicle-fixed z-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	Normal force on front axle	$FzF = Fz_f$	Scalar – `1`
`Dual`	Normal force on the right and left front wheels	$FzF = \left[Fz_{fl}\ Fz_{fr}\right]$	Array – `[1x2]`

`FzM` — Normal force on middle wheels

`scalar` | `array`

Normal force on the middle wheels, Fz_M, along the vehicle-fixed z-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	Normal force on middle axle	$FzM = Fz_m$	Scalar – `1`
`Dual`	Normal force on the right and left middle wheels	$FzM = \left[Fz_{ml}\ Fz_{rl}\right]$	Array – `[1x2]`

`FzR` — Normal force on rear wheels

`scalar` | `array`

Normal force on the rear wheels, Fz_R, along the vehicle-fixed z-axis, in N.

Vehicle Track Setting	Description	Variable	Signal Dimension
`Single (bicycle)`	Normal force on rear wheel	$FzR = Fz_r$	Scalar – `1`
`Dual`	Normal force on the right and left rear wheels	$FzR = \left[Fz_{rl}\ Fz_{rr}\right]$	Array – `[1x2]`

Parameters

Options

`Vehicle track` — Number of vehicle wheels

`Dual` (default) | `Single (bicycle)`

Use the **Vehicle track** parameter to specify the number of wheels.

Vehicle Track Setting	Implementation
`Single (bicycle)`	• Forces act along the center line of the axles. • No lateral load transfer.
`Dual`	Forces act at the axle hard-point locations.

`Axle forces` — Type of axle force

`External longitudinal velocity` (default) | `External longitudinal forces` | `External forces`

Use the **Axle forces** parameter to specify the type of force.

Axle Forces Setting	Implementation

`External longitudinal velocity`	• The block assumes that the external longitudinal velocity is in a quasi-steady state, so the longitudinal acceleration is approximately zero.
	• Because the motion is quasi-steady, the block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Generate virtual sensor signal data.
	  • Conduct high-level software studies that are not impacted by driveline or nonlinear tire responses.

`External longitudinal forces`	• The block uses the external longitudinal force to accelerate or brake the vehicle.
	• The block calculates lateral forces using the tire slip angles and linear cornering stiffness.
	• Consider this setting when you want to:
	  • Account for changes in the longitudinal velocity on the lateral and yaw motion.
	  • Specify the external longitudinal motion through a force instead of an external longitudinal velocity.
	  • Connect the block to tractive actuators, wheels, brakes, and hitches.

`External forces`	• The block uses the external lateral and longitudinal forces to steer, accelerate, or brake the vehicle. • The block does not use the steering input to calculate vehicle motion. • Consider this setting when you need tire models with more accurate nonlinear combined lateral and longitudinal slip.

Input Signals

`Front wheel steering` — `WhlAngF` input port

`on` (default) | `off`

Select to create input port `WhlAngF`.

`Middle wheel steering` — `WhlAngM` input port

`off` (default) | `on`

Select to create input port `WhlAngM`.

`Rear wheel steering` — `WhlAngR` input port

`off` (default) | `on`

Select to create input port `WhlAngR`.

`External wind` — WindXYZ input port

`off` (default) | `on`

Select to create input port `WindXYZ`.

`External friction` — Mu input port

`off` (default) | `on`

Select to create input port `Mu`.

Dependencies

To enable this parameter, set **Axle forces** to `External longitudinal forces` or `External forces`.

`External forces` — FExt input port

`off` (default) | `on`

Select to create input port `FExt`.

`External moments` — MExt input port

`off` (default) | `on`

Select to create input port `MExt`.

`Hitch forces` — Fh input port

`on` (default) | `off`

Select to create input port `Fh`.

`Hitch moments` — Mh input port

`on` (default) | `off`

Specify to create input port `Mh`.

`Initial longitudinal position` — X_o input port

`off` (default) | `on`

Specify to create input port `X_o`.

`Initial yaw angle` — psi_o input port

`off` (default) | `on`

Specify to create input port `psi_o`.

`Initial longitudinal velocity` — xdot_o input port

`off` (default) | `on`

Specify to create input port `xdot_o`.

Dependencies

To enable this parameter, set **Axle forces** to `External longitudinal forces` or `External forces`.

`Initial yaw rate` — r_o input port
`off` (default) | `on`

Specify to create input port `r_o`.

`Initial lateral position` — Y_o input port
`off` (default) | `on`

Specify to create input port `Y_o`.

`Air temperature` — AirTemp input port
`off` (default) | `on`

Specify to create input port `AirTemp`.

`Initial lateral velocity` — ydot_o input port
`off` (default) | `on`

Specify to create input port `ydot_o`.

Longitudinal

`Number of wheels on front axle, NF` — Front wheel count
`2` (default) | `scalar`

Number of wheels on the front axle, N_F, dimensionless.

`Number of wheels on middle axle, NM` — Middle wheel count
`2` (default) | `scalar`

Number of wheels on the middle axle, N_M, dimensionless.

`Number of wheels on rear axle, NR` — Rear wheel count
`2` (default) | `scalar`

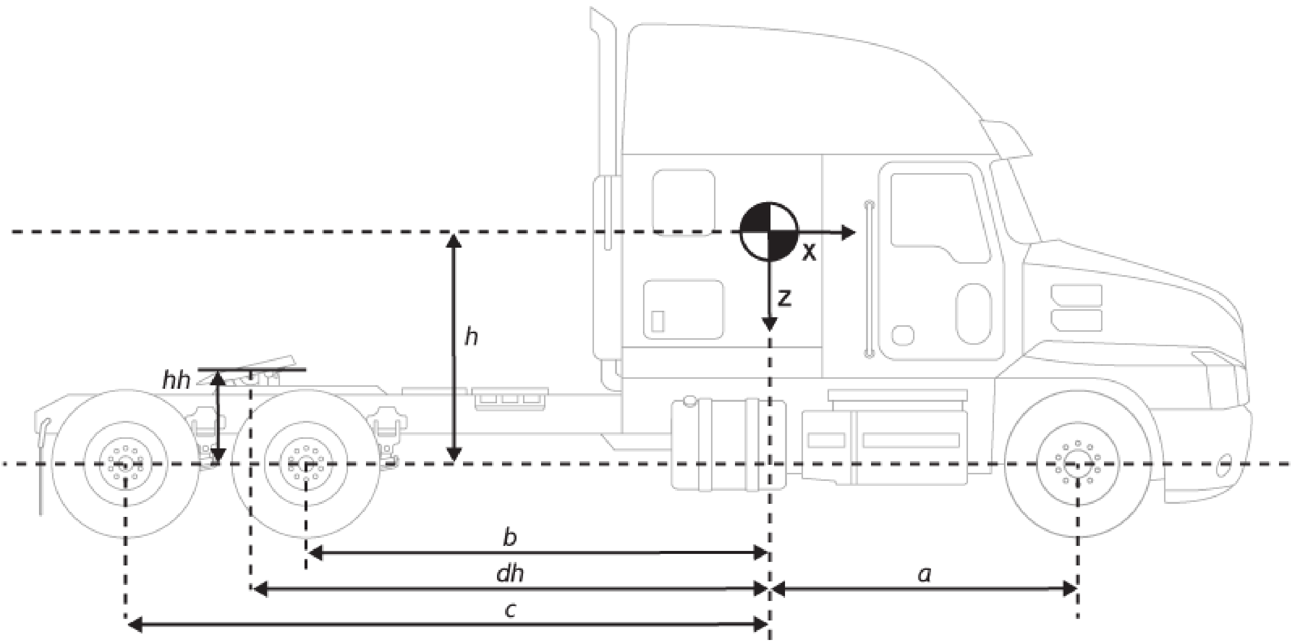
Number of wheels on the rear axle, N_R, dimensionless.

`Vehicle mass, m` — Vehicle mass
`47000` (default) | `scalar`

Vehicle mass, m, in kg.

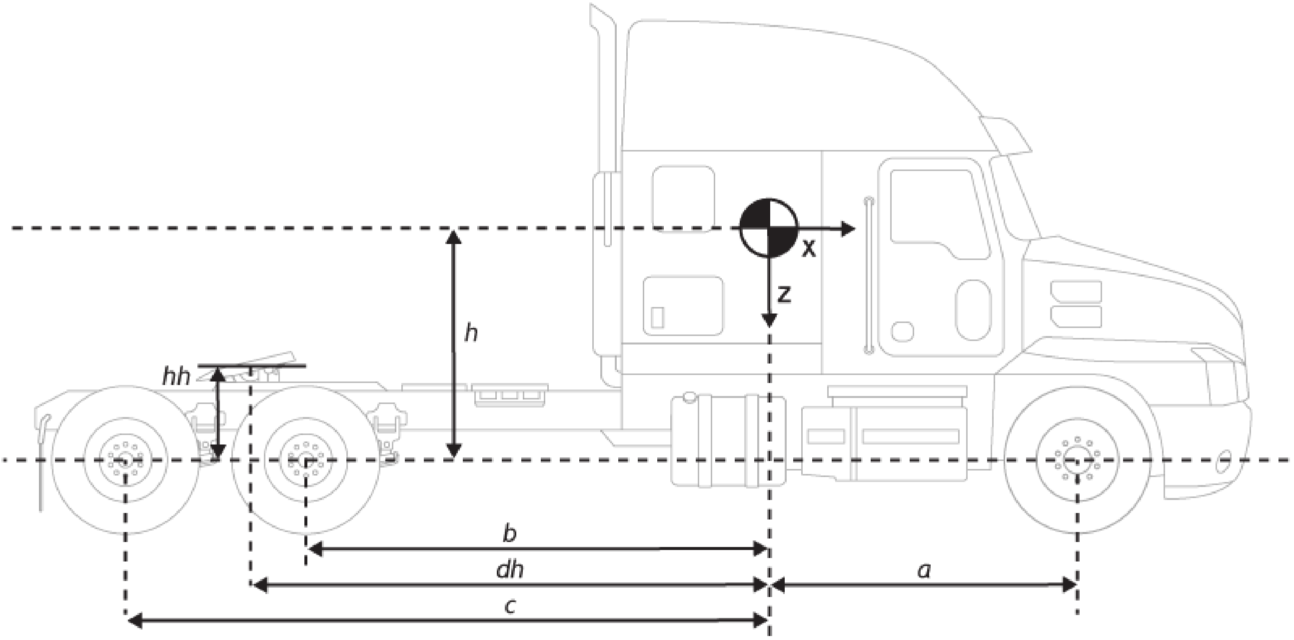
`Longitudinal distance from center of mass to front axle, a` — Distance from CM to front axle
`0.5` (default) | `scalar`

Distance from vehicle CM to front axle, a, in m.



`Longitudinal distance from center of mass to middle axle, b` — Distance from CM to middle axle
`4.5` (default) | `scalar`

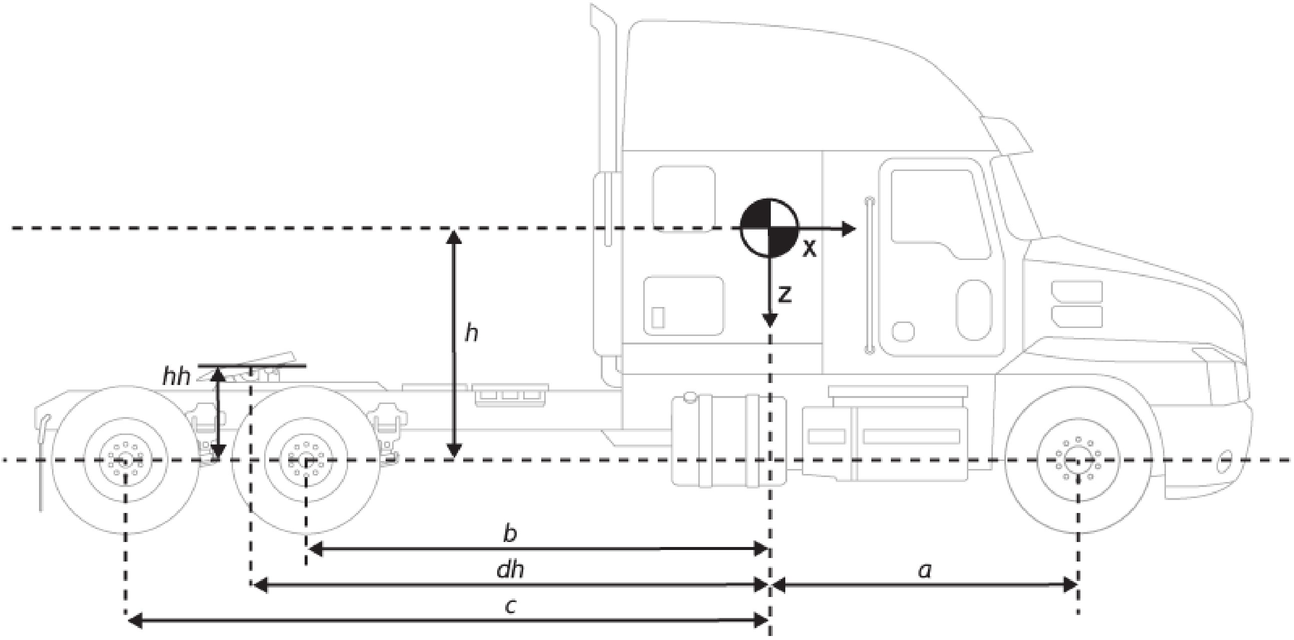
Distance from vehicle CM to middle axle, *b*, in m.



`Longitudinal distance from center of mass to rear axle, c` — Distance from CM to rear axle

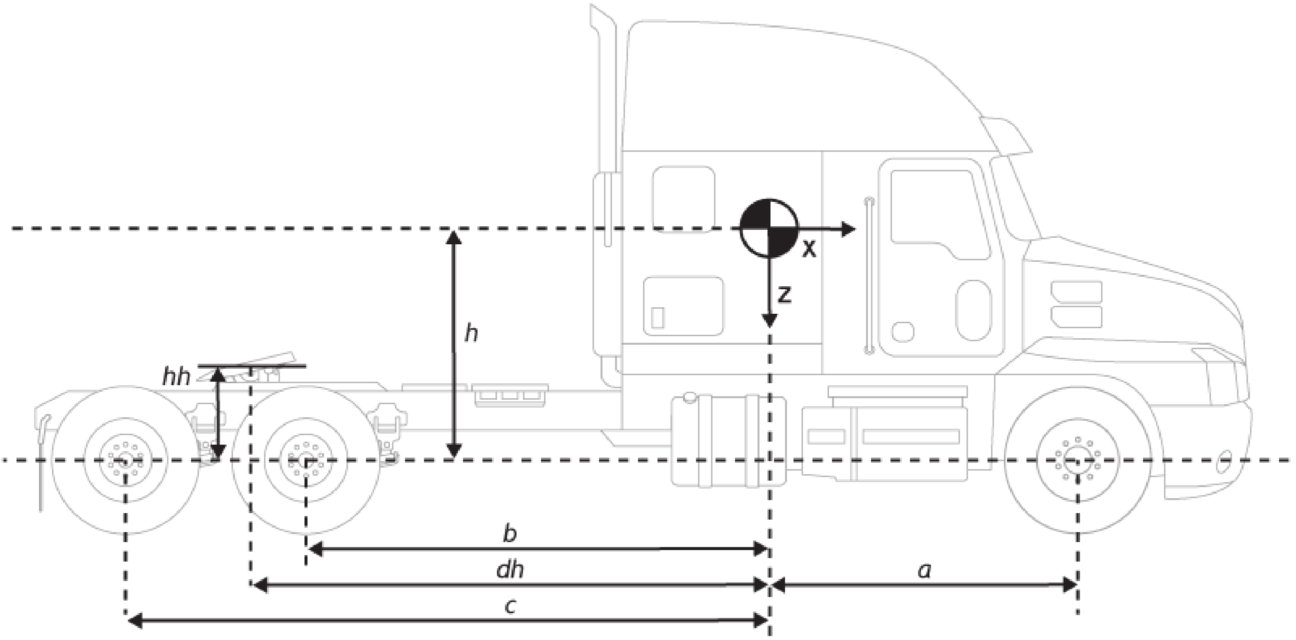
`5.7` (default) | `scalar`

Distance from vehicle CM to rear axle, *c*, in m.



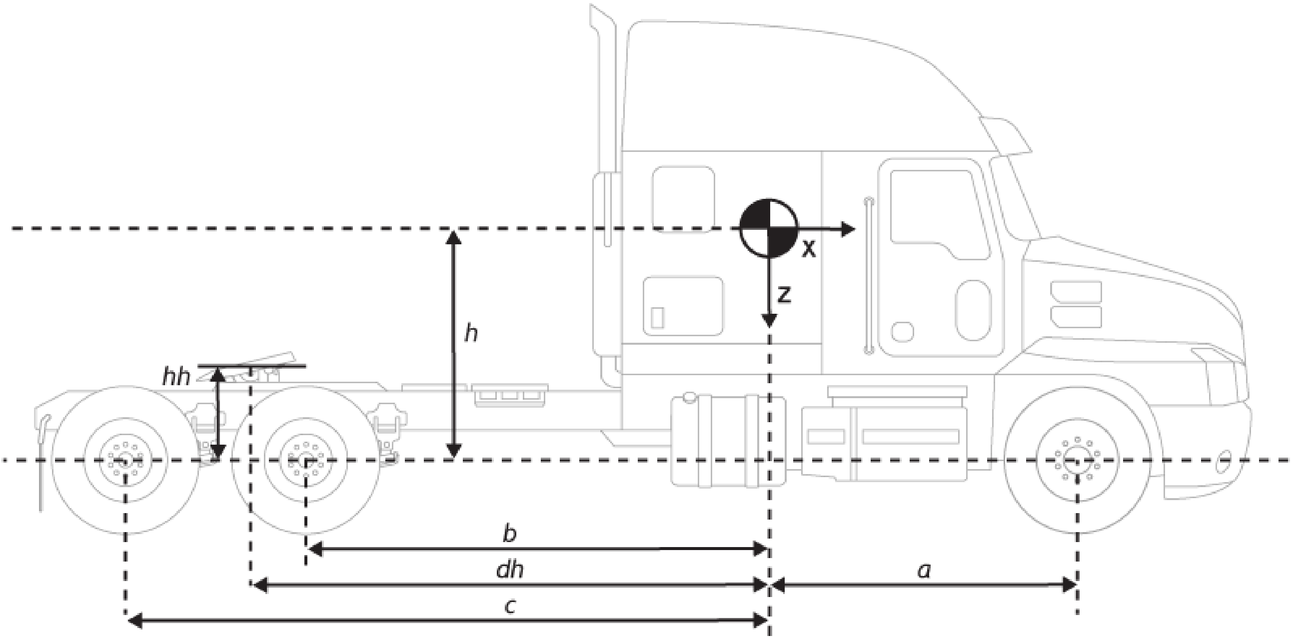
`Vertical distance from center of mass to axle plane, h` — Distance from CM to axle plane
`0.3` (default) | `scalar`

Vertical distance from vehicle CM to axle plane, *h*, in m.



`Vertical distance from hitch to axle plane, hh` — Distance from hitch to axle plane
`0.5` (default) | `scalar`

Vertical distance from hitch to axle plane, *hh*, in m.



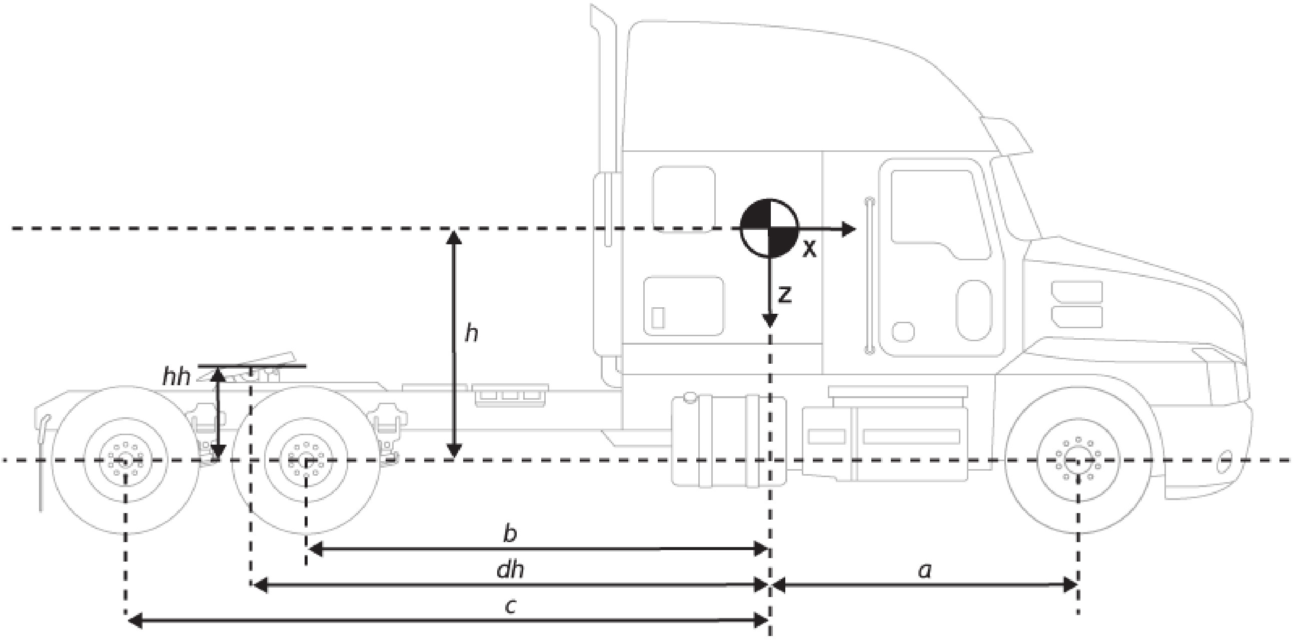
Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Longitudinal distance from center of mass to hitch, dh` — Distance from CM to hitch

5 (default) | `scalar`

Longitudinal distance from center of mass to hitch, *dh*, in m.



Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Initial inertial frame longitudinal position, X_o` — Initial longitudinal displacement

`0` (default) | `scalar`

Initial vehicle CG displacement along the earth-fixed *X*-axis, in m.

`Initial longitudinal velocity, xdot_o` — Initial longitudinal velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

Lateral

`Mapped corner stiffness` — Enable mapped corner stiffness

`off` (default) | `on`

Enables mapped corner stiffness calculation.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

`Include relaxation length dynamics` — Enable relaxation length dynamics

`on` (default) | `off`

Enables relaxation length dynamics.

Dependencies

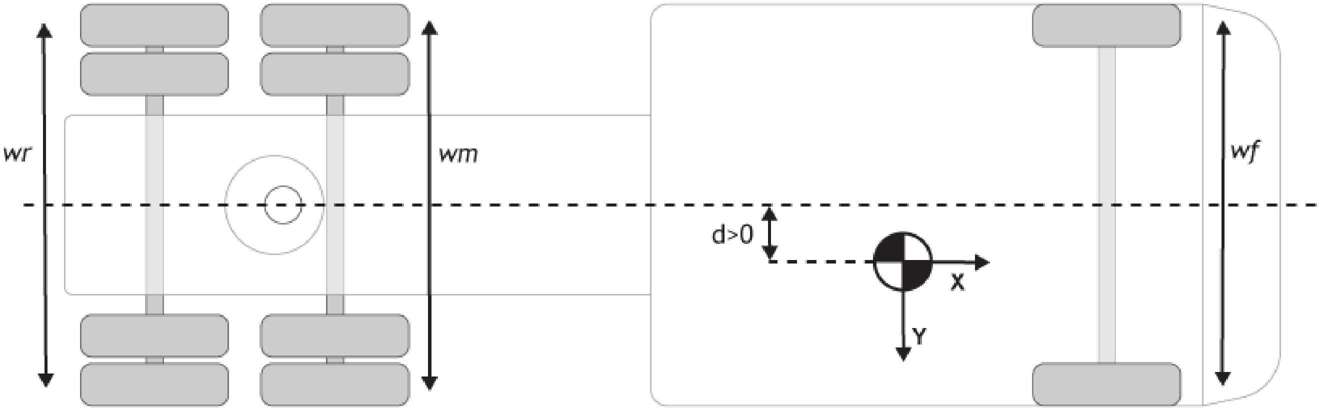
To enable this parameter:

1. Set **Axle forces** to one of these options:
    - `External longitudinal velocity`
    - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Lateral distance from geometric centerline to center of mass, d` — Distance from centerline to CM

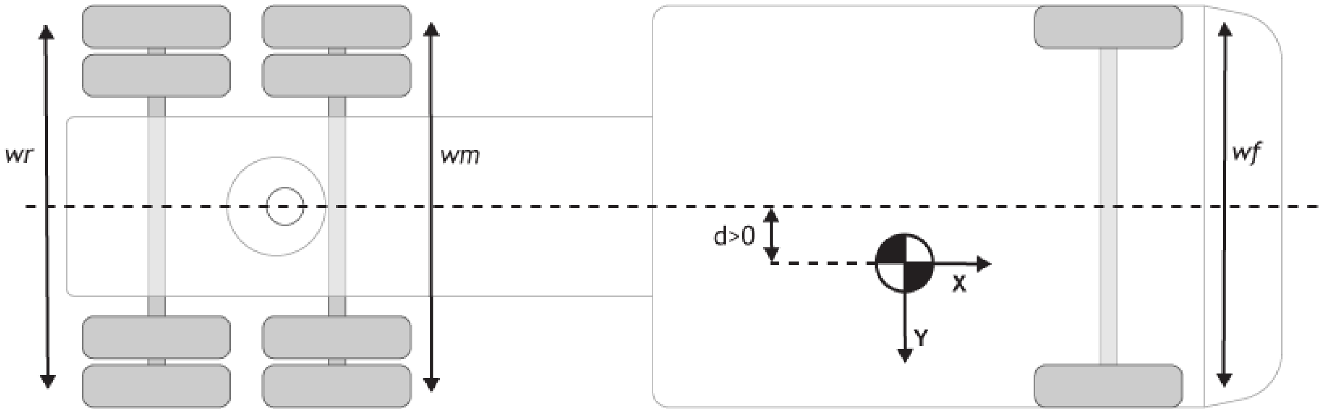
`0` (default) | `scalar`

Lateral distance from the geometric centerline to the center of mass, *d*, in m, along the vehicle-fixed *y*-axis. Positive values indicate that the vehicle CM is to the right of the geometric centerline. Negative values indicate that the vehicle CM is to the left of the geometric centerline.



`Track width, w` — Front, middle, and rear track widths
`[1.82,1.82,1.82]` (default) | `vector`

Front, middle, and rear track widths, *wf*, *wm*, and, *wr*, respectively, in m. Dimensions are `1-by-3`.



Dependencies

To enable this parameter, set **Vehicle track** to `Dual`.

`Front axle tire corner stiffness, Cy_f` — Front tire corner stiffness

`12e3` | `scalar`

Front tire corner stiffness, Cy_f, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Middle axle tire corner stiffness, Cy_m` — Middle tire corner stiffness

`11e3` | `scalar`

Middle axle tire corner stiffness, Cy_m, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Rear axle tire corner stiffness, Cy_r` — Rear tire corner stiffness

`11e3` | `scalar`

Rear axle tire corner stiffness, Cy_r, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Front tire(s) relaxation length, sigma_f` — Front tire relaxation length

`.1` (default) | `scalar`

Front tire relaxation length, σ_f, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Middle tire(s) relaxation length, sigma_m` — Middle tire relaxation length

`.1` (default) | `scalar`

Middle tire relaxation length, σ_m, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Rear tire(s) relaxation length, sigma_r` — Rear tire relaxation length

`.1` (default) | `scalar`

Rear tire relaxation length, σ_r, in m.

Dependencies

To enable this parameter:

1. Set **Vehicle track** to one of these options:
   - `Single 2-axle`
   - `Dual 2-axle`
   - `Single 3-axle`
   - `Dual 3-axle`
2. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
3. Do either of these:
   - Select **Mapped corner stiffness**.
   - Clear **Mapped corner stiffness** and select **Include relaxation length dynamics**.

`Front axle slip angle breakpoints, alpha_f_brk` — Breakpoints

`[-.1 .1]` (default) | `vector`

Front axle slip angle breakpoints, α_{fbrk}, in rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`

- `External longitudinal forces`

2 Select **Mapped corner stiffness**.

`Front axle tire corner data, Cy_f_data` — Front axle tire corner data

`[-9e3 9e3]` (default) | `vector`

Front axle tire corner data, Cy_{fdata}, in N/rad.

Dependencies

To enable this parameter:

1 Set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

2 Select **Mapped corner stiffness**.

`Middle axle slip angle breakpoints, alpha_m_brk` — Breakpoints

`[-.1 .1]` (default) | `vector`

Middle axle slip angle breakpoints, α_{mbrk}, in rad.

Dependencies

To enable this parameter:

1 Set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

2 Select **Mapped corner stiffness**.

`Middle axle tire corner data, Cy_m_data` — Middle axle tire corner data

`[-9e3 9e3]` (default) | `vector`

Middle axle tire corner data, Cy_{mdata}, in N/rad.

Dependencies

To enable this parameter:

1 Set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

2 Select **Mapped corner stiffness**.

`Rear axle slip angle breakpoints, alpha_r_brk` — Breakpoints

`[-.1 .1]` (default) | `vector`

Rear axle slip angle breakpoints, α_{rbrk}, in rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Rear axle tire corner data, Cy_r_data` — Rear axle tire corner data

`[-9e3 9e3]` (default) | `vector`

Rear axle tire corner data, Cy_{rdata}, in N/rad.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Select **Mapped corner stiffness**.

`Initial inertial frame lateral displacement, Y_o` — Initial lateral displacement

`0` (default) | `scalar`

Initial vehicle CG displacement along the earth-fixed *Y*-axis, in m.

`Initial lateral velocity, ydot_o` — Initial lateral velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along the vehicle-fixed *y*-axis, in m/s.

Yaw

`Yaw polar inertia, Izz` — Inertia

`4000` (default) | `scalar`

Yaw polar inertia, in kg*m^2.

`Initial yaw angle, psi_o` — Psi rotation

`0` (default) | `scalar`

Rotation of the vehicle-fixed frame about earth-fixed *Z*-axis (yaw), in rad.

`Initial yaw rate, r_o` — Yaw rate

`0` (default) | `scalar`

Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

Aerodynamic

`Longitudinal drag area, Af` — Effective vehicle cross-sectional area

2 (default) | `scalar`

Effective vehicle cross-sectional area, A_f, to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Air drag coefficient
`.3` (default) | `scalar`

Air drag coefficient, C_d. The value is dimensionless.

`Longitudinal lift coefficient, Cl` — Air lift coefficient
`.1` (default) | `scalar`

Air lift coefficient, C_l. The value is dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}. The value is dimensionless.

`Relative wind angle vector, beta_w` — Wind angle
`[0:0.01:0.3]` (default) | `vector`

Relative wind angle vector, β_w, in rad.

`Side force coefficient vector, Cs` — Side force coefficient
`[0:0.03:0.9]` (default) | `vector`

Side force coefficient vector coefficient, C_s. The value is dimensionless.

`Yaw moment coefficient vector, Cym` — Yaw moment drag
`[0:0.01:0.3]` (default) | `vector`

Yaw moment coefficient vector coefficient, C_{ym}. The value is dimensionless.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar`

Environmental absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Temperature
`273` (default) | `scalar`

Environmental absolute temperature, T, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity
`9.81` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

`Nominal friction scaling factor, mu` — Friction scale factor
`1` (default) | `scalar`

Nominal friction scale factor, μ. The value is dimensionless.

Dependencies

To enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **External Friction**.

Simulation

`Longitudinal velocity tolerance, xdot_tol` — Tolerance

`.01` (default) | `scalar`

Longitudinal velocity tolerance, in m/s.

`Nominal normal force, Fznom` — Normal force

`5000` (default) | `scalar`

Nominal normal force, in N.

Dependencies

To enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

`Geometric longitudinal offset from axle plane, longOff` — Longitudinal offset

`0` (default) | `scalar`

Vehicle chassis offset from the axle plane along the vehicle-fixed *x*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric lateral offset from center plane, latOff` — Lateral offset

`0` (default) | `scalar`

Vehicle chassis offset from the center plane along the vehicle-fixed *y*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric vertical offset from axle plane, vertOff` — Vertical offset

`0` (default) | `scalar`

Vehicle chassis offset from the axle plane along the vehicle-fixed *z*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Wrap Euler angles, wrapAng` — Wrap the Euler angles to the interval `[-pi, pi]`

`off` (default) | `on`

Wrap the Euler angles to the interval `[-pi, pi]`. For vehicle maneuvers that might undergo vehicle yaw rotations that are outside of this interval, consider clearing the parameter if you want to:

- Track the total vehicle yaw rotation.
- Avoid discontinuities in the vehicle state estimators.

Version History

Introduced in R2020a

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

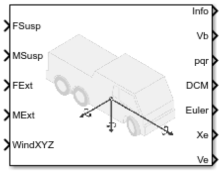
Trailer Body 3DOF

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Vehicle Body 6DOF Three Axles

Three-axle vehicle tractor body with translational and rotational motion
Library: Vehicle Dynamics Blockset / Vehicle Body



Description

The Vehicle Body 6DOF Three Axles block implements a six degrees-of-freedom (DOF) rigid three-axle vehicle body model that calculates longitudinal, lateral, vertical, pitch, roll, and yaw motion. Use the block to model three-axle vehicles like a tractor. The block accounts for body mass, inertia, aerodynamic drag, road incline, and weight distribution between the axle hard-point locations due to suspension and external forces and moments. Use the **Inertial Loads** parameters to analyze the vehicle dynamics under different loading conditions.

Connect the block to virtual sensors, suspension systems, or external systems like body control actuators. Use the Vehicle Body 6DOF Three Axles block in ride and handling studies to model the effects of drag forces, passenger loading, and suspension hardpoint locations.

To create additional input ports, under **Input signals**, select these block parameters.

Parameter	Input Port	Description
Front hitch forces	`FhF`	Hitch force applied to the body at the front hitch location, FhF_x, FhF_y, and FhF_z, in the vehicle-fixed frame
Front hitch moments	`MhF`	Hitch moment at the front hitch location, MhF_x, MhF_y, and MhF_z, about the vehicle-fixed frame
Rear hitch forces	`FhR`	Hitch force applied to the body at the rear hitch location, FhR_x, FhR_y, and FhR_z, in the vehicle-fixed frame
Rear hitch moments	`MhR`	Hitch moment at the rear hitch location, MhR_x, MhR_y, and MhR_z, about the vehicle-fixed frame

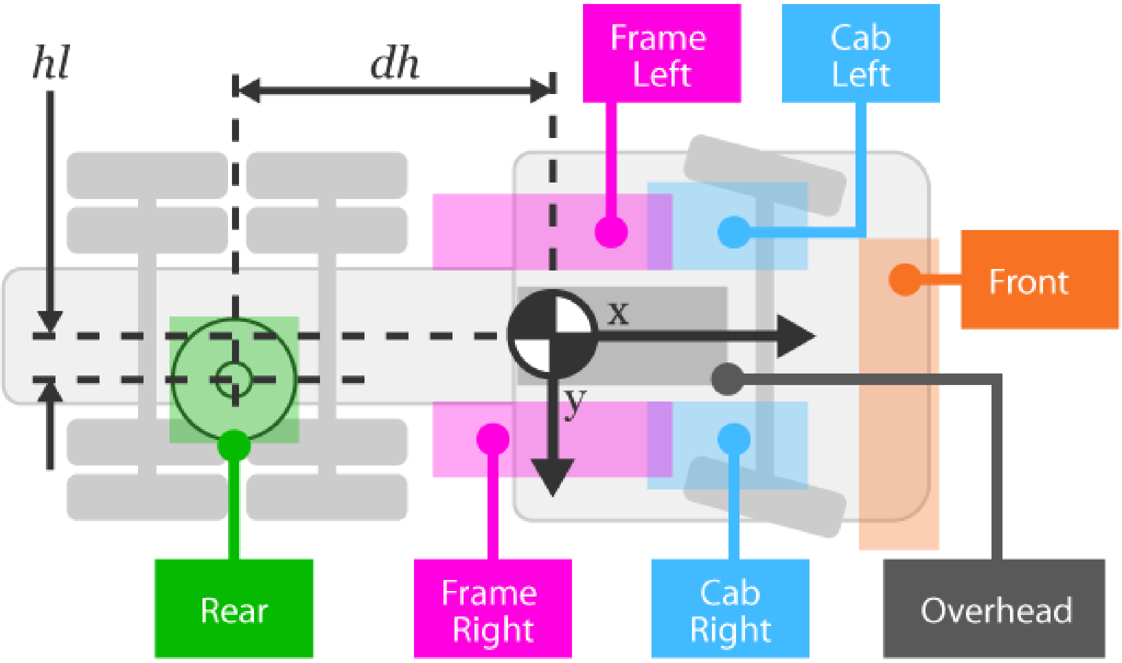
Inertial Loads

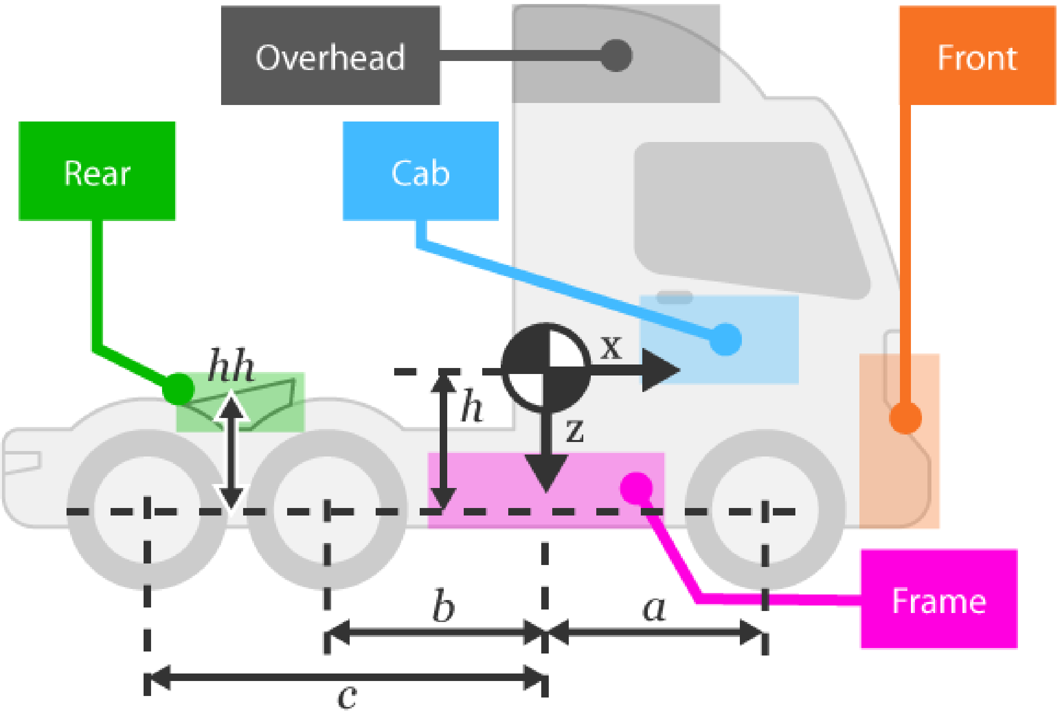
To analyze the vehicle dynamics under different loading conditions, use the **Inertial Loads** parameters. You can specify these loads:

- Tractor front
- Cab overhead
- Tractor frame left and frame right
- Cab left and cab right
- Tractor rear

For each of the loads, you can specify the mass, location, and inertia.

The illustrations provide the load locations and vehicle parameter dimensions. The table provides the corresponding location parameter sign settings.





This table summarizes the parameter settings that specify the load locations indicated by the dots. For the location, the block uses this distance vector:

- Front axle to load, along the vehicle-fixed *x*-axis
- Vehicle centerline to load, along the vehicle-fixed *y*-axis
- Front axle to load, along the vehicle-fixed *z*-axis

Load	Parameter	Example Location
Tractor front	**Distance vector from front axle, z1R**	• `z1R(1,1)<0` — Forward of the front axle • `z1R(1,2)>0` — Right of the vehicle centerline • `z1R(1,3)>0` — Above the front axle suspension hardpoint
Cab overhead	**Distance vector from front axle, z2R**	• `z2R(1,1)>0` — Rear of the front axle • `z2R(1,2)<0` — Left of the vehicle centerline • `z2R(1,3)>0` — Above the front axle suspension hardpoint
Tractor frame left	**Distance vector from front axle, z3R**	• `z3R(1,1)>0` — Rear of the front axle • `z3R(1,2)<0` — Left of the vehicle centerline • `z3R(1,3)>0` — Above the front axle suspension hardpoint
Tractor frame right	**Distance vector from front axle, z4R**	• `z4R(1,1)>0` — Rear of the front axle • `z4R(1,2)>0` — Right of the vehicle centerline • `z4R(1,3)>0` — Above the front axle suspension hardpoint
Cab left	**Distance vector from front axle, z5R**	• `z5R(1,1)>0` — Rear of the front axle • `z5R(1,2)<0` — Left of the vehicle centerline • `z5R(1,3)>0` — Above the front axle suspension hardpoint
Cab right	**Distance vector from front axle, z6R**	• `z6R(1,1)>0` — Rear of the front axle • `z6R(1,2)>0` — Right of the vehicle centerline • `z6R(1,3)>0` — Above the front axle suspension hardpoint
Tractor rear	**Distance vector from front axle, z7R**	• `z7R(1,1)>0` — Rear of the front axle • `z7R(1,2)>0` — Right of the vehicle centerline • `z7R(1,3)>0` — Above the front axle suspension hardpoint

Equations of Motion

To determine the vehicle motion, the block implements calculations for the rigid body vehicle dynamics, wind drag, inertial loads, and coordinate transformations. The body-fixed and vehicle-fixed coordinate systems are the same.

The block considers the rotation of a body-fixed coordinate frame about a flat earth-fixed inertial reference frame. The origin of the body-fixed coordinate frame is the vehicle center of gravity of the body.

The block uses this equation to calculate the translational motion of the body-fixed coordinate frame, where the applied forces $[F_x \; F_y \; F_z]^{\mathrm{T}}$ are in the body-fixed frame, and the mass of the body, m, is assumed to be constant.

$$\bar{F}_b = \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = m\left(\dot{\bar{V}}_b + \bar{\omega} \times \bar{V}_b\right)$$

$$\bar{M}_b = \begin{bmatrix} L \\ M \\ N \end{bmatrix} = I\dot{\bar{\omega}} + \bar{\omega} \times (I\bar{\omega})$$

$$I = \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix}$$

To determine the relationship between the body-fixed angular velocity vector, $[p \; q \; r]^{\mathrm{T}}$, and the rate of change of the Euler angles, $\left[\dot{\phi} \quad \dot{\theta} \quad \dot{\psi}\right]^T$, the block resolves the Euler rates into the body-fixed frame.

$$\begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \dot{\phi} \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} 0 \\ \dot{\theta} \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ \dot{\psi} \end{bmatrix} \equiv J^{-1} \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

Inverting J gives the required relationship to determine the Euler rate vector.

$$\begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = J \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} 1 & (\sin\phi\tan\theta) & (\cos\phi\tan\theta) \\ 0 & \cos\phi & -\sin\phi \\ 0 & \dfrac{\sin\phi}{\cos\theta} & \dfrac{\cos\phi}{\cos\theta} \end{bmatrix} \begin{bmatrix} p \\ q \\ r \end{bmatrix}$$

The applied forces and moments are the sum of the drag, gravitational, external, and suspension forces.

$$\bar{F}_b = \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \begin{bmatrix} F_{d_x} \\ F_{d_y} \\ F_{d_z} \end{bmatrix} + \begin{bmatrix} F_{g_x} \\ F_{g_y} \\ F_{g_z} \end{bmatrix} + \begin{bmatrix} F_{ext_x} \\ F_{ext_y} \\ F_{ext_z} \end{bmatrix} + \begin{bmatrix} F_{FL_x} \\ F_{FL_y} \\ F_{FL_z} \end{bmatrix} + \begin{bmatrix} F_{FR_x} \\ F_{FR_y} \\ F_{FR_z} \end{bmatrix} + \begin{bmatrix} F_{ML_x} \\ F_{ML_y} \\ F_{ML_z} \end{bmatrix} + \begin{bmatrix} F_{MR_x} \\ F_{MR_y} \\ F_{MR_z} \end{bmatrix} + \begin{bmatrix} F_{RL_x} \\ F_{RL_y} \\ F_{RL_z} \end{bmatrix} + \begin{bmatrix} F_{RR_x} \\ F_{RR_y} \\ F_{RR_z} \end{bmatrix}$$

$$\bar{M}_b = \begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} M_{d_x} \\ M_{d_y} \\ M_{d_z} \end{bmatrix} + \begin{bmatrix} M_{ext_x} \\ M_{ext_y} \\ M_{ext_z} \end{bmatrix} + \begin{bmatrix} M_{FL_x} \\ M_{FL_y} \\ M_{FL_z} \end{bmatrix} + \begin{bmatrix} M_{FR_x} \\ M_{FR_y} \\ M_{FR_z} \end{bmatrix} + \begin{bmatrix} M_{ML_x} \\ M_{ML_y} \\ M_{ML_z} \end{bmatrix} + \begin{bmatrix} M_{MR_x} \\ M_{MR_y} \\ M_{MR_z} \end{bmatrix} + \begin{bmatrix} M_{RL_x} \\ M_{RL_y} \\ M_{RL_z} \end{bmatrix} + \begin{bmatrix} M_{RR_x} \\ M_{RR_y} \\ M_{RR_z} \end{bmatrix} + \bar{M}_F$$

Calculation	**Implementation**
Load masses and inertias	The block uses the parallel axis theorem to resolve the individual load masses and inertias with the vehicle mass and inertia. $J_{ij} = I_{ij} + m(\lvert R\rvert^2\delta_{ij} - R_iR_j)$
Gravitational forces, F_g	The block uses the direction cosine matrix (DCM) to transform the gravitational vector in the inertial-fixed frame to the body-fixed frame.
Drag forces, F_d, and moments, M_d	To determine a relative airspeed, the block subtracts the wind speed from the vehicle center of mass (CM) velocity. Using the relative airspeed, the block determines the drag forces. $\bar{w} = \sqrt{(\dot{x} - w_x)^2 + (\dot{x} - w_x)^2 + (w_z)^2}$ $F_{dx} = -\frac{1}{2TR}C_dA_fP_{abs}(^{\bar{w}}$ $F_{dy} = -\frac{1}{2TR}C_sA_fP_{abs}(^{\bar{w}}$ $F_{dz} = -\frac{1}{2TR}C_lA_fP_{abs}(^{\bar{w}}$ Using the relative airspeed, the block determines the drag moments. $M_{dr} = -\frac{1}{2TR}C_{rm}A_fP_{abs}(^{\bar{w}}(a + c)$ $M_{dp} = -\frac{1}{2TR}C_{pm}A_fP_{abs}(^{\bar{w}}(a + c)$ $M_{dy} = -\frac{1}{2TR}C_{ym}A_fP_{abs}(^{\bar{w}}(a + c)$
External forces, F_{in}, and moments, M_{in}	The external forces and moments are input via ports **FExt** and **MExt**.
Suspension forces and moments	The block assumes that the suspension forces and moments act on these hardpoint locations: • F_{FL}, M_{FL} — Front left • F_{FR}, M_{FR} — Front right • F_{ML}, M_{ML} — Middle left • F_{MR}, M_{MR} — Middle right • F_{RL}, M_{RL} — Rear left • F_{RR}, M_{RR} — Rear right

The equations use these variables.

$x, \dot{x}, \ddot{x}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *x*-axis
$y, \dot{y}, \ddot{y}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed *y*-axis

$z, \dot{z}, \ddot{z}$	Vehicle CM displacement, velocity, and acceleration along the vehicle-fixed z-axis
φ	Rotation of the vehicle-fixed frame about the earth-fixed X-axis (roll)
θ	Rotation of the vehicle-fixed frame about the earth-fixed Y-axis (pitch)
ψ	Rotation of the vehicle-fixed frame about the earth-fixed Z-axis (yaw)
F_{FLx}, F_{FLy}, F_{FLz}	Suspension forces applied to the front left hardpoint along the vehicle-fixed x-, y-, and z-axes
F_{FRx}, F_{FRy}, F_{FRz}	Suspension forces applied to the front right hardpoint along the vehicle-fixed x-, y-, and z-axes
F_{MLx}, F_{MLy}, F_{MLz}	Suspension forces applied to the middle left hardpoint along the vehicle-fixed x-, y-, and z-axes
F_{MRx}, F_{MRy}, F_{MRz}	Suspension forces applied to the middle right hardpoint along the vehicle-fixed x-, y-, and z-axes
F_{RLx}, F_{RLy}, F_{RLz}	Suspension forces applied to the rear left hardpoint along the vehicle-fixed x-, y-, and z-axes
F_{RRx}, F_{RRy}, F_{RRz}	Suspension forces applied to the rear right hardpoint along the vehicle-fixed x-, y-, and z-axes
M_{FLx}, M_{FLy}, M_{FLz}	Suspension moment applied to the front left hardpoint about the vehicle-fixed x-, y-, and z-axes
M_{FRx}, M_{FRy}, M_{FRz}	Suspension moment applied to the front right hardpoint about the vehicle-fixed x-, y-, and z-axes
M_{MLx}, M_{MLy}, M_{MLz}	Suspension moment applied to the middle left hardpoint about the vehicle-fixed x-, y-, and z-axes
M_{MRx}, M_{MRy}, M_{MRz}	Suspension moment applied to the middle right hardpoint about the vehicle-fixed x-, y-, and z-axes
M_{RLx}, M_{RLy}, M_{RLz}	Suspension moment applied to the rear left hardpoint about the vehicle-fixed x-, y-, and z-axes
M_{RRx}, M_{RRy}, M_{RRz}	Suspension moment applied to the rear right hardpoint about the vehicle-fixed x-, y-, and z-axes
F_{extx}, F_{exty}, F_{extz}	External forces applied to the vehicle CM along the vehicle-fixed x-, y-, and z-axes
F_{dx}, F_{dy}, F_{dz}	Drag forces applied to the vehicle CM along the vehicle-fixed x-, y-, and z-axes
M_{extx}, M_{exty}, M_{extz}	External moment about the vehicle CM about the vehicle-fixed x-, y-, and z-axes
M_{dx}, M_{dy}, M_{dz}	Drag moment about the vehicle CM about the vehicle-fixed x-, y-, and z-axes
I	Vehicle body moments of inertia
a, b, c	Distance of the front, middle, and rear axles, respectively, from the normal projection point of the vehicle CM onto the common axle plane
h	Height of the vehicle CM above the axle plane
d	Lateral distance from the geometric centerline to the center of mass along the vehicle-fixed y-axis

hh_f, hh_r	Height of the front and rear hitches, respectively, above the axle plane along the vehicle-fixed *z*-axis
dh_f, dh_r	Longitudinal distance of the front and rear hitches, respectively, from the normal projection point of the vehicle CM onto the common axle plane
hl_f, hl_r	Lateral distance from center of mass to the front and rear hitches, respectively, along the vehicle-fixed *y*-axis
w_F, w_M, w_R	Front, middle, and rear track widths, respectively
C_d	Air drag coefficient acting along the vehicle-fixed *x*-axis
C_s	Air drag coefficient acting along the vehicle-fixed *y*-axis
C_l	Air drag coefficient acting along the vehicle-fixed *z*-axis
C_{rm}	Air drag roll moment acting about the vehicle-fixed *x*-axis
C_{pm}	Air drag pitch moment acting about the vehicle-fixed *y*-axis
C_{ym}	Air drag yaw moment acting about the vehicle-fixed *z*-axis
A_f	Frontal area
R	Atmospheric specific gas constant
T	Environmental air temperature
P_{abs}	Environmental absolute pressure
w_x, w_y, w_z	Wind speed along the vehicle-fixed *x*-, *y*-, and *z*-axes
W_x, W_y, W_z	Wind speed along inertial *X*-, *Y*-, and *Z*-axes

Ports

Input

`FSusp` — Suspension forces on vehicle

`3`-by-`6` array

Suspension longitudinal, lateral, and vertical suspension forces applied to the vehicle at the hardpoint location, in N, specified as a `3-by-6` array.

$$FSusp = \begin{bmatrix} F_{FLx} & F_{FRx} & F_{MLx} & F_{MRx} & F_{RLx} & F_{RRx} \\ F_{FLy} & F_{FRy} & F_{MLy} & F_{MRy} & F_{RLy} & F_{RRy} \\ F_{FLz} & F_{FRz} & F_{MLz} & F_{MRz} & F_{RLz} & F_{RRz} \end{bmatrix}$$

Array Element	Axle	Track	Force Axis
`FSusp(1,1)`	Front	Left	Vehicle-fixed *x*-axis (longitudinal)
`FSusp(1,2)`	Front	Right	
`FSusp(1,3)`	Middle	Left	
`FSusp(1,4)`	Middle	Right	
`FSusp(1,5)`	Rear	Left	
`FSusp(1,6)`	Rear	Right	
`FSusp(2,1)`	Front	Left	Vehicle-fixed *y*-axis (lateral)

Array Element	Axle	Track	Force Axis
`FSusp(2,2)`	Front	Right	
`FSusp(2,3)`	Middle	Left	
`FSusp(2,4)`	Middle	Right	
`FSusp(2,5)`	Rear	Left	
`FSusp(2,6)`	Rear	Right	
`FSusp(3,1)`	Front	Left	Vehicle-fixed *z*-axis (vertical)
`FSusp(3,2)`	Front	Right	
`FSusp(3,3)`	Middle	Left	
`FSusp(3,4)`	Middle	Right	
`FSusp(3,5)`	Rear	Left	
`FSusp(3,6)`	Rear	Right	

`MSusp` — Suspension moment on vehicle
`3-by-6` array

Suspension longitudinal, lateral, and vertical suspension moments applied about the vehicle at the hardpoint location, in N, specified as a `3-by-6` array.

$$MSusp = \begin{bmatrix} M_{FLx} & M_{FRx} & M_{MLx} & M_{MRx} & M_{RLx} & M_{RRx} \\ M_{FLy} & M_{FRz} & M_{MLy} & M_{MRy} & M_{RLy} & M_{RRy} \\ M_{FLz} & M_{FRz} & M_{MLz} & M_{MRz} & M_{RLz} & M_{RRz} \end{bmatrix}$$

Array Element	Axle	Track	Moment Axis
`MSusp(1,1)`	Front	Left	Vehicle-fixed *x*-axis (longitudinal)
`MSusp(1,2)`	Front	Right	
`MSusp(1,3)`	Middle	Left	
`MSusp(1,4)`	Middle	Right	
`MSusp(1,5)`	Rear	Left	
`MSusp(1,6)`	Rear	Right	
`MSusp(2,1)`	Front	Left	Vehicle-fixed *y*-axis (lateral)
`MSusp(2,2)`	Front	Right	
`MSusp(2,3)`	Middle	Left	
`MSusp(2,4)`	Middle	Right	
`MSusp(2,5)`	Rear	Left	
`MSusp(2,6)`	Rear	Right	
`MSusp(3,1)`	Front	Left	Vehicle-fixed *z*-axis (vertical)
`MSusp(3,2)`	Front	Right	
`MSusp(3,3)`	Middle	Left	
`MSusp(3,4)`	Middle	Right	

Array Element	Axle	Track	Moment Axis
`MSusp(3,5)`	Rear	Left	
`MSusp(3,6)`	Rear	Right	

`FExt` — External forces acting on vehicle

`vector`

External forces on the vehicle, in N, specified as a `1-by-3` or `3-by-1` vector.

$$\text{FExt} = F_{ext} = \left[F_{ext_x}\ F_{ext_y}\ F_{ext_z}\right] or \begin{bmatrix} F_{ext_x} \\ F_{ext_y} \\ F_{ext_z} \end{bmatrix}$$

Array Element	Force Axis
`FExt(1,1)`	Vehicle-fixed *x*-axis (longitudinal)
`FExt(1,2)` or `FExt(2,1)`	Vehicle-fixed *y*-axis (lateral)
`FExt(1,3)` or `FExt(3,1)`	Vehicle-fixed *z*-axis (vertical)

`MExt` — External moments acting on vehicle

`vector`

External moments acting on the vehicle, in N·m, specified as a `1-by-3` or `3-by-1` vector.

$$\text{MExt} = M_{ext} = \left[M_{ext_x}\ M_{ext_y}\ M_{ext_z}\right] or \begin{bmatrix} M_{ext_x} \\ M_{ext_y} \\ M_{ext_z} \end{bmatrix}$$

Array Element	Force Axis
`MExt(1,1)`	Vehicle-fixed *x*-axis (longitudinal)
`MExt(1,2)` or `MExt(2,1)`	Vehicle-fixed *y*-axis (lateral)
`MExt(1,3)` or `MExt(3,1)`	Vehicle-fixed *z*-axis (vertical)

`Fh` — Hitch force on the body

`array`

Hitch force applied to the body at the hitch location, Fh_x, Fh_y, Fh_z, in the vehicle-fixed frame, in N, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch forces**.

`Mh` — Hitch moment about body

`array`

Hitch moment at the hitch location, Mh_x, Mh_y, Mh_z, about the vehicle-fixed frame, in N·m, specified as a `1-by-3` or `3-by-1` array.

Dependencies

To enable this port, under **Input signals**, select **Hitch moments**.

`WindXYZ` — Wind speed

`array`

Wind speed, W_x, W_y, W_z along inertial *X*-, *Y*-, and *Z*-axes, in m/s, specified as a `1-by-3` or `3-by-1` array.

`AirTemp` — Ambient air temperature

`scalar`

Ambient air temperature, T_{air}, in K, specified as a scalar.

Dependencies

To enable this port, under **Environment**, select **Air temperature**.

Output

`Info` — Vehicle body information

bus

Vehicle body information, returned as a bug signal containing the following values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CM displacement along the earth-fixed *X*-axis	Computed	m
			`Y`	Vehicle CM displacement along the earth-fixed *Y*-axis	Computed	m
			`Z`	Vehicle CM displacement along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Vehicle CM velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Vehicle CM velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Vehicle CM velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Ang`	`phi`	Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	Computed	rad
			`theta`	Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	Computed	rad

Signal					Description	Value	Units
			`psi`		Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad
	`FrntAxl`	`Lft`	`Disp`	`X`	Front left axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front left axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front left axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Front left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front left axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front left axle velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Rght`	`Disp`	`X`	Front right axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Front right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Front right axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Front right axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Front right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Front right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`MidlAxl`	`Lft`	`Disp`	`X`	Middle left axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Middle left axle displacement along the earth-fixed *Y*-axis	Computed	m

Signal					Description	Value	Units
				`Z`	Middle left axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Middle left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Middle left axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Middle left axle velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Rght`	`Disp`	`X`	Middle right axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Middle right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Middle right axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Middle right axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Middle right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Middle right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`RearAxl`	`Lft`	`Disp`	`X`	Rear left axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear left axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear left axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Rear left axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear left axle velocity along the earth-fixed *Y*-axis	Computed	m/s

Signal					**Description**	**Value**	**Units**
				`Zdot`	Rear left axle velocity along the earth-fixed *Z*-axis	Computed	m/s
		`Rght`	`Disp`	`X`	Rear right axle displacement along the earth-fixed *X*-axis	Computed	m
				`Y`	Rear right axle displacement along the earth-fixed *Y*-axis	Computed	m
				`Z`	Rear right axle displacement along the earth-fixed *Z*-axis	Computed	m
			`Vel`	`Xdot`	Rear right axle velocity along the earth-fixed *X*-axis	Computed	m/s
				`Ydot`	Rear right axle velocity along the earth-fixed *Y*-axis	Computed	m/s
				`Zdot`	Rear right axle velocity along the earth-fixed *Z*-axis	Computed	m/s
	`Hitch`	`Disp`	`X`		Hitch offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`		Hitch offset from the axle plane along the earth-fixed *Y*-axis	Computed	m
			`Z`		Hitch offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`		Hitch velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`		Hitch velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`		Hitch velocity along the earth-fixed *Z*-axis	Computed	m/s
	`Geom`	`Disp`	`X`		Vehicle chassis offset from the axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`		Vehicle chassis offset from center plane along the earth-fixed *Y*-axis	Computed	m

Signal				Description	Value	Units
			`Z`	Vehicle chassis offset from the axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Vehicle chassis offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Vehicle chassis offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Vehicle chassis offset velocity along the earth-fixed *Z*-axis	Computed	m/s
`BdyFrm`	`Cg`	`Vel`	`xdot`	Vehicle CM velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle CM velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle CM velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	Computed	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	Computed	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s
		`Acc`	`ax`	Vehicle CM acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CM acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CM acceleration along the vehicle-fixed *z*-axis	Computed	gn
			`xddot`	Vehicle CM acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CM acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2

Signal					Description	Value	Units
			`zddot`		Vehicle CM acceleration along the vehicle-fixed *z*-axis	Computed	m/s^2
		`DCM`			Direction cosine matrix	Computed	rad
	`Forces`	`Body`	`Fx`		Net force on the vehicle CM along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Net force on the vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Net force on the vehicle CM along the vehicle-fixed *z*-axis	Computed	N
		`Ext`	`Fx`		External force on the vehicle CM along the vehicle-fixed *x*-axis	Input	N
			`Fy`		External force on the vehicle CM along the vehicle-fixed *x*-axis	Input	N
			`Fz`		External force on the vehicle CM along the vehicle-fixed *x*-axis	Input	N
		`FrntAxl`	`Lft`	`Fx`	Front left axle velocity along the earth-fixed *Y*-axis	Computed	N
				`Fy`	Lateral force on the left side of the front axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the left side of the front axle along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right side of the front axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right side of the front axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right side of the front axle along the vehicle-fixed *z*-axis	Computed	N

Signal					Description	Value	Units
		`MidlAxl`	`Lft`	`Fx`	Longitudinal force on the left side of the middle axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Longitudinal force on the left side of the middle axle along the vehicle-fixed *x*-axis	Computed	N
				`Fz`	Normal force on the left side of the middle axle along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right side of the middle axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right side of the middle axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right side of the middle axle along the vehicle-fixed *z*-axis	Computed	N
		`RearAxl`	`Lft`	`Fx`	Longitudinal force on the left side of the rear axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the left side of the rear axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the left side of the rear axle along the vehicle-fixed *z*-axis	Computed	N
			`Rght`	`Fx`	Longitudinal force on the right side of the rear axle along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Lateral force on the right side of the rear axle left along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Normal force on the right side of the rear axle along the vehicle-fixed *z*-axis	Computed	N

Signal						Description	Value	Units
		`Hitch`	`Fx`			Hitch force applied to the body at the hitch location along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Hitch force applied to the body at the hitch location along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Hitch force applied to the body at the hitch location along the vehicle-fixed *z*-axis	Computed	N
		`Tires`	`FrntTires`	`Lft`	`Fx`	Front left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Front right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Front right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Front right tire force along the vehicle-fixed *z*-axis	Computed	N
			`MidlTires`	`Lft`	`Fx`	Middle left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Middle left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Middle left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Middle right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Middle right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Middle right tire force along the vehicle-fixed *z*-axis	Computed	N

Signal						Description	Value	Units
			`RearTires`	`Lft`	`Fx`	Rear left tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear left tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear left tire force along the vehicle-fixed *z*-axis	Computed	N
				`Rght`	`Fx`	Rear right tire force along the vehicle-fixed *x*-axis	Computed	N
					`Fy`	Rear right tire force along the vehicle-fixed *y*-axis	Computed	N
					`Fz`	Rear right tire force along the vehicle-fixed *z*-axis	Computed	N
		`Drag`	`Fx`			Drag force on the vehicle CM along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Drag force on the vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Drag force on the vehicle CM along the vehicle-fixed *z*-axis	Computed	N
		`Grvty`	`Fx`			Gravity force on the vehicle CM along the vehicle-fixed *x*-axis	Computed	N
			`Fy`			Gravity force on the vehicle CM along the vehicle-fixed *y*-axis	Computed	N
			`Fz`			Gravity force on the vehicle CM along the vehicle-fixed *z*-axis	Computed	N
	`Moments`	`Body`	`Mx`			Body moment on the vehicle CM about the vehicle-fixed *x*-axis	Computed	N·m
			`My`			Body moment on the vehicle CM about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`			Body moment on the vehicle CM about the vehicle-fixed *z*-axis	Computed	N·m
		`Drag`	`Mx`			Drag moment on the vehicle CM about the vehicle-fixed *x*-axis	Computed	N·m

Signal					Description	Value	Units
			My		Drag moment on the vehicle CM about the vehicle-fixed *y*-axis	Computed	N·m
			Mz		Drag moment on the vehicle CM about the vehicle-fixed *z*-axis	Computed	N·m
		Ext	Mx		External moment on the vehicle CG about the vehicle-fixed *x*-axis	Computed	N·m
			My		External moment on the vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			Mz		External moment on the vehicle CG about the vehicle-fixed *z*-axis	Computed	N·m
		Hitch	Mx		Hitch moment at the hitch location about vehicle-fixed *x*-axis	Computed	N·m
			My		Hitch moment at the hitch location about vehicle-fixed *y*-axis	Computed	N·m
			Mz		Hitch moment at the hitch location about vehicle-fixed *z*-axis	Computed	N·m
	FrntAxl	Lft	Disp	x	Front left axle displacement along the vehicle-fixed *x*-axis	Computed	m
				y	Front left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				z	Front left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			Vel	xdot	Front left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				ydot	Front left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				zdot	Front left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		Rght	Disp	x	Front right axle displacement along the vehicle-fixed *x*-axis	Computed	m

Signal					Description	Value	Units
				`y`	Front right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Front right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Front right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Front right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Front right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`MidlAxl`	`Lft`	`Disp`	`x`	Middle left axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Middle left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Middle left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Middle left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Middle left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Middle left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Rght`	`Disp`	`x`	Middle right axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Middle right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Middle right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Middle right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s

Signal					Description	Value	Units
				`ydot`	Middle right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Middle right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`RearAxl`	`Lft`	`Disp`	`x`	Rear left axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear left axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear left axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear left axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear left axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear left axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Rght`	`Disp`	`x`	Rear right axle displacement along the vehicle-fixed *x*-axis	Computed	m
				`y`	Rear right axle displacement along the vehicle-fixed *y*-axis	Computed	m
				`z`	Rear right axle displacement along the vehicle-fixed *z*-axis	Computed	m
			`Vel`	`xdot`	Rear right axle velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Rear right axle velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Rear right axle velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`Hitch`	`Disp`		`x`	Hitch offset from the axle plane along the vehicle-fixed *x*-axis	Input	m

Signal				Description	Value	Units
			`y`	Hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
			`z`	Hitch offset from the axle plane along the vehicle-fixed *z*-axis	Input	m
		`Vel`	`xdot`	Hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Hitch offset velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`Pwr`	`PwrExt`		Applied external power	Computed	W
		`Drag`		Power loss due to drag	Computed	W
	`Geom`	`Disp`	`x`	Vehicle chassis offset from the axle plane along the vehicle-fixed *x*-axis	Input	m
			`y`	Vehicle chassis offset from center plane along the vehicle-fixed *y*-axis	Input	m
			`z`	Vehicle chassis offset from the axle plane along the vehicle-fixed *z*-axis	Input	m
		`Vel`	`xdot`	Vehicle chassis offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle chassis offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle chassis offset velocity along the vehicle-fixed *z*-axis	Computed	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad

`Vb` — Vehicle velocity along vehicle-fixed frame

`vector`

Vehicle CM velocity along the vehicle-fixed *x*-, *y*-, *z*-axes, respectively, in m/s, returned as a vector.

`pqr` — Vehicle angular velocity about vehicle-fixed frame

`vector`

Vehicle CM angular velocity about the vehicle-fixed *x*- (roll rate), *y*- (pitch rate), *z*-axes (yaw rate), respectively, in rad/s, returned as a vector.

`DCM` — Direction cosine matrix
`array`

Direction cosine matrix, in rad, returned as an array.

`Euler` — Euler angles
`array`

Euler angles, φ, θ, and ψ, respectively, in rad, returned as an array.

`Xe` — Vehicle position in inertial reference frame
`vector`

Vehicle CM position along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively, in m, returned as a vector.

`Ve` — Vehicle velocity in inertial reference frame
`vector`

Vehicle CM velocity along inertial-fixed *X*-, *Y*-, *Z*-axes, respectively, in m/s, returned as a vector.

Parameters

Block Options

Input Signals

`Hitch forces` — Create hitch force input port
`off` (default) | `on`

Select to create an input port, `Fh`, for the hitch forces.

`Hitch moments` — Create hitch moment input port
`off` (default) | `on`

Select to create an input port, `Mh`, for the hitch moments.

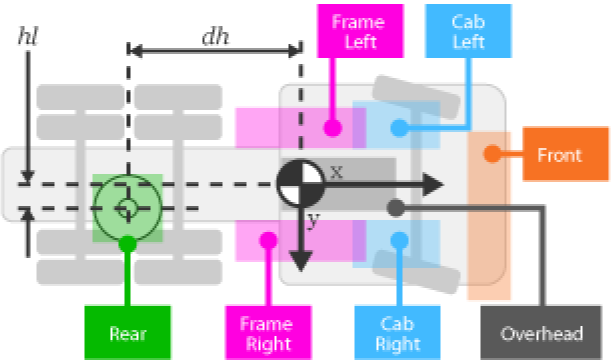
Chassis

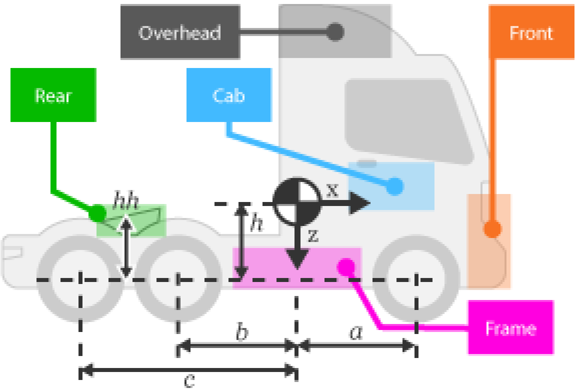
`Vehicle mass, m` — Mass
`2000` (default) | `scalar`

Vehicle mass, *m*, in kg.

`Longitudinal distance from center of mass to front axle, a` — Distance from center of mass to front axle
`1.4` (default) | `scalar`

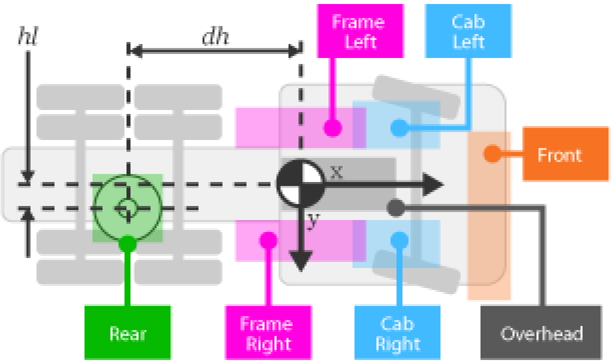
Distance from the vehicle CM to the front axle, *a*, in m.

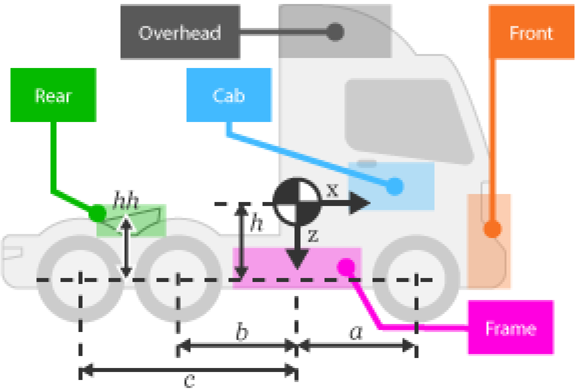




`Longitudinal distance from center of mass to middle axle, b` — Distance from center of mass to middle axle
`1.6` (default) | `scalar`

Distance from the vehicle CM to the middle axle, *b*, in m.

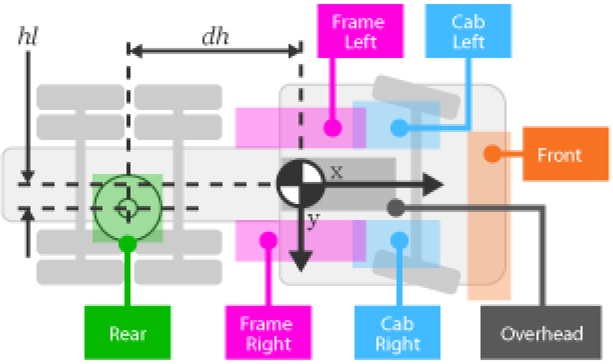


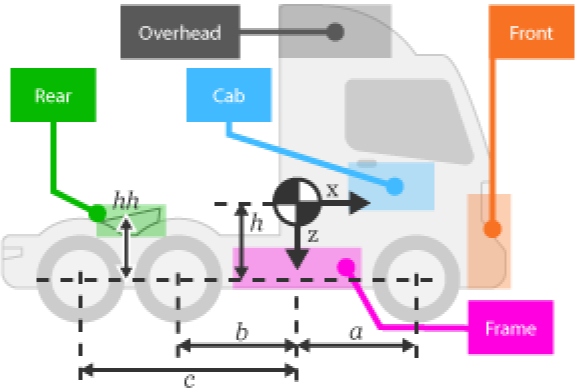


`Longitudinal distance from center of mass to rear axle, c` — Distance from center of mass to rear axle

`1.8` (default) | `scalar`

Distance from the vehicle CM to the rear axle, *c*, in m.





`Lateral distance from geometric centerline to center of mass, d` — Distance from geometric centerline to center of mass

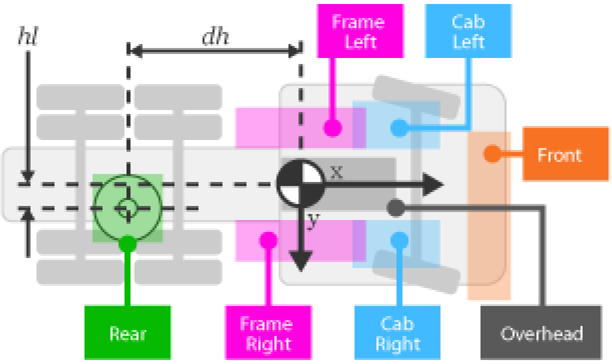
`0` (default) | `scalar`

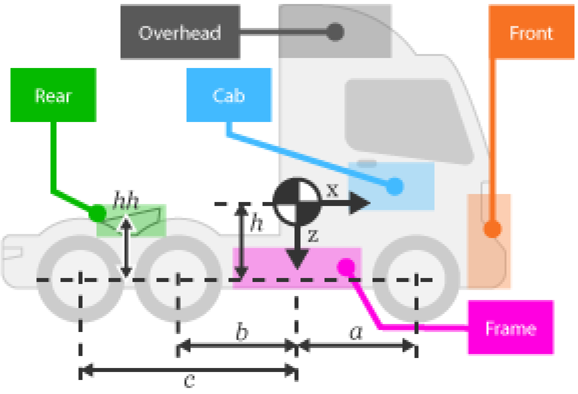
Lateral distance from the geometric centerline to the CM, *d*, in m, along the vehicle-fixed *y*. Positive values indicate that the vehicle CM is to the right of the geometric centerline. Negative values indicate that the vehicle CM is to the left of the geometric centerline.

`Vertical distance from center of mass to axle plane, h` — Distance

`.35` (default) | `scalar`

Vertical distance from the vehicle CM to the axle plane, *h*, in m.

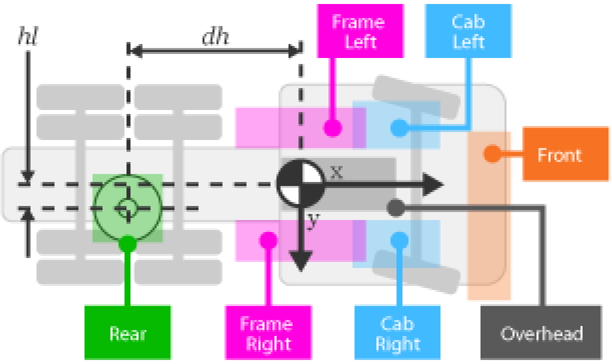


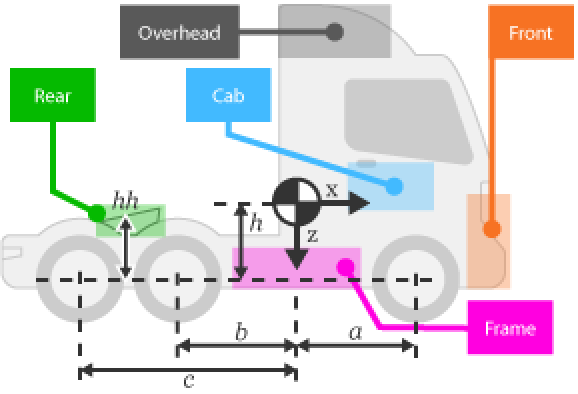


`Longitudinal distance from center of mass to hitch, dh` — Longitudinal distance from CM to hitch

1 (default) | `scalar`

Longitudinal distance from the CM to the hitch, *dh*, in m.





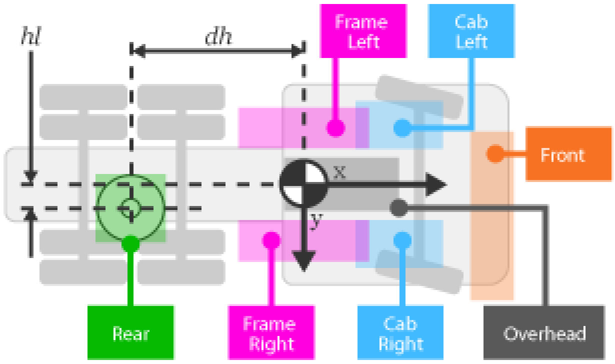
Dependencies

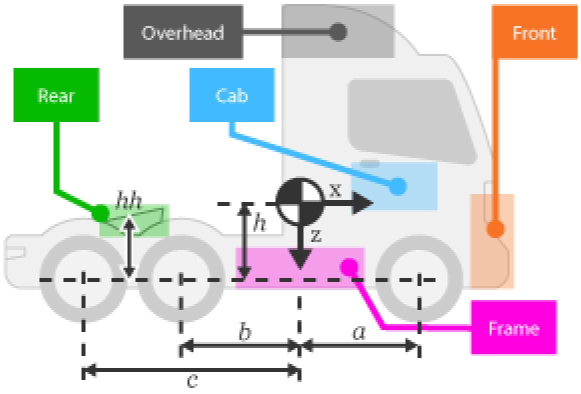
To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Longitudinal distance from center of mass to hitch, hl` — Lateral distance from CM to hitch

`0` (default) | `scalar`

Lateral distance from the CM to the hitch, *hl*, in m.





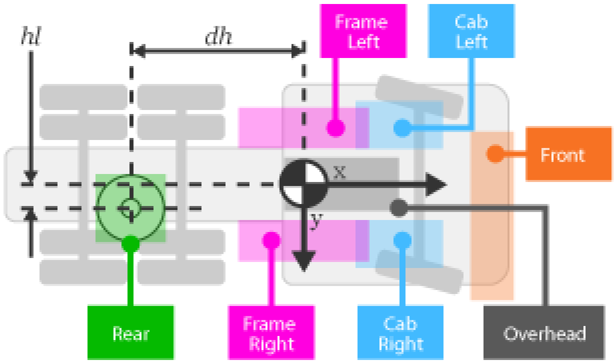
Dependencies

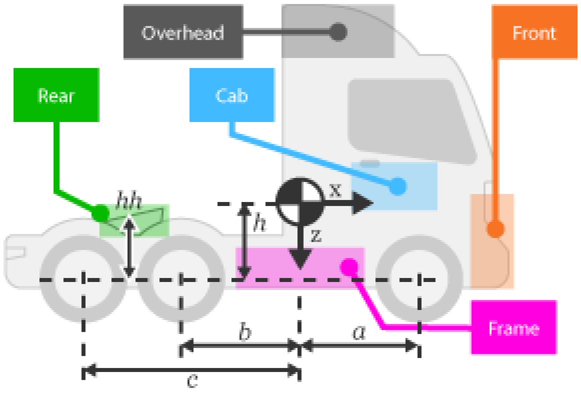
To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Vertical distance from hitch to axle plane, hh` — Distance from hitch to axle plane

`0.1` (default) | `scalar`

Vertical distance from the hitch to the axle plane, *hh*, in m.





Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Initial position in the inertial frame [Xeo,Yeo,Zeo], Xe_o` — Initial position

`[0,0,0]` (default) | `vector`

Initial position of the vehicle in the inertial frame, Xe_o, in m.

`Initial velocity in body axes [xdot_o,ydot_o,zdot_o], xbdot_o` — Initial velocity

`[0,0,0]` (default) | `vector`

Initial vehicle CM velocity along the vehicle-fixed *x*, *y*-, and *z*-axes, respectively, in m/s.

`Initial Euler orientation [roll, pitch, yaw], eul_o` — Initial Euler rotation

`[0,0,0]` (default) | `vector`

Initial Euler rotation of the vehicle-fixed frame about the earth-fixed *X*- (roll), *Y*- (pitch), *Z*-axes (yaw), respectively, in rad.

`Initial body rotation rates [p,q,r], p_o` — Initial rotation rate

`[0,0,0]` (default) | `vector`

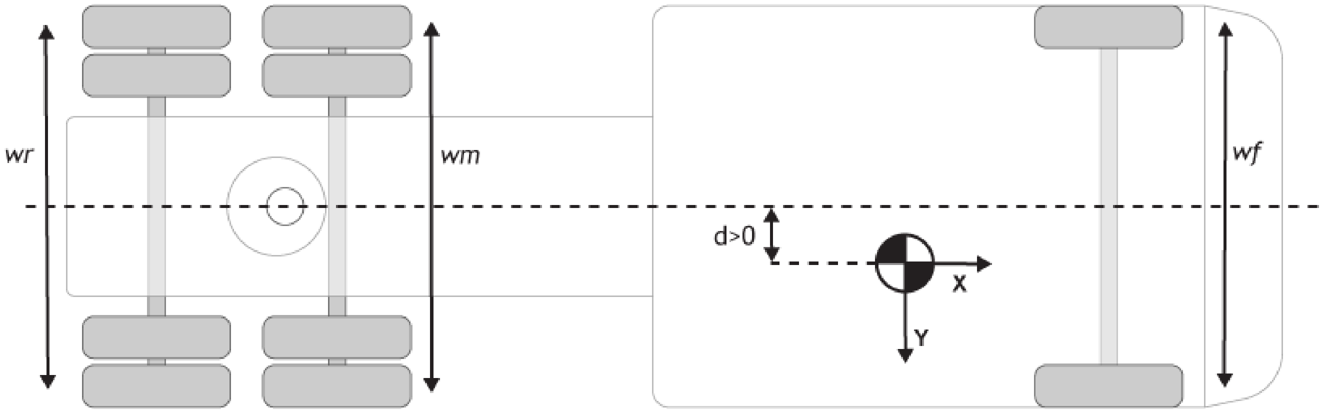
Initial vehicle CM angular velocity about the vehicle-fixed *x*- (roll rate), *y*- (pitch rate), *z*-axes (yaw rate), respectively, in rad/s.

`Chassis inertia tensor, Iveh` — Inertia
`[430 0 0; 0 1900 0; 0 0 2100]` (default) | `array`

Vehicle inertia tensor, I_{veh}, in kg*m^2. Dimensions are `3-by-3`.

`Track widths [front,rear], w` — Widths
`[1.9,1.9,1.9]` (default) | `vector`

Front, middle, and rear track widths, *wf*, *wm*, and, *wr*, respectively, in m. Dimensions are `1-by-3`.



Inertial Loads

Tractor Front

`Mass, z1m` — Tractor front mass
`0` (default) | `scalar`

Mass, *z1m*, in kg.

`Distance vector from front axle, z1R` — Tractor front distance from front axle
`[-.25,.125,.15]` (default) | `vector`

Distance vector from front axle to load, *z1R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z1R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z1R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z1R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Forward of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z1R(1,1)` < 0 • `z1R(1,2)` > 0 • `z1R(1,3)` > 0

`Inertia tensor, z1I` — Tractor front inertia

`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

Inertia tensor, *z1I*, in kg·m^2. Dimensions are `3-by-3`.

$$z1I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Cab Overhead

`Mass, z2m` — Cab overhead mass

`0` (default) | `scalar`

Mass, *z2m*, in kg.

`Distance vector from front axle, z2R` — Cab overhead distance from front axle

`[1.4,0,.8]` (default) | `vector`

Distance vector from front axle to load, *z2R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z2R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z2R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis

Array Element	Description
`z2R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
- Rear of the front axle	- `z2R(1,1)` > 0
- Left of the vehicle centerline	- `z2R(1,2)` < 0
- Above the front axle suspension hardpoint	- `z2R(1,3)` > 0

`Inertia tensor, z2I` — Cab overhead inertia

`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

Inertia tensor, *z2I*, in kg·m^2. Dimensions are `3-by-3`.

$$z2I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Tractor Frame Left

`Mass, z3m` — Tractor frame left mass

`0` (default) | `scalar`

Mass, *z3m*, in kg.

`Distance vector from front axle, z3R` — Tractor frame left distance from front axle

`[.75,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z3R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z3R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z3R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z3R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
- Rear of the front axle - Left of the vehicle centerline - Above the front axle suspension hardpoint	- `z3R(1,1)` > 0 - `z3R(1,2)` < 0 - `z3R(1,3)` > 0

`Inertia tensor, z3I` — Tractor frame left inertia

`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z3I*, in kg·m^2. Dimensions are `3-by-3`.

$$z3I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Tractor Frame Right

`Mass, z4m` — Tractor frame right mass

`0` (default) | `scalar`

Mass, *z4m*, in kg.

`Distance vector from front axle, z4R` — Tractor frame right distance from front axle

`[.75,.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z4R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z4R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z4R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z4R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
- Rear of the front axle - Right of the vehicle centerline - Above the front axle suspension hardpoint	- `z4R(1,1)` > 0 - `z4R(1,2)` > 0 - `z4R(1,3)` > 0

`Inertia tensor, z4I` — Tractor frame right inertia

`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z4I*, in kg·m^2. Dimensions are `3-by-3`.

$$z4I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Cab Left

`Mass, z5m` — Cab left mass

`0` (default) | `scalar`

Mass, z5m, in kg.

`Distance vector from front axle, z5R` — Cab left distance from front axle

`[1.25,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z5R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z5R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z5R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z5R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Left of the vehicle centerline • Above the front axle suspension hardpoint	• `z5R(1,1)` > 0 • `z5R(1,2)` < 0 • `z5R(1,3)` > 0

`Inertia tensor, z5I` — Cab left inertia

`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z5I*, in kg·m^2. Dimensions are `3-by-3`.

$$z5I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Cab Right

`Mass, z6m` — Cab right mass

`0` (default) | `scalar`

Mass, *z6m*, in kg.

`Distance vector from front axle, z6R` — Cab right distance from front axle

`[1.25,-.5,.4]` (default) | `vector`

Distance vector from front axle to load, *z6R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z6R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z6R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z6R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z6R(1,1)` > 0 • `z6R(1,2)` > 0 • `z6R(1,3)` > 0

`Inertia tensor, z6I` — Cab right inertia

`[5,-.1,-2;-2,9,.1;-.1,.1,6].*0` (default) | `array`

Inertia tensor, *z6I*, in kg·m^2. Dimensions are `3-by-3`.

$$z6I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Tractor Rear

`Mass, z7m` — Tractor rear mass

`0` (default) | `scalar`

Mass, *z7m*, in kg.

`Distance vector from front axle, z7R` — Tractor rear mass distance from front axle

`[2,0,.25]` (default) | `vector`

Distance vector from front axle to load, *z7R*, in m. Dimensions are `1-by-3`.

Array Element	Description
`z7R(1,1)`	Front suspension hardpoint to load, along the vehicle-fixed *x*-axis
`z7R(1,2)`	Vehicle centerline to load, along the vehicle-fixed *y*-axis
`z7R(1,3)`	Front suspension hardpoint to load, along the vehicle-fixed *z*-axis

For example, this table summarizes the parameter settings that specify the load location.

Example Location	Sign
• Rear of the front axle • Right of the vehicle centerline • Above the front axle suspension hardpoint	• `z7R(1,1)` > 0 • `z7R(1,2)` > 0 • `z7R(1,3)` > 0

`Inertia tensor, z7I` — Tractor rear inertia

`[1.4,-.2,.1;-.2,1.4,.1;.1,.1,2.25].*0` (default) | `array`

Inertia tensor, *z7I*, in kg·m^2. Dimensions are `3-by-3`.

$$z7I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix}$$

The tensor uses a coordinate system with an origin at the load CM.

- *x*-axis along the vehicle-fixed *x*-axis
- *y*-axis along the vehicle-fixed *y*-axis
- *z*-axis along the vehicle-fixed *z*-axis

Aerodynamic

`Longitudinal drag area, Af` — Vehicle cross-sectional area

2 (default) | `scalar`

Effective vehicle cross-sectional area, A_f to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Air drag coefficient

`.3` (default) | `scalar`

Air drag coefficient, C_d, dimensionless.

`Longitudinal lift coefficient, Cl` — Air lift coefficient
`.1` (default) | `scalar`

Air lift coefficient, C_l, dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}, dimensionless.

`Relative wind angle vector, beta_w` — Wind angle
`[0:0.001:0.01]` (default) | `vector`

Relative wind angle vector, β_w, in rad.

`Side force coefficient vector, Cs` — Side force drag
`[0:0.01:0.1]` (default) | `vector`

Side force coefficient vector coefficient, C_s, dimensionless.

`Yaw moment coefficient vector, Cym` — Yaw moment drag
`[0:0.001:0.01]` (default) | `vector`

Yaw moment coefficient vector coefficient, C_{ym}, dimensionless.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar`

Environmental air absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Ambient air temperature
`273` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity
`9.81` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

Simulation

`Longitudinal velocity tolerance, xdot_tol` — Tolerance
`.1` (default) | `scalar`

Longitudinal velocity tolerance, $xdot_{tol}$, in m/s.

The block uses this parameter to avoid a division by zero when it calculates the body slip angle, β.

`Geometric longitudinal offset from axle plane, longOff` — Longitudinal offset
`0` (default) | `scalar`

Vehicle chassis offset from the axle plane along the body-fixed *x*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric lateral offset from center plane, latOff` — Lateral offset
`0` (default) | `scalar`

Vehicle chassis offset from center plane along the body-fixed *y*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Geometric vertical offset from axle plane, vertOff` — Vertical offset
`0` (default) | `scalar`

Vehicle chassis offset from the axle plane along the body-fixed *z*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independently of the vehicle CG.

`Wrap Euler angles, wrapAng` — Selection
`on` (default) | `off`

Wrap the Euler angles to the interval `[-pi, pi]`. For vehicle maneuvers that might undergo vehicle yaw rotations that are outside of the interval, consider clearing the parameter if you want to:

- Track the total vehicle yaw rotation.
- Avoid discontinuities in the vehicle state estimators.

Version History

Introduced in R2020b

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

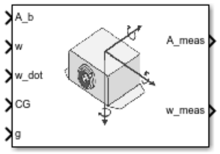
Vehicle Body 3DOF Longitudinal | Vehicle Body 6DOF | Vector Concatenate, Matrix Concatenate

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

Three-axis Inertial Measurement Unit

Implement three-axis inertial measurement unit (IMU)
Library: Vehicle Dynamics Blockset / Sensors



Description

The Three-Axis Inertial Measurement Unit block implements an inertial measurement unit (IMU) containing a three-axis accelerometer and a three-axis gyroscope.

For a description of the equations and application of errors, see Three-axis Accelerometer (Aerospace Blockset) and Three-axis Gyroscope (Aerospace Blockset).

Limitations

- Vibropendulous error, hysteresis affects, anisoelastic bias and anisoinertial bias are not accounted for in this block.
- This block is not intended to model the internal dynamics of different forms of the instrument.

Ports

Input

`A_b` — Actual accelerations
three-element vector

Actual accelerations in body-fixed axes, specified as a three-element vector, in selected units.

Data Types: `double`

`w` — Angular rates
three-element vector

Angular rates in body-fixed axes, specified as a three-element vector, in radians per second.

Data Types: `double`

`w_dot` — Angular accelerations
three-element vector

Angular accelerations in body-fixed axes, specified as a three-element vector, in radians per second squared.

Data Types: `double`

`CG` — Location of center of gravity
three-element vector

Location of the center of gravity, specified as a three-element vector, in selected units.

Data Types: `double`

`g` — Gravity
three-element vector

Gravity in body axis, specified as a three-element vector, in selected units.

Data Types: `double`

Output

`A_meas` — Measured accelerations
three-element vector

Measured accelerations from the accelerometer, specified as a three-element vector, in selected units.

Data Types: `double`

`w_meas` — Measured angular rates
three-element vector

Measured angular rates from the gyroscope, specified as a three-element vector, in radians per second.

Data Types: `double`

Parameters

Main

`Units` — Units
`Metric (MKS)` (default) | `English`

Input and output units, specified as:

Units	Acceleration	Length
`Metric (MKS)`	Meters per second squared	Meters
`English` (British Imperial)	Feet per second squared	Feet

Programmatic Use
Block Parameter: `units`
Type: character vector
Values: `'Metric (MKS)'` | `'English'`
Default: `'Metric (MKS)'`

`IMU location` — IMU location
`[0 0 0]` (default) | three-element vector

The location of the IMU, which is also the accelerometer group location, from the vehicle center of gravity, along the vehicle-fixed axis. This measurement reference is the same for the center of gravity input. The units are in selected length units.

Programmatic Use
Block Parameter: `imu`
Type: character vector
Values: three-element vector
Default: `'[0 0 0]'`

`Update rate` — Update rate

`0` (default) | real, double scalar

Update rate of the accelerometer and gyroscope, specified as a real, double scalar, in seconds. An update rate of 0 creates a continuous accelerometer and continuous gyroscope. If you select the **Noise on** parameter and the update rate is 0, the block updates the noise at a rate of 0.1.

Tip If you:

- Update this parameter value to 0 (continuous)
- Configure a fixed-step solver for the model

you must also select the **Automatically handle rate transition for data transfer** check box in the **Solver** pane. This check box enables the software to handle rate transitions correctly.

Programmatic Use
Block Parameter: `a_Ts`
Type: character vector
Values: real, double scalar
Default: `'0'`

Accelerometer

`Second order dynamics for accelerometer` — Second-order dynamics

`on` (default) | `off`

To apply second-order dynamics to acceleration readings, select this check box.

Programmatic Use
Block Parameter: `dtype_a`
Type: character vector
Values: `'on'` | `'off'`
Default: `'on'`

`Accelerometer natural frequency (rad/sec)` — Accelerometer natural frequency

`190` (default) | real, double scalar

Natural frequency of the accelerometer, specified as a real, double scalar, in radians per second.

Programmatic Use
Block Parameter: `w_a`
Type: character vector
Values: real, double scalar
Default: `'190'`

Dependencies

To enable this parameter, select **Second order dynamics for accelerometer**.

`Accelerometer damping ratio` — Accelerometer damping ratio

`0.707` (default) | real, double scalar

Damping ratio of the accelerometer, specified as a real, double scalar, with no dimensions.

Programmatic Use

Block Parameter: `z_a`
Type: character vector
Values: real, double scalar
Default: `'0.707'`

Dependencies

To enable this parameter, select **Second order dynamics for accelerometer**.

`Accelerometer scale factor and cross-coupling` — Scale factor and cross coupling

`[1 0 0; 0 1 0; 0 0 1]` (default) | 3-by-3 matrix

Scale factor and cross-coupling, specified as a 3-by-3 matrix, to skew the accelerometer from body axes and to scale accelerations along body axes.

Programmatic Use

Block Parameter: `a_sf_cc`
Type: character vector
Values: 3-by-3 matrix
Default: `'[1 0 0; 0 1 0; 0 0 1]'`

`Accelerometer measurement bias` — Accelerometer measurement bias

`[0 0 0]` (default) | three-element vector

Long-term biases along the accelerometer axes, specified as a three-element vector, in selected acceleration units.

Programmatic Use

Block Parameter: `a_bias`
Type: character vector
Values: three-element vector
Default: `'[0 0 0]'`

`Accelerometer upper and lower limits` — Minimum and maximum values of acceleration

`[-inf -inf -inf inf inf inf]` (default) | six-element vector

Three minimum values and three maximum values of acceleration in each of accelerometer axes, specified as a six-element vector, in selected acceleration units.

Programmatic Use

Block Parameter: `a_sat`
Type: character vector
Values: six-element vector
Default: `'[-inf -inf -inf inf inf inf]'`

Gyroscope

`Second-order dynamics for gyro` — Gyroscope second-order dynamics

on (default) | `off`

To apply second-order dynamics to gyroscope readings, select this check box.

Programmatic Use
Block Parameter: `dtype_g`
Type: character vector
Values: `'on'` | `'off'`
Default: `'on'`

`Gyro natural frequency (rad/sec)` — Gyroscope natural frequency

`190` (default) | real, double scalar

Natural frequency of the gyroscope, specified as a real, double scalar, in radians per second.

Programmatic Use
Block Parameter: `w_g`
Type: character vector
Values: real, double scalar
Default: `'190'`

Dependencies

To enable this parameter, select **Second-order dynamics for gyro**.

`Gyro damping ratio` — Gyroscope damping ratio

`0.707` (default) | real, double scalar

Damping ratio of the gyroscope, specified as a real, double scale, with no dimensions.

Programmatic Use
Block Parameter: `z_g`
Type: character vector
Values: real, double scalar
Default: `'0.707'`

Dependencies

To enable this parameter, select **Second-order dynamics for gyro**.

`Gyro scale factors and cross-coupling` — Gyroscope scale factors and cross-coupling

`[1 0 0; 0 1 0; 0 0 1]` (default) | 3-by-3 matrix

Gyroscope scale factors and cross-coupling, specified as a 3-by-3 matrix, to skew the gyroscope from body axes and to scale angular rates along body axes.

Programmatic Use
Block Parameter: `g_sf_cc`
Type: character vector
Values: 3-by-3 matrix
Default: `'[1 0 0; 0 1 0; 0 0 1]'`

`Gyro measurement bias` — Gyroscope measurement bias

`[0 0 0]` (default) | three-element vector

Long-term biases along the gyroscope axes, specified a three-element vector, in radians per second.

Programmatic Use
Block Parameter: `g_bias`

Type: character vector
Values: three-element vector
Default: `'[0 0 0]'`

`G-sensitive bias` — Maximum change in rates

`[0 0 0]` (default) | three-element vector

Maximum change in rates due to linear acceleration, specified as a three-element vector, in radians per second per g-unit.

Programmatic Use
Block Parameter: `g_sens`
Type: character vector
Values: three-element vector
Default: `'[0 0 0]'`

`Gyro upper and lower limits` — Minimum and maximum values of angular rates

`[-inf -inf -inf inf inf inf]` (default) | six-element vector

Three minimum values and three maximum values of angular rates in each of the gyroscope axes, specified as a six-element vector, in radians per second.

Programmatic Use
Block Parameter: `g_sat`
Type: character vector
Values: six-element vector
Default: `'[-inf -inf -inf inf inf inf]'`

Noise

`Noise on` — White noise

`on` (default) | `off`

To apply white noise to acceleration and gyroscope readings, select this check box.

Programmatic Use
Block Parameter: `a_rand`
Type: character vector
Values: `'on'` | `'off'`
Default: `'on'`

`Noise seeds` — Noise seeds

`[23093 23094 23095 23096 23097 23098]` (default) | six-element vector

Scalar seeds for the Gaussian noise generator for each axis of the accelerometer and gyroscope, specified as a six-element vector.

Programmatic Use
Block Parameter: `a_seeds`
Type: character vector
Values: six-element vector
Default: `'[23093 23094 23095 23096 23097 23098]'`

Dependencies

To enable this parameter, select **Noise on**.

`Noise power` — Noise power
`[0.001 0.001 0.001 0.0001 0.0001 0.0001]` (default) | six-element vector

Height of the power spectral density (PSD) of the white noise for each axis of the accelerometer and gyroscope, specified as a six-element vector, in:

- (m/s^2)/Hz for `Metric (MKS)`
- (ft/s^2)/Hz for `English`

Programmatic Use
Block Parameter: `a_pow`
Type: character vector
Values: six-element vector
Default: `'[0.001 0.001 0.001 0.0001 0.0001 0.0001]'`

Dependencies

To enable this parameter, select **Noise on**.

Version History

Introduced in R2020a

References

[1] Rogers, R. M., *Applied Mathematics in Integrated Navigation Systems*, AIAA Education Series, 2000.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

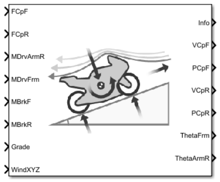
See Also

Three-axis Gyroscope | Three-axis Accelerometer

Motorcycle Body Longitudinal In-Plane

Longitudinal in-plane motorcycle vehicle motion

Library: Powertrain Blockset / Vehicle Dynamics
Vehicle Dynamics Blockset / Vehicle Body



Description

The Motorcycle Body Longitudinal In-Plane block implements a longitudinal in-plane motorcycle body model to calculate longitudinal, vertical, and pitch motion. The block accounts for:

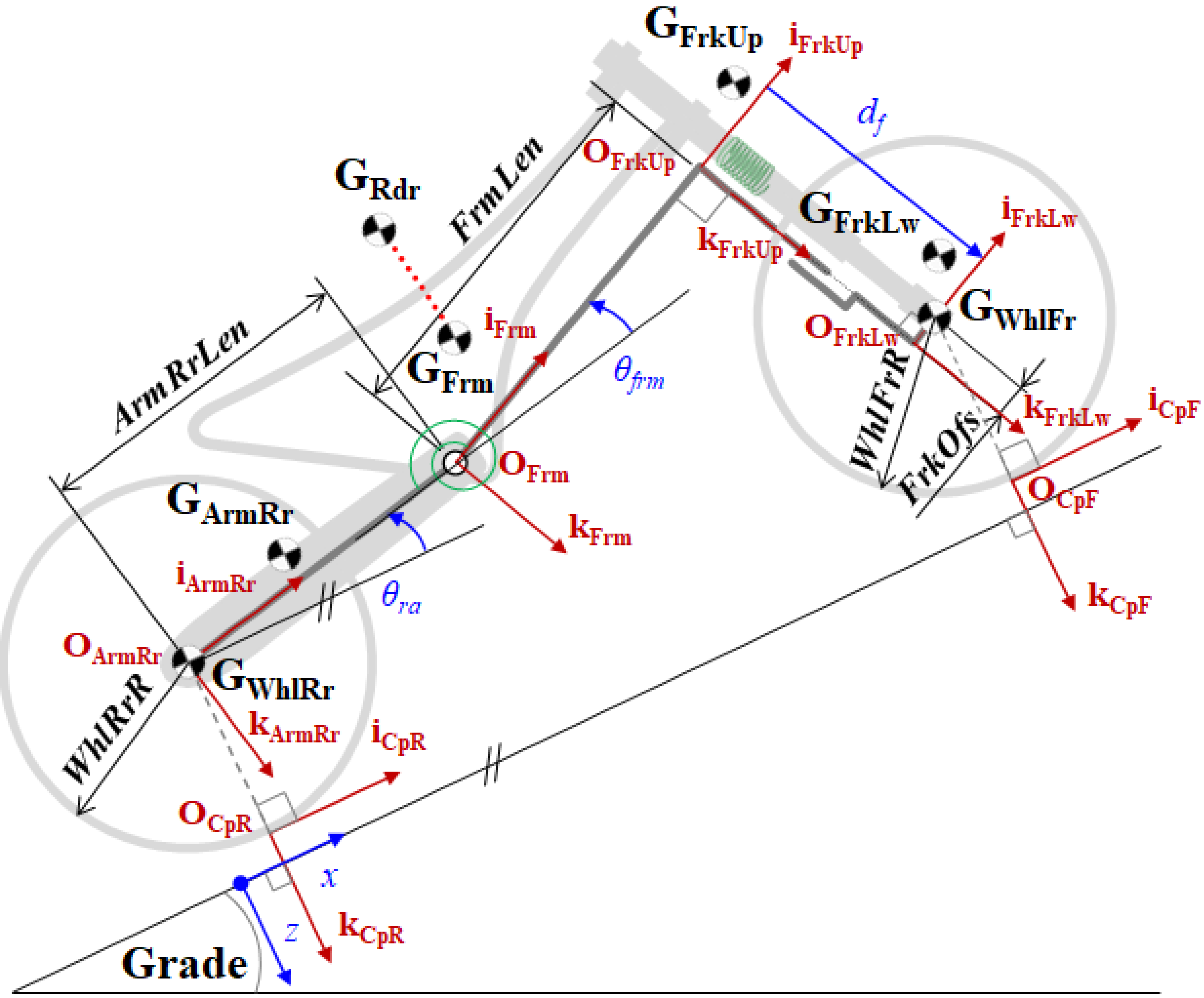
- Mass of the frame, rear arm, front upper fork, front lower fork, front wheel, and rear wheel
- In-plane dynamic effects of the frame, front lower fork, front wheel, rear wheel, rear suspension, front suspension, rear wheel damper, rear arm, and chain
- External forces, external moments, and aerodynamic drag
- Road incline
- Weight distribution between the axles due to acceleration

Consider using this block to represent motorcycle motion in powertrain and fuel economy studies, for example, in studies with heavy breaking or acceleration or road profiles that contain larger vertical changes.

The block uses rigid-body vehicle motion, suspension system forces, and wind and drag forces to calculate the forces on the motorcycle frames. The block then determines the position and velocity of motorcycle at the front and rear contact patches.

Layout

To determine the rigid-body motorcycle motion, the block uses right-handed (RH) *Cartesian* reference frames systems attached to the motorcycle. *i*, *j*, and *k* are orthogonal unit vectors attached to the frames.



Frame	Variable in Figure	Description
Road	x, z	Road-fixed coordinate system. x is along road grade, and z points downward.
Motorcycle main frame - i_{Frm} – Forward along vector given by θ_{frm} - k_{Frm} – Downward - j_{Frm} – Orthogonal to motorcycle plane	O_{Frm}	Main frame origin
	G_{Frm}	Center of mass (CM) of the main frame with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively
	G_{Rdr}	CM of the rider with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively
	Θ_{frm}	Main frame rotation about j_{Frm}
Upper fork - i_{FrkUp} – Forward along vector given by θ_{frm} - k_{FrkUp} – Downward	O_{FrkUp}	Upper fork origin

Frame	Variable in Figure	Description
• j_{FrkUp} – Orthogonal to motorcycle plane	G_{FrkUp}	CM of the upper fork with respect to O_{FrkUp}, along i_{FrkUp} and k_{FrkUp}, respectively
Lower fork • i_{FrkLw} – Forward along vector given by θ_{frm} • k_{FrkLw} – Downward • j_{FrkLw} – Orthogonal to motorcycle plane	O_{FrkLw}	Lower fork origin
	G_{FrkLw}	CM of the lower fork with respect to O_{FrkLw}, along i_{FrkLw} and k_{FrkLw}, respectively
Rear arm • i_{ArmRr} – Forward along vector given by θ_{ra} • k_{ArmRr} – Downward • j_{ArmRr} – Orthogonal to motorcycle plane	O_{ArmRr}	Rear arm origin
	G_{ArmRr}	CM of the rear arm with respect to O_{ArmRr}, along i_{ArmRr} and k_{ArmRr}, respectively
	Θ_{ra}	Rear arm rotation about j_{ArmRr}
Front wheel contact patch • i_{CpF} – Forward along vector given by road-fixed x- axis • k_{CpF} – Downward along vector given by road-fixed z- axis • j_{CpF} – Orthogonal to motorcycle plane	O_{CpF}	Front wheel contact patch origin
Rear wheel contact patch • i_{CpR} – Forward along vector given by road-fixed x- axis • k_{CpR} – Downward along vector given by road-fixed z- axis • j_{CpR} – Orthogonal to motorcycle plane	O_{CpR}	Rear wheel contact patch origin

Use the parameters in this table to specify the geometric layout of your motorcycle.

Parameter			Variable in Figure
Initial conditions	**Position**	**Rear contact patch longitudinal coordinate, CpRrX0**	O_{CpR} with respect to road-fixed coordinate system, along x
		Rear contact patch vertical coordinate, CpRrZ0	O_{CpR} with respect to road-fixed coordinate system, along z
		Pitch angle of rear arm, ArmRrAng0	θ_{ra}
		Pitch angle of main frame, FrmAng0	θ_{Frm}

Parameter			Variable in Figure
		Fork length, FrkFrL0	d_f
Frame		**Center of mass location, FrmCmPxz**	G_{Frm} with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively
		Length, FrmLen	*FrmLen*
Rider		**Center of mass location, RdrCmPxz**	G_{Rdr} with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively
Front Fork	**Upper**	**Position, FrkUpCmPxz**	G_{FrkUp} with respect to O_{FrkUp}, along i_{FrkUp} and k_{FrkUp}, respectively
		Offset, FrkOfs	*FrkOfs*
	Lower	**Position, FrkLwCmPxz**	G_{FrkLw} with respect to O_{FrkLw}, along i_{FrkLw} and k_{FrkLw}, respectively
Rear Arm		**Position, ArmRrCmPxz**	G_{ArmRr} with respect to O_{ArmRr}, along i_{ArmRr} and k_{ArmRr}, respectively
		Length, ArmRrLen	*ArmRrLen*
Wheels	**Front**	**Radius, WhlFrR**	*WhlFrR*
	Rear	**Radius, WhlRrR**	*WhlRrR*
Suspension	**Front**	**Equilibrium length, FrkLwL0**	d_f
	Rear	**Equilibrium angle, ShkRrAng0**	θ_{Frm}

Input Signals

You can use these block parameters to create additional input ports. This table summarizes the settings.

Input Signals Pane Parameter	Input Port	Description
External forces	`FExt`	External longitudinal and vertical forces applied at equivalent rider and motorcycle center of mass (CM).
External moments	`MExt`	External moment about equivalent rider and motorcycle CM, for example, moment due to rider physical motion.
External front wheel moment	`MWhlF`	External moment at the front wheel G_{WhlFr}, for example, wheel motors and external intermittent friction-related disturbances.
External rear wheel moment	`MWhlR`	External moment at the rear wheel G_{WhlRr}, for example, wheel motors and external intermittent friction-related disturbances.
Grade angle	`Grade`	Road grade angle.
Wind velocity	`WindXYZ`	Wind speed.
Ambient temperature	`Temp`	Ambient air temperature. Consider this option if you want to vary the temperature during run-time.

Suspension System

Use the **Suspension type** parameter to specify the type of suspension.

Setting	Description
`Simple`	Block models the suspension force and moment as a spring-damper system: • Suspension force at the upper fork • Suspension moment at the rear arm
`User-defined`	Input the suspension force and moment: • `FSuspF` – Suspension force at the upper fork • `MSuspR` – Suspension moment at the rear arm

Wind and Drag Forces

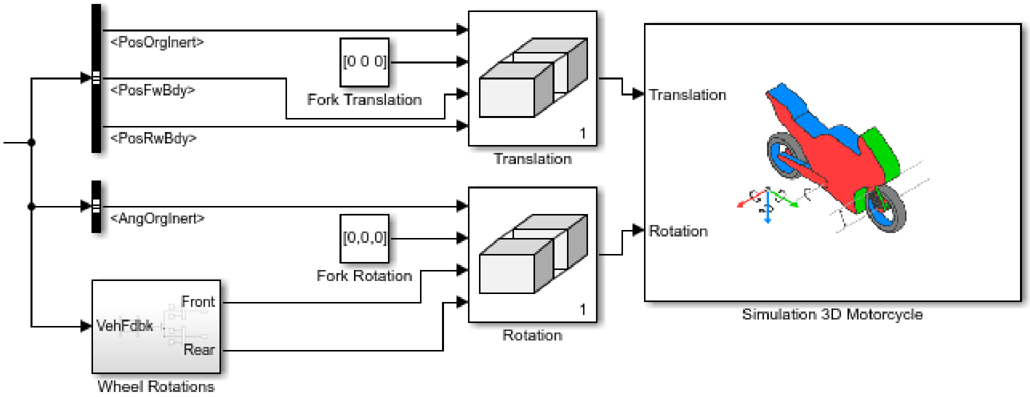
The block subtracts the wind speeds from the vehicle velocity components to obtain a net relative airspeed. To calculate the drag force and moments acting on the motorcycle, the block uses the net relative airspeed.

Use in 3D Environment

To co-simulate in the Unreal Engine® and provide a motorcycle with the motion calculated by the Motorcycle Body Longitudinal In-Plane block:

1. Put the Simulation 3D Motorcycle block in your model.
2. Route these the Info bus port signals to the Simulation 3D Motorcycle input ports Translation and Rotation.

   - `PosOrgInert`
   - `PosFwBdy`
   - `PosRwBdy`
   - `AngOrgInert`



For more information about using the block in the 3D environment, see “Longitudinal Motorcycle Braking Test”.

Power Accounting

The block accounts for the power transferred, not transferred, and stored.

Bus Signal			**Description**
`PwrInfo`	`PwrTrnsfrd` — Power transferred between blocks • Positive signals indicate flow into block • Negative signals indicate flow out of block	`PwrFxExt`	Mechanical power from longitudinal external force
		`PwrFzExt`	Mechanical power from vertical external force
		`PwrMyExt`	Mechanical power from external pitch moment
	`PwrNotTrnsfrd` — Power crossing the block boundary, but not transferred • Positive signals indicate an input • Negative signals indicate a loss	`PwrFxDrag`	Mechanical power loss from longitudinal drag force
		`PwrFzDrag`	Mechanical power loss from vertical lift
		`PwrMyDrag`	Mechanical power loss from pitch moment drag
	`PwrStored` — Stored energy rate of change • Positive signals indicate an increase • Negative signals indicate a decrease	`PwrStoredGrvty`	Rate change in gravitational potential energy
		`PwrStoredxdot`	Rate of change of longitudinal kinetic energy
		`PwrStoredzdot`	Rate of change of vertical kinetic energy
		`PwrStoredq`	Rate of change of rotational pitch kinetic energy
		`PwrStoredFsFzSprng`	Stored spring energy from front suspension
		`PwrStoredFsRzSprng`	Stored spring energy from rear suspension

Ports

Input

FCpF — Longitudinal and vertical forces at front wheel contact patch
`vector`

Longitudinal and vertical forces at front wheel contact patch O_{CpF}, along i_{CpF} and k_{CpF}, in N. Signal vector dimensions are `[1x2]` or `[2x1]`.

FCpR — Longitudinal and vertical forces at rear wheel contact patch
`vector`

Longitudinal and vertical forces at rear wheel contact patch O_{CpR}, along i_{CpR} and k_{CpR}, in N. Signal vector dimensions are `[1x2]` or `[2x1]`.

`MDrvArmR` — Drive chain moment at rear arm

`scalar`

Drive chain moment at rear arm O_{ArmRr}, about j_{ArmRr}, in N·m.

`MDrvFrm` — Drive chain moment at frame

`scalar`

Drive chain moment at the frame O_{Frm}, about j_{Frm}, in N·m.

`FExt` — External longitudinal and vertical forces at frame

`vector`

External longitudinal and vertical forces applied at equivalent rider and motorcycle center of mass (CM), along i_{Frm} and k_{Frm}, in N. Signal vector dimensions are `[1x2]` or `[2x1]`.

Dependencies

To create this port, select **External forces**.

`MExt` — External moment about frame

`scalar`

External moment about equivalent rider and motorcycle CM, j_{Frm}, for example, moment due to rider physical motion, in N·m.

Dependencies

To create this port, select **External moments**.

`MBrkF` — Brake moment at front wheel

`scalar`

Brake moment at the front wheel G_{WhlFr}, about j_{WhlFr}, in N·m.

`MBrkR` — Brake moment at rear wheel

`scalar`

Brake moment at the rear wheel G_{WhlRr}, about j_{WhlRr}, in N·m.

`MWhlF` — External moment at front wheel

`scalar`

External moment at the front wheel G_{WhlFr}, in N·m.

Dependencies

To create this port, select **External front wheel moment**.

`MWhlR` — External moment at rear wheel

`scalar`

External moment at the rear wheel G_{WhlRr}, in N·m.

Dependencies

To create this port, select **External rear wheel moment**.

`FSuspF` — External suspension force at upper fork

`scalar`

External suspension force at upper fork O_{FrkUp}, along k_{FrkUp}, in N.

Dependencies

To create this port, set **Suspension type** to `User-defined`.

`MSuspR` — External suspension moment at rear arm

`scalar`

External suspension force at upper fork O_{ArmRr}, about j_{ArmRr}, in N·m.

Dependencies

To create this port, set **Suspension type** to `User-defined`.

`Grade` — Road grade angle

`scalar`

Road grade angle, γ, in deg.

Dependencies

To create this port, select **Grade angle**.

`WindXYZ` — Wind speed

`array`

Wind speed, W_X, W_Y, W_Z along earth-fixed X-, Y-, and Z-axes, in m/s. Signal vector dimensions are `[1x3]` or `[3x1]`.

Dependencies

To create this port, select **Wind velocity**.

`Temp` — Ambient air temperature

`scalar`

Ambient air temperature, T_{air}, in K. Considering this option if you want to vary the temperature during run-time.

Dependencies

To create this port, select **Ambient temperature**.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal		Signal	Units
`Geom`	`PosOrgInert`	Main frame position along the earth-fixed axes	m

Signal					**Signal**	**Units**
				`PosFwBdy`	Front wheel center position relative to initial vehicle-fixed wheel position, along the vehicle Z-down *X*-, *Y*-, and *Z*-axes	m
				`PosRwBdy`	Rear wheel center position relative to initial vehicle-fixed wheel position, along the vehicle Z-down *X*-, *Y*-, and *Z*-axes	m
				`AngOrgInert`	Main frame rotation about the earth-fixed axes	rad
`Frame`	`Inert`	`Cg`	`Disp`	`X`	Vehicle CM displacement along the earth-fixed *X*-axis	m
				`Y`	Vehicle CM displacement along the earth-fixed *Y*-axis	m
				`Z`	Vehicle CM displacement along the earth-fixed *Z*-axis	m
			`Vel`	`Xdot`	Vehicle CM velocity along the earth-fixed *X*-axis	m/s
				`Ydot`	Vehicle CM velocity along the earth-fixed *Y*-axis	m/s
				`Zdot`	Vehicle CM velocity along the earth-fixed *Z*-axis	m/s
			`Ang`	`phi`	Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	rad
				`theta`	Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	rad
				`psi`	Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	rad
	`BdyFrm`	`Cg`	`Disp`	`x`	Vehicle CM position along the road-fixed *x*-axis	m
				`y`	Vehicle CM position along the road-fixed *y*-axis	m
				`z`	Vehicle CM position along the road-fixed *z*-axis	m
			`Vel`	`xdot`	Vehicle CM velocity along the road-fixed *x*-axis	m/s

Signal					Signal	Units
				`ydot`	Vehicle CM velocity along the road-fixed *y*-axis	m/s
				`zdot`	Vehicle CM velocity along the road-fixed *z*-axis	m/s
			`AngVel`	`p`	Vehicle angular velocity about the road-fixed *x*-axis (roll rate)	rad/s
				`q`	Vehicle angular velocity about the road-fixed *y*-axis (pitch rate)	rad/s
				`r`	Vehicle angular velocity about the road-fixed *z*-axis (yaw rate)	rad/s
			`Acc`	`ax`	Vehicle CM acceleration along the road-fixed *x*-axis	m/s^2
				`ay`	Vehicle CM acceleration along the road-fixed *y*-axis	m/s^2
				`az`	Vehicle CM acceleration along the road-fixed *z*-axis	m/s^2
				`xddot`	Vehicle CM acceleration along the road-fixed *x*-axis	m/s^2
				`yddot`	Vehicle CM acceleration along the road-fixed *y*-axis	m/s^2
				`zddot`	Vehicle CM acceleration along the road-fixed *z*-axis	m/s^2
			`AngAcc`	`pdot`	Vehicle angular acceleration about the road-fixed *x*-axis	rad/s^2
				`qdot`	Vehicle angular acceleration about the road-fixed *y*-axis	rad/s^2
				`rdot`	Vehicle angular acceleration about the road-fixed *z*-axis	rad/s^2
		`Forces`	`Ext`	`Fx`	External force on vehicle CM along the road-fixed *x*-axis	N
				`Fy`	External force on vehicle CM along the road-fixed *x*-axis	N
				`Fz`	External force on vehicle CM along the road-fixed *x*-axis	N

Signal					Signal	Units
			`Drag`	`Fx`	Drag force on vehicle CM along the road-fixed *x*-axis	N
				`Fy`	Drag force on vehicle CM along the road-fixed *y*-axis	N
				`Fz`	Drag force on vehicle CM along the road-fixed *z*-axis	N
			`Grvty`	`Fx`	Gravity force on vehicle CM along the road-fixed *x*-axis	N
				`Fy`	Gravity force on vehicle CM along the road-fixed *y*-axis	N
				`Fz`	Gravity force on vehicle CM along the road-fixed *z*-axis	N
		`Moments`	`Drag`	`Mx`	Drag moment on vehicle CM about the road-fixed *x*-axis	N·m
				`My`	Drag moment on vehicle CM about the road-fixed *z*-axis	N·m
				`Mz`	Drag moment on vehicle CM about the road-fixed *z*-axis	N·m
			`Ext`	`Mx`	External moment on vehicle CG about the road-fixed *x*-axis	N·m
				`My`	External moment on vehicle CG about the road-fixed *y*-axis	N·m
				`Mz`	External moment on vehicle CG about the road-fixed *z*-axis	N·m
		`Pwr`	`PwrExt`		Applied external power	W
			`Drag`		Power loss due to drag	W
	`PwrInfo`	`PwrTrnsfrd`	`PwrFxExt`		Mechanical power from longitudinal external force	W
			`PwrFzExt`		Mechanical power from vertical external force	W
			`PwrMyExt`		Mechanical power from external pitch moment	W
		`PwrNotTrnsfrd`	`PwrFxDrag`		Mechanical power loss from longitudinal drag force	W

Signal						Signal	Units
			PwrFzDrag			Mechanical power loss from vertical lift force	W
			PwrMyDrag			Mechanical power loss from pitch moment drag	W
		PwrStored	PwrStoredGrvty			Rate change in gravitational potential energy	W
			PwrStoredxdot			Rate of change of longitudinal kinetic energy	W
			PwrStoredzdot			Rate of change of vertical kinetic energy	W
			PwrStoredq			Rate of change of rotational pitch kinetic energy	W
	Genrl	Vel	xdot			Vehicle CM velocity along the road-fixed *x*-axis	m/s
			zdot			Vehicle CM velocity along the road-fixed *z*-axis	m/s
		Ang	thetafrm			Pitch angle of main frame	rad
		AngVel	thetafrmdot			Main frame rotational velocity	rad/s
		AngAcc	thetafrmddot			Main frame rotational acceleration	rad/s^2
Whl	Genrl	Frnt	Cp	Disp	x	Front wheel contact patch position along the road-fixed *x*-axis	m
					z	Front wheel contact patch position along the road-fixed *z*-axis	m
				Vel	xdot	Front wheel contact patch velocity along the road-fixed *x*-axis	m/s
					zdot	Front wheel contact patch velocity along the road-fixed *z*-axis	m/s
				Acc	xddot	Front wheel contact patch acceleration along the road-fixed *x*-axis	m/s^2
					zddot	Front wheel contact patch acceleration along the road-fixed *z*-axis	m/s^2
			Axl	Vel	xdot	Front wheel axle velocity along the road-fixed *x*-axis	m/s

Signal						Signal	Units
					`zdot`	Front wheel axle velocity along the road-fixed *z*-axis	m/s
		`Rear`	`Cp`	`Disp`	`x`	Rear wheel contact patch position along the road-fixed *x*-axis	m
					`z`	Rear wheel contact patch position along the road-fixed *z*-axis	m
				`Vel`	`xdot`	Rear wheel contact patch velocity along the road-fixed *x*-axis	m/s
					`zdot`	Rear wheel contact patch velocity along the road-fixed *z*-axis	m/s
				`Acc`	`xddot`	Rear wheel contact patch acceleration along the road-fixed *x*-axis	m/s^2
					`zddot`	Rear wheel contact patch acceleration along the road-fixed *z*-axis	m/s^2
			`Axl`	`Vel`	`xdot`	Rear wheel axle velocity along the road-fixed *x*-axis	m/s
					`zdot`	Rear wheel axle velocity along the road-fixed *z*-axis	m/s
`RearArm`	`Genrl`	`Vel`	`xdot`			Rear arm velocity along the road-fixed *x*-axis	m/s
			`zdot`			Rear arm velocity along the road-fixed *z*-axis	m/s
		`Ang`	`thetara`			Pitch angle of rear arm	rad
		`AngVel`	`thetaradot`			Rear arm rotational velocity	rad/s
		`AngAcc`	`thetaraddot`			Rear arm rotational acceleration	rad/s^2
`Fork`	`Genrl`	`Upr`	`Vel`	`xdot`		Upper fork velocity along the road-fixed *x*-axis	m/s
				`zdot`		Upper fork velocity along the road-fixed *z*-axis	m/s
		`Lwr`	`Disp`	`df`		Fork length	m
			`Vel`	`xdot`		Lower fork velocity along the road-fixed *x*-axis	m/s
				`zdot`		Lower fork velocity along the road-fixed *z*-axis	m/s
				`dfdot`		Fork length velocity	m/s

Signal					Signal	Units
			`Acc`	`dfddot`	Fork length acceleration	m/s^2
`Susp`	`Genrl`	`Rear`	`Moments`	`Mthetafrm`	Rear suspension moment at frame	N·m
		`Frnt`	`Forces`	`Fdf`	Suspensive force at upper fork	N

`VCpF` — Longitudinal, lateral, and vertical velocity at front wheel contact patch
`vector`

Longitudinal, lateral, and vertical velocity at front wheel contact patch O_{CpF}, along i_{CpF} and k_{CpF}, in m/s. Signal vector dimensions are `[1x3]` or `[3x1]`. The lateral component is set to 0.

`PCpF` — Longitudinal, lateral, and vertical position at front wheel contact patch
`vector`

Longitudinal, lateral, and vertical position at front wheel contact patch O_{CpF}, along i_{CpF} and k_{CpF}, in m. Signal vector dimensions are `[1x3]` or `[3x1]`. The lateral component is set to 0.

`VCpR` — Longitudinal, lateral, and vertical velocity at rear wheel contact patch
`vector`

Longitudinal,lateral, and vertical velocity at rear wheel contact patch O_{CpR}, along i_{CpR} and k_{CpR}, in m/s. Signal vector dimensions are `[1x3]` or `[3x1]`. The lateral component is set to 0.

`PCpR` — Longitudinal, lateral, and vertical position at rear wheel contact patch
`vector`

Longitudinal, lateral, and vertical position at rear wheel contact patch O_{CpR}, along i_{CpR}, and k_{CpR}, in m. Signal vector dimensions are `[1x3]` or `[3x1]`. The lateral component is set to 0.

`ThetaFrm` — Main frame pitch angle
`scalar`

Main frame pitch angle, Θ_{frm}, in rad.

`ThetaArmR` — Rear arm pitch angle
`scalar`

Rear arm pitch angle, Θ_{ra}, in rad.

Parameters

Options

`Suspension type` — Type of suspension
`Simple` (default) | `User-defined`

Use the **Suspension type** parameter to specify the type of suspension.

Setting	Description
`Simple`	Block models the suspension force and moment as a spring-damper system: • Suspension force at the upper fork • Suspension moment at the rear arm
`User-defined`	Input the suspension force and moment: • `FSuspF` – Suspension force at the upper fork • `MSuspR` – Suspension moment at the rear arm

Input signals

`External forces` — `FExt` input port
`off` (default) | `on`

Specify to create input port `FExt`.

`External moments` — `MExt` input port
`off` (default) | `on`

Specify to create input port `MExt`.

`External front wheel moment` — `MWhlF` input port
`off` (default) | `on`

Specify to create input port `MWhlF`. Consider using this port to input external moments such as wheel motors and external intermittent friction-related disturbances.

`External rear wheel moment` — `MWhlR` input port
`off` (default) | `on`

Specify to create input port `MWhlR`. Consider using this port to input external moments such as wheel motors and external intermittent friction-related disturbances.

`Grade angle` — `Grade` input port
`on` (default) | `off`

Specify to create input port `Grade`.

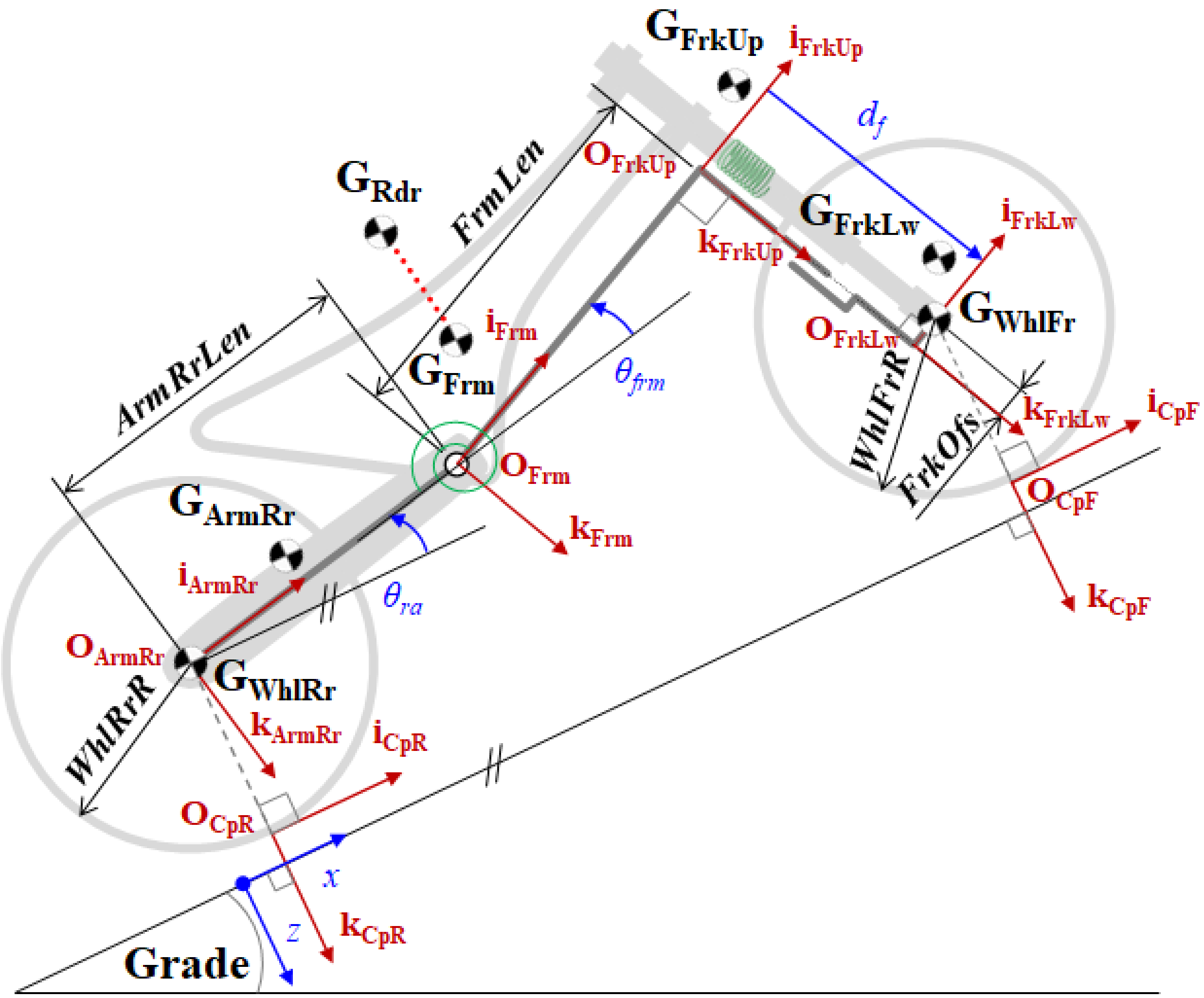
`Wind velocity` — `WindXYZ` input port
`on` (default) | `off`

Specify to create input port `WindXYZ`.

`Ambient temperature` — `Temp` input port
`off` (default) | `on`

Specify to create input port `Temp`.

Layout



Use the parameters in this table to specify the geometric layout of your motorcycle.

Parameter			Variable in Figure
Initial conditions	**Position**	**Rear contact patch longitudinal coordinate, CpRrX0**	O_{CpR} with respect to road-fixed coordinate system, along x
		Rear contact patch vertical coordinate, CpRrZ0	O_{CpR} with respect to road-fixed coordinate system, along z
		Pitch angle of rear arm, ArmRrAng0	θ_{ra}
		Pitch angle of main frame, FrmAng0	θ_{Frm}
		Fork length, FrkFrL0	d_f

Parameter			Variable in Figure
Frame		**Center of mass location, FrmCmPxz**	G_{Frm} with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively
		Length, FrmLen	*FrmLen*
Rider		**Center of mass location, RdrCmPxz**	G_{Rdr} with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively
Front Fork	**Upper**	**Position, FrkUpCmPxz**	G_{FrkUp} with respect to O_{FrkUp}, along i_{FrkUp} and k_{FrkUp}, respectively
		Offset, FrkOfs	*FrkOfs*
	Lower	**Position, FrkLwCmPxz**	G_{FrkLw} with respect to O_{FrkLw}, along i_{FrkLw} and k_{FrkLw}, respectively
Rear Arm		**Position, ArmRrCmPxz**	G_{ArmRr} with respect to O_{ArmRr}, along i_{ArmRr} and k_{ArmRr}, respectively
		Length, ArmRrLen	*ArmRrLen*
Wheels	**Front**	**Radius, WhlFrR**	*WhlFrR*
	Rear	**Radius, WhlRrR**	*WhlRrR*
Suspension	**Front**	**Equilibrium length, FrkLwL0**	d_f
	Rear	**Equilibrium angle, ShkRrAng0**	θ_{Frm}

Frame

`Center of mass location, FrmCmPxz` — Frame location

`[0.255, -0.02]` (default) | `vector`

Center of mass location of the frame, G_{Frm}. Specified as a vector with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively.

`Mass, FrmMass` — Frame mass

`223` (default) | `scalar`

Frame mass, *FrmMass*, in kg.

`Mass moment of inertia, FrmIyy` — Frame inertia

`26.2` (default) | `scalar`

Mass moment of inertia, *FrmIyy*, in kg·m^2.

`Length, FrmLen` — Frame length

`0.730` (default) | `scalar`

Length of the frame, *FrmLen*, in m.

Rider

`Center of mass location, RdrCmPxz` — Rider location

`[0.275, -0.61]` (default) | `vector`

Center of mass location of the rider, G_{Rdr}. Specified as a vector with respect to O_{Frm}, along i_{Frm} and k_{Frm}, respectively.

`Mass, RdrMass` — Rider mass
`78` (default) | `scalar`

Rider mass, *RdrMass*, in kg.

`Mass moment of inertia, RdrIyy` — Rider inertia
`26.2` (default) | `scalar`

Rider mass moment of inertia, *RdrIyy*, in kg·m^2.

Front Fork - Upper

`Position, FrkUpCmPxz` — Upper fork location
`[0.023, -0.098]` (default) | `vector`

Center of mass location of the upper fork, G_{FrkUp}. Specified as a vector with respect to O_{FrkUp}, along i_{FrkUp} and k_{FrkUp}, respectively.

`Mass, FrkUpMass` — Upper fork mass
`8.8` (default) | `scalar`

Upper fork mass, *FrkUpMass*, in kg.

`Mass moment of inertia, FrmIyy` — Upper fork inertia
`0.14` (default) | `scalar`

Upper fork mass moment of inertia, *FrkUpIyy*, in kg·m^2.

`Offset, FrkOfs` — Upper fork offset
`0.034` (default) | `scalar`

Upper fork offset, *FrkOfs*, in m.

Front Fork - Lower

`Position, FrkLwCmPxz` — Lower fork location
`[-0.029, -0.189]` (default) | `vector`

Center of mass location of the lower fork, G_{FrkLw}. Specified as a vector with respect to O_{FrkLw}, along i_{FrkLw} and k_{FrkLw}, respectively.

`Mass, FrkLwMass` — Lower fork mass
`7.0` (default) | `scalar`

Lower fork mass, *FrkLwMass*, in kg.

`Mass moment of inertia, FrkLwIyy` — Lower fork inertia
`0.18` (default) | `scalar`

Lower fork mass moment of inertia, *FrkLwIyy*, in kg·m^2.

Rear Arm

`Position, ArmRrCmPxz` — Rear arm location
`[0.275, -0.052]` (default) | `vector`

Center of mass location of the rear arm, G_{ArmRr}. Specified as a vector with respect to O_{ArmRr}, along i_{ArmRr} and k_{ArmRr}, respectively.

`Mass, ArmRrMass` — Rear arm mass

`10` (default) | `scalar`

Rear arm mass, *ArmRrMass*, in kg.

`Mass moment of inertia, ArmRrIyy` — Rear arm inertia

`0.8` (default) | `scalar`

Rear arm mass moment of inertia, *ArmRrIyy*, in kg·m^2.

`Length, ArmRrLen` — Rear arm length

`0.535` (default) | `scalar`

Rear arm length, *ArmRrLen*, in m.

Wheels - Front

`Mass, WhlFrMass` — Front wheel mass

`12` (default) | `scalar`

Front wheel mass, *WhlFrMass*, in kg.

`Radius, WhlFrR` — Front wheel radius

`0.3` (default) | `scalar`

Front wheel radius, *WhlFrR*, in m.

Wheels - Rear

`Mass, WhlRrMass` — Rear wheel mass

`16.2` (default) | `scalar`

Rear wheel mass, *WhlRrMass*, in kg.

`Radius, WhlRrR` — Rear wheel radius

`0.33` (default) | `scalar`

Rear wheel radius, *WhlRrR*, in m.

Suspension - Front

`Stiffness, SuspFrK` — Front suspension stiffness

`25e3` (default) | `scalar`

Front suspension stiffness at O_{FrkUp}, along k_{FrkUp}, in N/m.

`Damping, SuspFrC` — Front suspension damping

`1250` (default) | `scalar`

Front suspension damping, at O_{FrkUp}, along k_{FrkUp}, in N·s/m.

`Equilibrium length, FrkLwL0` — Front suspension equilibrium length

`0.473` (default) | `scalar`

Front suspension equilibrium length, d_f, in m.

Suspension - Rear

`Stiffness, SuspRrK` — Rear arm suspension stiffness
`1500` (default) | `scalar`

Rear arm suspension stiffness at O_{ArmRr}, about j_{ArmRr}, in N/rad.

`Damping, SuspRrC` — Rear arm suspension damping
`150` (default) | `scalar`

Rear arm suspension damping at O_{ArmRr}, about j_{ArmRr}, in N·s/rad.

`Equilibrium angle, ShkRrAng0` — Rear suspension equilibrium angle
`0` (default) | `scalar`

Rear suspension equilibrium angle, θ_{Frm}, in rad.

Aerodynamic

`Longitudinal drag area, Af` — Area
`2` (default) | `scalar`

Effective vehicle cross-sectional area, A_f to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Drag
`.2` (default) | `scalar`

Air drag coefficient, C_d, dimensionless.

`Longitudinal lift coefficient, Cl` — Lift
`.1` (default) | `scalar`

Air lift coefficient, C_l, dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag
`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}, dimensionless.

`Pitch moment length, Lcpm` — Pitch drag
`2` (default) | `scalar`

Pitch moment length, $Lcpm$, in m.

Environment

`Gravitational acceleration, g` — Gravity
`9.80665` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar`

Environmental air absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Ambient air temperature
`273` (default) | `scalar`

Ambient air temperature, T_{air}, in K.

Dependencies

To enable this parameter, clear **Ambient temperature**.

Initial conditions

Position

`Rear contact patch longitudinal coordinate, CpRrX0` — Longitudinal coordinate
`0` (default) | `scalar`

Rear contact patch longitudinal coordinate, O_{CpR}, with respect to road-fixed coordinate system, along `x`, in m.

`Rear contact patch vertical coordinate, CpRrZ0` — Vertical coordinate
`0` (default) | `scalar`

Rear contact patch vertical coordinate, O_{CpR}, with respect to road-fixed coordinate system, along `z`, in m.

`Pitch angle of rear arm, ArmRrAng0` — Rear arm angle
`0.0590379` (default) | `scalar`

Pitch angle of rear arm, θ_{ra}, in rad.

`Pitch angle of main frame, FrmAng0` — Angle length
`0.377024` (default) | `scalar`

Pitch angle of main frame, θ_{Frm}, in rad.

`Fork length, FrkFrL0` — Fork length
`0.4262193` (default) | `scalar`

Fork length, d_f, in m.

Velocity

`Longitudinal velocity of rear contact patch` — Longitudinal velocity
`0` (default) | `scalar`

Rear contact patch longitudinal coordinate, $\dot{O}_{CpR}$, with respect to road-fixed coordinate system, along `x`, in m/s.

`Vertical velocity of rear contact patch, CpRrVz0` — Vertical velocity
`0` (default) | `scalar`

Vertical velocity of rear contact patch, $\dot{O}_{CpR}$, with respect to road-fixed coordinate system, along `z`, in m/s.

`Pitch rate of rear arm, ArmRrAngV0` — Pitch rate
`0` (default) | `scalar`

Pitch rate of rear arm, $\dot{\theta}_{ra}$, in rad/s.

`Pitch rate of main frame, FrmAngV0` — Pitch rate
`0` (default) | `scalar`

Pitch rate of main frame, $\dot{\theta}_{Frm}$, in rad/s.

`Lower fork deformation velocity, FrkLwV0` — Deformation velocity
`0` (default) | `scalar`

Lower fork deformation velocity, $\dot{d}_f$, in m/s.

Coordinate Offsets

`Longitudinal offset, longOff` — Longitudinal offset
`0` (default) | `scalar`

Vehicle main frame offset along the earth-fixed *X*-axis, in m.

`Lateral offset, latOff` — Lateral offset
`0` (default) | `scalar`

Vehicle main frame offset along the earth-fixed *Y*-axis, in m.

`Vertical offset, vertOff` — Vertical offset
`0` (default) | `scalar`

Vehicle main frame offset along the earth-fixed *Z*-axis, in m.

`Roll offset, pitchOff` — Roll offset
`0` (default) | `scalar`

Vehicle main frame offset about the earth-fixed *X*-axis, in rad.

`Pitch offset, pitchOff` — Pitch offset
`0` (default) | `scalar`

Vehicle main frame offset about the earth-fixed *Y*-axis, in rad.

`Yaw offset, pitchOff` — Yaw offset
`0` (default) | `scalar`

Vehicle main frame offset about the earth-fixed *Z*-axis, in rad.

Version History

Introduced in R2021b

References

[1] Giner, David Moreno. “Symbolic-Numeric Tools for the Analysis of Motorcycle Dynamics. Development of a Virtual Rider for Motorcycles Based on Model Predictive Control.” PhD diss., Universidad Miguel Hernández de Elche, 2016.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Motorcycle Chain

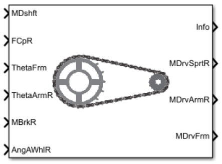
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“Longitudinal Motorcycle Braking Test”

Motorcycle Chain

Implement motorcycle chain

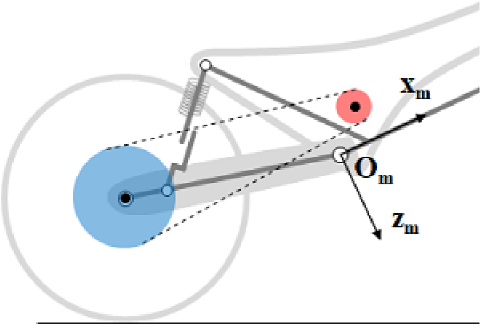
Library: Powertrain Blockset / Drivetrain / Couplings
Vehicle Dynamics Blockset / Powertrain / Drivetrain / Couplings



Description

The Motorcycle Chain block implements the dynamic effects of a motorcycle chain on the Motorcycle Body Longitudinal In-Plane block, including dynamic tension and moment drive coupling.

This figure shows how the chain relates geometrically to the motorcycle frame, rear arm, and rear wheel.



Frame	Variable in Figure	Description
Motorcycle main frame • x_m – Forward along vector pointing to front fork • z_m – Downward • y_m – Orthogonal to motorcycle plane	O_m	Main frame origin

Ports

Input

`MDshft` — Drive shaft moment on front sprocket
`scalar`

Drive shaft moment on front sprocket about y_m, in N·m.

`FCpR` — Longitudinal and vertical forces at rear wheel contact patch

`vector`

Longitudinal and vertical forces at rear wheel contact patch O_{CpR}, along i_{CpR} and k_{CpR}, in N. Signal vector dimensions are `[1x2]` or `[2x1]`.

`ThetaFrm` — Main frame pitch angle

`scalar`

Main frame pitch angle, Θ_{frm}, in rad.

`ThetaArmR` — Rear arm pitch angle

`scalar`

Rear arm pitch angle, Θ_{ra}, in rad.

`MBrkR` — Brake moment at rear wheel

`scalar`

Brake moment at the rear wheel G_{WhlRr}, about j_{WhlRr}, in N·m.

`AngAWhlR` — Rear wheel angular acceleration

`scalar`

Rear wheel angular acceleration, in rad/s^2.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal	Description	Units
`FChn`	Chain force applied to rear arm	N
`AngVSprtR`	Angular velocity of rear sprocket	rad/s
`MDrvSprtR`	Wheel damper moment applied to rear sprocket	N·m
`WhlDmpAng`	Angle between rear sprocket and rear wheel	rad

`MDrvSprtR` — Wheel damper moment at rear sprocket

`scalar`

Wheel damper moment applied to rear sprocket, in N·m.

`MDrvArmR` — Drive chain moment at rear arm

`scalar`

Drive chain moment at rear arm O_{ArmRr}, about j_{ArmRr}, in N·m.

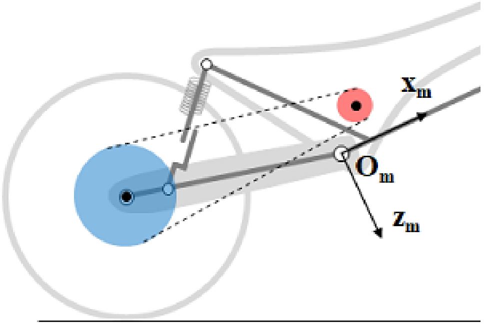
`MDrvFrm` — Drive chain moment at frame

`scalar`

Drive chain moment at the frame O_{Frm}, about j_{Frm}, in N·m.

Parameters

This figure shows how the chain relates geometrically to the motorcycle frame, rear arm, and rear wheel.



Front Sprocket

`Coordinates, SprktFrPxz` — Front sprocket position
`[0.05 -0.05]` (default) | `vector`

Position of front sprocket, *SprktFrPxz*, along x_m z_m, respectively, in m.

`Mass moment of inertia, SprktFrIyy` — Front sprocket inertia
`0.005` (default) | `scalar`

Front sprocket mass moment of inertia, *SprktFrIyy*, in kg·m^2.

`Radius, SprktFrR` — Front sprocket radius
`0.04` (default) | `scalar`

Front sprocket radius, *SprktFrR*, in m.

Rear Sprocket

`Mass moment of inertia, SprktRrIyy` — Rear sprocket inertia
`0.01` (default) | `scalar`

Rear sprocket mass moment of inertia, *SprktRrIyy*, in kg·m^2.

`Radius, SprktRrR` — Rear sprocket radius
`0.12` (default) | `scalar`

Rear sprocket radius, *SprktRrR*, in m.

Rear Wheel

`Mass moment of inertia, WhlRrIyy` — Rear wheel inertia
`0.66` (default) | `scalar`

Rear wheel mass moment of inertia, *WhlRrIyy*, in kg·m^2.

`Radius, WhlRrR` — Rear wheel radius
`0.33` (default) | `scalar`

Rear wheel radius, *WhlRrR*, in m.

Swing Arm

`Arm length, ArmRrLen` — Swing arm length
`0.535` (default) | `scalar`

Arm length, *ArmRrLen*, in m.

Wheel Damper

`Stiffness, WhlDmpK` — Wheel damper stiffness
`1e4` (default) | `scalar`

Wheel damper stiffness, *WhlDmpK*, in N/rad.

`Damping, WhlDmpC` — Wheel damping
`1e2` (default) | `scalar`

Wheel damper damping, *WhlDmpC*, in N·s/rad.

`Equilibrium angle` — Wheel damper equilibrium angle
`-15e-3` (default) | `scalar`

Equilibrium angle, *WhlDmpAng0*, in rad.

Initial Conditions

`Rear sprocket angular velocity, SprktRrAngV0` — Angular velocity
`0` (default) | `scalar`

Rear sprocket angular velocity, *SprktRrAngV0*, in rad/s.

`Rear wheel angular velocity, WhlRrAngV0` — Angular velocity
`0` (default) | `scalar`

Rear wheel angular velocity, *WhlRrAngV0*, in rad/s.

Version History

Introduced in R2021b

References

[1] Giner, David Moreno. “Symbolic-Numeric Tools for the Analysis of Motorcycle Dynamics. Development of a Virtual Rider for Motorcycles Based on Model Predictive Control.” PhD diss., Universidad Miguel Hernández de Elche, 2016.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Motorcycle Body Longitudinal In-Plane

Topics

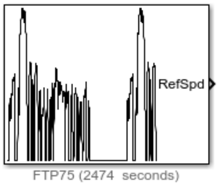
“Coordinate Systems in Vehicle Dynamics Blockset”

Vehicle Scenario Blocks

Drive Cycle Source

Standard or specified longitudinal drive cycle

Library: Powertrain Blockset / Vehicle Scenario Builder
Vehicle Dynamics Blockset / Vehicle Scenarios / Drive Cycle and Maneuvers



Description

The Drive Cycle Source block generates a standard or user-specified longitudinal drive cycle. The block output is the specified vehicle longitudinal speed, which you can use to:

- Predict the engine torque and fuel consumption that a vehicle requires to achieve desired speed and acceleration for a given gear shift reference.
- Produce realistic velocity and shift references for closed loop acceleration and braking commands for vehicle control and plant models.
- Study, tune, and optimize vehicle control, system performance, and system robustness over multiple drive cycles.
- Identify the faults within tolerances specified by standardized tests, including:
  - EPA dynamometer driving schedules[1]
  - Worldwide Harmonised Light Vehicle Test Procedure (WLTP) laboratory tests[2]

For the drive cycles, you can use:

- Drive cycles from predefined sources. By default, the block includes the `FTP–75` drive cycle. To install additional drive cycles from a support package, see “Support Package for Maneuver and Drive Cycle Data”. The support package has drive cycles that include the gear shift schedules, for example `JC08` and `CUEDC`.
- Workspace variables that define your own drive cycles.
- `.mat`, `.xls`, `.xlsx`, or `.txt` files.
- Wide open throttle (WOT) parameters, including initial and nominal reference speed, deceleration start time, and final reference speed.

To achieve the goals listed in the table, use the specified Drive Cycle Source block parameter options.

Goal	Action
Repeat the drive cycle if the simulation run time exceeds the drive cycle length.	Select **Repeat cyclically**.

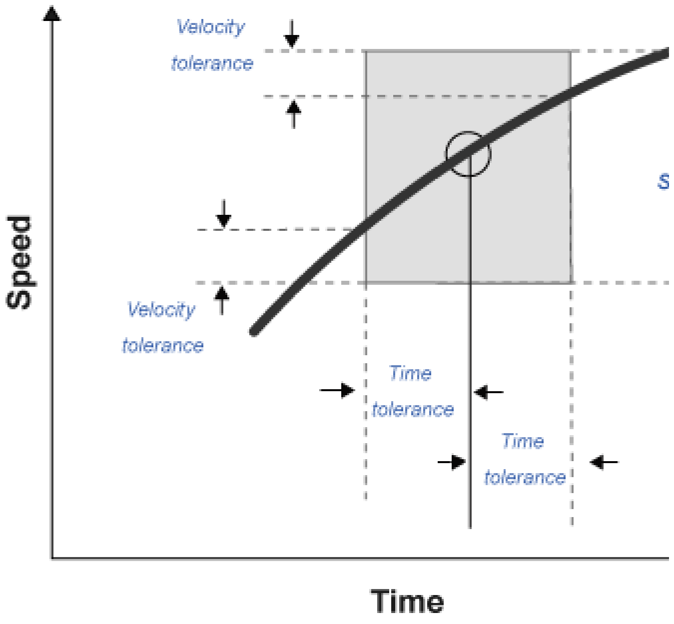
Goal	Action
Output the acceleration, as calculated by Savitzky-Golay differentiation.	Select **Output acceleration**.
Specify a sample period for discrete applications.	Specify a **Output sample period (0 for continuous), dt** parameter.
Update the simulation run time so that it equals the length of the drive cycle.	Click **Update simulation time**. If a model configuration reference exists, the block does not enable this option.
Plot the drive cycle in a MATLAB® figure.	Click **Plot drive cycle**.
Specify the drive cycle using a workspace variable.	Click **Specify variable**. The block: • Sets the **Drive cycle source** parameter to `Workspace variable`. • Enables the **From workspace** parameter. Specify the workspace variable so that it contains time, velocity, and, optionally, the gear shift schedule. For examples, see “Create Drive Cycles Using Workspace Variables” on page 6-5.
Specify the drive cycle using a file.	Click **Select file**. The block: • Sets the **Drive cycle source** parameter to `.mat, .xls, .xlsx or .txt file`. • Enables the **Drive cycle source file** parameter. Specify a file that contains time, velocity, and, optionally, the gear shift schedule.
Output drive cycle gear.	Specify a drive cycle that contains a gear shift schedule. You can use: • A support package to install standard drive cycles that include the gear shift schedules, for example `JC08` and `CUEDC`. • Workspace variables. • `.mat`, `.xls`, `.xlsx`, or `.txt` files. Click **Output gear shift data**.
Install additional drive cycles from a support package.	Click **Install additional drive cycles**. The block enables the parameter if you can install additional drive cycles from a support package.
Identify drive cycle faults within tolerances specified by standardized tests.	On the **Fault Tracking** tab, use the parameters to specify the fault tolerances. If the vehicle speed is not within the allowable speed range, the block sets a fault condition.

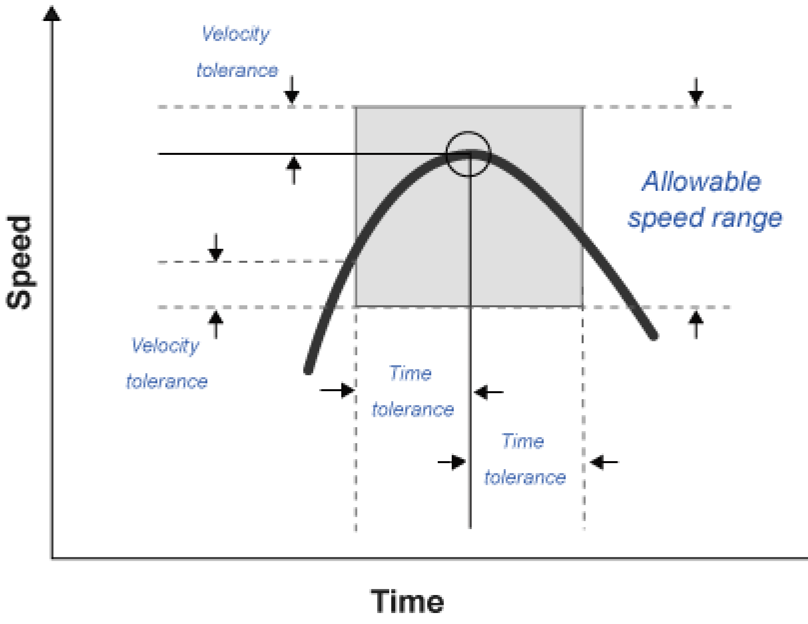
Fault and Failure Tracking

On the **Fault Tracking** tab, use the parameters to specify the fault tolerances. If the vehicle speed or time is not within the allowable range, the block sets a fault condition.

Parameter	**Description**	**Setting**	
		EPA Standard[1]	**WLTP Tests**[2]
Speed tolerance	Speed tolerance above the highest point and below the lowest point of the drive cycle speed trace within the time tolerance.	2.0 mph	2.0 km/h
Time tolerance	Time that the block uses to determine the speed tolerance.	1.0 s	1.0 s
Maximum number of faults	Maximum number of faults during the drive cycle.	*Not specified*	10
Maximum single fault time	Maximum fault duration.	2.0 s	1.0 s
Maximum total fault time	Maximum accumulated time spent under fault condition.	*Not specified*	*Not specified*

These figures illustrate how the block uses the velocity and time tolerances to determine the allowable speed range.



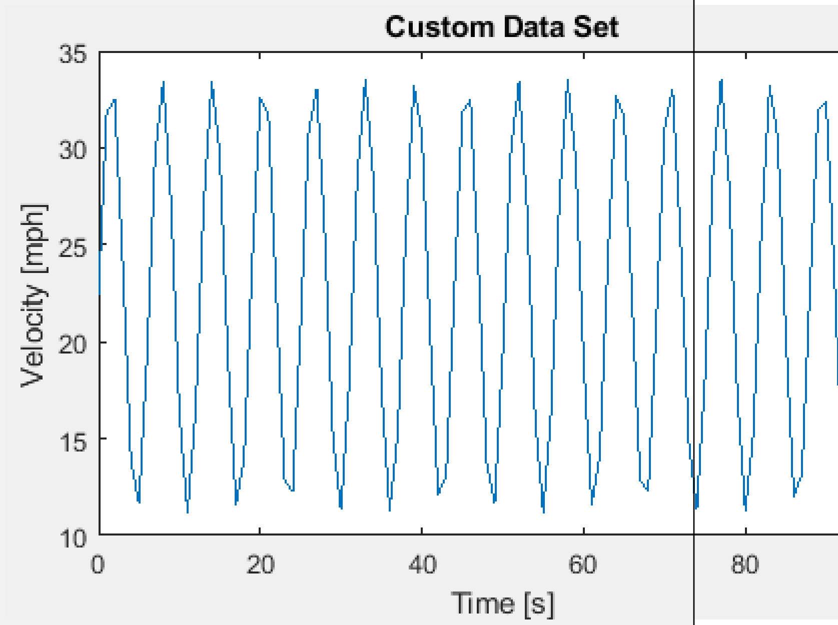


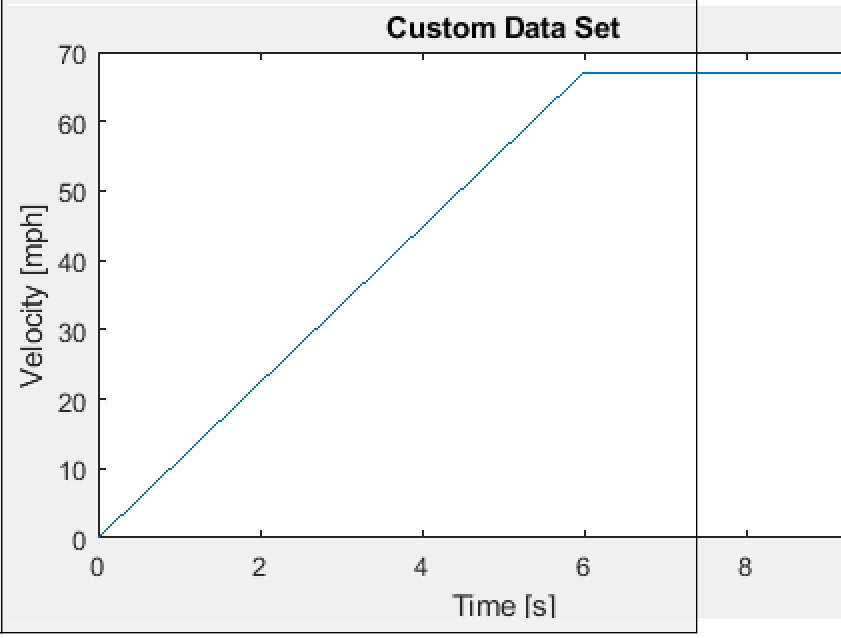
Create Drive Cycles Using Workspace Variables

If you set **Drive cycle source** to `Workspace variable`, you can specify a workspace variable that defines the drive cycle.

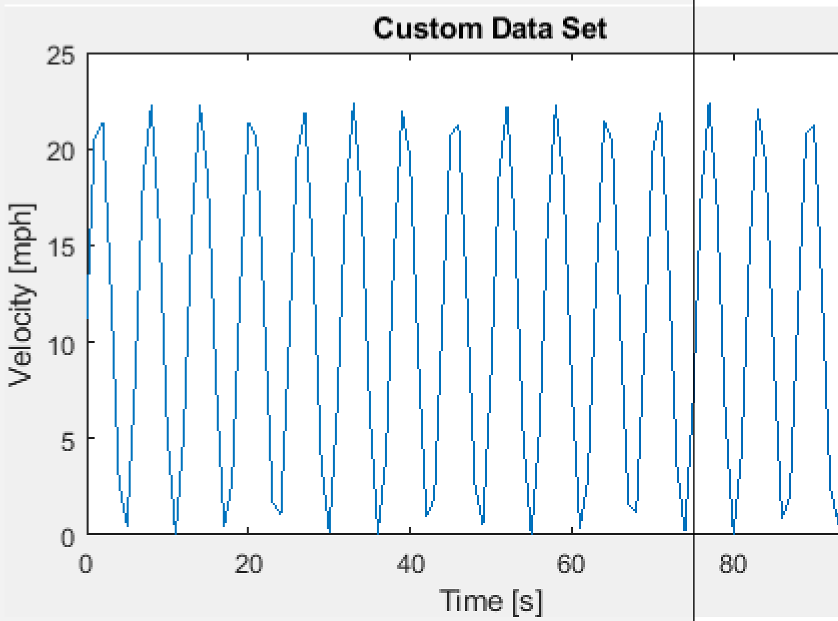
This table provides examples for using workspace variables to create your own drive cycles.

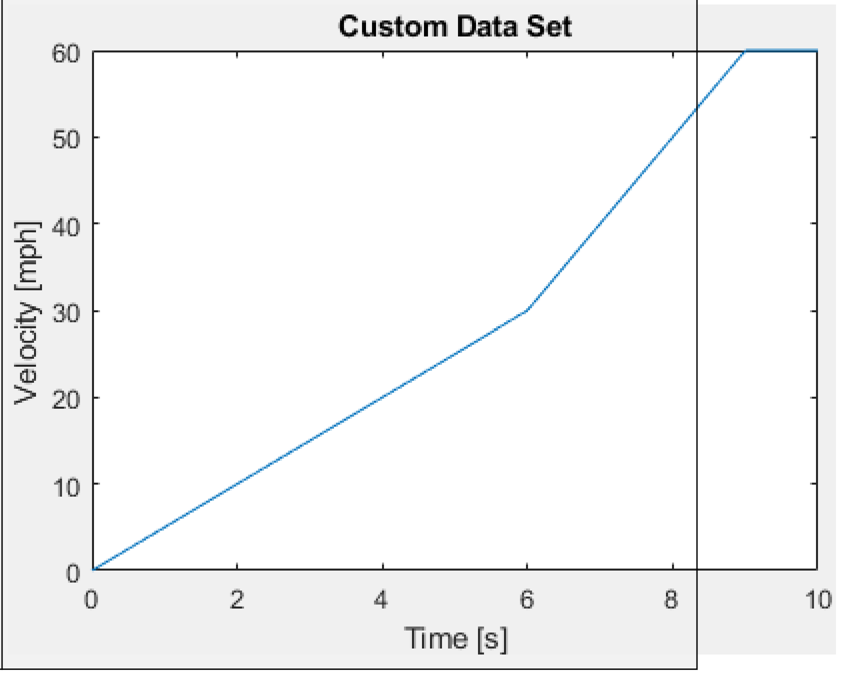
Workspace Variable	Source Velocity Unit	Output Velocity Unit	Drive Cycle Plot

Structure without a gear shift schedule. **From workspace** set to `myCycleS`.
`t = 0:1:100;`
`xdot = 5.*sin(t)+10;`
`myCycleS.time = t';`
`myCycleS.signals.values = xdot';`
	`m/s`	`mph`	

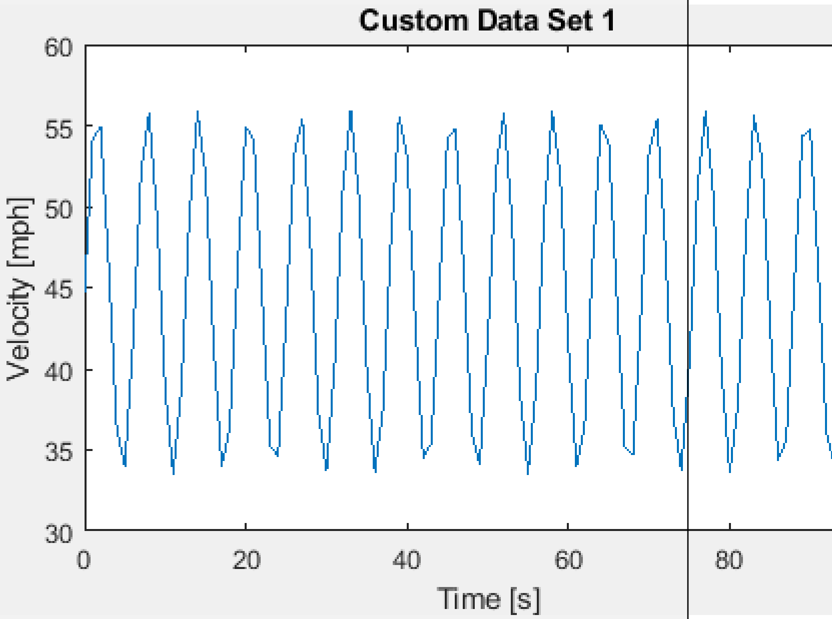
Structure with a gear shift schedule. **From workspace** set to `myCycleS`.
`gears=[0, 1, 2, 3, 3, 4, 4, 4, 4, 4, 4];`
`t=0:1:10;`
`xdot=[0,5,10,15,20,25,30,30,30,30,30];`
`myCycleS.time=t';`
`myCycleS.signals.values=[xdot',gears'];`
	`m/s`	`mph`	

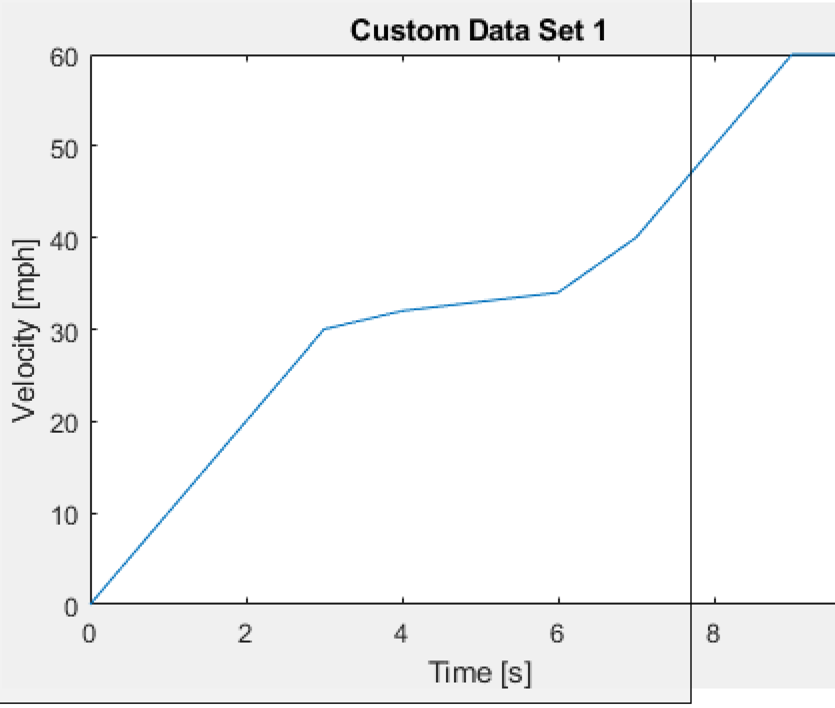
Workspace Variable	Source Velocity Unit	Output Velocity Unit	Drive Cycle Plot

2-D array without a gear shift schedule. **From workspace** set to `myCycleA`.
`t = 0:1:100;`
`xdot = 5.*sin(t)+5;`
`myCycleA = [t',xdot'];`
	`m/s`	`mph`	

2-D array with a gear shift schedule. **From workspace** set to `myCycleA`.
`gears=[0, 1, 2, 3, 4, 4, 4, 5, 5, 5, 5];`
`t=0:1:10;`
`xdot=[0,5,10,15,20,25,30,40,50,60,60];`
`myCycleA=[t',xdot',gears'];`
	`mph`	`mph`	

Workspace Variable	Source Velocity Unit	Output Velocity Unit	Drive Cycle Plot

Time series object without a gear shift schedule. **From workspace** set to `myCycleT`.
`myCycleT = timeseries;`
`t = 0:1:100;`
`xdot = 5.*sin(t)+20;`
`myCycleT.Data = xdot';`
`myCycleT.Time = t;`
	`m/s`	`mph`	

Time series object without a gear shift schedule. **From workspace** set to `myCycleT`.
`myCycleT = timeseries;`
`gears=[0, 1, 2, 3, 4, 4, 4, 5, 5, 5, 5];`
`t=0:1:10;`
`xdot=[0,10,20,30,32,33,34,40,50,60,60];`
`myCycleT.Data = [xdot',gears'];`
`myCycleT.Time = t';`
	`mph`	`mph`	

Ports

Input

`VelFdbk` — Vehicle longitudinal speed
scalar

Longitudinal vehicle speed.

Dependencies

To enable this port, on the **Fault Tracking** tab, select **Enable fault tracking**. Set the **Velocity feedback units, inUnit** parameter to the `VelFdbk` input port signal units.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal		Description
`Reference Speed`		Vehicle reference speed
`Reference Accel`		Vehicle reference acceleration
`Gear`		Vehicle gear
`Fault`	`UpprBnd`	Upper bound of allowable vehicle speed range.
	`LowerBnd`	Lower bound of allowable vehicle speed range.
	`Fault`	Boolean value indicating fault condition: • 1 — Fault • 0 — No fault If the vehicle speed is not within the allowable speed range, the block sets a fault condition.
	`FaultCnt`	Number of faults.
	`CumFaultTime`	Cumulative time spent in fault condition.
	`SnglFaultTime`	Tim spent in a single fault.
	`Fail`	Boolean value indicating fault failure: • 1 — Failure • 0 — No failure If the fault conditions exceed the maximum number of faults, maximum single fault time, or maximum total fault time, the block sets a fault failure.

Dependencies

To enable this port, on the **Fault Tracking** tab, select **Enable fault tracking**.

`RefSpd` — Vehicle reference speed

`scalar`

Vehicle reference speed, in units that you specify. To specify the units, use the **Output velocity units** parameter.

`RefAcc` — Vehicle reference acceleration

`scalar`

To calculate the acceleration, the block implements Savitzky-Golay differentiation using a second-order polynomial with a three-sample point filter.

Dependencies

To create the output acceleration port, select **Output acceleration**. Selecting **Output acceleration** enables the **Output acceleration units** parameter.

Gear — Vehicle gear

`scalar`

Dependencies

To enable this port:

1. Specify a drive cycle that contains a gear shift schedule. You can use:
    - A support package to install standard drive cycles that include the gear shift schedules, for example `JC08` and `CUEDC`.
    - Workspace variables.
    - `.mat`, `.xls`, `.xlsx`, or `.txt` files.
2. Select **Output gear shift** data.

Parameters

Cycle Setup

Setup

`Drive cycle source` — Select the drive cycle source

`FTP75` (default) | `Wide Open Throttle (WOT)` | `Workspace variable` | `.mat, .xls, .xlsx or .txt file`

- `FTP75` — Load the FTP75 drive cycle from a `.mat` file into a 1-D Lookup Table block. The FTP75 represents a city drive cycle that you can use to determine tailpipe emissions and fuel economy of passenger cars. To install additional drive cycles from a support package, see “Support Package for Maneuver and Drive Cycle Data”.
- `Wide Open Throttle (WOT)` — Use WOT parameters to specify a drive cycle for performance testing.
- `Workspace variable` — Specify time, speed, and, optionally, gear data as a structure, 2-D array, or time series object.
- `.mat, .xls, .xlsx or .txt file` — Specify a file that contains time, speed and, optionally, gear data in column format.

Once you have installed additional cycles, you can use `set_param` to set the drive cycle. For example, to use drive cycle `US06`:

```
set_param([gcs '/Drive Cycle Source'],'cycleVar','US06')
```

Dependencies

The table summarizes the parameter dependencies.

Drive Cycle Source	Enables Parameter
`Wide Open Throttle (WOT)`	**Start time, t_wot1**
	Initial reference speed, xdot_woto
	Nominal reference speed, xdot_wot1
	Time to start deceleration, wot2
	Final reference speed, xdot_wot2
	WOT simulation time, t_wotend
	Source velocity units
`Workspace variable`	**From workspace**
	Source velocity units
	Output gear shift data, if drive cycle includes gear shift schedule
`.mat, .xls, .xlsx or .txt file`	**Drive cycle source file**
	Source velocity units
	Output gear shift data, if drive cycle includes gear shift schedule

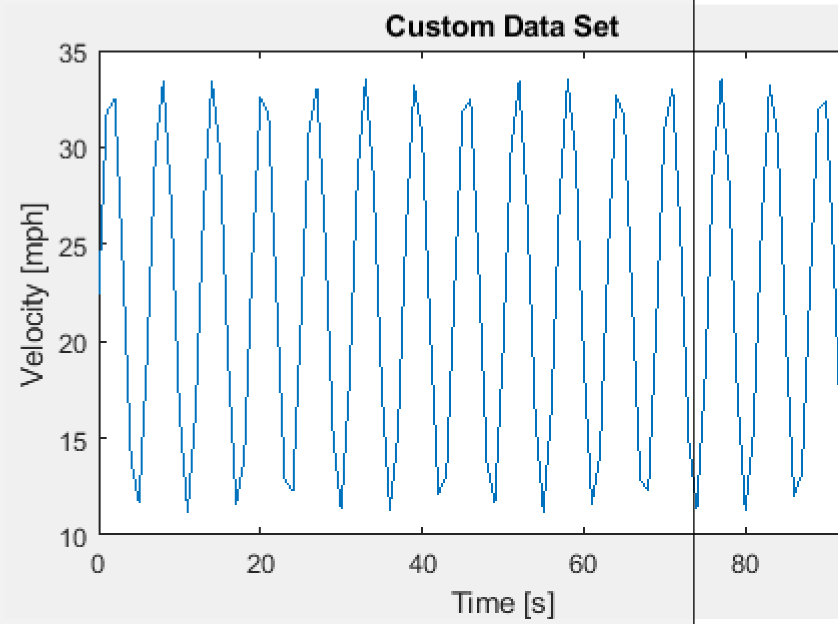
`From workspace` — Workspace
`variable`

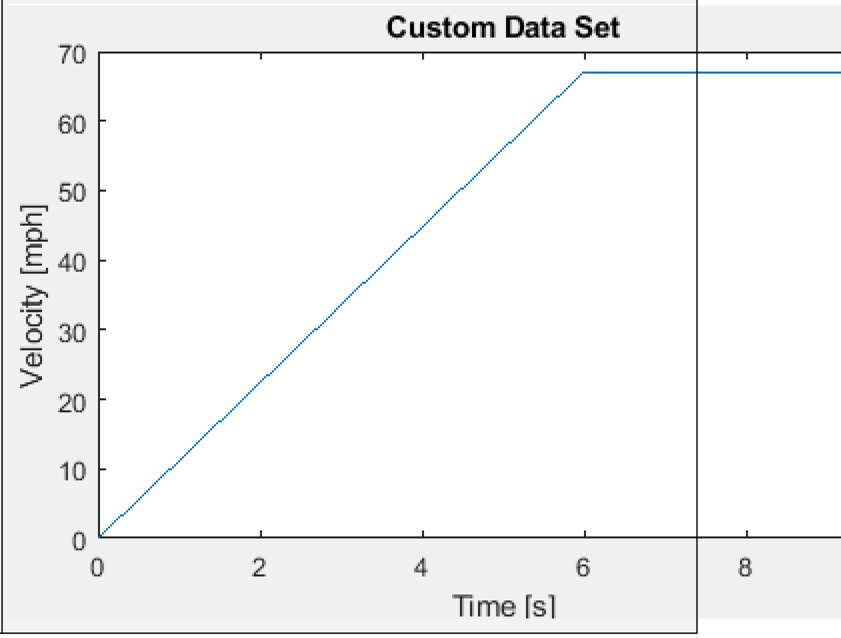
Monotonically increasing time, velocity, and, optionally, gear data, specified by a structure, 2-D array, or time series object. Enter units for velocity in the **Source velocity units** parameter field.

A valid point must exist for each corresponding time value. You cannot specify `inf`, `empty`, or `NaN`.

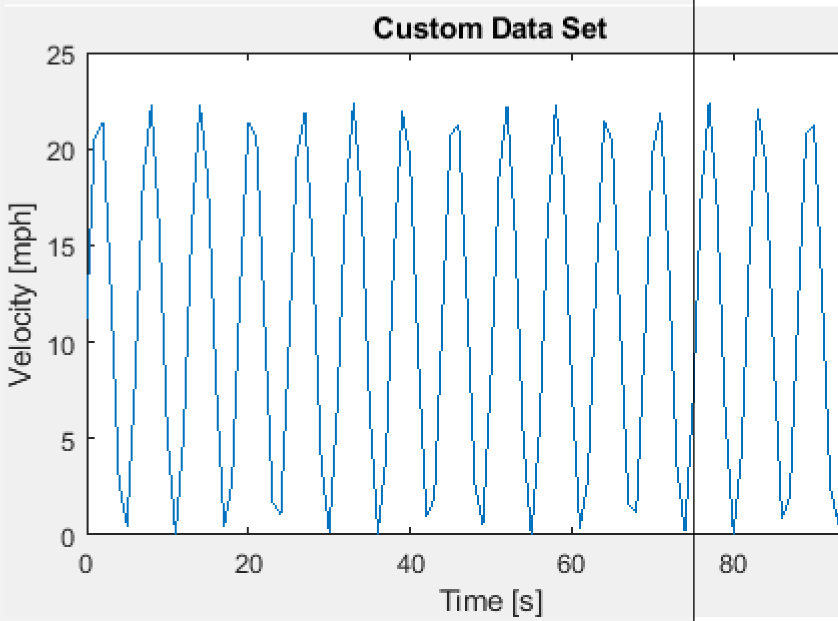
This table provides examples for using workspace variables to create your own drive cycles.

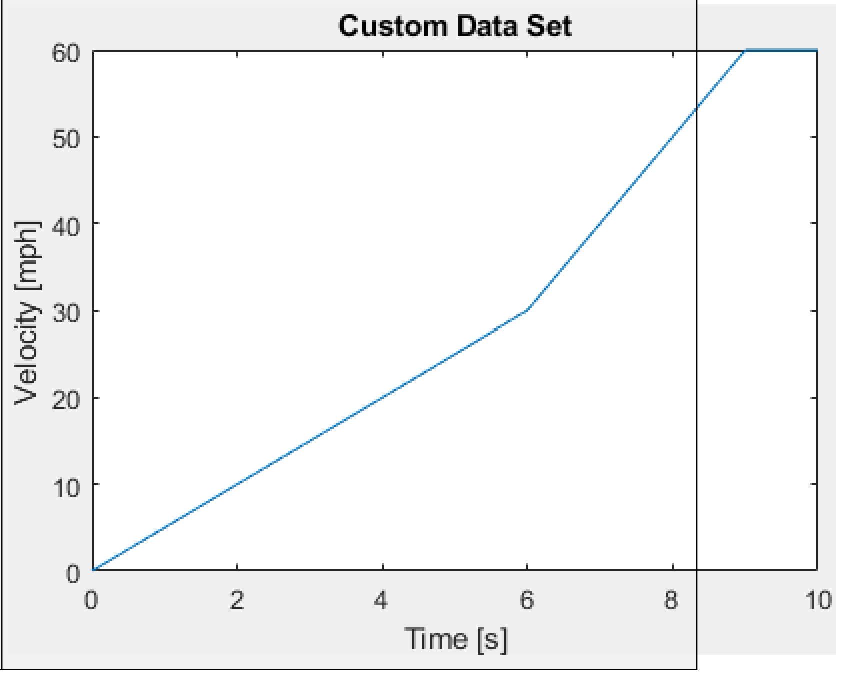
Workspace Variable	**Source Velocity Unit**	**Output Velocity Unit**	**Drive Cycle Plot**

Structure without a gear shift schedule. **From workspace** set to `myCycleS`.
`t = 0:1:100;`
`xdot = 5.*sin(t)+10;`
`myCycleS.time = t';`
`myCycleS.signals.values = xdot';`
	`m/s`	`mph`	

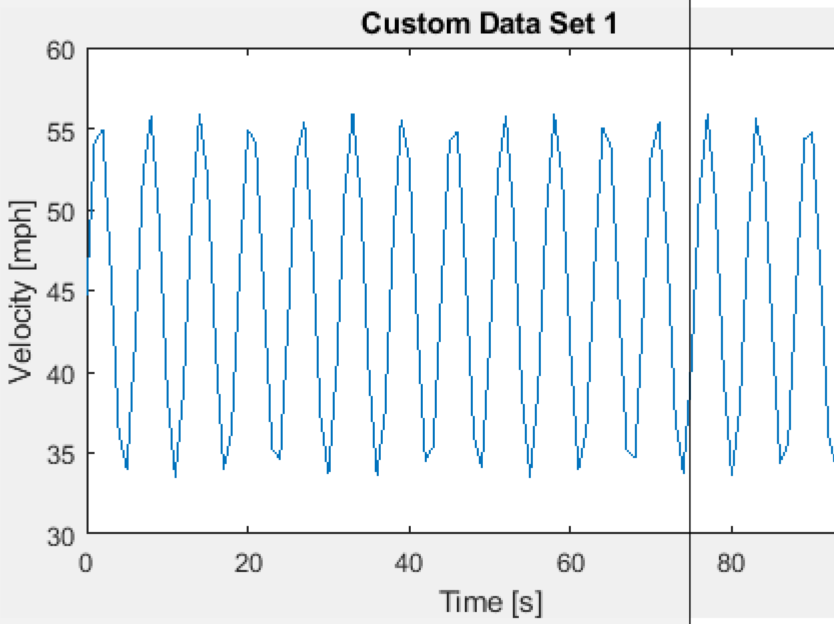
Structure with a gear shift schedule. **From workspace** set to `myCycleS`.
`gears=[0, 1, 2, 3, 3, 4, 4, 4, 4, 4, 4];`
`t=0:1:10;`
`xdot=[0,5,10,15,20,25,30,30,30,30,30];`
`myCycleS.time=t';`
`myCycleS.signals.values=[xdot',gears'];`
	`m/s`	`mph`	

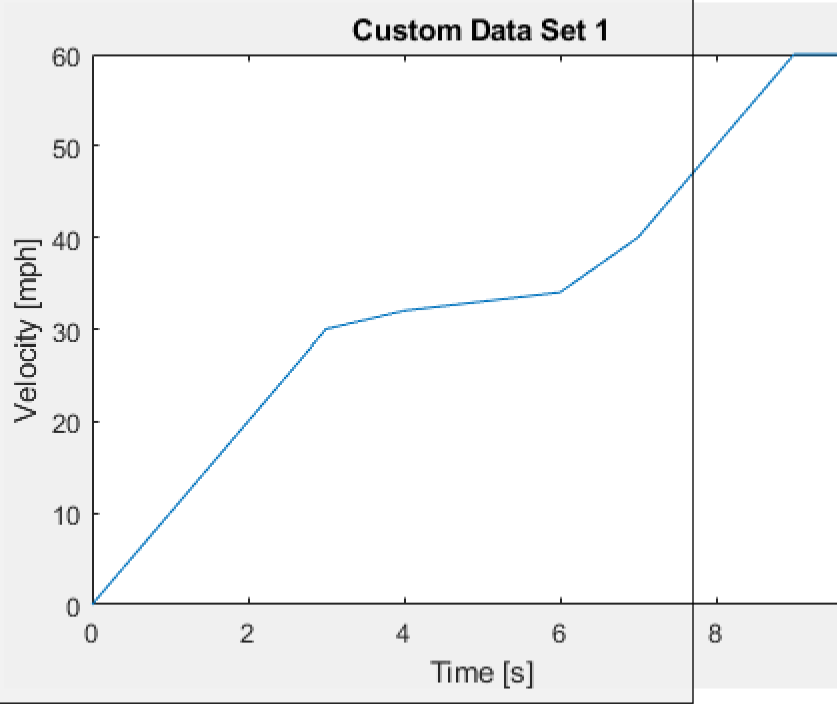
Workspace Variable	Source Velocity Unit	Output Velocity Unit	Drive Cycle Plot

2-D array without a gear shift schedule. **From workspace** set to `myCycleA`.
`t = 0:1:100;`
`xdot = 5.*sin(t)+5;`
`myCycleA = [t',xdot'];`
	`m/s`	`mph`	

2-D array with a gear shift schedule. **From workspace** set to `myCycleA`.
`gears=[0, 1, 2, 3, 4, 4, 4, 5, 5, 5, 5];`
`t=0:1:10;`
`xdot=[0,5,10,15,20,25,30,40,50,60,60];`
`myCycleA=[t',xdot',gears'];`
	`mph`	`mph`	

Workspace Variable	Source Velocity Unit	Output Velocity Unit	Drive Cycle Plot

Time series object without a gear shift schedule. **From workspace** set to `myCycleT`.
`myCycleT = timeseries;`
`t = 0:1:100;`
`xdot = 5.*sin(t)+20;`
`myCycleT.Data = xdot';`
`myCycleT.Time = t;`
	`m/s`	`mph`	

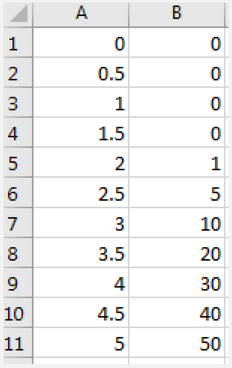
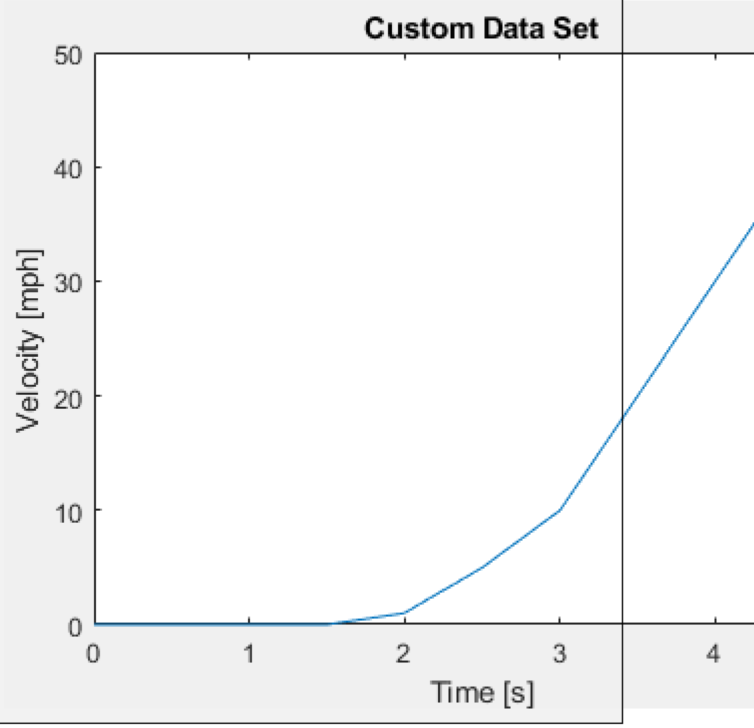
Time series object without a gear shift schedule. **From workspace** set to `myCycleT`.
`myCycleT = timeseries;`
`gears=[0, 1, 2, 3, 4, 4, 4, 5, 5, 5, 5];`
`t=0:1:10;`
`xdot=[0,10,20,30,32,33,34,40,50,60,60];`
`myCycleT.Data = [xdot',gears'];`
`myCycleT.Time = t';`
	`mph`	`mph`	

Dependencies

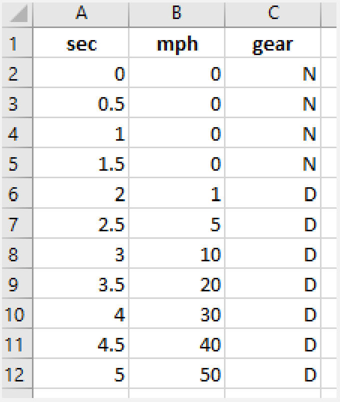
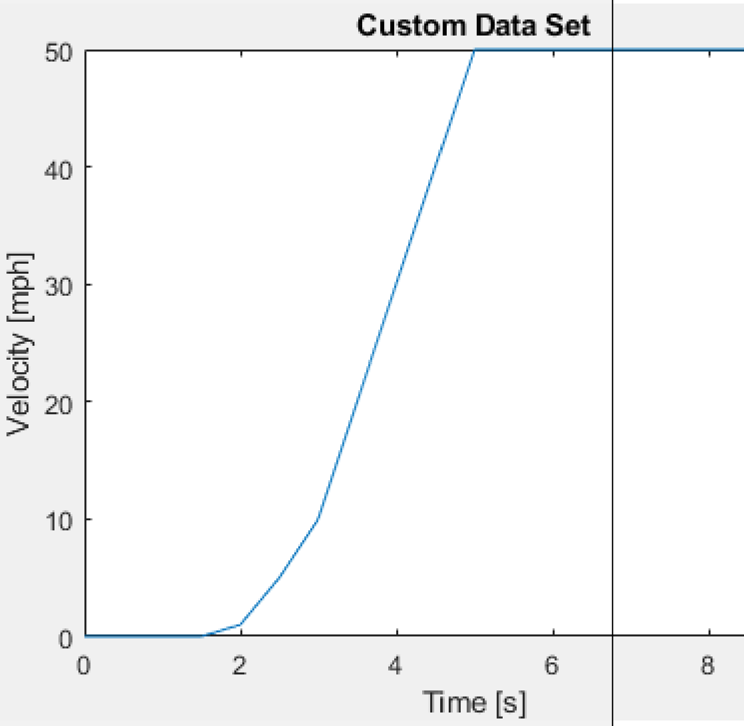
To enable this parameter, select `Workspace variable` from **Drive cycle source**.

`Drive cycle source file` — File name
`.mat, .xls, .xlsx or .txt`

File containing monotonically increasing time, velocity, and, optionally, gear in column or comma-separated format. The block ignores units in the file. Enter units for velocity in the **Source velocity units** parameter field.

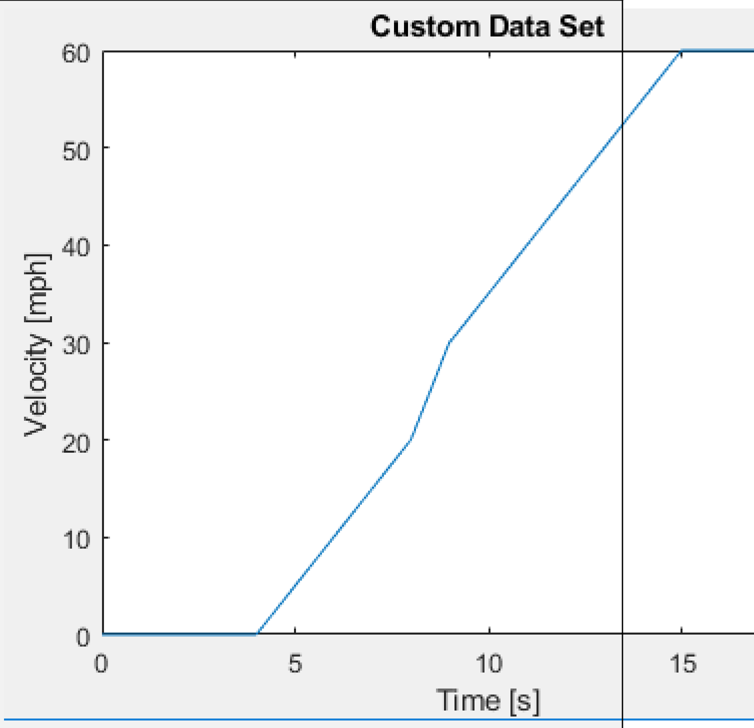
<table>
<tr><th>File</th><th>Source Velocity Unit</th><th>Output Velocity Unit</th><th>Drive Cycle Plot</th></tr>
<tr><td>An <code>.xls</code> or <code>.xlsx</code> file with time in column A and velocity in column B.

<table>
<tr><th></th><th>A</th><th>B</th></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>2</td><td>0.5</td><td>0</td></tr>
<tr><td>3</td><td>1</td><td>0</td></tr>
<tr><td>4</td><td>1.5</td><td>0</td></tr>
<tr><td>5</td><td>2</td><td>1</td></tr>
<tr><td>6</td><td>2.5</td><td>5</td></tr>
<tr><td>7</td><td>3</td><td>10</td></tr>
<tr><td>8</td><td>3.5</td><td>20</td></tr>
<tr><td>9</td><td>4</td><td>30</td></tr>
<tr><td>10</td><td>4.5</td><td>40</td></tr>
<tr><td>11</td><td>5</td><td>50</td></tr>
</table></td><td><code>mph</code></td><td><code>mph</code></td><td>
</td></tr>
</table>

File	Source Velocity Unit	Output Velocity Unit	Drive Cycle Plot

An `.xls` or `.xlsx` file with time in column A, velocity in column B, and gear in column C. The block:
- Ignores the units in the file.
- Converts the gear information to integers:
  - N to 0
  - D to 2

	`mph`	`mph`	

	A	B	C
1	sec	mph	gear
2	0	0	N
3	0.5	0	N
4	1	0	N
5	1.5	0	N
6	2	1	D
7	2.5	5	D
8	3	10	D
9	3.5	20	D
10	4	30	D
11	4.5	40	D
12	5	50	D

File	Source Velocity Unit	Output Velocity Unit	Drive Cycle Plot

A `.txt` with time in column 1 and velocity in column 2. The block ignores the header and units information.
`Time   Speed`
`sec    mph`
`0      0`
`1      0`
`2      0`
`3      0`
`4      0`
`5      5`
`6      10`
`7      15`
`8      20`
`9      30`
`10     35`
`11     40`
`12     45`
`13     50`
`14     55`
`15     60`
`16     60`
`17     60`
`18     60`
`19     60`
`20     60`
	`mph`	`mph`	

If you provide the gear schedule using **P**, **R**, **N**, **D**, **L**, **OD**, the block maps the gears to integers.

Gear	Integer
P	`80`
R	`-1`
N	`0`
L	`1`
D	`2`
OD	Next integer after highest specified gear.

For example, the block converts the gear schedule `P P N L D 3 4 5 6 5 4 5 6 7 OD 7` to `80 80 0 1 2 3 4 5 6 5 4 5 6 7 8 7`.

Dependencies

To enable this parameter, select `.mat, .xls, .xlsx or .txt file` from **Drive cycle source**.

`Repeat cyclically` — Repeat drive cycle

`off` (default) | `on`

Repeat the drive cycle if the simulation run time exceeds the length of the drive cycle.

`Output acceleration` — Output the acceleration

`off` (default)

To calculate the acceleration, the block implements Savitzky-Golay differentiation using a second-order polynomial with a three-sample point filter.

Dependencies

To create the output acceleration port, select **Output acceleration**. Selecting **Output acceleration** enables the **Output acceleration units** parameter.

`Output gear shift data` — Output the gear

`off` (default) | `on`

Dependencies

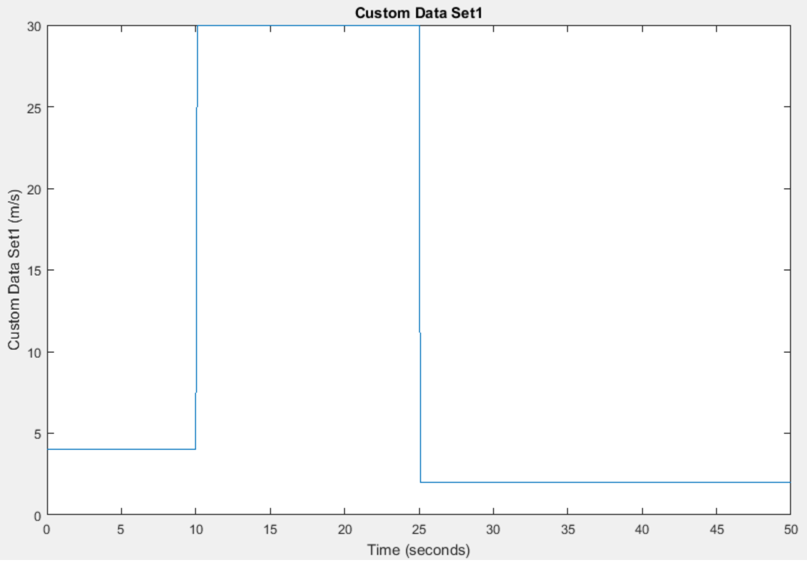
- Specify a drive cycle that contains a gear shift schedule. You can use:
  - A support package to install standard drive cycles that include the gear shift schedules, for example `JC08` and `CUEDC`.
  - Workspace variables.
  - `.mat`, `.xls`, `.xlsx`, or `.txt` files.
- Clicking this parameter creates input port **Gear**.

WOT

`Start time, t_wot1` — Drive cycle start time

`5` (default) | `scalar`

Drive cycle start time, in s. For example, this plot shows a drive cycle with a start time of `10` s.



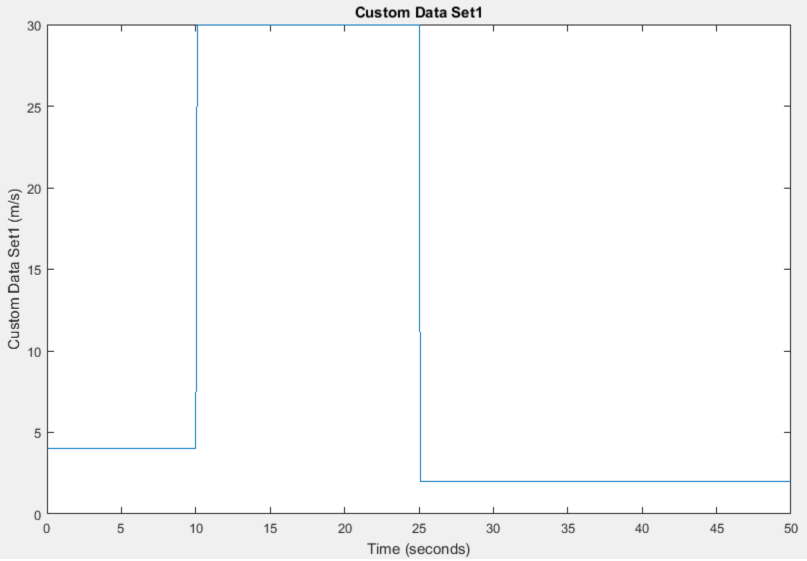
Dependencies

To enable this parameter, select the **Drive cycle source** parameter `Wide Open Throttle (WOT)`.

`Initial reference speed, xdot_woto` — Speed

`0` (default) | `scalar`

Initial reference speed, in units that you specify with the **Source velocity units** parameter. For example, this plot shows a drive cycle with an initial reference speed of `4` m/s.



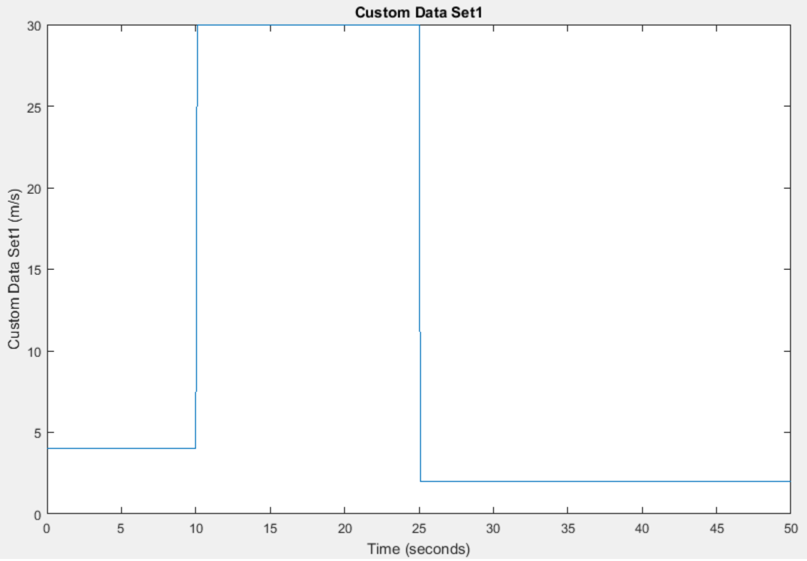
Dependencies

To enable this parameter, select the **Drive cycle source** parameter `Wide Open Throttle (WOT)`.

`Nominal reference speed, xdot_wot1` — Speed

`30` (default) | `scalar`

Nominal reference speed, in units that you specify with the **Source velocity units** parameter. For example, this plot shows a drive cycle with a nominal reference speed of `30` m/s.



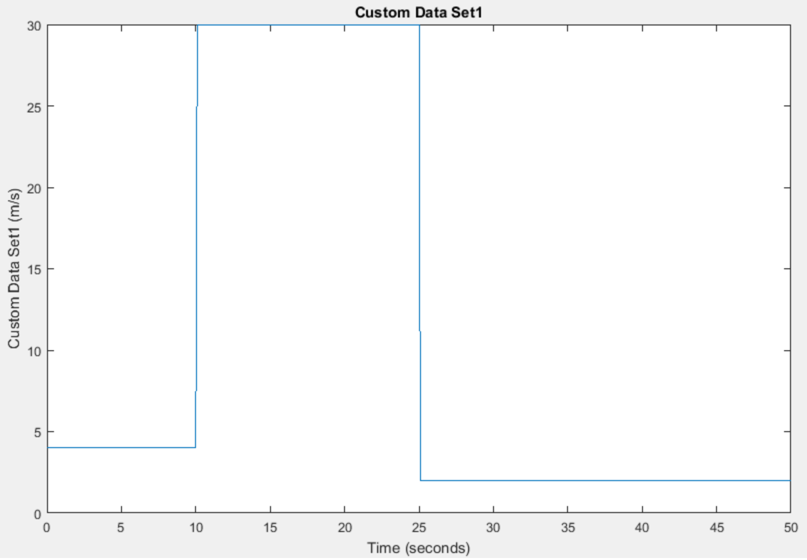
Dependencies

To enable this parameter, select the **Drive cycle source** parameter `Wide Open Throttle (WOT)`.

`Time to start deceleration, wot2` — Time

`20` (default) | `scalar`

Time to start vehicle deceleration, in s. For example, this plot shows a drive cycle with vehicle deceleration starting at 25 s.



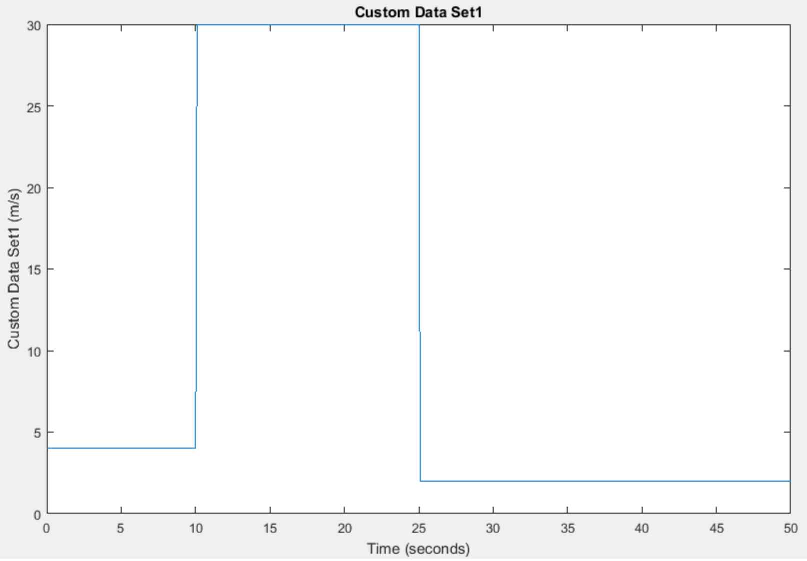
Dependencies

To enable this parameter, select the **Drive cycle source** parameter `Wide Open Throttle (WOT)`.

`Final reference speed, xdot_wot2` — Speed

`0` (default) | `scalar`

Final reference speed, in units that you specify with the **Source velocity units** parameter. For example, this plot shows a drive cycle with a final reference speed of 2 m/s.



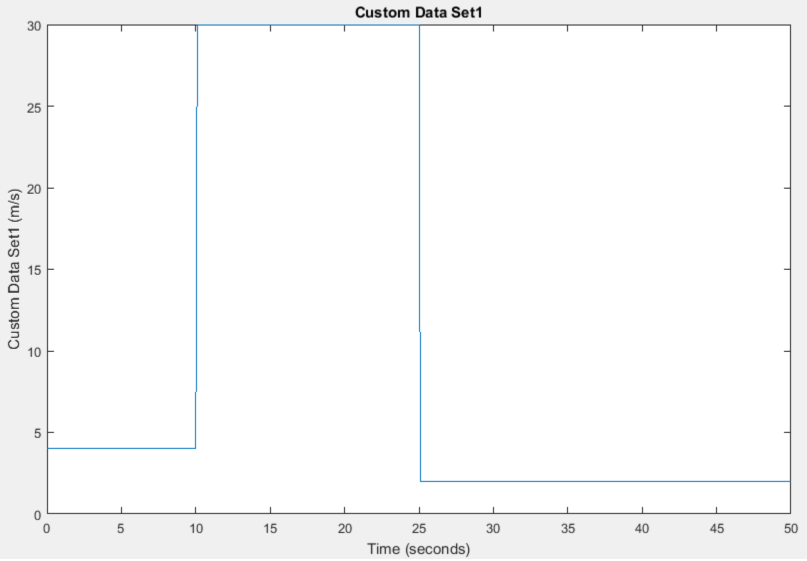
Dependencies

To enable this parameter, select the **Drive cycle source** parameter `Wide Open Throttle (WOT)`.

`WOT simulation time, t_wotend` — Time

`30` (default) | `scalar`

Drive cycle WOT simulation time, in s. For example, this plot shows a drive cycle with a simulation time of `50` s.



Dependencies

To enable this parameter, select the **Drive cycle source** parameter `Wide Open Throttle (WOT)`.

Units and Sample Period

`Source velocity units` — Specify velocity units

`m/s` (default)

Input velocity units.

Dependencies

To enable this parameter, select the **Drive cycle source** parameter `Wide Open Throttle (WOT)`, `Workspace variable`, or `.mat, .xls, .xlsx or .txt file`.

`Output velocity units` — Specify velocity units

`m/s` (default)

Output velocity units.

`Output acceleration units` — Specify acceleration units

`m/s^2` (default)

Specify the output acceleration units.

Dependencies

To enable this parameter, select **Output acceleration**.

`Output sample period (0) for continuous` — Sample rate

`0` (default) | `scalar`

Sample rate. Set to `0` for continuous sample period. For a discrete period, specify a non-zero rate.

Fault Tracking

Fault Settings

`Enable fault tracking` — Enable fault tracking

`off` (default) | `on`

Select this parameter to enable drive cycle fault tracking. Use the parameters to specify the fault tolerances. If the vehicle speed is not within the allowable speed range, the block sets a fault condition.

Dependencies

Selecting this parameter enables these parameters:

- **Speed tolerance, velBnd**
- **Speed tolerance units, velBndUnit**
- **Velocity feedback units, inUnit**
- **Time tolerance, timeBnd**

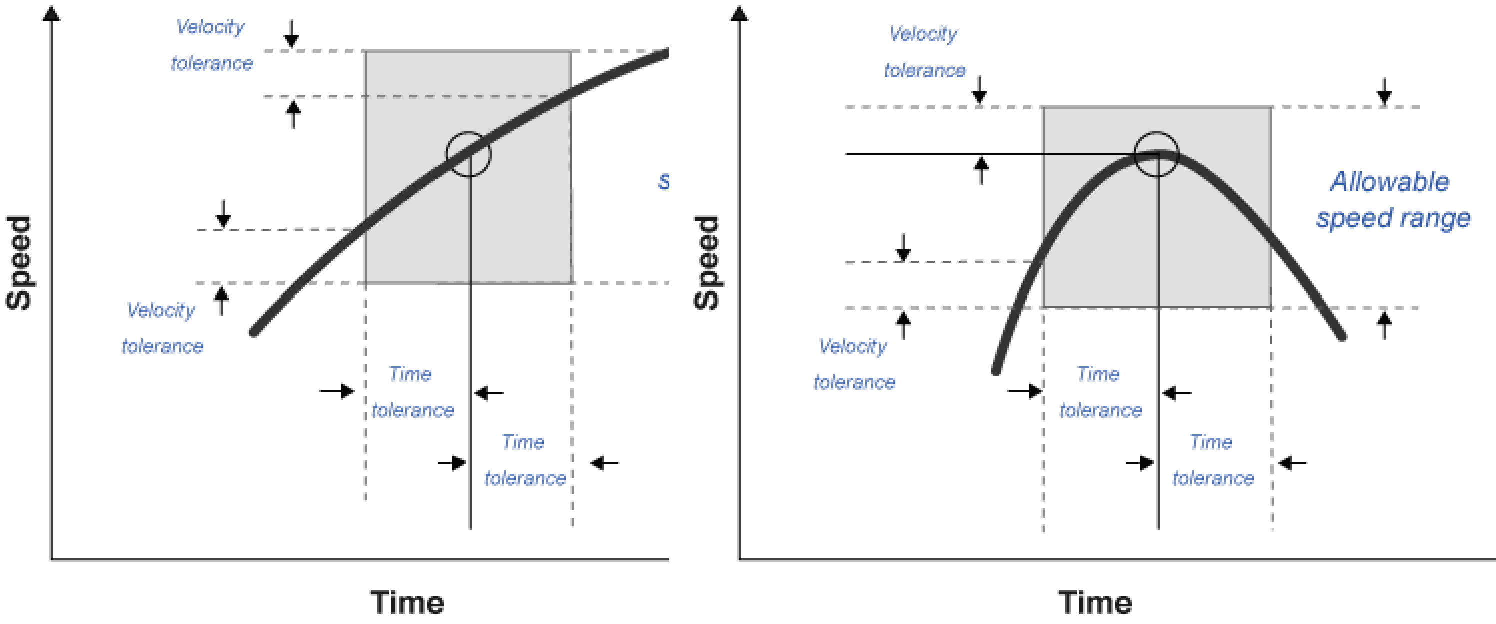
`Speed tolerance, velBnd` — Drive cycle speed tolerance

`2.0` (default) | `scalar`

The speed tolerance above the highest point and below the lowest point of the drive cycle speed trace within the time tolerance. If the vehicle speed is not within the allowable speed range, the block sets a fault condition. For the tolerances specified by the standardized tests, use these settings:

- EPA dynamometer driving schedules — `2.0`
- WLTP tests — `2.0`

These figures illustrate how the block uses the velocity and time tolerances to determine the allowable speed range.



Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Enable fault tracking**.

`Speed tolerance units, velBndUnit` — Set units

`mph` (default)

Speed tolerance units. For the units specified by the standardized tests, use these units:

- EPA dynamometer driving schedules — `m/s`
- WLTP tests — `km/h`

Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Enable fault tracking**.

`Velocity feedback units, inUnit` — Set velocity feedback units

`m/s` (default)

Velocity feedback units. Set the value to the `VelFdbk` input port signal units.

Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Enable fault tracking**.

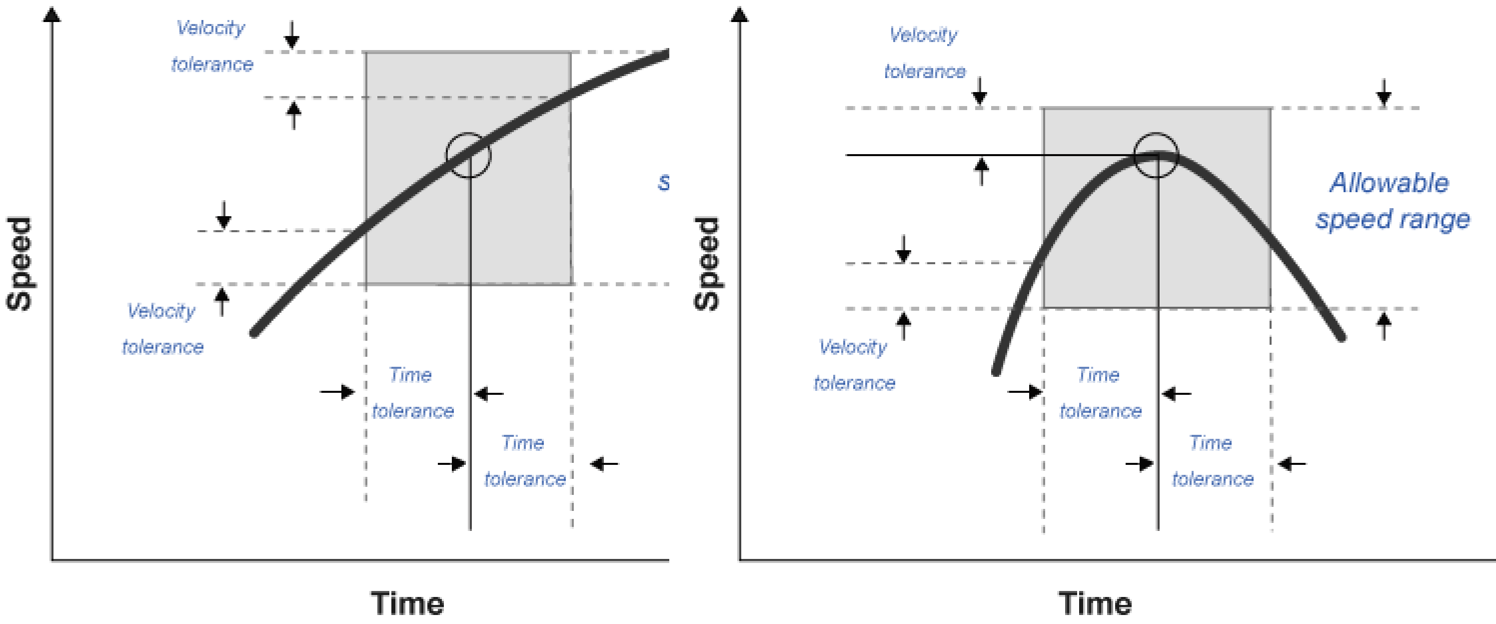
`Time tolerance, timeBnd` — Time tolerance

`1.0` (default) | `scalar`

Time that the block uses to determine the speed tolerance. If the vehicle speed is not within the allowable speed range, the block sets a fault condition. For the time tolerances specified by the standardized tests, use these settings:

- EPA dynamometer driving schedules — `1.0`
- WLTP tests — `1.0`

These figures illustrate how the block uses the velocity and time tolerances to determine the allowable speed range.



Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Enable fault tracking**.

Failure Settings

`Enable failure tracking` — Enable failure tracking

`off` (default) | `on`

Select this parameter to enable drive cycle failure tracking.

Dependencies

To enable this parameter, select **Enable fault tracking**. Selecting **Enable failure tracking** parameter enables these parameters:

- **Stop simulation when trace fails, stopSim**
- **Maximum number of faults, maxFaultCnt**

- **Maximum single fault time, maxFaultTime**
- **Maximum total fault time, maxTotFaultTime**

`Maximum number of faults, maxFaultCnt` — Maximum number of faults

`10` (default) | `scalar`

Maximum number of faults during the drive cycle. For the number specified by the standardized tests, use these settings:

- EPA dynamometer driving schedules — *Not specified*
- WLTP tests — `10`

If the number of faults exceeds the maximum number of faults, the block sets a fault failure.

Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Enable failure tracking**.

`Maximum single fault time, maxFaultTime` — Maximum duration of single fault

`2.0` (default) | `scalar`

Maximum duration of single fault, in s. For the time specified by the standardized tests, use these settings:

- EPA dynamometer driving schedules — `2.0`
- WLTP tests — `1.0`

If the fault duration exceeds the maximum single fault time, the block sets a fault failure.

Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Enable failure tracking**.

`Maximum total fault time, maxTotFaultTime` — Maximum total fault time

`15.0` (default) | `scalar`

Maximum accumulated time spent under fault condition, in s.

If the accumulated time spent under fault condition exceeds the maximum total fault time, the block sets a fault failure.

Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Enable failure tracking**.

Simulation Trace

`Display simulation trace` — Display velocity trace

`off` (default) | `on`

Select this parameter to display a velocity trace window. Selecting this parameter can slow the simulation time.

Dependencies

Selecting this parameter enables these parameters:

- **Simulation trace update rate, dtTrace**
- **Simulation trace display window, traceWindow**

`Simulation trace update rate, dtTrace` — Trace update rate

`1` (default) | `scalar`

Simulation trace update rate, in s. Set to `0` for continuous sample period. For a discrete period, specify a non-zero rate.

Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Display simulation trace**.

`Simulation trace display window, traceWindow` — Trace window update rate

`10` (default) | `scalar`

Simulation trace window update rate, in s.

Dependencies

To enable this parameter, on the **Fault Tracking** tab, select **Display simulation trace**.

Version History

Introduced in R2017a

References

[1] Environmental Protection Agency (EPA). *EPA urban dynamometer driving schedule*. 40 CFR 86.115-78, July 1, 2001.

[2] European Union Commission. "Speed trace tolerances". *European Union Commission Regulation*. 32017R1151, Sec 1.2.6.6, June 1, 2017.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Lateral Driver | Longitudinal Driver | Predictive Driver

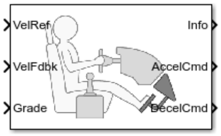
Topics

“Support Package for Maneuver and Drive Cycle Data”
“Time Series Objects and Collections”

Longitudinal Driver

Longitudinal speed-tracking controller

Library: Powertrain Blockset / Vehicle Scenario Builder
Vehicle Dynamics Blockset / Vehicle Scenarios / Driver



Description

The Longitudinal Driver block implements a longitudinal speed-tracking controller. Based on reference and feedback velocities, the block generates normalized acceleration and braking commands that can vary from 0 through 1. You can use the block to model the dynamic response of a driver or to generate the commands necessary to track a longitudinal drive cycle.

Configurations

External Actions

Use the **External Actions** parameters to create input ports for signals that can disable, hold, or override the closed-loop acceleration or deceleration commands. The block uses this priority order for the input commands: disable (highest), hold, override.

This table summarizes the external action parameters.

Goal	External Action Parameter	Input Ports	Data Type
Override the accelerator command with an input acceleration command.	**Accelerator override**	`EnablAccelOvr`	`Boolean`
		`AccelOvrCmd`	`double`
Hold the acceleration command at the current value.	**Accelerator hold**	`AccelHld`	`Boolean`
Disable the acceleration command.	**Accelerator disable**	`AccelZero`	`Boolean`
Override the decelerator command with an input deceleration command.	**Decelerator override**	`EnablDecelOvr`	`Boolean`
		`DecelOvrCmd`	`double`
Hold the decelerator command at current value.	**Decelerator hold**	`DecelHld`	`Boolean`
Disable the decelerator command.	**Decelerator disable**	`DecelZero`	`Boolean`

Controller

Use the **Control type, cntrlType** parameter to specify one of these control options.

Setting	Block Implementation
`PI`	Proportional-integral (PI) control with tracking windup and feed-forward gains.
`Scheduled PI`	PI control with tracking windup and feed-forward gains that are a function of vehicle velocity.
`Predictive`	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path. To implement the MacAdam model, the block: • Represents the dynamics as a linear single track (bicycle) vehicle • Minimizes the previewed error signal at a single point *T** seconds ahead in time • Accounts for the driver lag deriving from perceptual and neuromuscular mechanisms

Shift

Use the **Shift type, shftType** parameter to specify one of these shift options.

Setting	Block Implementation
`None`	No transmission. Block outputs a constant gear of 1. Use this setting to minimize the number of parameters you need to generate acceleration and braking commands to track forward vehicle motion. This setting does not allow reverse vehicle motion.
`Reverse, Neutral, Drive`	Block uses a Stateflow® chart to model reverse, neutral, and drive gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using simple reverse, neutral, and drive gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses the initial gear and time required to shift to shift the vehicle up into drive or down into reverse or neutral. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.

Setting	Block Implementation
`Scheduled`	Block uses a Stateflow chart to model reverse, neutral, park, and N-speed gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using reverse, neutral, park, and N-speed gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses these parameters to determine the: • Initial gear • Upshift and downshift accelerator pedal positions • Upshift and downshift velocity • Timing for shifting and engaging forward and reverse from neutral For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.
`External`	Block uses the input gear, vehicle state, and velocity feedback to generate acceleration and braking commands to track forward and reverse vehicle motion. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.

Gear Signal

Use the **Output gear signal** parameter to create the `GearCmd` output port. The `GearCmd` signal contains the integer value of the commanded vehicle gear.

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Controller: PI Speed-Tracking

If you set the control type to `PI` or `Scheduled PI`, the block implements proportional-integral (PI) control with tracking windup and feed-forward gains. For the `Scheduled PI` configuration, the block uses feed forward gains that are a function of vehicle velocity.

To calculate the speed control output, the block uses these equations.

Setting	Equation
`PI`	$y = \frac{K_{ff}}{v_{nom}} v_{ref} + \frac{K_p e_{ref}}{v_{nom}} + \int \left(\frac{K_i e_{ref}}{v_{nom}} + K_{aw} e_{out} \right) dt + K_g \theta$

Setting	**Equation**
`Scheduled PI`	$y = \frac{K_{ff}(v)}{v_{nom}} v_{ref} + \frac{K_p(v) e_{ref}}{v_{nom}} + \int \left(\frac{K_i(v) e_{ref}}{v_{nom}} + K_{aw} e_{out} \right) e_{ref} dt + K_g(v)\theta$

where:

$$e_{ref} = v_{ref} - v$$

$$e_{out} = y_{sat} - y$$

$$y_{sat} = \begin{cases} -1 & y < -1 \\ y & -1 \le y \le 1 \\ 1 & 1 < y \end{cases}$$

The velocity error low-pass filter uses this transfer function.

$$H(s) = \frac{1}{\tau_{err} s + 1} \quad \text{for} \quad \tau_{err} > 0$$

To calculate the acceleration and braking commands, the block uses these equations.

$$y_{acc} = \begin{cases} 0 & y_{sat} < 0 \\ y_{sat} & 0 \le y_{sat} \le 1 \\ 1 & 1 < y_{sat} \end{cases}$$

$$y_{dec} = \begin{cases} 0 & y_{sat} > 0 \\ -y_{sat} & -1 \le y_{sat} \le 0 \\ 1 & y_{sat} < -1 \end{cases}$$

The equations use these variables.

v_{nom}	Nominal vehicle speed
K_p	Proportional gain
K_i	Integral gain
K_{aw}	Anti-windup gain
K_{ff}	Velocity feed-forward gain
K_g	Grade angle feed-forward gain
θ	Grade angle
τ_{err}	Error filter time constant
y	Nominal control output magnitude
y_{sat}	Saturated control output magnitude
e_{ref}	Velocity error
e_{out}	Difference between saturated and nominal control outputs
y_{acc}	Acceleration signal
y_{dec}	Braking signal
v	Velocity feedback signal

v_{ref}	Reference velocity signal

Controller: Predictive Speed-Tracking

If you set the **Control type, cntrlType** parameter to `Predictive`, the block implements an optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path. To implement the MacAdam model, the block:

- Represents the dynamics as a linear single track (bicycle) vehicle
- Minimizes the previewed error signal at a single point T* seconds ahead in time
- Accounts for the driver lag deriving from perceptual and neuromuscular mechanisms

Vehicle Dynamics

For longitudinal motion, the block implements these linear dynamics.

$$x_1 = v$$

$$\dot{x}_1 = x_2 = \frac{K_{pt}}{m} - g\sin(\gamma) + F_r x_1$$

In matrix notation:

$$\dot{x} = Fx + g\bar{u}$$

where:

$$x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

$$F = \begin{bmatrix} 0 & 1 \\ \frac{F_r}{m} & 0 \end{bmatrix}$$

$$g = \begin{bmatrix} 0 \\ \frac{K_{pt}}{m} \end{bmatrix}$$

$$\bar{u} = u - \frac{m^2}{K_{pt}} g\sin(\gamma)$$

The block uses this equation for the rolling resistance.

$$F_r = -\left[\tanh(x_1)\left(\frac{a_r}{x_1} + c_r x_1\right) + b_r\right]$$

The single-point model assumes a minimum previewed error signal at a single point T^* seconds ahead in time. a^* is the driver ability to predict the future vehicle response based on the current steering control input. b^* is the driver ability to predict the future vehicle response based on the current vehicle state. The block uses these equations.

$$a* = (T*)m^T\left[I + \sum_{n=1}^{\infty}\frac{F^n(T*)^n}{(n+1)!}\right]ge$$

$$b* = m^T\left[I + \sum_{n=1}^{\infty}\frac{F^n(T*)^n}{n!}\right]$$

where:

$$m^T = [1\ \ 1]$$

The equations use these variables.

a, b	Forward and rearward tire location, respectively
m	Vehicle mass
I	Vehicle rotational inertia
a^*, $\boldsymbol{b}^*$	Driver prediction scalar and vector gain, respectively
$\boldsymbol{x}$	Predicted vehicle state vector
v	Longitudinal velocity
$\boldsymbol{F}$	System matrix
K_{pt}	Tractive force and brake limit
γ	Grade angle
$\boldsymbol{g}$	Control coefficient vector
g	Gravitational constant
T^*	Preview time window
$f(t+T^*)$	Previewed path input T* seconds ahead
U	Forward vehicle velocity
$\boldsymbol{m^T}$	Constant observer vector; provides vehicle lateral position
F_r	Rolling resistance
a_r	Static rolling and driveline resistance
b_r	Linear rolling and driveline resistance
c_r	Aerodynamic rolling and driveline resistance

Optimization

The single-point model implemented by the block finds the steering command that minimizes a local performance index, J, over the current preview interval, (t, $t+T$).

$$J = \frac{1}{T}\int_t^{t+T}[f(\eta) - y(\eta)]^2 d\eta$$

To minimize J with respect to the steering command, this condition must be met.

$$\frac{dJ}{du} = 0$$

You can express the optimal control solution in terms of a current non-optimal and corresponding nonzero preview output error T^* seconds ahead[1, 2, 3].

$$u^o(t) = u(t) + \frac{e(t + T^*)}{a^*}$$

The block uses the preview distance and vehicle longitudinal velocity to determine the preview time window.

$$T^* = \frac{L}{U}$$

The equations use these variables.

T^*	Preview time window
$f(t+T^*)$	Previewed path input T^* sec ahead
$y(t+T^*)$	Previewed plant output T^* sec ahead
$e(t+T^*)$	Previewed error signal T^* sec ahead
$u(t)$, $u^o(t)$	Steer angle and optimal steer angle, respectively
L	Preview distance
J	Performance index
U	Forward (longitudinal) vehicle velocity

Driver Lag

The single-point model implemented by the block introduces a driver lag. The driver lag accounts for the delay when the driver is tracking tasks. Specifically, it is the transport delay deriving from perceptual and neuromuscular mechanisms. To calculate the driver transport delay, the block implements this equation.

$$H(s) = e^{-s\tau}$$

The equations use these variables.

τ	Driver transport delay
$y(t+T^*)$	Previewed plant output T^* sec ahead
$e(t+T^*)$	Previewed error signal T^* sec ahead
$u(t)$, $u^o(t)$	Steer angle and optimal steer angle, respectively
J	Performance index

Ports

Input

`VelRef` — Reference vehicle velocity
`scalar`

Reference velocity, v_{ref}, in m/s.

`EnblAccelOvr` — Enable acceleration command override
`scalar`

Enable acceleration command override.

Dependencies

To enable this port, select **Acceleration override**.

Data Types: `Boolean`

`AccelOvrCmd` — Acceleration override command
`scalar`

Acceleration override command, normalized from 0 through 1.

Dependencies

To enable this port, select **Acceleration override**.

Data Types: `double`

`AccelHld` — Acceleration hold
`scalar`

Boolean signal that holds the acceleration command at the current value.

Dependencies

To enable this port, select **Acceleration hold**.

Data Types: `Boolean`

`AccelZero` — Disable acceleration command
`scalar`

Disable acceleration command.

Dependencies

To enable this port, select **Acceleration disable**.

Data Types: `Boolean`

`EnblDecelOvr` — Enable deceleration command override
`scalar`

Enable deceleration command override.

Dependencies

To enable this port, select **Deceleration override**.

Data Types: `Boolean`

`DecelOvrCmd` — Deceleration override command
`scalar`

Deceleration override command, normalized from 0 through 1.

Dependencies

To enable this port, select **Deceleration override**.

Data Types: `double`

`DecelHld` — Deceleration hold
`scalar`

Boolean signal that holds the deceleration command at the current value.

Dependencies

To enable this port, select **Deceleration hold**.

Data Types: `Boolean`

`DecelZero` — Disable deceleration command
`scalar`

Disable deceleration command.

Dependencies

To enable this port, select **Deceleration disable**.

Data Types: `Boolean`

`ExtGear` — Gear
`scalar`

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Dependencies

To enable this port, set **Shift type, shftType** to `External`.

`VelFdbk` — Longitudinal vehicle velocity
`scalar`

Longitudinal vehicle velocity, U, in the vehicle-fixed frame, in m/s.

`Grade` — Road grade angle
`scalar`

Road grade angle, θ or γ, in deg.

Output

`Info` — Bus signal
bus

Bus signal containing these block calculations.

Signal		Variable	Description
`Accel`		y_{acc}	Commanded vehicle acceleration, normalized from 0 through 1
`Decel`		y_{dec}	Commanded vehicle deceleration, normalized from 0 through 1
`Gear`			Integer value of commanded gear
`Clutch`			Clutch command
`Err`		e_{ref}	Difference in reference vehicle speed and vehicle speed
`ErrSqrSum`		$\int_0^t e_{ref}^2 dt$	Integrated square of error
`ErrMax`		$\max(e_{ref}(t))$	Maximum error during simulation
`ErrMin`		$\min(e_{ref}(t))$	Minimum error during simulation
`ExtActions`	`EnblAccelOvr`		Override the accelerator command with an input acceleration command
	`AccelOvrCmd`		Input accelerator override command
	`AccelHld`		Hold the acceleration command at the current value
	`AccelZero`		Disable the acceleration command
	`EnblDecelOvr`		Override the decelerator command with an input deceleration command
	`DecelOvrCmd`		Input deceleration override command
	`DecelHld`		Hold the decelerator command at current value
	`DecelZero`		Disable the decelerator command

`AccelCmd` — Commanded vehicle acceleration
`scalar`

Commanded vehicle acceleration, y_{acc}, normalized from 0 through 1.

`DecelCmd` — Commanded vehicle deceleration
`scalar`

Commanded vehicle deceleration, y_{dec}, normalized from 0 through 1.

`GearCmd` — Commanded vehicle gear
`scalar`

Integer value of commanded vehicle gear.

Gear	Integer
Park	`80`
Reverse	`-1`

Gear	Integer
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Dependencies

To enable this port, select **Output gear signal**.

Parameters

External Actions

`Accelerator override` — Override acceleration command
`off` (default) | `on`

Select to override the acceleration command with an input acceleration command.

Dependencies

Selecting this parameter creates the `EnblAccelOvr` and `AccelOvrCmd` input ports.

`Accelerator hold` — Hold acceleration command
`off` (default) | `on`

Select to hold the acceleration command.

Dependencies

Selecting this parameter creates the `AccelHld` input port.

`Accelerator disable` — Disable acceleration command
`off` (default) | `on`

Select to disable the acceleration command.

Dependencies

Selecting this parameter creates the `AccelZero` input port.

`Decelerator override` — Override deceleration command
`off` (default) | `on`

Select to override the deceleration command with an input deceleration command.

Dependencies

Selecting this parameter creates the `EnblDecelOvr` and `DecelOvrCmd` input ports.

`Decelerator hold` — Hold deceleration command
`off` (default) | `on`

Select to hold the deceleration command.

Dependencies

Selecting this parameter creates the `DecelHld` input port.

`Decelerator disable` — Disable deceleration command

`off` (default) | `on`

Select to disable the deceleration command.

Dependencies

Selecting this parameter creates the `DecelZero` input port.

Configuration

`Control type, cntrlType` — Longitudinal control

`PI` (default) | `Scheduled PI` | `Predictive`

Type of longitudinal control.

Setting	Block Implementation
`PI`	Proportional-integral (PI) control with tracking windup and feed-forward gains.
`Scheduled PI`	PI control with tracking windup and feed-forward gains that are a function of vehicle velocity.
`Predictive`	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path. To implement the MacAdam model, the block: • Represents the dynamics as a linear single track (bicycle) vehicle • Minimizes the previewed error signal at a single point *T** seconds ahead in time • Accounts for the driver lag deriving from perceptual and neuromuscular mechanisms

`Shift type, shftType` — Shift type

`None` (default) | `Reverse, Neutral, Drive` | `Scheduled` | `External`

Shift type.

Setting	Block Implementation
`None`	No transmission. Block outputs a constant gear of 1. Use this setting to minimize the number of parameters you need to generate acceleration and braking commands to track forward vehicle motion. This setting does not allow reverse vehicle motion.

Setting	Block Implementation
`Reverse, Neutral, Drive`	Block uses a Stateflow chart to model reverse, neutral, and drive gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using simple reverse, neutral, and drive gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses the initial gear and time required to shift to shift the vehicle up into drive or down into reverse or neutral. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.
`Scheduled`	Block uses a Stateflow chart to model reverse, neutral, park, and N-speed gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using reverse, neutral, park, and N-speed gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses these parameters to determine the: • Initial gear • Upshift and downshift accelerator pedal positions • Upshift and downshift velocity • Timing for shifting and engaging forward and reverse from neutral For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.
`External`	Block uses the input gear, vehicle state, and velocity feedback to generate acceleration and braking commands to track forward and reverse vehicle motion. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.

`Reference and feedback units, velUnits` — Velocity units

m/s (default)

Vehicle velocity reference and feedback units.

Dependencies

If you set **Control type, cntrlType** control type to `Scheduled` or `Scheduled PI`, the block uses the **Reference and feedback units, velUnits** for the **Nominal speed, vnom** parameter dimension.

If you set **Shift Type, shftType** to `Scheduled`, the block uses the **Longitudinal velocity units, velUnits** for these parameter dimensions:

- **Upshift velocity data table, upShftTbl**

- **Downshift velocity data table, dwnShftTbl**

`Output gear signal` — Create `GearCmd` output port

`off` (default) | `on`

Specify to create output port `GearCmd`.

Control

Longitudinal

`Proportional gain, Kp` — Gain

`10` (default) | `scalar`

Proportional gain, K_p, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Integral gain, Ki` — Gain

`5` (default) | `scalar`

Proportional gain, K_i, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Velocity feed-forward, Kff` — Gain

`.1` (default) | `scalar`

Velocity feed-forward gain, K_{ff}, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Grade angle feed-forward, Kg` — Gain

`0` (default) | `scalar`

Grade angle feed-forward gain, K_g, in 1/deg.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Velocity gain breakpoints, VehVelVec` — Breakpoints

`[0 100]` (default) | `vector`

Velocity gain breakpoints, *VehVelVec*, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Velocity feed-forward gain values, KffVec` — Gain

`[.1 .1]` (default) | `vector`

Velocity feed-forward gain values, *KffVec*, as a function of vehicle velocity, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Proportional gain values, KpVec` — Gain

`[10 10]` (default) | `vector`

Proportional gain values, *KpVec*, as a function of vehicle velocity, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Integral gain values, KiVec` — Gain

`[5 5]` (default) | `vector`

Integral gain values, *KiVec*, as a function of vehicle velocity, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Grade angle feed-forward values, KgVec` — Grade gain

`[0 0]` (default) | `vector`

Grade angle feed-forward values, *KgVec*, as a function of vehicle velocity, in 1/deg.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Nominal speed, vnom` — Nominal vehicle speed

`5` (default) | `scalar`

Nominal vehicle speed, v_{nom}, in units specified by the **Reference and feedback units, velUnits** parameter. The block uses the nominal speed to normalize the controller gains.

Dependencies

To create this parameter, set **Control type** to `PI` or `Scheduled PI`.

`Anti-windup, Kaw` — Gain

`1` (default) | `scalar`

Anti-windup gain, K_{aw}, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI` or `Scheduled PI`.

`Error filter time constant, tauerr` — Filter

`.01` (default) | `scalar`

Error filter time constant, τ_{err}, in s. To disable the filter, enter 0.

Dependencies

To create this parameter, set **Control type** to `PI` or `Scheduled PI`.

Predictive

`Vehicle mass, m` — Mass

`1500` (default) | `scalar`

Vehicle mass, *m*, in kg.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Effective vehicle total tractive force, Kpt` — Tractive force

`3000` (default) | `scalar`

Effective vehicle total tractive force, K_{pt}, in N.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Driver response time, tau` — Tau

`.1` (default) | `scalar`

Driver response time, τ, in s.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Preview distance, L` — Distance

`2` (default) | `scalar`

Driver preview distance, *L*, in m.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Rolling resistance coefficient, aR` — Resistance

`200` (default) | `scalar`

Static rolling and driveline resistance coefficient, a_R, in N. Block uses the parameter to estimate the constant acceleration or braking effort.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Rolling and driveline resistance coefficient, bR` — Resistance

`2.5` (default) | `scalar`

Rolling and driveline resistance coefficient, b_R, in N·s/m. Block uses the parameter to estimate the linear velocity-dependent acceleration or braking effort.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Aerodynamic drag coefficient, cR` — Drag

`.5` (default) | `scalar`

Aerodynamic drag coefficient, c_R, in N·s^2/m^2. Block uses the parameter to estimate the quadratic velocity-dependent acceleration or braking effort.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Gravitational constant, g` — Gravitational constant

`9.81` (default) | `scalar`

Gravitational constant, g, in m/s^2.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

Shift

Reverse, Neutral, Drive

`Initial gear, GearInit` — Initial gear

`0` (default) | `scalar`

Integer value of the initial gear. The block uses the initial gear to generate acceleration and braking commands to track forward and reverse vehicle motion.

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Dependencies

To create this parameter, set **Shift type, shftType** to `Reverse, Neutral, Drive` or `Scheduled`. If you specify `Reverse, Neutral, Drive`, the **Initial Gear, GearInit** parameter value can be only `-1`, `0`, or `1`.

`Time required to shift, tShift` — Time

`.1` (default) | `scalar`

Time required to shift, *tShift*, in s. The block uses the time required to shift to generate acceleration and braking commands to track forward and reverse vehicle motion using reverse, neutral, and drive gear shift scheduling.

Dependencies

To create this parameter, set **Shift type, shftType** to `Reverse, Neutral, Drive`.

Scheduled

`Initial gear, GearInit` — Initial gear

`0` (default) | `scalar`

Integer value of the initial gear. The block uses the initial gear to generate acceleration and braking commands to track forward and reverse vehicle motion.

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Dependencies

To create this parameter, set **Shift type, shftType** to `Reverse, Neutral, Drive` or `Scheduled`. If you specify `Reverse, Neutral, Drive`, the **Initial Gear, GearInit** parameter value can be only `-1`, `0`, or `1`.

`Up and down shift accelerator pedal positions, pdlVec` — Pedal position breakpoints

`[0.1 0.4 0.5 0.9]` (default) | `[1-by-m] vector`

Pedal position breakpoints for lookup tables when calculating upshift and downshift velocities, dimensionless. Vector dimensions are 1 by the number of pedal position breakpoints, `m`.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Upshift velocity data table, upShftTbl` — Table

`[m-by-n] array`

Upshift velocity data as a function of pedal position and gear, in units specified by the **Reference and feedback units, velUnits** parameter. Upshift velocities indicate the vehicle velocity at which the gear should increase by 1.

The array dimensions are `m` pedal positions by `n` gears. The first column of data, when `n` equals 1, is the upshift velocity for the neutral gear.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Downshift velocity data table, dwnShftTbl` — Table

`[m-by-n] array`

Downshift velocity data as a function of pedal position and gear, in units specified by the **Reference and feedback units, velUnits** parameter. Downshift velocities indicate the vehicle velocity at which the gear should decrease by 1.

The array dimensions are `m` pedal positions by `n` gears. The first column of data, when `n` equals 1, is the downshift velocity for the neutral gear.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Time required to shift, tClutch` — Time

`.5` (default) | `scalar`

Time required to shift, t_{Clutch}, in s.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Time required to engage reverse from neutral, tRev` — Time

`.5` (default) | `scalar`

Time required to engage reverse from neutral, t_{Rev}, in s.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Time required to engage park from neutral, tPark` — Time

`120` (default) | `scalar`

Time required to engage park from neutral, t_{Park}, in s.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

Version History

Introduced in R2017a

References

[1] MacAdam, C. C. "An Optimal Preview Control for Linear Systems". *Journal of Dynamic Systems, Measurement, and Control*. Vol. 102, Number 3, Sept. 1980.

[2] MacAdam, C. C. "Application of an Optimal Preview Control for Simulation of Closed-Loop Automobile Driving ". *IEEE Transactions on Systems, Man, and Cybernetics*. Vol. 11, Issue 6, June 1981.

[3] MacAdam, C. C. *Development of Driver/Vehicle Steering Interaction Models for Dynamic Analysis*. Final Technical Report UMTRI-88-53. Ann Arbor, Michigan: The University of Michigan Transportation Research Institute, Dec. 1988.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using Simulink® Coder™.

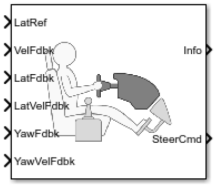
See Also

Drive Cycle Source | Lateral Driver | Predictive Driver

Lateral Driver

Lateral path-tracking controller

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Driver



Description

The Lateral Driver block implements a control model to generate normalized steering commands that track a lateral reference displacement. The normalized steering commands can vary between -1 to 1. To model the dynamics, the block uses a linear single track (bicycle) model. Use the Lateral Driver block to:

- Close the loop between a predefined path and actual vehicle motion.
- Generate steering commands that track predefined paths. You can connect the Lateral Driver block output to steering block inputs.

Configurations

External Actions

Use the **External Actions** parameters to create input ports for signals that can disable, hold, or override the closed-loop steering command. The block uses this priority order for the input commands: disable (highest), hold, override. The block uses this priority order for the input commands: disable (highest), hold, override.

This table summarizes the external action parameters.

Goal	External Action Parameter	Input Ports	Data Type
Override the steering command with an input steering command.	**Steering override**	`EnblSteerOvr`	`Boolean`
		`SteerOvrCmd`	`double`
Hold the steering command at the current value.	**Steering hold**	`SteerHld`	`Boolean`
Disable the steering command.	**Steering disable**	`SteerZero`	`Boolean`

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

Also, you can specify a tire wheel angle saturation limit using the **Tire wheel angle limit, theta** parameter.

Control Type and Units

Use the **Lateral control type, controlTypeLat** parameter to specify the type of lateral control. The table specifies the block implementation.

Setting	Block Implementation
`Predictive` (default)	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path.

<table>
<tr><th>Setting</th><th>Block Implementation</th></tr>
<tr><td><code>Stanley</code></td><td>
<p>Controller that uses the Stanley[4] method to minimize the position error and the angle error of the current pose with respect to the reference pose.</p>
<p>On the Reference Control pane, use the:</p>
Vector input for poses parameter to input the to specify the input.
<table>
<tr><th>Setting</th><th>Implementation</th></tr>
<tr><td><code>off</code> (default)</td><td>Block uses the longitudinal, lateral, and yaw reference (<code>LongRef</code>, <code>LatRef</code>, <code>LatRef</code>) input ports and the feedback (<code>LongFdbk</code>, <code>LatFdbk</code>, <code>LatFdbk</code>) input ports for the reference and feedback pose.</td></tr>
<tr><td><code>on</code></td><td>Block uses input ports, <code>RefPose</code> and <code>CurrPose</code>, for the reference and feedback pose, respectively.</td></tr>
</table>
Include dynamics parameter to specify the type of model for the controller to use.
<table>
<tr><th>Setting</th><th>Implementation</th></tr>
<tr><td><code>off</code> (default)</td><td>Controller uses a kinematic bicycle model that is suitable for path following in low-speed environments such as parking lots, where inertial effects are minimal.</td></tr>
<tr><td><code>on</code></td><td>Controller uses a dynamic bicycle model that is suitable for path following in high-speed environments such as highways, where inertial effects are more pronounced.</td></tr>
</table>
</td></tr>
</table>

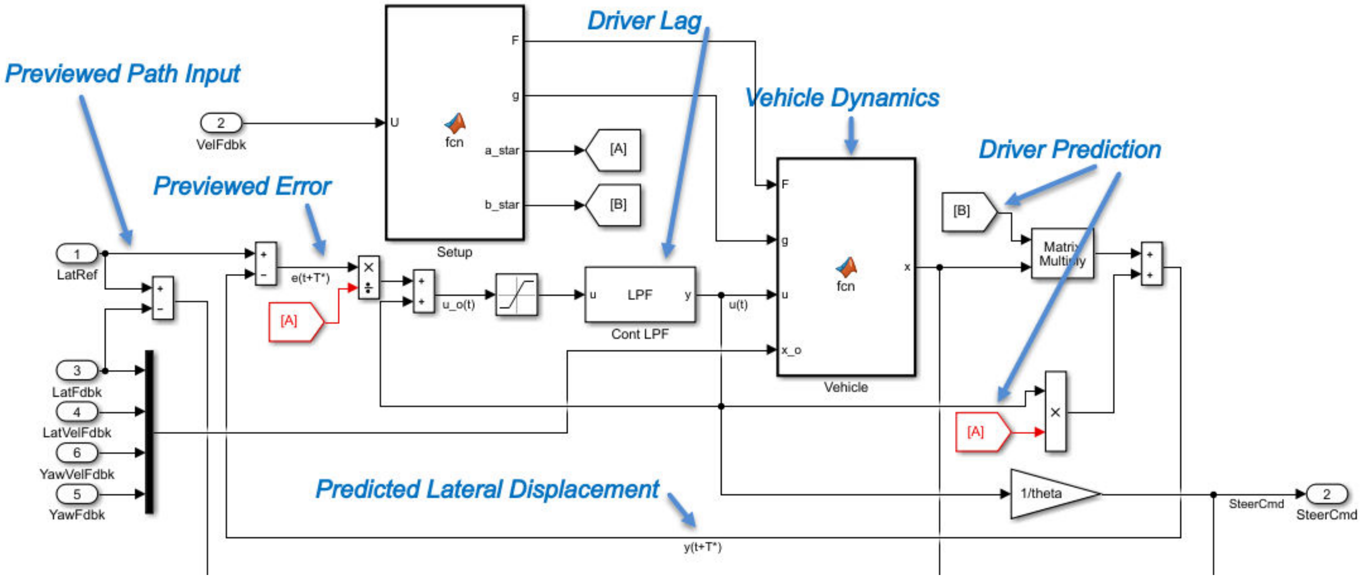
Use the **Angular units, angUnits** parameter to specify the angular units for the input and output ports.

Controller: Predictive Lateral Path-Tracking

If you set **Lateral control type, controlTypeLat** to `Predictive`, the Lateral Driver block implements an optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path. To implement the MacAdam model, the block:

- Represents the dynamics as a linear single track (bicycle) vehicle
- Minimizes the previewed error signal at a single point T* seconds ahead in time
- Accounts for the driver lag deriving from perceptual and neuromuscular mechanisms

This figure illustrates the block implementation of the single-point version of the driver model.



Vehicle Dynamics

For lateral and yaw motion, the block implements these linear dynamic equations.

$$\dot{y} = v + U\psi$$

$$\dot{v} = \left[-\frac{2(C_{\alpha F} + C_{\alpha R})}{mU}\right]v + \left[\frac{2(bC_{\alpha R} - aC_{\alpha F})}{mU} - U\right]r + \left(\frac{2C_{\alpha F}}{m}\right)\delta_F$$

$$\dot{r} = \left[\frac{2(bC_{\alpha R} - aC_{\alpha F})}{IU}\right]v + \left[-\frac{2\left(a^2C_{\alpha F} + b^2C_{\alpha R}\right)}{IU}\right]r + \left(\frac{2aC_{\alpha F}}{I}\right)\delta_F$$

$$\dot{\psi} = r$$

In matrix notation:

$$\dot{x} = Fx + g\delta_F$$

where:

$$x = \begin{bmatrix} y \\ v \\ r \\ \psi \end{bmatrix}$$

$$F = \begin{bmatrix} 0 & 1 & 0 & U \\ 0 & -2\dfrac{C_{\alpha F} + C_{\alpha R}}{mU} & 2\dfrac{bC_{\alpha R} - aC_{\alpha F}}{mU} - U & 0 \\ 0 & 2\dfrac{bC_{\alpha R} - aC_{\alpha F}}{IU} & -2\dfrac{a^2C_{\alpha F} + b^2C_{\alpha R}}{IU} & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

$$x = \begin{bmatrix} 0 \\ \dfrac{2C_{\alpha F}}{m} \\ \dfrac{2aC_{\alpha F}}{I} \\ 0 \end{bmatrix}$$

The single-point model assumes a minimum previewed error signal at a single point T* seconds ahead in time. a* is the driver ability to predict the future vehicle response based on the current steering control input. b* is the driver ability to predict the future vehicle response based on the current vehicle state. The block uses these equations.

$$a* = T*m^T\left[I + \sum_{n=1}^{\infty} \frac{F^n(T*)^n}{(n+1)!}\right]g$$

$$b* = m^T\left[I + \sum_{n=1}^{\infty} \frac{F^n(T*)^n}{n!}\right]$$

where:

$$m^T = [1\ \ 0\ \ 0\ \ 0]$$

The equations use these variables.

a, b	Forward and rearward tire location, respectively
m	Vehicle mass
I	Vehicle rotational inertia
$C_{\alpha F}$	Front tire cornering coefficient
$C_{\alpha R}$	Rear tire cornering coefficient
a*, $\boldsymbol{b}$*	Driver prediction scalar and vector gain, respectively
$\boldsymbol{x}$	Predicted vehicle state vector
v	Lateral velocity

r	Yaw rate
Ψ	Front wheel heading angle
y	Lateral displacement
$\boldsymbol{F}$	System matrix
δ, δ_F	Steer angle and front axle steer angle, respectively
$\boldsymbol{g}$	Control coefficient vector
U	Forward (longitudinal) vehicle velocity
T^*	Preview time window
$f(t+T^*)$	Previewed path input T* seconds ahead
U	Forward vehicle velocity
$\boldsymbol{m}^{\boldsymbol{T}}$	Constant observer vector; provides vehicle lateral position

Optimization

The single-point model implemented by the block finds the steering command that minimizes a local performance index, *J*, over the current preview interval, (*t*, *t*+*T*).

$$J = \frac{1}{T}\int_{t}^{t+T}[f(\eta) - y(\eta)]^2 d\eta$$

To minimize *J* with respect to the steering command, this condition must be met.

$$\frac{dJ}{du} = 0$$

You can express the optimal control solution in terms of a current non-optimal and corresponding nonzero preview output error *T** seconds ahead[1, 2, 3].

$$u^o(t) = u(t) + \frac{e(t + T^*)}{a^*}$$

The block uses the preview distance and vehicle longitudinal velocity to determine the preview time window.

$$T^* = \frac{L}{U}$$

The equations use these variables.

T^*	Preview time window
$f(t+T^*)$	Previewed path input T^* sec ahead
$y(t+T^*)$	Previewed plant output T^* sec ahead
$e(t+T^*)$	Previewed error signal T^* sec ahead
$u(t)$, $u^o(t)$	Steer angle and optimal steer angle, respectively
L	Preview distance
J	Performance index
U	Forward (longitudinal) vehicle velocity

Driver Lag

The single-point model implemented by the block introduces a driver lag. The driver lag accounts for the delay when the driver is tracking tasks. Specifically, it is the transport delay deriving from perceptual and neuromuscular mechanisms. To calculate the driver transport delay, the block implements this equation.

$$H(s) = e^{-s\tau}$$

The equations use these variables.

τ	Driver transport delay
$y(t+T^*)$	Previewed plant output T^* sec ahead
$e(t+T^*)$	Previewed error signal T^* sec ahead
$u(t)$, $u^o(t)$	Steer angle and optimal steer angle, respectively
J	Performance index

Controller: Stanley Lateral Path-Tracking

If you set **Lateral control type, controlTypeLat** to `Stanley`, the block implements the Stanley method[4]. To compute the steering angle command, the Stanley controller minimizes the position error and the angle error of the current pose with respect to the reference pose. The driving direction of the vehicle determines these error values.

To compute the steering angle command, the controller minimizes the position error and the angle error of the current pose with respect to the reference pose.

- The position error is the lateral distance from the vehicle center-of-gravity (CG) to the reference point on the path.
- The angle error is the angle of the vehicle with respect to reference path.

Ports

Input

`LongRef` — Longitudinal displacement reference

`scalar`

Longitudinal center of mass (CM) displacement reference, in the inertial reference frame, in m.

Dependencies

To enable this port:

- Set **Lateral control type, controlTypeLat** to `Stanley`
- Clear **Vector input for poses**

`LatRef` — Lateral displacement reference

`scalar`

Lateral center of mass (CM) displacement reference, in the inertial reference frame, in m.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and clear **Vector input for poses**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`EnblSteerOvr` — Enable steering command override
`scalar`

Enable steering command override.

Dependencies

To enable this port, select **Steering override**.

Data Types: `Boolean`

`SteerOvrCmd` — Steering override command
`scalar`

Steering override command.

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

Dependencies

To enable this port, select **Steering override**.

Data Types: `double`

`SteerHld` — Steering hold
`scalar`

Boolean signal that holds the steering command at the current value.

Dependencies

To enable this port, select **Steering hold**.

Data Types: `Boolean`

`SteerZero` — Disable steering command

`scalar`

Disable steering command.

Dependencies

To enable this port, select **Steering disable**.

Data Types: `Boolean`

`YawRef` — Yaw angle reference

`scalar`

Vehicle yaw angle, Ψ_o, in the inertial reference frame, in units specified by **Angular units, angUnits**.

Dependencies

To enable this port:

- Set **Lateral control type, controlTypeLat** to `Stanley`
- Clear **Vector input for poses**

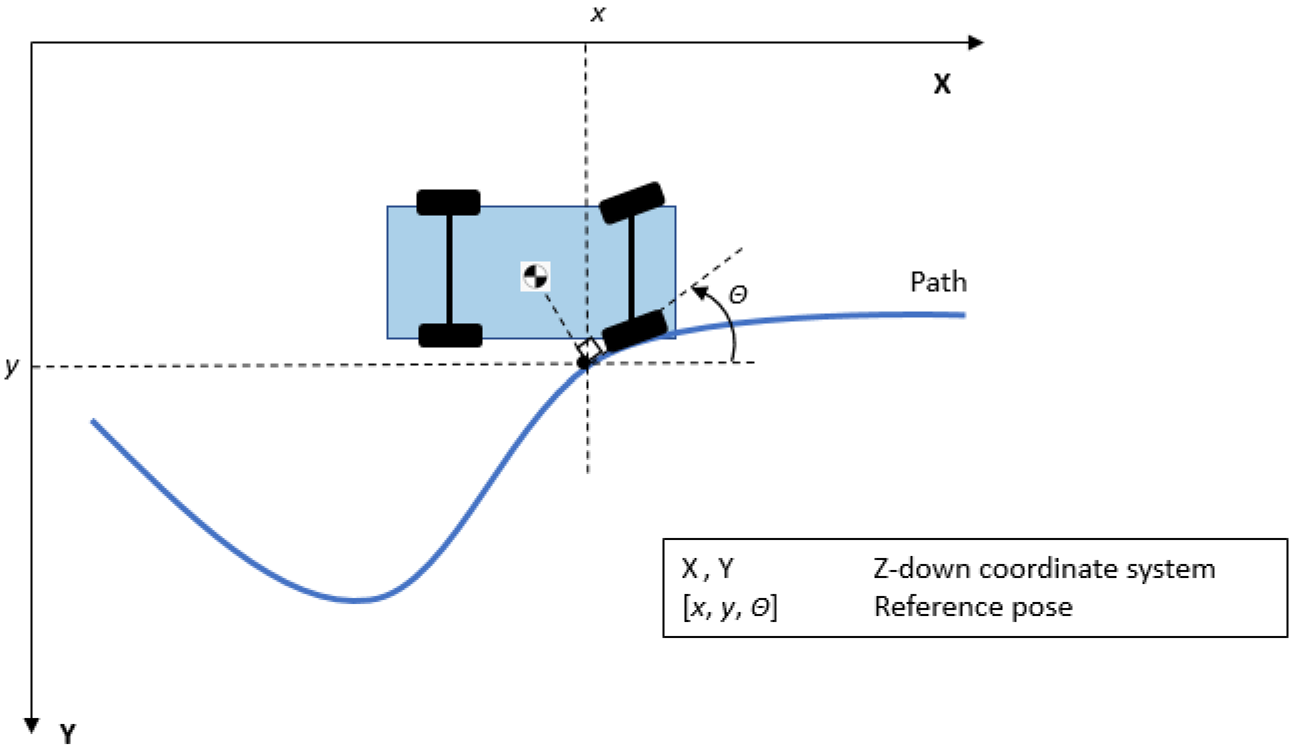
`RefPose` — Reference pose

[x, y, Θ] vector

Reference pose, specified as an [x, y, Θ] vector. x and y are in meters, and Θ are in units specified by **Angular units, angUnits**.

x and y specify the reference point to steer the vehicle toward. Θ specifies the orientation angle of the path at this reference point and is positive in the counterclockwise direction.

The reference point is the point on the path that is closest to the vehicle CG. You can use the either the Z-up or Z-down vehicle coordinate system, as long you use the same coordinate system (Z-up or Z-down) for block inputs and parameters.



Dependencies

To enable this port, set **Lateral control type, controlTypeLat** to `Stanley` and select **Vector input for poses**.

Data Types: `single` | `double`

`VelFdbk` — Longitudinal vehicle velocity

`scalar`

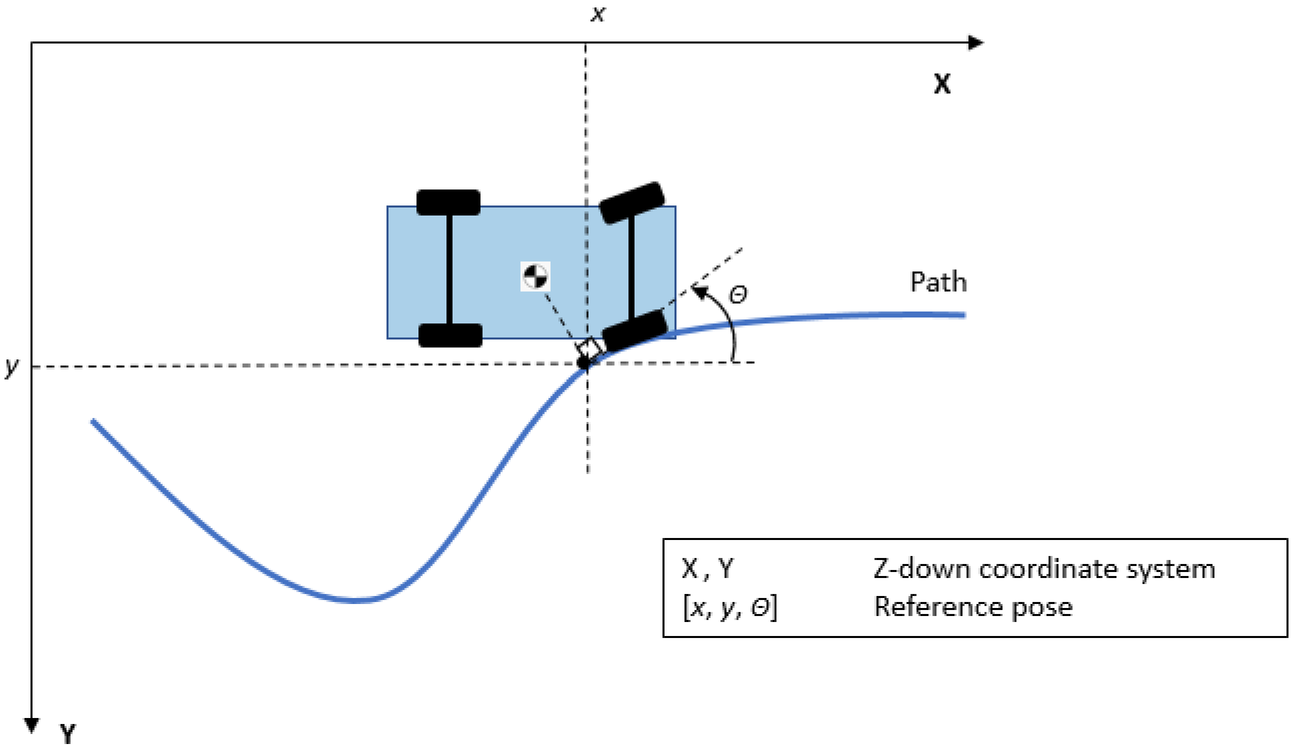
Longitudinal vehicle velocity, U, in the vehicle-fixed frame, in m/s.

`CurrPose` — Current pose

$[x, y, \Theta]$ vector

Current pose of the vehicle, specified as an $[x, y, \Theta]$ vector. x and y are in meters, and Θ is in units specified by **Angular units, angUnits**.

x and y specify the location of the vehicle, which is defined as the vehicle CG. You can use the either the Z-up or Z-down vehicle coordinate system, as long you use the same coordinate system (Z-up or Z-down) for block inputs and parameters.



Dependencies

To enable this port, set **Lateral control type, controlTypeLat** to `Stanley` and select **Vector input for poses**.

Data Types: `single` | `double`

`LatFdbk` — Lateral displacement
`scalar`

Lateral CM displacement, y_o, in the inertial reference frame, in m.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and clear **Vector input for poses**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`LatVelFdbk` — Lateral vehicle velocity
`scalar`

Lateral vehicle velocity, v_o , in the vehicle-fixed frame, in m/s.

Dependencies

To enable this port, Set **Lateral control type, controlTypeLat** to `Predictive`.

`YawFdbk` — Vehicle yaw angle
`scalar`

Vehicle yaw angle, Ψ_o, in the inertial reference frame, in units specified by **Angular units, angUnits**.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and clear **Vector input for poses**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`YawVelFdbk` — Yaw rate

`scalar`

Yaw rate, r_o, in the vehicle-fixed frame, in units specified by **Angular units, angUnits** per sec.

Dependencies

To enable this port, Set **Lateral control type, controlTypeLat** to `Predictive`.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal		Variable	Description
`Predicted`	`y`	y	Predicted lateral displacement, in the vehicle-fixed frame.
	`ydot`	v	Predicted lateral velocity, in the vehicle-fixed frame.
	`psi`	Ψ	Predicted front wheel heading angle.
	`r`	r	Predicted yaw rate, in the vehicle-fixed frame.
`SteerCmd`		δ_F	Commanded steer angle.
`Err`		e_{ref}	Difference in reference vehicle position and vehicle position.
`ErrSqrSum`		$\int_0^t e_{ref}{}^2 dt$	Integrated square of error.
`ErrMax`		$\max(e_{ref}(t))$	Maximum error during simulation.
`ErrMin`		$\min(e_{ref}(t))$	Minimum error during simulation.
`ExtActions`	`EnblSteerOvr`		Override the steering command with an input deceleration command.
	`SteerOvrCmd`		Input steering override command
	`SteerHld`		Hold the steering command at the current value
	`SteerZero`		Disable the steering command

`SteerCmd` — Steer angle command

`scalar`

Commanded steer angle, δ_F.

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

Parameters

Configuration

`Steering override` — Override steering command

`off` (default) | `on`

Select to override the steering command with an input steering command.

Dependencies

Selecting this parameter creates the `EnblSteerOvr` and `SteerOvrCmd` input ports.

`Steering hold` — Hold steering command

`off` (default) | `on`

Select to hold the steering command.

Dependencies

Selecting this parameter creates the `SteerHld` input port.

`Steering disable` — Disable steering command

`off` (default) | `on`

Select to disable the steering command.

Dependencies

Selecting this parameter creates the `SteerZero` input port.

`Output handwheel angle` — Steering port units in rad

`off` (default) | `on`

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

Dependencies

To create the `SteerOvrCmd` input port, select **Steering override**.

`Lateral control type, controlTypeLat` — Controller

`Predictive` (default) | `Stanley`

Use the **Lateral control type, controlTypeLat** parameter to specify the type of lateral control. The table specifies the block implementation.

Setting	Block Implementation
`Predictive` (default)	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path.

<table>
<tr><th>Setting</th><th>Block Implementation</th></tr>
<tr><td>`Stanley`</td><td>Controller that uses the Stanley[4] method to minimize the position error and the angle error of the current pose with respect to the reference pose.
On the **Reference Control** pane, use the:
• **Vector input for poses** parameter to input the to specify the input.
<table>
<tr><th>Setting</th><th>Implementation</th></tr>
<tr><td>`off` (default)</td><td>Block uses the longitudinal, lateral, and yaw reference (`LongRef`, `LatRef`, `LatRef`) input ports and the feedback (`LongFdbk`, `LatFdbk`, `LatFdbk`) input ports for the reference and feedback pose.</td></tr>
<tr><td>`on`</td><td>Block uses input ports, `RefPose` and `CurrPose`, for the reference and feedback pose, respectively.</td></tr>
</table>
• **Include dynamics** parameter to specify the type of model for the controller to use.
<table>
<tr><th>Setting</th><th>Implementation</th></tr>
<tr><td>`off` (default)</td><td>Controller uses a kinematic bicycle model that is suitable for path following in low-speed environments such as parking lots, where inertial effects are minimal.</td></tr>
<tr><td>`on`</td><td>Controller uses a dynamic bicycle model that is suitable for path following in high-speed environments such as highways, where inertial effects are more pronounced.</td></tr>
</table>
</td></tr>
</table>

`Angular units, angUnits` — Input and output port angular units

`rad` (default) | `deg`

Input and output port angular units.

Reference Control

Predictive

`Driver response time, tau` — Response time

`0.1` (default) | `scalar`

Driver response time, τ, in s.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Predictive`.

`Preview distance, L` — Distance

`3` (default) | `scalar`

Driver preview distance, *L*, in m. Used to determine the preview time window, T^*.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Predictive`.

Stanley

`Vector input for poses` — Select to create `RefPose` and `CurrPose` input ports

`off` (default) | `on`

Select this parameter to create the `RefPose` and `CurrPose` input ports.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Include dynamics` — Select to include dynamics

`off` (default) | `on`

The controller computes this command using the Stanley method, whose control law is based on both a kinematic and dynamic bicycle model. To change between models, use this parameter.

Setting	Implementation
`off`	Controller uses a kinematic bicycle model that is suitable for path following in low-speed environments such as parking lots, where inertial effects are minimal.
`on`	Controller uses a dynamic bicycle model that is suitable for path following in high-speed environments such as highways, where inertial effects are more pronounced.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Position gain of forward motion, PositionGainF` — Position gain of vehicle in forward motion

`2.5` (default) | positive real scalar

Position gain of the vehicle when it is in forward motion, specified as a positive scalar. This value determines how much the position error affects the steering angle. Typical values are in the range [1, 5]. Increase this value to increase the magnitude of the steering angle.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Position gain of reverse motion, PositionGainF` — Position gain of vehicle in reverse motion

`2.5` (default) | positive real scalar

Position gain of the vehicle when it is in reverse motion, specified as a positive scalar. This value determines how much the position error affects the steering angle. Typical values are in the range [1, 5]. Increase this value to increase the magnitude of the steering angle.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Yaw rate feedback gain, YawRateGain` — Yaw rate feedback gain

`.2` (default) | nonnegative real scalar

Yaw rate feedback gain, specified as a nonnegative real scalar. This value determines how much weight is given to the current yaw rate of the vehicle when the block computes the steering angle command.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.

`Steering angle feedback gain, DelayGain` — Steering angle feedback gain

`.2` (default) | nonnegative real scalar

Steering angle feedback gain, specified as a nonnegative real scalar. This value determines how much the difference between the current steering angle command, **SteerCmd**, and the current steering angle, **CurrSteer**, affects the next steering angle command.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.

Vehicle Parameters

`Forward location of tire, a` — Along vehicle longitudinal axis

`1.41` (default) | `scalar`

Forward location of tire, *a*, in m. Distance from vehicle cg to forward tire location, along vehicle longitudinal axis.

`Rearward location of tire, b` — Along vehicle longitudinal axis

`1.41` (default) | `scalar`

Rearward location of tire, *b*, in m. Absolute value of distance from vehicle cg to rearward tire location, along vehicle longitudinal axis.

`Vehicle mass, m` — Mass

`2016` (default) | `scalar`

Vehicle mass, *m*, in kg.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`Front tire cornering coefficient, Cy_f` — Coefficient

`25266` (default) | `scalar`

Cornering stiffness coefficient, $C_{\alpha F}$, in N/rad.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`Rear tire cornering coefficient, Cy_r` — Coefficient

`70933` (default) | `scalar`

Cornering stiffness coefficient, $C_{\alpha R}$, in N/rad.

Dependencies

To enable this port, set **Lateral control type, controlTypeLat** to `Predictive`.

`Vehicle rotational inertia, I` — Inertia about yaw axis

`4013` (default) | `scalar`

Vehicle rotational inertia, I, about the vehicle yaw axis, in N·m·s^2.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Predictive`.

`Nominal steering ratio, Ksteer` — Steering ratio

`18` (default) | `scalar`

Steering ratio, K_{steer}. The value has no dimension.

Dependencies

To enable this parameter, select **Output handwheel angle**.

`Tire wheel angle limit, theta` — Angle limit

`45*pi/180` (default) | `scalar`

Tire wheel angle limit, θ, in rad.

Version History

Introduced in R2018a

References

[1] MacAdam, C. C. "An Optimal Preview Control for Linear Systems". *Journal of Dynamic Systems, Measurement, and Control*. Vol. 102, Number 3, Sept. 1980.

[2] MacAdam, C. C. "Application of an Optimal Preview Control for Simulation of Closed-Loop Automobile Driving ". *IEEE Transactions on Systems, Man, and Cybernetics*. Vol. 11, Issue 6, June 1981.

[3] MacAdam, C. C. *Development of Driver/Vehicle Steering Interaction Models for Dynamic Analysis*. Final Technical Report UMTRI-88-53. Ann Arbor, Michigan: The University of Michigan Transportation Research Institute, Dec. 1988.

[4] Hoffmann, Gabriel M., Claire J. Tomlin, Michael Montemerlo, and Sebastian Thrun. "Autonomous Automobile Trajectory Tracking for Off-Road Driving: Controller Design, Experimental Validation and Racing." *American Control Conference*. 2007, pp. 2296–2301. doi:10.1109/ACC.2007.4282788

Extended Capabilities

C/C++ Code Generation

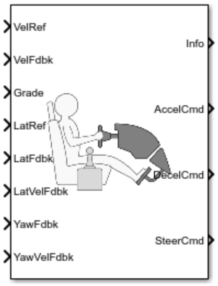
Generate C and C++ code using Simulink® Coder™.

See Also

Longitudinal Driver | Predictive Driver

Predictive Driver

Predictive driver controller to track longitudinal speed and lateral path
Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Driver



Description

The Predictive Driver block implements a controller that generates normalized steering, acceleration, and braking commands to track longitudinal velocity and a lateral reference displacement. The normalized commands can vary between -1 to 1. The controller uses a single-track (bicycle) model for optimal single-point preview control.

Configurations

External Actions

Use the **External Actions** parameters to create input ports for signals that you can use to simulate standard test maneuvers. The block uses this priority order for the input commands: disable (highest), hold, override.

This table summarizes the external action parameters.

Goal	External Action Parameter	Input Ports	Data Type
Override the accelerator command with an input acceleration command.	**Accelerator override**	`EnablAccelOvr`	`Boolean`
		`AccelOvrCmd`	`double`
Hold the acceleration command at the current value.	**Accelerator hold**	`AccelHld`	`Boolean`
Disable the acceleration command.	**Accelerator disable**	`AccelZero`	`Boolean`
Override the decelerator command with an input deceleration command.	**Decelerator override**	`EnablDecelOvr`	`Boolean`
		`DecelOvrCmd`	`double`
Hold the decelerator command at current value.	**Decelerator hold**	`DecelHld`	`Boolean`
Disable the decelerator command.	**Decelerator disable**	`DecelZero`	`Boolean`

Goal	External Action Parameter	Input Ports	Data Type
Override the steering command with an input steering command.	**Steering override**	`EnblSteerOvr`	`Boolean`
		`SteerOvrCmd`	`double`
Hold the steering command at the current value.	**Steering hold**	`SteerHld`	`Boolean`
Disable the steering command.	**Steering disable**	`SteerZero`	`Boolean`

Controllers

Use the **Longitudinal control type, cntrlType** parameter to specify one of these control options.

Setting	Block Implementation
`PI`	Proportional-integral (PI) control with tracking windup and feed-forward gains.
`Scheduled PI`	PI control with tracking windup and feed-forward gains that are a function of vehicle velocity.
`Predictive`	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path. To implement the MacAdam model, the block: • Represents the dynamics as a linear single track (bicycle) vehicle • Minimizes the previewed error signal at a single point *T** seconds ahead in time • Accounts for the driver lag deriving from perceptual and neuromuscular mechanisms

Use the **Lateral control type, controlTypeLat** parameter to specify the type of lateral control. The table specifies the block implementation.

Setting	Block Implementation
`Predictive` (default)	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path.

<table>
<tr><th>Setting</th><th>Block Implementation</th></tr>
<tr><td><code>Stanley</code></td><td>
<p>Controller that uses the Stanley[4] method to minimize the position error and the angle error of the current pose with respect to the reference pose.</p>
<p>On the Reference Control pane, use the:</p>
Vector input for poses parameter to input the to specify the input.
<table>
<tr><th>Setting</th><th>Implementation</th></tr>
<tr><td><code>off</code> (default)</td><td>Block uses the longitudinal, lateral, and yaw reference (<code>LongRef</code>, <code>LatRef</code>, <code>LatRef</code>) input ports and the feedback (<code>LongFdbk</code>, <code>LatFdbk</code>, <code>LatFdbk</code>) input ports for the reference and feedback pose.</td></tr>
<tr><td><code>on</code></td><td>Block uses input ports, <code>RefPose</code> and <code>CurrPose</code>, for the reference and feedback pose, respectively.</td></tr>
</table>
Include dynamics parameter to specify the type of model for the controller to use.
<table>
<tr><th>Setting</th><th>Implementation</th></tr>
<tr><td><code>off</code> (default)</td><td>Controller uses a kinematic bicycle model that is suitable for path following in low-speed environments such as parking lots, where inertial effects are minimal.</td></tr>
<tr><td><code>on</code></td><td>Controller uses a dynamic bicycle model that is suitable for path following in high-speed environments such as highways, where inertial effects are more pronounced.</td></tr>
</table>
</td></tr>
</table>

Shift

Use the **Shift type, ShftType** parameter to specify one of these shift options.

Setting	Block Implementation
`None`	No transmission. Block outputs a constant gear of 1. Use this setting to minimize the number of parameters you need to generate acceleration and braking commands to track forward vehicle motion. This setting does not allow reverse vehicle motion.

Setting	Block Implementation
`Reverse, Neutral, Drive`	Block uses a Stateflow chart to model reverse, neutral, and drive gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using simple reverse, neutral, and drive gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses the initial gear and time required to shift to shift the vehicle up into drive or down into reverse or neutral. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.
`Scheduled`	Block uses a Stateflow chart to model reverse, neutral, park, and N-speed gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using reverse, neutral, park, and N-speed gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses these parameters to determine the: • Initial gear • Upshift and downshift accelerator pedal positions • Upshift and downshift velocity • Timing for shifting and engaging forward and reverse from neutral For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.
`External`	Block uses the input gear, vehicle state, and velocity feedback to generate acceleration and braking commands to track forward and reverse vehicle motion. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.

Units

Use the and **Longitudinal velocity units, velUnits** and **Angular units, angUnits** parameter to specify the units for the input and output ports.

Gear Signal

Use the **Output gear signal** parameter to create the `GearCmd` output port. The `GearCmd` signal contains the integer value of the commanded vehicle gear.

Gear	Integer
Park	`80`
Reverse	`-1`

Gear	Integer
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Output Handwheel Angle

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

Adaptive Drift Control

To enable adaptive drift control, select **Advanced Options** > **Enable drift management**.

Consider enabling drift control to improve path and speed tracking. If the block determines that drifting improves path and or speed tracking, the controller re-plans the tracking horizon with a best-fit stable drifting path. The controller will opt out of the drifting under any of these conditions:

- Drifting is no longer possible.
- Drifting deviates too much from original predetermined path.
- Drifting compares unfavorably to normal driving when speed-tracking.

Controller: PI Speed-Tracking

If you set the control type to `PI` or `Scheduled PI`, the block implements proportional-integral (PI) control with tracking windup and feed-forward gains. For the `Scheduled PI` configuration, the block uses feed forward gains that are a function of vehicle velocity.

To calculate the speed control output, the block uses these equations.

Setting	Equation
`PI`	$y = \frac{K_{ff}}{v_{nom}} v_{ref} + \frac{K_p e_{ref}}{v_{nom}} + \int \left(\frac{K_i e_{ref}}{v_{nom}} + K_{aw} e_{out} \right) dt + K_g \theta$
`Scheduled PI`	$y = \frac{K_{ff}(v)}{v_{nom}} v_{ref} + \frac{K_p(v) e_{ref}}{v_{nom}} + \int \left(\frac{K_i(v) e_{ref}}{v_{nom}} + K_{aw} e_{out} \right) e_{ref} dt + K_g(v) \theta$

where:

$$e_{ref} = v_{ref} - v$$

$$e_{out} = y_{sat} - y$$

$$y_{sat} = \begin{cases} -1 & y < -1 \\ y & -1 \le y \le 1 \\ 1 & 1 < y \end{cases}$$

The velocity error low-pass filter uses this transfer function.

$$H(s) = \frac{1}{\tau_{err}s + 1} \quad \text{for} \quad \tau_{err} > 0$$

To calculate the acceleration and braking commands, the block uses these equations.

$$y_{acc} = \begin{cases} 0 & y_{sat} < 0 \\ y_{sat} & 0 \le y_{sat} \le 1 \\ 1 & 1 < y_{sat} \end{cases}$$

$$y_{dec} = \begin{cases} 0 & y_{sat} > 0 \\ -y_{sat} & -1 \le y_{sat} \le 0 \\ 1 & y_{sat} < -1 \end{cases}$$

The equations use these variables.

v_{nom}	Nominal vehicle speed
K_p	Proportional gain
K_i	Integral gain
K_{aw}	Anti-windup gain
K_{ff}	Velocity feed-forward gain
K_g	Grade angle feed-forward gain
θ	Grade angle
τ_{err}	Error filter time constant
y	Nominal control output magnitude
y_{sat}	Saturated control output magnitude
e_{ref}	Velocity error
e_{out}	Difference between saturated and nominal control outputs
y_{acc}	Acceleration signal
y_{dec}	Braking signal
v	Velocity feedback signal
v_{ref}	Reference velocity signal

Controller: Predictive Speed-Tracking

If you set the **Longitudinal control type, cntrlType** or **Lateral control type, cntrlType** to `Predictive`, the block implements an optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path. To implement the MacAdam model, the block:

- Represents the dynamics as a linear single track (bicycle) vehicle
- Minimizes the previewed error signal at a single point *T** seconds ahead in time
- Accounts for the driver lag deriving from perceptual and neuromuscular mechanisms

Vehicle Dynamics

For lateral and yaw motion, the block implements these linear dynamic equations.

$$x_1 = U$$

$$\dot{x}_1 = x_2 = \frac{K_{pt}}{m} + \quad vr - g\sin(\gamma) + F_r x_1$$

$$\dot{y} = v + U\psi$$

$$\dot{v} = \left[-\frac{2(C_{\alpha F} + C_{\alpha R})}{mU}\right]v + \left[\frac{2(bC_{\alpha R} - aC_{\alpha F})}{mU} - U\right]r + \left(\frac{2C_{\alpha F}}{m}\right)\delta_F$$

$$\dot{r} = \left[\frac{2(bC_{\alpha R} - aC_{\alpha F})}{IU}\right]v + \left[-\frac{2\left(a^2C_{\alpha F} + b^2C_{\alpha R}\right)}{IU}\right]r + \left(\frac{2aC_{\alpha F}}{I}\right)\delta_F$$

$$\dot{\psi} = r$$

In matrix notation:

$$\dot{x} = Fx + gu$$

where:

$$x = \begin{bmatrix} x_1 \\ x_2 \\ y \\ v \\ r \\ \psi \end{bmatrix}$$

$$F = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ \frac{F_r}{m} & 0 & 0 & 0 & v & 0 \\ 0 & 0 & 0 & 1 & 0 & U \\ 0 & 0 & 0 & -\frac{2(C_{\alpha F} + C_{\alpha R})}{mU} & \frac{2(bC_{\alpha R} - aC_{\alpha F})}{mU} - U & 0 \\ 0 & 0 & 0 & \frac{2(bC_{\alpha R} - aC_{\alpha F})}{IU} & -\frac{2\left(a^2 C_{\alpha F} + b^2 C_{\alpha R}\right)}{IU} & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

$$g = \begin{bmatrix} 0 & 0 \\ \frac{K_{pt}}{m} & 0 \\ 0 & 0 \\ 0 & \frac{2C_{\alpha F}}{m} \\ 0 & \frac{2aC_{\alpha F}}{I} \\ 0 & 0 \end{bmatrix}$$

$$u = \begin{bmatrix} \bar{u} \\ \delta_F \end{bmatrix}$$

$$\bar{u} = u - \frac{m^2}{K_{pt}} g \sin(\gamma)$$

The single-point model assumes a minimum previewed error signal at a single point *T** seconds ahead in time. *a** is the driver ability to predict the future vehicle response based on the current steering control input. *b** is the driver ability to predict the future vehicle response based on the current vehicle state. The block uses these equations.

$$a* = (T*)m^T[I + \sum_{n=1}^{\infty} \frac{F^n (T*)^n}{(n+1)!}]g$$

$$b* = m^T[I + \sum_{n=1}^{\infty} \frac{F^n (T*)^n}{n!}]$$

$$m^T = [1 \;\; 1 \;\; 1 \;\; 0 \;\; 0 \;\; 0]$$

The equations use these variables.

a, b	Forward and rearward tire location, respectively
m	Vehicle mass
I	Vehicle rotational inertia
$C_{\alpha F}$	Front tire cornering coefficient
$C_{\alpha R}$	Rear tire cornering coefficient
a^*, $\mathbf{b}^*$	Driver prediction scalar and vector gain, respectively
$\mathbf{x}$	Predicted vehicle state vector
v	Lateral velocity
r	Yaw rate
Ψ	Front wheel heading angle
y	Lateral displacement
$\mathbf{F}$	System matrix
δ, δ_F	Steer angle and front axle steer angle, respectively
γ	Grade angle
$\mathbf{g}$	Control coefficient vector
U	Forward (longitudinal) vehicle velocity
T^*	Preview time window
$f(t+T^*)$	Previewed path input T* seconds ahead
$\mathbf{u}$	Tractive force
$\mathbf{m}^T$	Constant observer vector; provides vehicle lateral position
a_r	Static rolling and driveline resistance
b_r	Linear rolling and driveline resistance
c_r	Aerodynamic rolling and driveline resistance
F_r	Rolling resistance

Optimization

The single-point model implemented by the block finds the steering command that minimizes a local performance index, J, over the current preview interval, (t, $t+T$).

$$J = \frac{1}{T}\int_{t}^{t+T}[f(\eta) - y(\eta)]^2 d\eta$$

To minimize J with respect to the steering command, this condition must be met.

$$\frac{dJ}{du} = 0$$

You can express the optimal control solution in terms of a current non-optimal and corresponding nonzero preview output error T^* seconds ahead[1, 2, 3].

$$u^o(t) = u(t) + \frac{e(t+T^*)}{a^*}$$

The block uses the preview distance and vehicle longitudinal velocity to determine the preview time window.

$$T^* = \frac{L}{U}$$

The equations use these variables.

T^*	Preview time window
$f(t+T^*)$	Previewed path input T^* sec ahead
$y(t+T^*)$	Previewed plant output T^* sec ahead
$e(t+T^*)$	Previewed error signal T^* sec ahead
$u(t)$, $u^o(t)$	Steer angle and optimal steer angle, respectively
L	Preview distance
J	Performance index
U	Forward (longitudinal) vehicle velocity

Driver Lag

The single-point model implemented by the block introduces a driver lag. The driver lag accounts for the delay when the driver is tracking tasks. Specifically, it is the transport delay deriving from perceptual and neuromuscular mechanisms. To calculate the driver transport delay, the block implements this equation.

$$H(s) = e^{-s\tau}$$

The equations use these variables.

τ	Driver transport delay
$y(t+T^*)$	Previewed plant output T^* sec ahead
$e(t+T^*)$	Previewed error signal T^* sec ahead
$u(t)$, $u^o(t)$	Steer angle and optimal steer angle, respectively
J	Performance index

Controller: Stanley Lateral Path-Tracking

If you set **Lateral control type, controlTypeLat** to `Stanley`, the block implements the Stanley method[4]. To compute the steering angle command, the Stanley controller minimizes the position error and the angle error of the current pose with respect to the reference pose. The driving direction of the vehicle determines these error values.

To compute the steering angle command, the controller minimizes the position error and the angle error of the current pose with respect to the reference pose.

- The position error is the lateral distance from the vehicle center-of-gravity (CG) to the reference point on the path.
- The angle error is the angle of the vehicle with respect to reference path.

Ports

Input

`VelRef` — Reference vehicle velocity
`scalar`

Reference velocity, v_{ref}, in units specified by **Longitudinal velocity units, velUnits**.

`LongRef` — Longitudinal displacement reference
`scalar`

Longitudinal center of mass (CM) displacement reference, in the inertial reference frame, in m.

Dependencies

To enable this port:

1. Set **Lateral control type, controlTypeLat** to `Stanley`.
2. Clear **Vector input for poses**.

`LatRef` — Lateral displacement reference
`scalar`

Lateral center of mass (CM) displacement reference, in the inertial reference frame, in m.

Dependencies

To enable this port, do one of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and clear **Vector input for poses**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`YawRef` — Yaw angle reference
`scalar`

Vehicle yaw angle, Ψ_o, in the inertial reference frame, in units specified by **Angular units, angUnits**.

Dependencies

To enable this port:

- Set **Lateral control type, controlTypeLat** to `Stanley`
- Clear **Vector input for poses**

`EnblSteerOvr` — Enable steering command override
`scalar`

Enable steering command override.

Dependencies

To enable this port, select **Steering override**.

Data Types: `Boolean`

`SteerOvrCmd` — Steering override command

`scalar`

Steering override command.

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

Dependencies

To enable this port, select **Steering override**.

Data Types: `double`

`SteerHld` — Steering hold

`scalar`

Boolean signal that holds the steering command at the current value.

Dependencies

To enable this port, select **Steering hold**.

Data Types: `Boolean`

`SteerZero` — Disable steering command

`scalar`

Disable steering command.

Dependencies

To enable this port, select **Steering disable**.

Data Types: `Boolean`

`EnblAccelOvr` — Enable acceleration command override

`scalar`

Enable acceleration command override.

Dependencies

To enable this port, select **Acceleration override**.

Data Types: `Boolean`

`AccelOvrCmd` — Acceleration override command

`scalar`

Acceleration override command, normalized from 0 through 1.

Dependencies

To enable this port, select **Acceleration override**.

Data Types: `double`

`AccelHld` — Acceleration hold

`scalar`

Boolean signal that holds the acceleration command at the current value.

Dependencies

To enable this port, select **Acceleration hold**.

Data Types: `Boolean`

`AccelZero` — Disable acceleration command

`scalar`

Disable acceleration command.

Dependencies

To enable this port, select **Acceleration disable**.

Data Types: `Boolean`

`EnblDecelOvr` — Enable deceleration command override

`scalar`

Enable deceleration command override.

Dependencies

To enable this port, select **Deceleration override**.

Data Types: `Boolean`

`DecelOvrCmd` — Deceleration override command

`scalar`

Deceleration override command, normalized from 0 through 1.

Dependencies

To enable this port, select **Deceleration override**.

Data Types: `double`

`DecelHld` — Deceleration hold

`scalar`

Boolean signal that holds the deceleration command at the current value.

Dependencies

To enable this port, select **Deceleration hold**.

Data Types: `Boolean`

`DecelZero` — Disable deceleration command

`scalar`

Disable deceleration command.

Dependencies

To enable this port, select **Deceleration disable**.

Data Types: `Boolean`

`ExtGear` — Gear

`scalar`

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Dependencies

To enable this port, set **Shift type, shftType** to `External`.

`Grade` — Road grade angle

`scalar`

Road grade angle, γ, in deg.

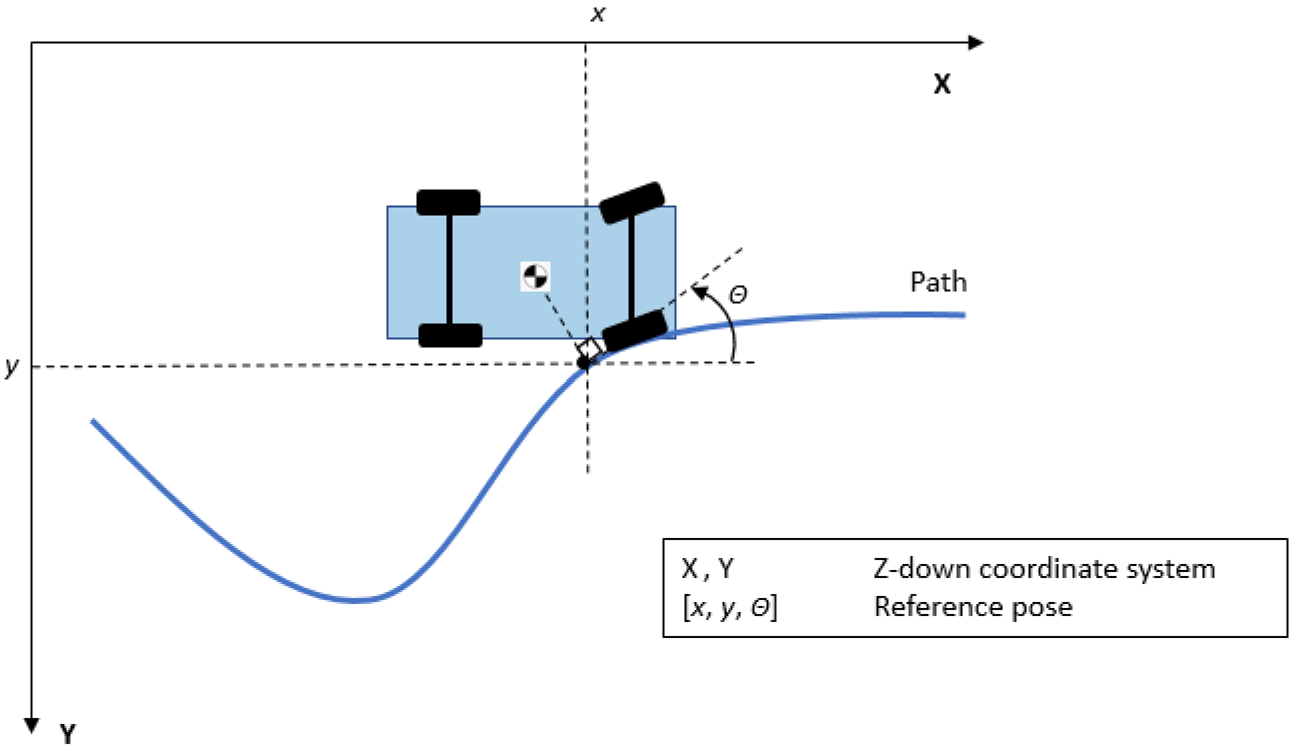
`RefPose` — Reference pose

[x, y, Θ] vector

Reference pose, specified as an [x, y, Θ] vector. x and y are in meters, and Θ are in units specified by **Angular units, angUnits**.

x and y specify the reference point to steer the vehicle toward. Θ specifies the orientation angle of the path at this reference point and is positive in the counterclockwise direction.

The reference point is the point on the path that is closest to the vehicle CG. You can use the either the Z-up or Z-down vehicle coordinate system, as long you use the same coordinate system (Z-up or Z-down) for block inputs and parameters.



Dependencies

To enable this port:

1. Set **Lateral control type, controlTypeLat** to `Stanley`.
2. Select **Vector input for poses**.

Data Types: `single` | `double`

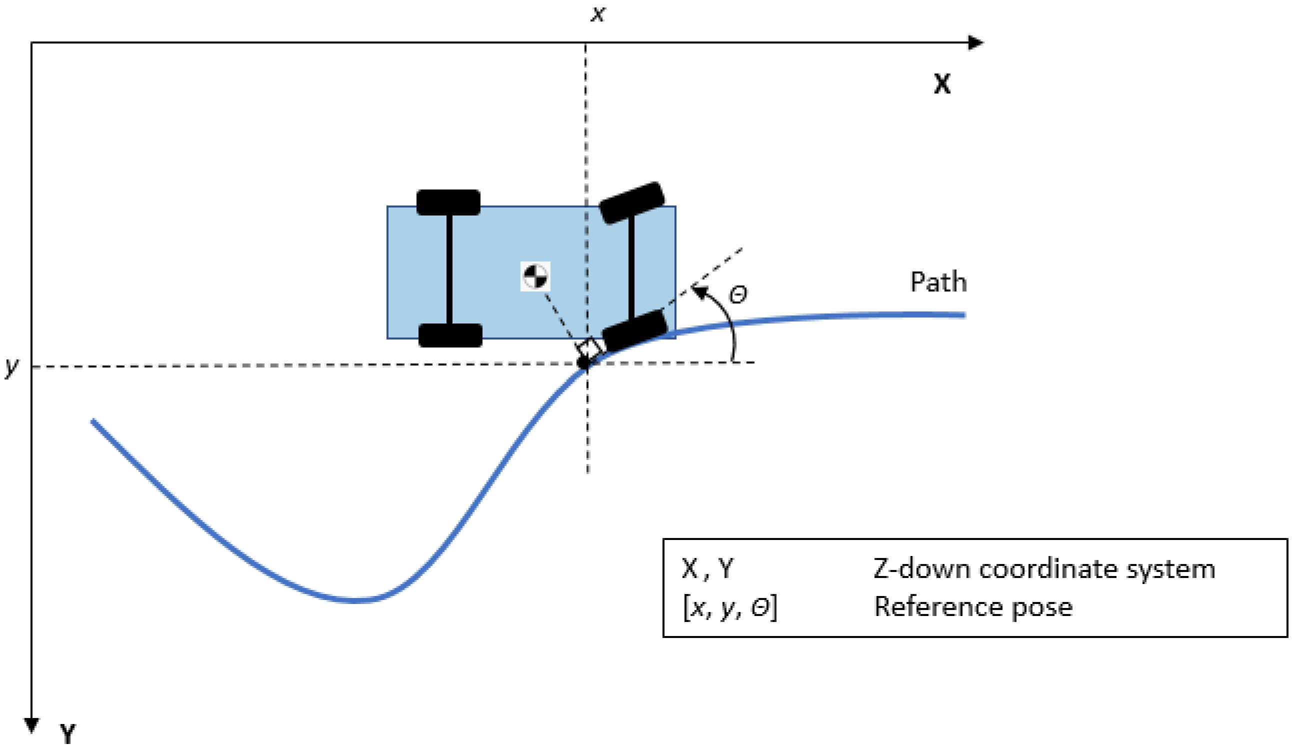
`VelFdbk` — Longitudinal vehicle velocity
`scalar`

Longitudinal vehicle velocity, *U*, in the vehicle-fixed frame, in units specified by **Longitudinal velocity units, velUnits**.

`CurrPose` — Current pose
[*x*, *y*, *Θ*] vector

Current pose of the vehicle, specified as an [*x*, *y*, *Θ*] vector. *x* and *y* are in meters, and *Θ* is in units specified by **Angular units, angUnits**.

x and *y* specify the location of the vehicle, which is defined as the vehicle CG. You can use the either the Z-up or Z-down vehicle coordinate system, as long you use the same coordinate system (Z-up or Z-down) for block inputs and parameters.



Dependencies

To enable this port, set **Lateral control type, controlTypeLat** to `Stanley` and select **Vector input for poses**.

Data Types: `single` | `double`

`LatFdbk` — Lateral displacement

`scalar`

Lateral CM displacement, y_o, in the inertial reference frame, in m.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and clear **Vector input for poses**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`LatVelFdbk` — Lateral vehicle velocity

`scalar`

Lateral vehicle velocity, v_o , in the vehicle-fixed frame, in m/s.

Dependencies

To enable this port, Set **Lateral control type, controlTypeLat** to `Predictive`.

`YawFdbk` — Vehicle yaw angle

`scalar`

Vehicle yaw angle, Ψ_o, in the inertial reference frame, in units specified by **Angular units, angUnits**.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and clear **Vector input for poses**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`YawVelFdbk` — Yaw rate

`scalar`

Yaw rate, r_o, in the vehicle-fixed frame, in units specified by **Angular units, angUnits** per sec.

Dependencies

To enable this port, Set **Lateral control type, controlTypeLat** to `Predictive`.

Output

`Info` — Bus signal

bus

Bus signal containing these block calculations.

Signal			Variable	Description
`Steer`			δ_F	Commanded steer angle, normalized from 0 through 1
`Accel`			y_{acc}	Commanded vehicle acceleration, normalized from 0 through 1
`Decel`			y_{dec}	Commanded vehicle deceleration, normalized from 0 through 1
`Gear`				Integer value of commanded gear
`Clutch`				Clutch command
`Err`	`LatErr`	`Err`	e_{ref}	Difference in reference vehicle position and vehicle position.
		`ErrSqrSum`	$\int_0^t e_{ref}^2 dt$	Integrated square of error.
		`ErrMax`	$\max(e_{ref}(t))$	Maximum error during simulation.
		`ErrMin`	$\min(e_{ref}(t))$	Minimum error during simulation.
	`LngErr`	`Err`	e_{ref}	Difference in reference vehicle speed and vehicle speed
		`ErrSqrSum`	$\int_0^t e_{ref}^2 dt$	Integrated square of error
		`ErrMax`	$\max(e_{ref}(t))$	Maximum error during simulation

Signal			Variable	Description
		`ErrMin`	$\min(e_{ref}(t))$	Minimum error during simulation
`ExtActions`	`EnblSteerOvr`			Override the steering command with an input deceleration command
	`SteerOvrCmd`			Input steering override command
	`SteerHld`			Hold the steering command at the current value
	`SteerZero`			Disable the steering command
	`EnblAccelOvr`			Override the accelerator command with an input acceleration command
	`AccelOvrCmd`			Input accelerator override command
	`AccelHld`			Hold the acceleration command at the current value
	`AccelZero`			Disable the acceleration command
	`EnblDecelOvr`			Override the decelerator command with an input deceleration command
	`DecelOvrCmd`			Input deceleration override command
	`DecelHld`			Hold the decelerator command at current value
	`DecelZero`			Disable the decelerator command

`SteerCmd` — Steer angle command

`scalar`

Commanded steer angle, δ_F.

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

`AccelCmd` — Commanded vehicle acceleration

`scalar`

Commanded vehicle acceleration, y_{acc}, normalized from 0 through 1.

`DecelCmd` — Commanded vehicle deceleration

`scalar`

Commanded vehicle deceleration, y_{dec}, normalized from 0 through 1.

`GearCmd` — Commanded vehicle gear

`scalar`

Integer value of commanded vehicle gear.

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Dependencies

To enable this port, select **Output gear signal**.

Parameters

Configuration

External Actions

`Accelerator override` — Override acceleration command

`off` (default) | `on`

Select to override the acceleration command with an input acceleration command.

Dependencies

Selecting this parameter creates the `EnblAccelOvr` and `AccelOvrCmd` input ports.

`Accelerator hold` — Hold acceleration command

`off` (default) | `on`

Select to hold the acceleration command.

Dependencies

Selecting this parameter creates the `AccelHld` input port.

`Accelerator disable` — Disable acceleration command

`off` (default) | `on`

Select to disable the acceleration command.

Dependencies

Selecting this parameter creates the `AccelZero` input port.

`Decelerator override` — Override deceleration command

`off` (default) | `on`

Select to override the deceleration command with an input deceleration command.

Dependencies

Selecting this parameter creates the `EnblDecelOvr` and `DecelOvrCmd` input ports.

`Decelerator hold` — Hold deceleration command
`off` (default) | `on`

Select to hold the deceleration command.

Dependencies

Selecting this parameter creates the `DecelHld` input port.

`Decelerator disable` — Disable deceleration command
`off` (default) | `on`

Select to disable the deceleration command.

Dependencies

Selecting this parameter creates the `DecelZero` input port.

`Steering override` — Override steering command
`off` (default) | `on`

Select to override the steering command with an input steering command.

Dependencies

Selecting this parameter creates the `EnblSteerOvr` and `SteerOvrCmd` input ports.

`Steering hold` — Hold steering command
`off` (default) | `on`

Select to hold the steering command.

Dependencies

Selecting this parameter creates the `SteerHld` input port.

`Steering disable` — Disable steering command
`off` (default) | `on`

Select to disable the steering command.

Dependencies

Selecting this parameter creates the `SteerZero` input port.

Control and Shift

`Longitudinal control type, cntrlType` — Longitudinal control
`PI` (default) | `Scheduled PI` | `Predictive`

Type of longitudinal control.

Setting	Block Implementation
`PI`	Proportional-integral (PI) control with tracking windup and feed-forward gains.
`Scheduled PI`	PI control with tracking windup and feed-forward gains that are a function of vehicle velocity.
`Predictive`	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path. To implement the MacAdam model, the block: • Represents the dynamics as a linear single track (bicycle) vehicle • Minimizes the previewed error signal at a single point *T** seconds ahead in time • Accounts for the driver lag deriving from perceptual and neuromuscular mechanisms

`Lateral control type, controlTypeLat` — Controller

`Predictive` (default) | `Stanley`

Use the **Lateral control type, controlTypeLat** parameter to specify the type of lateral control. The table specifies the block implementation.

Setting	Block Implementation
`Predictive` (default)	Optimal single-point preview (look ahead) control model developed by C. C. MacAdam[1, 2, 3]. The model represents driver steering control behavior during path-following and obstacle avoidance maneuvers. Drivers preview (look ahead) to follow a predefined path.

Setting	Block Implementation
`Stanley`	Controller that uses the Stanley[4] method to minimize the position error and the angle error of the current pose with respect to the reference pose. On the **Reference Control** pane, use the: • **Vector input for poses** parameter to input the to specify the input. <table><tr><th>Setting</th><th>Implementation</th></tr><tr><td>`off` (default)</td><td>Block uses the longitudinal, lateral, and yaw reference (`LongRef`, `LatRef`, `LatRef`) input ports and the feedback (`LongFdbk`, `LatFdbk`, `LatFdbk`) input ports for the reference and feedback pose.</td></tr><tr><td>`on`</td><td>Block uses input ports, `RefPose` and `CurrPose`, for the reference and feedback pose, respectively.</td></tr></table>• **Include dynamics** parameter to specify the type of model for the controller to use. <table><tr><th>Setting</th><th>Implementation</th></tr><tr><td>`off` (default)</td><td>Controller uses a kinematic bicycle model that is suitable for path following in low-speed environments such as parking lots, where inertial effects are minimal.</td></tr><tr><td>`on`</td><td>Controller uses a dynamic bicycle model that is suitable for path following in high-speed environments such as highways, where inertial effects are more pronounced.</td></tr></table>

`Shift type, shftType` — Shift type

`None` (default) | `Reverse, Neutral, Drive` | `Scheduled` | `External`

Shift type.

Setting	Block Implementation
`None`	No transmission. Block outputs a constant gear of 1. Use this setting to minimize the number of parameters you need to generate acceleration and braking commands to track forward vehicle motion. This setting does not allow reverse vehicle motion.

Setting	Block Implementation
`Reverse, Neutral, Drive`	Block uses a Stateflow chart to model reverse, neutral, and drive gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using simple reverse, neutral, and drive gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses the initial gear and time required to shift to shift the vehicle up into drive or down into reverse or neutral. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.
`Scheduled`	Block uses a Stateflow chart to model reverse, neutral, park, and N-speed gear shift scheduling. Use this setting to generate acceleration and braking commands to track forward and reverse vehicle motion using reverse, neutral, park, and N-speed gear shift scheduling. Depending on the vehicle state and vehicle velocity feedback, the block uses these parameters to determine the: • Initial gear • Upshift and downshift accelerator pedal positions • Upshift and downshift velocity • Timing for shifting and engaging forward and reverse from neutral For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.
`External`	Block uses the input gear, vehicle state, and velocity feedback to generate acceleration and braking commands to track forward and reverse vehicle motion. For neutral gears, the block uses braking commands to control the vehicle speed. For reverse gears, the block uses an acceleration command to generate torque and a brake command to reduce vehicle speed.

`Longitudinal velocity units, velUnits` — Velocity units

`m/s` (default)

Vehicle velocity reference and feedback units.

Dependencies

If you set **Longitudinal control type, CntrlType** control type to `Scheduled` or `Scheduled PI`, the block uses the **Longitudinal velocity units, velUnits** for the **Nominal speed, vnom** parameter dimension.

If you set **Shift Type, shftType** to `Scheduled`, the block uses the **Longitudinal velocity units, velUnits** for these parameter dimensions:

- **Upshift velocity data table, upShftTbl**

- **Downshift velocity data table, dwnShftTbl**

`Angular units, angUnits` — Input and output port angular units

`rad` (default) | `deg`

Input and output port angular units.

`Output gear signal` — Create `GearCmd` output port

`off` (default) | `on`

Specify to create output port `GearCmd`.

`Output handwheel angle` — Steering port units in rad

`off` (default) | `on`

Use the **Output handwheel angle** parameter to specify the units for the steering ports.

Setting	Block Implementation	Port
`off` (default)	Commanded steer angle, normalized from -1 through 1. The block uses the tire wheel angle saturation limit **Tire wheel angle limit, theta** parameter to normalize the command.	`SteerCmd` — Output
	Overrides the steering command with an input steering command normalized from -1 through 1.	`SteerOvrCmd` — Input
`on`	Commanded steer angle, in units specified by **Angular units, angUnits**.	`SteerCmd` — Output
	Overrides the steering command with an input steering command, in units specified by **Angular units, angUnits**.	`SteerOvrCmd` — Input

Dependencies

To create the `SteerOvrCmd` input port, select **Steering override**.

Reference Control

Longitudinal

`Proportional gain, Kp` — Gain

`10` (default) | `scalar`

Proportional gain, K_p, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Integral gain, Ki` — Gain

`5` (default) | `scalar`

Proportional gain, K_i, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Velocity feed-forward, Kff` — Gain

`.1` (default) | `scalar`

Velocity feed-forward gain, K_{ff}, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Grade angle feed-forward, Kg` — Gain

`0` (default) | `scalar`

Grade angle feed-forward gain, K_g, in 1/deg.

Dependencies

To create this parameter, set **Control type** to `PI`.

`Velocity gain breakpoints, VehVelVec` — Breakpoints

`[0 100]` (default) | `vector`

Velocity gain breakpoints, *VehVelVec*, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Velocity feed-forward gain values, KffVec` — Gain

`[.1 .1]` (default) | `vector`

Velocity feed-forward gain values, *KffVec*, as a function of vehicle velocity, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Proportional gain values, KpVec` — Gain

`[10 10]` (default) | `vector`

Proportional gain values, *KpVec*, as a function of vehicle velocity, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Integral gain values, KiVec` — Gain

`[5 5]` (default) | `vector`

Integral gain values, *KiVec*, as a function of vehicle velocity, dimensionless.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Grade angle feed-forward values, KgVec` — Grade gain

`[0 0]` (default) | `vector`

Grade angle feed-forward values, *KgVec*, as a function of vehicle velocity, in 1/deg.

Dependencies

To create this parameter, set **Control type** to `Scheduled PI`.

`Nominal speed, vnom` — Nominal vehicle speed

`5` (default) | `scalar`

Nominal vehicle speed, v_{nom}, in units specified by the **Reference and feedback units, velUnits** parameter. The block uses the nominal speed to normalize the controller gains.

Dependencies

To create this parameter, set **Control type** to `PI` or `Scheduled PI`.

`Anti-windup, Kaw` — Gain

`1` (default) | `scalar`

Anti-windup gain, K_{aw}, dimensionless.

Dependencies

To create this parameter, set **Control type** to `PI` or `Scheduled PI`.

`Error filter time constant, tauerr` — Filter

`.01` (default) | `scalar`

Error filter time constant, τ_{err}, in s. To disable the filter, enter 0.

Dependencies

To create this parameter, set **Control type** to `PI` or `Scheduled PI`.

Predictive

`Driver response time, tau` — Response time

`0.1` (default) | `scalar`

Driver response time, τ, in s.

Dependencies

To enable this parameter, Set **Longitudinal control type, cntrlType** or **Lateral control type, controlTypeLat** to `Predictive`.

`Preview distance, L` — Distance

`3` (default) | `scalar`

Driver preview distance, L, in m. Used to determine the preview time window, T^*.

Dependencies

To enable this parameter, Set **Longitudinal control type, cntrlType** or **Lateral control type, controlTypeLat** to `Predictive`.

`Effective vehicle total tractive force, Kpt` — Tractive force

`3000` (default) | `scalar`

Effective vehicle total tractive force, K_{pt}, in N.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Rolling resistance coefficient, aR` — Resistance

`200` (default) | `scalar`

Static rolling and driveline resistance coefficient, a_R, in N. Block uses the parameter to estimate the constant acceleration or braking effort.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Rolling and driveline resistance coefficient, bR` — Resistance

`2.5` (default) | `scalar`

Rolling and driveline resistance coefficient, b_R, in N·s/m. Block uses the parameter to estimate the linear velocity-dependent acceleration or braking effort.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Aerodynamic drag coefficient, cR` — Drag

`.5` (default) | `scalar`

Aerodynamic drag coefficient, c_R, in N·s^2/m^2. Block uses the parameter to estimate the quadratic velocity-dependent acceleration or braking effort.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

`Gravitational constant, g` — Gravitational constant

`9.81` (default) | `scalar`

Gravitational constant, g, in m/s^2.

Dependencies

To create this parameter, set **Longitudinal control type, cntrlType** to `Predictive`.

Stanley

`Vector input for poses` — Select to create `RefPose` and `CurrPose` input ports

`off` (default) | `on`

Select this parameter to create the `RefPose` and `CurrPose` input ports.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Include dynamics` — Select to include dynamics

`off` (default) | `on`

The controller computes this command using the Stanley method, whose control law is based on both a kinematic and dynamic bicycle model. To change between models, use this parameter.

Setting	Implementation
`off`	Controller uses a kinematic bicycle model that is suitable for path following in low-speed environments such as parking lots, where inertial effects are minimal.
`on`	Controller uses a dynamic bicycle model that is suitable for path following in high-speed environments such as highways, where inertial effects are more pronounced.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Position gain of forward motion, PositionGainF` — Position gain of vehicle in forward motion

`2.5` (default) | positive real scalar

Position gain of the vehicle when it is in forward motion, specified as a positive scalar. This value determines how much the position error affects the steering angle. Typical values are in the range [1, 5]. Increase this value to increase the magnitude of the steering angle.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Position gain of reverse motion, PositionGainF` — Position gain of vehicle in reverse motion

`2.5` (default) | positive real scalar

Position gain of the vehicle when it is in reverse motion, specified as a positive scalar. This value determines how much the position error affects the steering angle. Typical values are in the range [1, 5]. Increase this value to increase the magnitude of the steering angle.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley`.

`Yaw rate feedback gain, YawRateGain` — Yaw rate feedback gain

`.2` (default) | nonnegative real scalar

Yaw rate feedback gain, specified as a nonnegative real scalar. This value determines how much weight is given to the current yaw rate of the vehicle when the block computes the steering angle command.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.

`Steering angle feedback gain, DelayGain` — Steering angle feedback gain

`.2` (default) | nonnegative real scalar

Steering angle feedback gain, specified as a nonnegative real scalar. This value determines how much the difference between the current steering angle command, **SteerCmd**, and the current steering angle, **CurrSteer**, affects the next steering angle command.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.

Advanced Options

`Enable drift management` — Select to enable drift management

`off` (default) | `on`

Consider enabling drift control to improve path and speed tracking. If the block determines that drifting improves path and or speed tracking, the controller re-plans the tracking horizon with a best-fit stable drifting path. The controller will opt out of the drifting under any of these conditions:

- Drifting is no longer possible.
- Drifting deviates too much from original predetermined path.
- Drifting compares unfavorably to normal driving when speed-tracking.

`Desired sideslip, BetaRef` — Desired sideslip

`20*pi/180` (default) | `scalar`

Desired sideslip, in units defined by **Angular units**.

Dependencies

To enable this parameter, set **Enable drift management**.

`Imposed sideslip error proportional gain, KpBeta` — Sideslip error

`1` (default) | `scalar`

Imposed sideslip error proportional gain, dimensionless.

Dependencies

To enable this parameter, set **Enable drift management**.

`Imposed lateral error proportional gain, KpDrift` — Lateral error

`2` (default) | `scalar`

Imposed lateral error proportional gain, dimensionless.

Dependencies

To enable this parameter, set **Enable drift management**.

`Imposed lateral error derivative gain, KdDrift` — Lateral error derivative

`1` (default) | `scalar`

Imposed lateral error derivative gain, dimensionless.

Dependencies

To enable this parameter, set **Enable drift management**.

`Imposed yaw rate error proportional gain, KpPsi` — Yaw rate error

`6` (default) | `scalar`

Imposed yaw rate error proportional gain, dimensionless.

Dependencies

To enable this parameter, set **Enable drift management**.

`Wheel speed feedback gain, KOmega` — Wheel speed

`30` (default) | `scalar`

Wheel speed feedback gain, dimensionless.

Dependencies

To enable this parameter, set **Enable drift management**.

`Desired wheel speed time constant, tOmega` — Desired wheel speed

`1` (default) | `scalar`

Desired wheel speed time constant, dimensionless.

Dependencies

To enable this parameter, set **Enable drift management**.

Vehicle Parameters

`Forward location of tire, a` — Along vehicle longitudinal axis

`1.41` (default) | `scalar`

Forward location of tire, *a*, in m. Distance from vehicle cg to forward tire location, along vehicle longitudinal axis.

`Rearward location of tire, b` — Along vehicle longitudinal axis

`1.41` (default) | `scalar`

Rearward location of tire, *b*, in m. Absolute value of distance from vehicle cg to rearward tire location, along vehicle longitudinal axis.

`Vehicle mass, m` — Mass

`2016` (default) | `scalar`

Vehicle mass, *m*, in kg.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`Front tire cornering coefficient, Cy_f` — Coefficient

`25266` (default) | `scalar`

Cornering stiffness coefficient, $C_{\alpha F}$, in N/rad.

Dependencies

To enable this port, do either of these:

- Set **Lateral control type, controlTypeLat** to `Stanley` and select **Include dynamics**.
- Set **Lateral control type, controlTypeLat** to `Predictive`.

`Rear tire cornering coefficient, Cy_r` — Coefficient

`70933` (default) | `scalar`

Cornering stiffness coefficient, $C_{\alpha R}$, in N/rad.

Dependencies

To enable this port, set **Lateral control type, controlTypeLat** to `Predictive`.

`Vehicle rotational inertia, I` — Inertia about yaw axis

`4013` (default) | `scalar`

Vehicle rotational inertia, I, about the vehicle yaw axis, in N·m·s^2.

Dependencies

To enable this parameter, Set **Lateral control type, controlTypeLat** to `Predictive`.

`Nominal steering ratio, Ksteer` — Steering ratio

`18` (default) | `scalar`

Steering ratio, K_{steer}. The value has no dimension.

Dependencies

To enable this parameter, select **Output handwheel angle**.

`Tire wheel angle limit, theta` — Angle limit

`45*pi/180` (default) | `scalar`

Tire wheel angle limit, θ, in rad.

Shift

Reverse, Neutral, Drive

`Initial gear, GearInit` — Initial gear

`0` (default) | `scalar`

Integer value of the initial gear. The block uses the initial gear to generate acceleration and braking commands to track forward and reverse vehicle motion.

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`

Gear	Integer
Gear	`Gear number`

Dependencies

To create this parameter, set **Shift type, shftType** to `Reverse, Neutral, Drive` or `Scheduled`. If you specify `Reverse, Neutral, Drive`, the **Initial Gear, GearInit** parameter value can be only `-1`, `0`, or `1`.

`Time required to shift, tShift` — Time

`.1` (default) | `scalar`

Time required to shift, *tShift*, in s. The block uses the time required to shift to generate acceleration and braking commands to track forward and reverse vehicle motion using reverse, neutral, and drive gear shift scheduling.

Dependencies

To create this parameter, set **Shift type, shftType** to `Reverse, Neutral, Drive`.

Scheduled

`Initial gear, GearInit` — Initial gear

`0` (default) | `scalar`

Integer value of the initial gear. The block uses the initial gear to generate acceleration and braking commands to track forward and reverse vehicle motion.

Gear	Integer
Park	`80`
Reverse	`-1`
Neutral	`0`
Drive	`1`
Gear	`Gear number`

Dependencies

To create this parameter, set **Shift type, shftType** to `Reverse, Neutral, Drive` or `Scheduled`. If you specify `Reverse, Neutral, Drive`, the **Initial Gear, GearInit** parameter value can be only `-1`, `0`, or `1`.

`Up and down shift accelerator pedal positions, pdlVec` — Pedal position breakpoints

`[0.1 0.4 0.5 0.9]` (default) | `[1-by-m] vector`

Pedal position breakpoints for lookup tables when calculating upshift and downshift velocities, dimensionless. Vector dimensions are 1 by the number of pedal position breakpoints, `m`.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Upshift velocity data table, upShftTbl` — Table

`[m-by-n] array`

Upshift velocity data as a function of pedal position and gear, in units specified by the **Reference and feedback units, velUnits** parameter. Upshift velocities indicate the vehicle velocity at which the gear should increase by 1.

The array dimensions are `m` pedal positions by `n` gears. The first column of data, when `n` equals 1, is the upshift velocity for the neutral gear.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Downshift velocity data table, dwnShftTbl` — Table

`[m-by-n] array`

Downshift velocity data as a function of pedal position and gear, in units specified by the **Reference and feedback units, velUnits** parameter. Downshift velocities indicate the vehicle velocity at which the gear should decrease by 1.

The array dimensions are `m` pedal positions by `n` gears. The first column of data, when `n` equals 1, is the downshift velocity for the neutral gear.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Time required to shift, tClutch` — Time

`.5` (default) | `scalar`

Time required to shift, t_{Clutch}, in s.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Time required to engage reverse from neutral, tRev` — Time

`.5` (default) | `scalar`

Time required to engage reverse from neutral, t_{Rev}, in s.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

`Time required to engage park from neutral, tPark` — Time

`120` (default) | `scalar`

Time required to engage park from neutral, t_{Park}, in s.

Dependencies

To create this parameter, set **Shift type, shftType** to `Scheduled`.

Version History

Introduced in R2018a

References

[1] MacAdam, C. C. "An Optimal Preview Control for Linear Systems". *Journal of Dynamic Systems, Measurement, and Control*. Vol. 102, Number 3, Sept. 1980.

[2] MacAdam, C. C. "Application of an Optimal Preview Control for Simulation of Closed-Loop Automobile Driving ". *IEEE Transactions on Systems, Man, and Cybernetics*. Vol. 11, Issue 6, June 1981.

[3] MacAdam, C. C. *Development of Driver/Vehicle Steering Interaction Models for Dynamic Analysis*. Final Technical Report UMTRI-88-53. Ann Arbor, Michigan: The University of Michigan Transportation Research Institute, Dec. 1988.

[4] Hoffmann, Gabriel M., Claire J. Tomlin, Michael Montemerlo, and Sebastian Thrun. "Autonomous Automobile Trajectory Tracking for Off-Road Driving: Controller Design, Experimental Validation and Racing." *American Control Conference*. 2007, pp. 2296–2301. doi:10.1109/ACC.2007.4282788

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

See Also

Lateral Driver | Longitudinal Driver

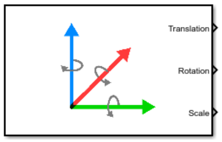
7

3D Simulation Blocks

Simulation 3D Actor Transform Get

Get actor translation, rotation, scale

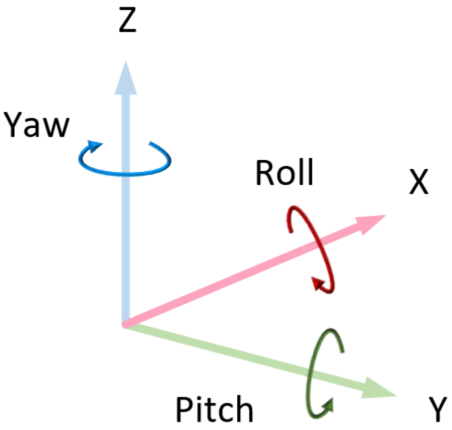
Library:	Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Core Aerospace Blockset / Animation / Simulation 3D Simulink 3D Animation / Simulation 3D



Description

The Simulation 3D Actor Transform Get block provides the actor translation, rotation, and scale for the Simulink simulation environment.

The block uses a vehicle-fixed coordinate system that is initially aligned with the inertial world coordinate system.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, initially parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor.

Tip Verify that the Simulation 3D Scene Configuration block executes before the Simulation 3D Actor Transform Get block. That way, the Unreal Engine 3D visualization environment prepares the data before the Simulation 3D Actor Transform Get block receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Actor Transform Get — `1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Output

`Translation` — Actor translation

`array`

Actor translation, in m. Array dimensions are number of parts per actor-by-`3`.

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Vehicle displacement along world *X*-, *Y*, and *Z*- axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Actor displacement relative to vehicle, in vehicle-fixed coordinate system initially aligned with world *X*-, *Y*, and *Z*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The `Translation` signal:

- Dimensions are `[5x3]`.
- Contains translation information according to the axle and wheel locations, relative to vehicle.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element
Vehicle, X_v	`Translation(1,1)`
Vehicle, Y_v	`Translation(1,2)`
Vehicle, Z_v	`Translation(1,3)`
Front left wheel, X_{FL}	`Translation(2,1)`
Front left wheel, Y_{FL}	`Translation(2,2)`
Front left wheel, Z_{FL}	`Translation(2,3)`
Front right wheel, X_{FR}	`Translation(3,1)`
Front right wheel, Y_{FR}	`Translation(3,2)`
Front right wheel, Z_{FR}	`Translation(3,3)`

Translation	Array Element
Rear left wheel, X_{RL}	`Translation(4,1)`
Rear left wheel, Y_{RL}	`Translation(4,2)`
Rear left wheel, Z_{RL}	`Translation(4,3)`
Rear right wheel, X_{RR}	`Translation(5,1)`
Rear right wheel, Y_{RR}	`Translation(5,2)`
Rear right wheel, Z_{RR}	`Translation(5,3)`

`Rotation` — Actor rotation
`array`

Actor rotation across a [-pi/2, pi/2] range, in rad. Array dimensions are number of parts per actor-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Vehicle rotation about vehicle-fixed pitch, roll, and yaw *Y*-, *Z*-, and *X*- axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Actor rotation about vehicle-fixed pitch, roll, and yaw *Y*-, *Z*-, and *X*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The `Rotation` signal:

- Dimensions are `[5x3]`.
- Contains rotation information according to the axle and wheel locations.

$$Rotation = \begin{bmatrix} Pitch_v & Roll_v & Yaw_v \\ Pitch_{FL} & Roll_{FL} & Yaw_{FL} \\ Pitch_{FR} & Roll_{FR} & Yaw_{FR} \\ Pitch_{RL} & Roll_{RL} & Yaw_{RL} \\ Pitch_{RR} & Roll_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element
Vehicle, $Pitch_v$	`Rotation(1,1)`
Vehicle, $Roll_v$	`Rotation(1,2)`
Vehicle, Yaw_v	`Rotation(1,3)`
Front left wheel, $Pitch_{FL}$	`Rotation(2,1)`
Front left wheel, $Roll_{FL}$	`Rotation(2,2)`
Front left wheel, Yaw_{FL}	`Rotation(2,3)`
Front right wheel, $Pitch_{FR}$	`Rotation(3,1)`
Front right wheel, $Roll_{FR}$	`Rotation(3,2)`
Front right wheel, Yaw_{FR}	`Rotation(3,3)`
Rear left wheel, $Pitch_{RL}$	`Rotation(4,1)`
Rear left wheel, $Roll_{RL}$	`Rotation(4,2)`
Rear left wheel, Yaw_{RL}	`Rotation(4,3)`

Rotation	Array Element
Rear right wheel, $Pitch_{RR}$	`Rotation(5,1)`
Rear right wheel, $Roll_{RR}$	`Rotation(5,2)`
Rear right wheel, Yaw_{RR}	`Rotation(5,3)`

`Scale` — Actor scale

`array`

Actor scale. Array dimensions are number of number of parts per actor-by-3.

- `Scale(1,1)`, `Scale(1,2)`, and `Scale(1,3)` — Vehicle scale along world *X*-, *Y*-, and *Z*- axes, respectively.
- `Scale(...,1)`, `Scale(...,2)`, and `Scale(...,3)` — Actor scale along world *X*-, *Y*-, and *Z*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The `Scale` signal:

- Dimensions are `[5x3]`.
- Contains scale information according to the axle and wheel locations.

$$Scale = \begin{bmatrix} X_{V_{scale}} & Y_{V_{scale}} & Z_{V_{scale}} \\ X_{FL_{scale}} & Y_{FL_{scale}} & Z_{FL_{scale}} \\ X_{FR_{scale}} & Y_{FR_{scale}} & Z_{FR_{scale}} \\ X_{RL_{scale}} & Y_{RL_{scale}} & Z_{RL_{scale}} \\ X_{RR_{scale}} & Y_{RR_{scale}} & Z_{RR_{scale}} \end{bmatrix}$$

Scale	Array Element
Vehicle, $X_{v_{scale}}$	`Scale(1,1)`
Vehicle, $Y_{v_{scale}}$	`Scale(1,2)`
Vehicle, $Z_{v_{scale}}$	`Scale(1,3)`
Front left wheel, $X_{FL_{scale}}$	`Scale(2,1)`
Front left wheel, $Y_{FL_{scale}}$	`Scale(2,2)`
Front left wheel, $Z_{FL_{scale}}$	`Scale(2,3)`
Front right wheel, $X_{FR_{scale}}$	`Scale(3,1)`
Front right wheel, $Y_{FR_{scale}}$	`Scale(3,2)`
Front right wheel, $Z_{FR_{scale}}$	`Scale(3,3)`
Rear left wheel, $X_{RL_{scale}}$	`Scale(4,1)`
Rear left wheel, $Y_{RL_{scale}}$	`Scale(4,2)`
Rear left wheel, $Z_{RL_{scale}}$	`Scale(4,3)`
Rear right wheel, $X_{RR_{scale}}$	`Scale(5,1)`
Rear right wheel, $Y_{RR_{scale}}$	`Scale(5,2)`
Rear right wheel, $Z_{RR_{scale}}$	`Scale(5,3)`

Parameters

`Tag for actor in 3D scene, ActorTag` — Name

`SimulinkActor1` (default) | character vector

Actor name.

Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor.

The block does not support multiple instances of the same actor tag. To refer to the same scene actor when you use the 3D block pairs (e.g. Simulation 3D Actor Transform Get and Simulation 3D Actor Transform Set), specify the same **Tag for actor in 3D scene, ActorTag** parameter.

`Number of parts per actor to get, NumberOfParts` — Name

`1` (default) | `scalar`

Number of parts per actor. Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor. Typically, a vehicle actor with a body and four wheels has 5 parts.

The block does not support multiple instances of the same actor tag. To refer to the same scene actor when you use the 3D block pairs (e.g. Simulation 3D Actor Transform Get and Simulation 3D Actor Transform Set), specify the same **Tag for actor in 3D scene, ActorTag** parameter.

`Sample time` — Sample time

`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Version History

Introduced in R2018a

See Also

Simulation 3D Actor Transform Set | Simulation 3D Camera Get | Simulation 3D Scene Configuration | Vehicle Terrain Sensor

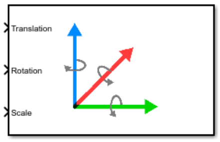
Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Unreal Engine Simulation Environment Requirements and Limitations"

Simulation 3D Actor Transform Set

Set actor translation, rotation, scale

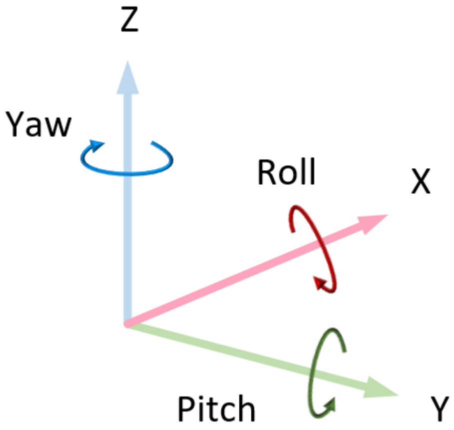
Library:	Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Core Aerospace Blockset / Animation / Simulation 3D Simulink 3D Animation / Simulation 3D



Description

The Simulation 3D Actor Transform Set block sets the actor translation, rotation, and scale in the 3D visualization environment.

The block uses a vehicle-fixed coordinate system that is initially aligned with the inertial world coordinate system.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, initially parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor.

Tip Verify that the Simulation 3D Actor Transform Set block executes before the Simulation 3D Scene Configuration block. That way, Simulation 3D Actor Transform Set prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Actor Transform Set — `-1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Input

`Translation` — Actor translation

`array`

Actor translation, in m. Array dimensions are number of parts per actor-by-`3`.

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Vehicle displacement along world *X*-, *Y*, and *Z*- axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Actor displacement relative to vehicle, in vehicle-fixed coordinate system initially aligned with world *X*-, *Y*, and *Z*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The `Translation` signal:

- Dimensions are `[5x3]`.
- Contains translation information according to the axle and wheel locations, relative to vehicle.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element
Vehicle, X_v	`Translation(1,1)`
Vehicle, Y_v	`Translation(1,2)`
Vehicle, Z_v	`Translation(1,3)`
Front left wheel, X_{FL}	`Translation(2,1)`
Front left wheel, Y_{FL}	`Translation(2,2)`
Front left wheel, Z_{FL}	`Translation(2,3)`
Front right wheel, X_{FR}	`Translation(3,1)`
Front right wheel, Y_{FR}	`Translation(3,2)`

Translation	Array Element
Front right wheel, Z_{FR}	`Translation(3,3)`
Rear left wheel, X_{RL}	`Translation(4,1)`
Rear left wheel, Y_{RL}	`Translation(4,2)`
Rear left wheel, Z_{RL}	`Translation(4,3)`
Rear right wheel, X_{RR}	`Translation(5,1)`
Rear right wheel, Y_{RR}	`Translation(5,2)`
Rear right wheel, Z_{RR}	`Translation(5,3)`

`Rotation` — Actor rotation

`array`

Actor rotation across a [-pi/2, pi/2] range, in rad. Array dimensions are number of parts per actor-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Vehicle rotation about vehicle-fixed pitch, roll, and yaw *Y*-, *Z*-, and *X*- axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Actor rotation about vehicle-fixed pitch, roll, and yaw *Y*-, *Z*-, and *X*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The `Rotation` signal:

- Dimensions are `[5x3]`.
- Contains rotation information according to the axle and wheel locations.

$$Rotation = \begin{bmatrix} Pitch_v & Roll_v & Yaw_v \\ Pitch_{FL} & Roll_{FL} & Yaw_{FL} \\ Pitch_{FR} & Roll_{FR} & Yaw_{FR} \\ Pitch_{RL} & Roll_{RL} & Yaw_{RL} \\ Pitch_{RR} & Roll_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element
Vehicle, $Pitch_v$	`Rotation(1,1)`
Vehicle, $Roll_v$	`Rotation(1,2)`
Vehicle, Yaw_v	`Rotation(1,3)`
Front left wheel, $Pitch_{FL}$	`Rotation(2,1)`
Front left wheel, $Roll_{FL}$	`Rotation(2,2)`
Front left wheel, Yaw_{FL}	`Rotation(2,3)`
Front right wheel, $Pitch_{FR}$	`Rotation(3,1)`
Front right wheel, $Roll_{FR}$	`Rotation(3,2)`
Front right wheel, Yaw_{FR}	`Rotation(3,3)`
Rear left wheel, $Pitch_{RL}$	`Rotation(4,1)`
Rear left wheel, $Roll_{RL}$	`Rotation(4,2)`

Rotation	Array Element
Rear left wheel, Yaw_{RL}	`Rotation(4,3)`
Rear right wheel, $Pitch_{RR}$	`Rotation(5,1)`
Rear right wheel, $Roll_{RR}$	`Rotation(5,2)`
Rear right wheel, Yaw_{RR}	`Rotation(5,3)`

`Scale` — Actor scale

`array`

Actor scale. Array dimensions are number of number of parts per actor-by-3.

- `Scale(1,1)`, `Scale(1,2)`, and `Scale(1,3)` — Vehicle scale along world *X*-, *Y*-, and *Z*- axes, respectively.
- `Scale(...,1)`, `Scale(...,2)`, and `Scale(...,3)` — Actor scale along world *X*-, *Y*-, and *Z*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The `Scale` signal:

- Dimensions are `[5x3]`.
- Contains scale information according to the axle and wheel locations.

$$Scale = \begin{bmatrix} X_{V_{scale}} & Y_{V_{scale}} & Z_{V_{scale}} \\ X_{FL_{scale}} & Y_{FL_{scale}} & Z_{FL_{scale}} \\ X_{FR_{scale}} & Y_{FR_{scale}} & Z_{FR_{scale}} \\ X_{RL_{scale}} & Y_{RL_{scale}} & Z_{RL_{scale}} \\ X_{RR_{scale}} & Y_{RR_{scale}} & Z_{RR_{scale}} \end{bmatrix}$$

Scale	Array Element
Vehicle, $X_{v_{scale}}$	`Scale(1,1)`
Vehicle, $Y_{v_{scale}}$	`Scale(1,2)`
Vehicle, $Z_{v_{scale}}$	`Scale(1,3)`
Front left wheel, $X_{FL_{scale}}$	`Scale(2,1)`
Front left wheel, $Y_{FL_{scale}}$	`Scale(2,2)`
Front left wheel, $Z_{FL_{scale}}$	`Scale(2,3)`
Front right wheel, $X_{FR_{scale}}$	`Scale(3,1)`
Front right wheel, $Y_{FR_{scale}}$	`Scale(3,2)`
Front right wheel, $Z_{FR_{scale}}$	`Scale(3,3)`
Rear left wheel, $X_{RL_{scale}}$	`Scale(4,1)`
Rear left wheel, $Y_{RL_{scale}}$	`Scale(4,2)`
Rear left wheel, $Z_{RL_{scale}}$	`Scale(4,3)`
Rear right wheel, $X_{RR_{scale}}$	`Scale(5,1)`
Rear right wheel, $Y_{RR_{scale}}$	`Scale(5,2)`

Scale	Array Element
Rear right wheel, $Z_{RR_{scale}}$	`Scale(5,3)`

Parameters

Actor Setup

`Tag for actor in 3D scene, ActorTag` — Name

`SimulinkActor1` (default) | character vector

Actor name.

Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor.

The block does not support multiple instances of the same actor tag. To refer to the same scene actor when you use the 3D block pairs (e.g. Simulation 3D Actor Transform Get and Simulation 3D Actor Transform Set), specify the same **Tag for actor in 3D scene, ActorTag** parameter.

`Number of parts per actor to set, NumberOfParts` — Name

`1` (default) | `scalar`

Number of parts per actor. Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor. Typically, a vehicle actor with a body and four wheels has 5 parts.

The block does not support multiple instances of the same actor tag. To refer to the same scene actor when you use the 3D block pairs (e.g. Simulation 3D Actor Transform Get and Simulation 3D Actor Transform Set), specify the same **Tag for actor in 3D scene, ActorTag** parameter.

Initial Values

`Initial array values to translate actor per part, Translation` — Actor initial position

`[0 0 0]` (default) | `array`

Actor initial position, along world *X*-, *Y*-, and *Z*- axes, in m.

Array dimensions are number of parts per actor-by-3.

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Vehicle displacement along world *X*-, *Y*, and *Z*- axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Actor displacement relative to vehicle, in vehicle-fixed coordinate system initially aligned with world *X*-, *Y*, and *Z*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The parameter:

- Dimensions are `[5x3]`.
- Contains translation information according to the axle and wheel locations, relative to vehicle.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element
Vehicle, X_v	`Translation(1,1)`
Vehicle, Y_v	`Translation(1,2)`
Vehicle, Z_v	`Translation(1,3)`
Front left wheel, X_{FL}	`Translation(2,1)`
Front left wheel, Y_{FL}	`Translation(2,2)`
Front left wheel, Z_{FL}	`Translation(2,3)`
Front right wheel, X_{FR}	`Translation(3,1)`
Front right wheel, Y_{FR}	`Translation(3,2)`
Front right wheel, Z_{FR}	`Translation(3,3)`
Rear left wheel, X_{RL}	`Translation(4,1)`
Rear left wheel, Y_{RL}	`Translation(4,2)`
Rear left wheel, Z_{RL}	`Translation(4,3)`
Rear right wheel, X_{RR}	`Translation(5,1)`
Rear right wheel, Y_{RR}	`Translation(5,2)`
Rear right wheel, Z_{RR}	`Translation(5,3)`

`Initial array values to rotate actor per part, Rotation` — Actor initial rotation

`[0 0 0]` (default) | `array`

Actor initial rotation about world *X*-, *Y*-, and *Z*- axes across a [-pi/2, pi/2] range, in rad.

Array dimensions are number of parts per actor-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Vehicle rotation about vehicle-fixed pitch, roll, and yaw *Y*-, *Z*-, and *X*- axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Actor rotation about vehicle-fixed pitch, roll, and yaw *Y*-, *Z*-, and *X*- axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The parameter:

- Dimensions are `[5x3]`.
- Contains rotation information according to the axle and wheel locations.

$$Rotation = \begin{bmatrix} Pitch_v & Roll_v & Yaw_v \\ Pitch_{FL} & Roll_{FL} & Yaw_{FL} \\ Pitch_{FR} & Roll_{FR} & Yaw_{FR} \\ Pitch_{RL} & Roll_{RL} & Yaw_{RL} \\ Pitch_{RR} & Roll_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	**Array Element**
Vehicle, $Pitch_v$	`Rotation(1,1)`
Vehicle, $Roll_v$	`Rotation(1,2)`
Vehicle, Yaw_v	`Rotation(1,3)`
Front left wheel, $Pitch_{FL}$	`Rotation(2,1)`
Front left wheel, $Roll_{FL}$	`Rotation(2,2)`
Front left wheel, Yaw_{FL}	`Rotation(2,3)`
Front right wheel, $Pitch_{FR}$	`Rotation(3,1)`
Front right wheel, $Roll_{FR}$	`Rotation(3,2)`
Front right wheel, Yaw_{FR}	`Rotation(3,3)`
Rear left wheel, $Pitch_{RL}$	`Rotation(4,1)`
Rear left wheel, $Roll_{RL}$	`Rotation(4,2)`
Rear left wheel, Yaw_{RL}	`Rotation(4,3)`
Rear right wheel, $Pitch_{RR}$	`Rotation(5,1)`
Rear right wheel, $Roll_{RR}$	`Rotation(5,2)`
Rear right wheel, Yaw_{RR}	`Rotation(5,3)`

`Initial array values to scale actor per part, Scale` — Actor initial scale

`[1 1 1]` (default) | `array`

Actor initial scale.

Array dimensions are number of number of parts per actor-by-3.

- `Scale(1,1)`, `Scale(1,2)`, and `Scale(1,3)` — Vehicle scale along world *X*-, *Y*, and *Z*- axes, respectively.
- `Scale(...,1)`, `Scale(...,2)`, and `Scale(...,3)` — Actor scale along world *X*-, *Y*, and *Z*-axes, respectively.

For example, consider a vehicle actor with a vehicle body and four wheels. The parameter:

- Dimensions are `[5x3]`.
- Contains scale information according to the axle and wheel locations.

$$Scale = \begin{bmatrix} X_{V_{scale}} & Y_{V_{scale}} & Z_{V_{scale}} \\ X_{FL_{scale}} & Y_{FL_{scale}} & Z_{FL_{scale}} \\ X_{FR_{scale}} & Y_{FR_{scale}} & Z_{FR_{scale}} \\ X_{RL_{scale}} & Y_{RL_{scale}} & Z_{RL_{scale}} \\ X_{RR_{scale}} & Y_{RR_{scale}} & Z_{RR_{scale}} \end{bmatrix}$$

Scale	Array Element	Scale Axis
Vehicle, $X_{v_{scale}}$	`Scale(1,1)`	World X-axis
Vehicle, $Y_{v_{scale}}$	`Scale(1,2)`	World Y-axis
Vehicle, $Z_{v_{scale}}$	`Scale(1,3)`	World Z-axis
Front left wheel, $X_{FL_{scale}}$	`Scale(2,1)`	World X-axis
Front left wheel, $Y_{FL_{scale}}$	`Scale(2,2)`	World Y-axis
Front left wheel, $Z_{FL_{scale}}$	`Scale(2,3)`	World Z-axis
Front right wheel, $X_{FR_{scale}}$	`Scale(3,1)`	World X-axis
Front right wheel, $Y_{FR_{scale}}$	`Scale(3,2)`	World Y-axis
Front right wheel, $Z_{FR_{scale}}$	`Scale(3,3)`	World Z-axis
Rear left wheel, $X_{RL_{scale}}$	`Scale(4,1)`	World X-axis
Rear left wheel, $Y_{RL_{scale}}$	`Scale(4,2)`	World Y-axis
Rear left wheel, $Z_{RL_{scale}}$	`Scale(4,3)`	World Z-axis
Rear right wheel, $X_{RR_{scale}}$	`Scale(5,1)`	World X-axis
Rear right wheel, $Y_{RR_{scale}}$	`Scale(5,2)`	World Y-axis
Rear right wheel, $Z_{RR_{scale}}$	`Scale(5,3)`	World Z-axis

`Sample time` — Sample time
`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Version History

Introduced in R2018a

See Also

Simulation 3D Actor Transform Get | Simulation 3D Camera Get | Simulation 3D Scene Configuration | Vehicle Terrain Sensor

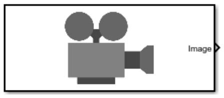
Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Unreal Engine Simulation Environment Requirements and Limitations"

Simulation 3D Camera Get

Camera image

Library:	Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Core Aerospace Blockset / Animation / Simulation 3D Simulink 3D Animation / Simulation 3D



Description

The Simulation 3D Camera Get block provides an interface to an ideal camera in the 3D visualization environment. The image output is a red, green, and blue (RGB) array.

If you set the sample time to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block. To use this sensor, ensure that the Simulation 3D Scene Configuration block is in your model.

Tip Verify that the Simulation 3D Scene Configuration block executes before the Simulation 3D Camera Get block. That way, the Unreal Engine 3D visualization environment prepares the data before the Simulation 3D Camera Get block receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Camera Get — `1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Output

`Image` — 3D output camera image

m-by-*n*-by-3 array of RGB triplet values

3D output camera image, returned as an *m*-by-*n*-by-3 array of RGB triplet values. *m* is the vertical resolution of the image, and *n* is the horizontal resolution of the image.

Data Types: `int8` | `uint8`

Parameters

Mounting

`Sensor identifier` — Number to identify unique sensor

`0` (default) | positive integer

Unique sensor identifier, specified as a positive integer. This number is used to identify a specific sensor. The sensor identifier distinguishes between sensors in a multi-sensor system.

Example: 2

`Vehicle name` — Name of a vehicle

`Scene Origin` (default) | character vector

Vehicle name. Block provides a list of vehicles in the model. If you select `Scene Origin`, the block places a sensor at the scene origin.

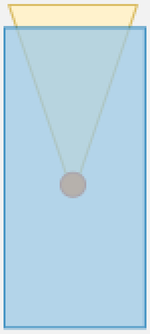
Example: `SimulinkVehicle1`

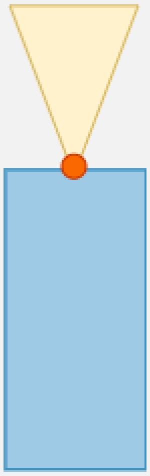
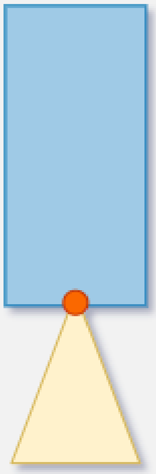
`Vehicle mounting location` — Sensor mounting location

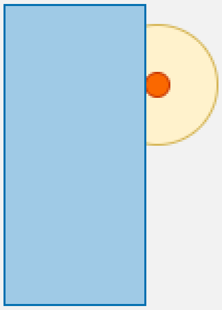
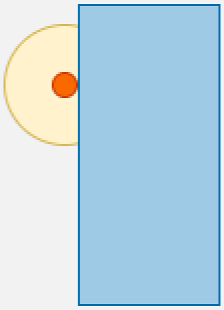
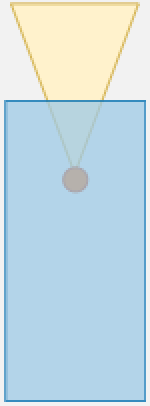
`Origin` (default) | `Front bumper` | `Rear bumper` | `Right mirror` | `Left mirror` | `Rearview mirror` | `Hood center` | `Roof center`

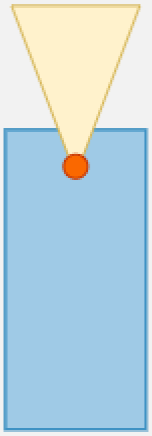
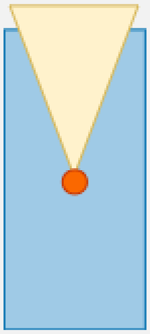
Sensor mounting location.

- When **Vehicle name** is `Scene Origin`, the block mounts the sensor to the origin of the scene, and **Mounting location** can be set to `Origin` only. During simulation, the sensor remains stationary.
- When **Vehicle name** is the name of a vehicle (for example, `SimulinkVehicle1`) the block mounts the sensor to one of the predefined mounting locations described in the table. During simulation, the sensor travels with the vehicle.

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Origin`	Forward-facing sensor mounted to the vehicle origin, which is on the ground and at the geometric center of the vehicle (see “Coordinate Systems in Vehicle Dynamics Blockset”) 	[0, 0, 0]

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Front bumper`	Forward-facing sensor mounted to the front bumper 	[0, 0, 0]
`Rear bumper`	Backward-facing sensor mounted to the rear bumper 	[0, 0, 180]

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Right mirror`	Downward-facing sensor mounted to the right side-view mirror 	[0, –90, 0]
`Left mirror`	Downward-facing sensor mounted to the left side-view mirror 	[0, –90, 0]
`Rearview mirror`	Forward-facing sensor mounted to the rearview mirror, inside the vehicle 	[0, 0, 0]

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Hood center`	Forward-facing sensor mounted to the center of the hood 	[0, 0, 0]
`Roof center`	Forward-facing sensor mounted to the center of the roof 	[0, 0, 0]

The (*X*, *Y*, *Z*) location of the sensor relative to the vehicle depends on the vehicle type. To specify the vehicle type, use the **Type** parameter of the Simulation 3D Scene Configuration block to which you are mounting. The tables show the *X*, *Y*, and *Z* locations of sensors in the vehicle coordinate system. In this coordinate system:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up from the ground.
- Roll, pitch, and yaw are clockwise-positive when looking in the positive direction of the *X*-axis, *Y*-axis, and *Z*-axis, respectively. When looking at a vehicle from the top down, then the yaw angle (that is, the orientation angle) is counterclockwise-positive, because you are looking in the negative direction of the axis.

Box Truck — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	5.10	0	0.60
`Rear bumper`	–5	0	0.60
`Right mirror`	2.90	1.60	2.10
`Left mirror`	2.90	–1.60	2.10
`Rearview mirror`	2.60	0.20	2.60
`Hood center`	3.80	0	2.10
`Roof center`	1.30	0	4.20

Hatchback — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	1.93	0	0.51
`Rear bumper`	–1.93	0	0.51
`Right mirror`	0.43	–0.84	1.01
`Left mirror`	0.43	0.84	1.01
`Rearview mirror`	0.32	0	1.27
`Hood center`	1.44	0	1.01
`Roof center`	0	0	1.57

Muscle Car — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	2.47	0	0.45
`Rear bumper`	–2.47	0	0.45
`Right mirror`	0.43	–1.08	1.01
`Left mirror`	0.43	1.08	1.01
`Rearview mirror`	0.32	0	1.20
`Hood center`	1.28	0	1.14
`Roof center`	–0.25	0	1.58

Sedan — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	2.42	0	0.51
`Rear bumper`	–2.42	0	0.51
`Right mirror`	0.59	–0.94	1.09
`Left mirror`	0.59	0.94	1.09
`Rearview mirror`	0.43	0	1.31
`Hood center`	1.46	0	1.11
`Roof center`	–0.45	0	1.69

Small Pickup Truck — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	3.07	0	0.51
`Rear bumper`	–3.07	0	0.51
`Right mirror`	1.10	–1.13	1.52
`Left mirror`	1.10	1.13	1.52
`Rearview mirror`	0.85	0	1.77
`Hood center`	2.22	0	1.59
`Roof center`	0	0	2.27

Sport Utility Vehicle — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	2.42	0	0.51
`Rear bumper`	–2.42	0	0.51
`Right mirror`	0.60	–1	1.35
`Left mirror`	0.60	1	1.35
`Rearview mirror`	0.39	0	1.55
`Hood center`	1.58	0	1.39
`Roof center`	–0.56	0	2

Example: `Origin`

`Specify offset` — Specify offset from mounting location
`off` (default) | `on`

Select this parameter to specify an offset from the mounting location.

`Relative translation [X, Y, Z]` — Translation offset from mounting location
`[0,0,0]` (default) | real-valued 1-by-3 vector

Specify a translation offset from the mount location, about the vehicle coordinate system *X*, *Y*, and *Z* axes. Units are in meters.

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up.

Example: `[0,0,0.01]`

Dependencies

To enable this parameter, select **Specify offset**.

`Relative rotation [Roll, Pitch, Yaw]` — Rotational offset from mounting location

`[0,0,0]` (default) | real-valued 1-by-3 vector

Specify a rotational offset from the mounting location, about the vehicle coordinate system *X*, *Y*, and *Z* axes. Units are in degrees.

- Roll angle is the angle of rotation about the *X*-axis of the vehicle coordinate system. A positive roll angle corresponds to a clockwise rotation when looking in the positive direction of the *X*-axis.
- Pitch angle is the angle of rotation about the *Y*-axis of the vehicle coordinate system. A positive pitch angle corresponds to a clockwise rotation when looking in the positive direction of the *Y*-axis.
- Yaw angle is the angle of rotation about the *Z* of the vehicle coordinate system. A positive yaw angle corresponds to a clockwise rotation when looking in the positive direction of the *Z*-axis.

Example: `[0,0,10]`

Dependencies

To enable this parameter, select **Specify offset**.

`Sample time` — Sample time

`-1` (default) | positive scalar

Sample time of the block in seconds. The 3D simulation environment frame rate is the inverse of the sample time.

If you set the sample time to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

Parameter

`Horizontal resolution` — Pixels

`uint32(1280)` (default) | `scalar`

Horizontal image resolution, in pixels.

`Vertical resolution` — Pixels

`uint32(720)` (default) | `scalar`

Vertical image resolution, in pixels.

`Horizontal field of view` — Field of view

`single(60)` (default) | `scalar`

Horizontal field of view (FOV), in deg.

Tips

- To understand how to set tag of **Sim 3d Scene Cap** and how it the tag is related to the block, see "Place Cameras on Actors in the Unreal Editor".

Version History

Introduced in R2018a

See Also

Simulation 3D Actor Transform Get | Simulation 3D Actor Transform Set | Simulation 3D Scene Configuration | Vehicle Terrain Sensor

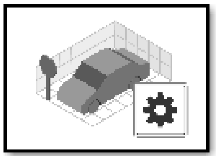
Topics

"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Scene Interrogation in 3D Environment"
"Unreal Engine Simulation Environment Requirements and Limitations"

Simulation 3D Scene Configuration

Scene configuration for 3D simulation environment

Library:	Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Core Aerospace Blockset / Animation / Simulation 3D Automated Driving Toolbox / Simulation 3D UAV Toolbox / Simulation 3D Simulink 3D Animation / Simulation 3D



Description

The Simulation 3D Scene Configuration block implements a 3D simulation environment that is rendered by using the Unreal Engine from Epic Games®. Vehicle Dynamics Blockset integrates the 3D simulation environment with Simulink so that you can query the world around the vehicle and virtually test perception, control, and planning algorithms. Using this block, you can also control the position of the sun and the weather conditions of a scene. For more details, see Sun Position and Weather on page 7-36.

You can simulate from a set of prebuilt scenes or from your own custom scenes. Scene customization requires the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package. For more details, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Note The Simulation 3D Scene Configuration block must execute after blocks that send data to the 3D environment and before blocks that receive data from the 3D environment. To verify the execution order of such blocks, right-click the blocks and select **Properties**. Then, on the **General** tab, confirm these **Priority** settings:

- For blocks that send data to the 3D environment, such as Simulation 3D Vehicle with Ground Following blocks, **Priority** must be set to `-1`. That way, these blocks prepare their data before the 3D environment receives it.
- For the Simulation 3D Scene Configuration block in your model, **Priority** must be set to `0`.
- For blocks that receive data from the 3D environment, such as Simulation 3D Message Get blocks, **Priority** must be set to `1`. That way, the 3D environment can prepare the data before these blocks receive it.

For more information about execution order, see “Control and Display Execution Order”.

Parameters

Scene

Scene Selection

`Scene source` — Source of scene

`Default Scenes` (default) | `Unreal Executable` | `Unreal Editor`

Source of the scene in which to simulate, specified as one of the options in the table.

Option	Description
`Default Scenes`	Simulate in one of the default, prebuilt scenes specified in the **Scene name** parameter.
`Unreal Executable`	Simulate in a scene that is part of an Unreal Engine executable file. Specify the executable file in the **Project name** parameter. Specify the scene in the **Scene** parameter. Select this option to simulate in custom scenes that have been packaged into an executable for faster simulation.
`Unreal Editor`	Simulate in a scene that is part of an Unreal Engine project (`.uproject`) file and is open in the Unreal® Editor. Specify the project file in the **Project** parameter. Select this option when developing custom scenes. By clicking **Open Unreal Editor**, you can co-simulate within Simulink and the Unreal Editor and modify your scenes based on the simulation results.

`Scene name` — Name of prebuilt 3D scene

`Straight road` (default) | `Curved road` | `Parking lot` | `Double lane change` | `Open surface` | `US city block` | `US highway` | `Virtual Mcity` | `Large parking lot`

Name of the prebuilt 3D scene in which to simulate, specified as one of these options. For details about a scene, see its listed corresponding reference page.

- `Straight road` — Straight Road
- `Curved road` — Curved Road
- `Parking lot` — Parking Lot
- `Double lane change` — Double Lane Change
- `Open surface` — Open Surface
- `US city block` — US City Block
- `US highway` — US Highway
- `Virtual Mcity` — Virtual Mcity

- `Large parking lot` — Large Parking Lot

The Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects contains customizable versions of these scenes. For details about customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Dependencies

To enable this parameter, set **Scene source** to `Default Scenes`.

`Project name` — Name of Unreal Engine executable file

`VehicleSimulation.exe` (default) | valid executable file name

Name of the Unreal Engine executable file, specified as a valid executable project file name. You can either browse for the file or specify the full path to the project file, using backslashes. To specify a scene from this file to simulate in, use the **Scene** parameter.

By default, **Project name** is set to `VehicleSimulation.exe`, which is on the MATLAB search path.

Example: `C:\Local\WindowsNoEditor\AutoVrtlEnv.exe`

Dependencies

To enable this parameter, set **Scene source** to `Unreal Executable`.

`Select ASAM OpenDRIVE file` — Specify an ASAM OpenDRIVE file

`off` (default) | `on`

Specify an ASAM OpenDRIVE® file. Select the Simulation 3D Scene Configuration block parameter **Select ASAM OpenDRIVE file** to specify an ASAM OpenDRIVE file. You will need an ASAM OpenDRIVE file if you want to perform any lane detection applications with custom scenes using the Simulation 3D Vision Detection Generator block.

Dependencies

This parameter is available when you set `Scene Source` is set to either `Unreal Executable` or `Unreal Engine`.

Data Types: `Boolean`

Scene — Name of scene from executable file

`/Game/Maps/HwStrght` (default) | path to valid scene name

Name of a scene from the executable file specified by the **Project name** parameter, specified as a path to a valid scene name.

When you package scenes from an Unreal Engine project into an executable file, the Unreal Editor saves the scenes to an internal folder within the executable file. This folder is located at the path `/Game/Maps`. Therefore, you must prepend `/Game/Maps` to the scene name. You must specify this path using forward slashes. For the file name, do not specify the `.umap` extension. For example, if the scene from the executable in which you want to simulate is named `myScene.umap`, specify **Scene** as `/Game/Maps/myScene`.

Alternatively, you can browse for the scene in the corresponding Unreal Engine project. These scenes are typically saved to the `Content/Maps` subfolder of the project. This subfolder contains all the scenes in your project. The scenes have the extension `.umap`. Select one of the scenes that you packaged into the executable file specified by the **Project name** parameter. Use backward slashes and specify the `.umap` extension for the scene.

By default, **Scene** is set to `/Game/Maps/HwStrght`, which is a scene from the default `VehicleSimulation.exe` executable file specified by the **Project name** parameter. This scene corresponds to the prebuilt **Straight Road** scene.

Example: `/Game/Maps/scene1`

Example: `C:\Local\myProject\Content\Maps\scene1.umap`

Dependencies

To enable this parameter, set **Scene source** to `Unreal Executable`.

`Project` — Name of Unreal Engine project file

valid project file name

Name of the Unreal Engine project file, specified as a valid project file name. You can either browse for the file or specify the full path to the file, using backslashes. The file must contain no spaces. To simulate scenes from this project in the Unreal Editor, click **Open Unreal Editor**. If you have an Unreal Editor session open already, then this button is disabled.

To run the simulation, in Simulink, click **Run**. Before you click **Play** in the Unreal Editor, wait until the Diagnostic Viewer window displays this confirmation message:

```
In the Simulation 3D Scene Configuration block, you set the scene source to 'Unreal Editor'.
In Unreal Editor, select 'Play' to view the scene.
```

This message confirms that Simulink has instantiated the scene actors, including the vehicles and cameras, in the Unreal Engine 3D environment. If you click **Play** before the Diagnostic Viewer window displays this confirmation message, Simulink might not instantiate the actors in the Unreal Editor.

Dependencies

To enable this parameter, set **Scene source** to `Unreal Editor`.

Scene Parameters

`Scene view` — Configure placement of virtual camera that displays scene

`Scene Origin` | vehicle name

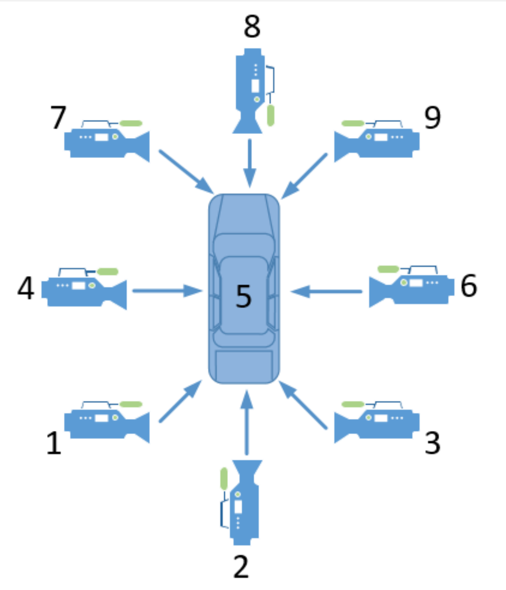
Configure the placement of the virtual camera that displays the scene during simulation.

- If your model contains no Simulation 3D Vehicle or Simulation 3D Vehicle with Ground Following blocks, then during simulation, you view the scene from a camera positioned at the scene origin.
- If your model contains at least one vehicle block, then by default, you view the scene from behind the first vehicle that was placed in your model. To change the view to a different vehicle, set **Scene view** to the name of that vehicle. The **Scene view** parameter list is populated with all the **Name** parameter values of the vehicle blocks contained in your model.

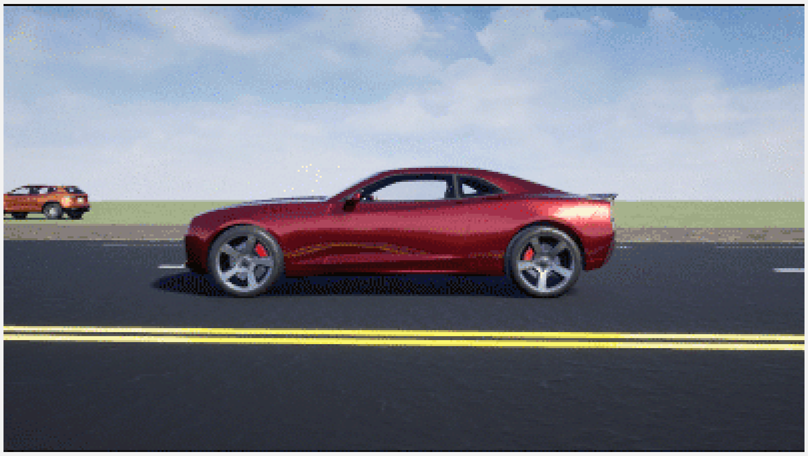
If you add a Simulation 3D Scene Configuration block to your model before adding any vehicle blocks, the virtual camera remains positioned at the scene. To reposition the camera to follow a vehicle, update this parameter.

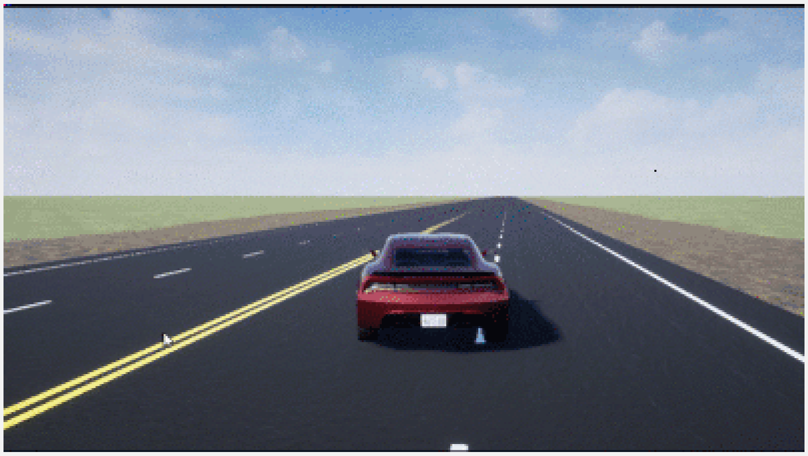
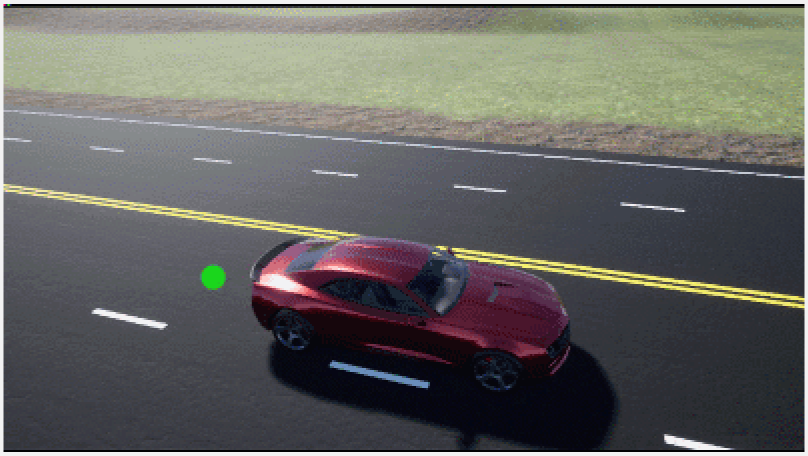
When **Scene view** is set to a vehicle name, during simulation, you can change the location of the camera around the vehicle.

To smoothly change the camera views, use these key commands.

Key	Camera View	
1	Back left	 **View Animated GIF** 
2	Back	
3	Back right	
4	Left	
5	Internal	
6	Right	
7	Front left	
8	Front	
9	Front right	
0	Overhead	

For additional camera controls, use these key commands.

Key	Camera Control
Tab	Cycle the view between all vehicles in the scene. **View Animated GIF** 
Mouse scroll wheel	Control the camera distance from the vehicle. **View Animated GIF** 

Key	Camera Control
L	Toggle a camera lag effect on or off. When you enable the lag effect, the camera view includes: • Position lag, based on the vehicle translational acceleration • Rotation lag, based on the vehicle rotational velocity This lag enables improved visualization of overall vehicle acceleration and rotation. **View Animated GIF** 
F	Toggle the free camera mode on or off. When you enable the free camera mode, you can use the mouse to change the pitch and yaw of the camera. This mode enables you to orbit the camera around the vehicle. **View Animated GIF** 

`Sample time` — Sample time of visualization engine

`.02` (default) | scalar greater than or equal to 0.01

Sample time, T_s, of the visualization engine, specified as a scalar greater than or equal to 0.01. Units are in seconds.

The graphics frame rate of the visualization engine is the inverse of the sample time. For example, if **Sample time** is `1/60`, then the visualization engine solver tries to achieve a frame rate of 60 frames per second. However, the real-time graphics frame rate is often lower due to factors such as graphics card performance and model complexity.

By default, blocks that receive data from the visualization engine, such as Simulation 3D Message blocks, inherit this sample rate.

`Display 3D simulation window` — Unreal Engine visualization

`on` (default) | `off`

Select whether to run simulations in the 3D visualization environment without visualizing the results, that is, in headless mode.

Consider running in headless mode in these cases:

- You want to run multiple 3D simulations in parallel to test models in different Unreal Engine scenarios.
- You want to optimize model parameters without visualizing the results. For example, consider using headless mode if you want to tune vehicle suspension parameters over a terrain scenario defined in Unreal Engine.

Dependencies

To enable this parameter, set **Scene source** to `Default Scenes` or `Unreal Executable`.

Weather

`Override scene weather` — Control the scene weather and sun position

`off` (default) | `on`

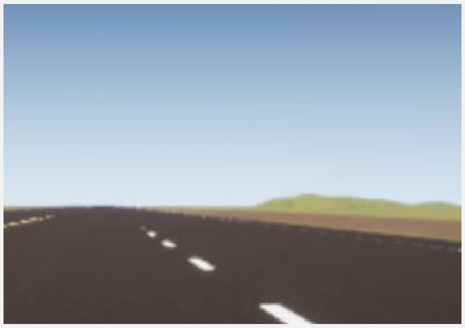
Select whether to control the scene weather and sun position during simulation. Use the enabled parameters to change the sun position, clouds, fog, and rain.

This table summarizes sun position settings for specific times of day.

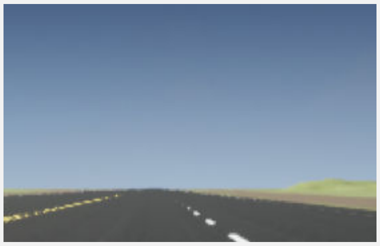
Time of Day	Settings	Unreal Editor Environment
Midnight	**Sun altitude**: -90 **Sun azimuth**: 180	

Time of Day	Settings	Unreal Editor Environment
Sunrise in the north	**Sun altitude**: 0 **Sun azimuth**: 180	
Noon	**Sun altitude**: 90 **Sun azimuth**: 180	

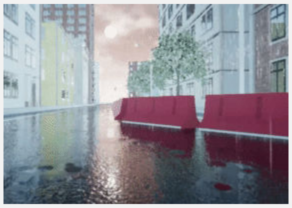
This table summarizes settings for specific cloud conditions.

Cloud Condition	Settings	Unreal Editor Environment
Clear	**Cloud opacity**: 0	
Heavy	**Cloud opacity**: 85	

This table summarizes settings for specific fog conditions.

Fog Condition	Settings	Unreal Editor Environment
None	**Fog density**: 0	
Heavy	**Fog density**: 100	

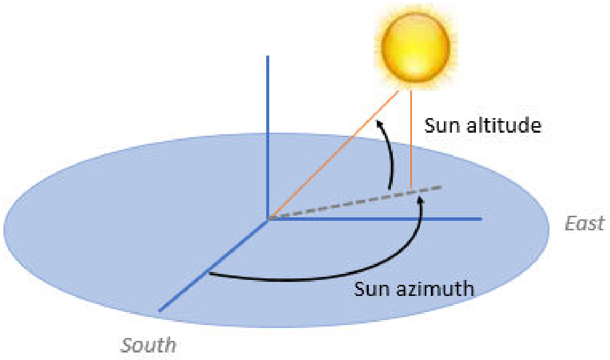
This table summarizes settings for specific rain conditions.

Rain Condition	Settings	Unreal Editor Environment
Light	**Cloud opacity**: 10 **Rain density**: 25	
Heavy	**Cloud opacity**: 10 **Rain density**: 80	

`Sun altitude` — Altitude angle between sun and horizon

`40` (default) | any value between `-90` and `90`

Altitude angle in a vertical plane between the sun's rays and the horizontal projection of the rays, in deg.



Use the **Sun altitude** and **Sun azimuth** parameters to control the time of day in the scene. For example, to specify sunrise in the north, set **Sun altitude** to 0 deg and **Sun azimuth** to 180 deg.

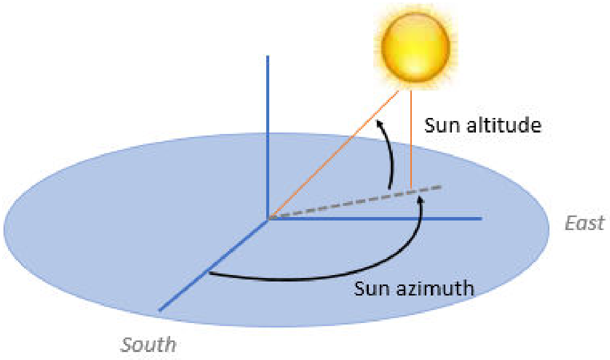
Dependencies

To enable this parameter, select **Override scene weather**.

`Sun azimuth` — Azimuth angle from south to horizontal projection of the sun ray

`90` (default) | any value between `0` and `360`

Azimuth angle in the horizontal plane measured from the south to the horizontal projection of the sun rays, in deg.



Use the **Sun altitude** and **Sun azimuth** parameters to control the time of day in the scene. For example, to specify sunrise in the north, set **Sun altitude** to 0 deg and **Sun azimuth** to 180 deg.

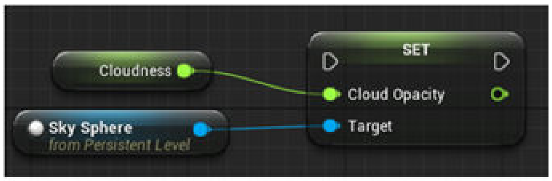
Dependencies

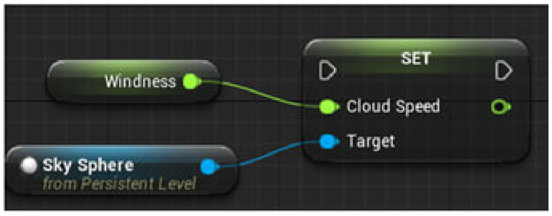
To enable this parameter, select **Override scene weather**.

`Cloud opacity` — Unreal Editor Cloud Opacity global actor target value

`10` (default) | any value between `0` and `100`

Parameter that corresponds to the Unreal Editor **Cloud Opacity** global actor target value, in percent. Zero is a cloudless scene.





Use the **Cloud opacity** and **Cloud speed** parameters to control clouds in the scene.

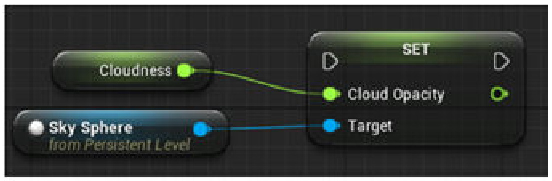
Dependencies

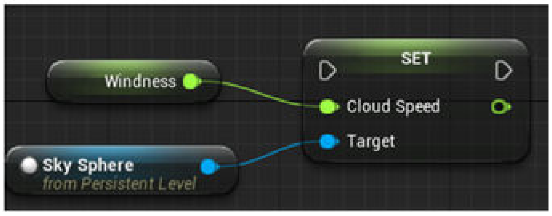
To enable this parameter, select **Override scene weather**.

`Cloud speed` — Unreal Editor Cloud Speed global actor target value

`1` (default) | any value between `-100` and `100`

Parameter that corresponds to the Unreal Editor **Cloud Speed** global actor target value. The clouds move from west to east for positive values and east to west for negative values.





Use the **Cloud opacity** and **Cloud speed** parameters to control clouds in the scene.

Dependencies

To enable this parameter, select **Override scene weather**.

`Fog density` — Unreal Editor Set Fog Density and Set Start Distance target values

`0` (default) | any value between `0` and `100`

Parameter that corresponds to the Unreal Editor **Set Fog Density** and **Set Start Distance** target values, in percent.

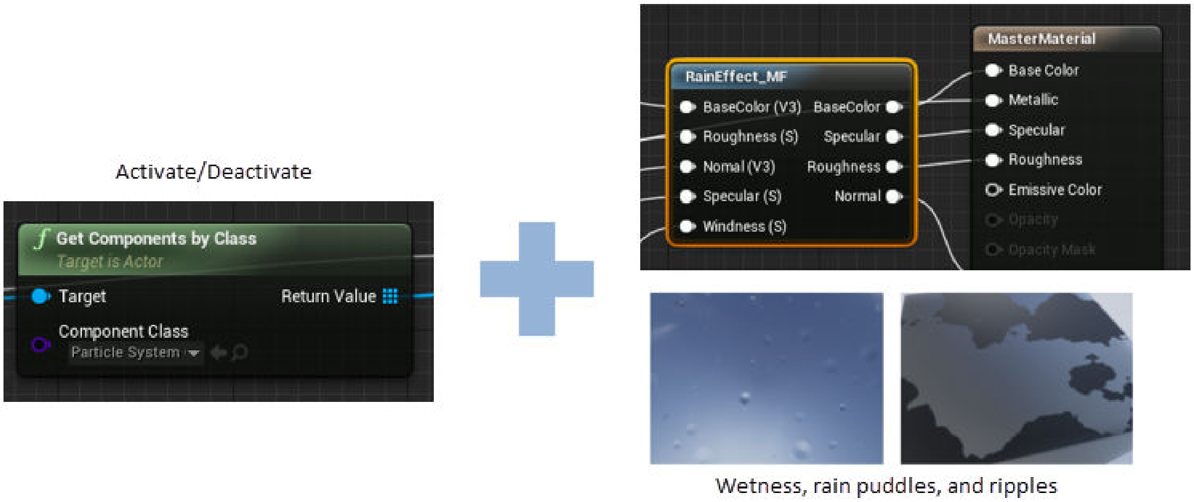
Dependencies

To enable this parameter, select **Override scene weather**.

`Rain density` — Unreal Editor local actor controlling rain density, wetness, rain puddles, and ripples

`0` (default) | any value between `0` and `100`

Parameter corresponding to the Unreal Editor local actor that controls rain density, wetness, rain puddles, and ripples, in percent.



Use the **Cloud opacity** and **Rain density** parameters to control rain in the scene.

Dependencies

To enable this parameter, select **Override scene weather**.

More About

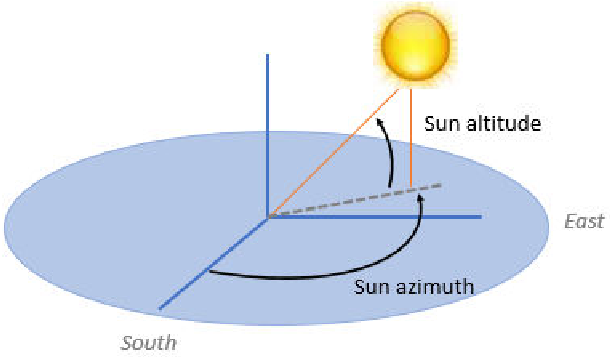
Sun Position and Weather

To control the scene weather and sun position, on the **Weather** tab, select **Override scene weather**. Use the enabled parameters to change the sun position, clouds, fog, and rain during the simulation.

Sun Position

Use **Sun altitude** and **Sun azimuth** to control the sun position.

- **Sun altitude** — Altitude angle in a vertical plane between the sun rays and the horizontal projection of the rays.
- **Sun azimuth** — Azimuth angle in the horizontal plane measured from the south to the horizontal projection of the sun rays.



This table summarizes sun position settings for specific times of day.

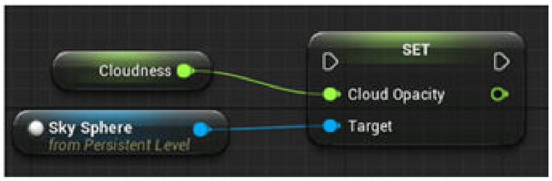
Time of Day	Settings	Unreal Editor Environment
Midnight	**Sun altitude**: -90 **Sun azimuth**: 180	
Sunrise in the north	**Sun altitude**: 0 **Sun azimuth**: 180	

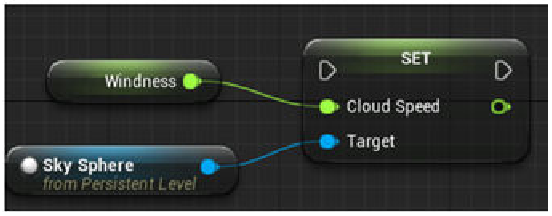
Time of Day	Settings	Unreal Editor Environment
Noon	**Sun altitude**: 90 **Sun azimuth**: 180	

Clouds

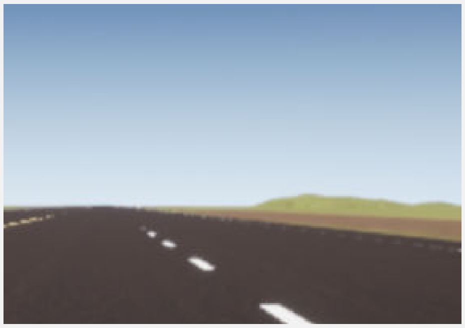
Use **Cloud opacity** and **Cloud speed** to control clouds in the scene.

- **Cloud opacity** — Unreal Editor **Cloud Opacity** global actor target value. Zero is a cloudless scene.
- **Cloud speed** — Unreal Editor **Cloud Speed** global actor target value. The clouds move from west to east for positive values and east to west for negative values.





This table summarizes settings for specific cloud conditions.

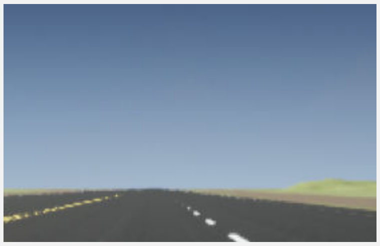
Cloud Condition	Settings	Unreal Editor Environment
Clear	**Cloud opacity**: 0	

Cloud Condition	Settings	Unreal Editor Environment
Heavy	**Cloud opacity**: 85	

Fog

Use **Fog density** to control fog in the scene. **Fog density** corresponds to the Unreal Editor **Set Fog Density**.

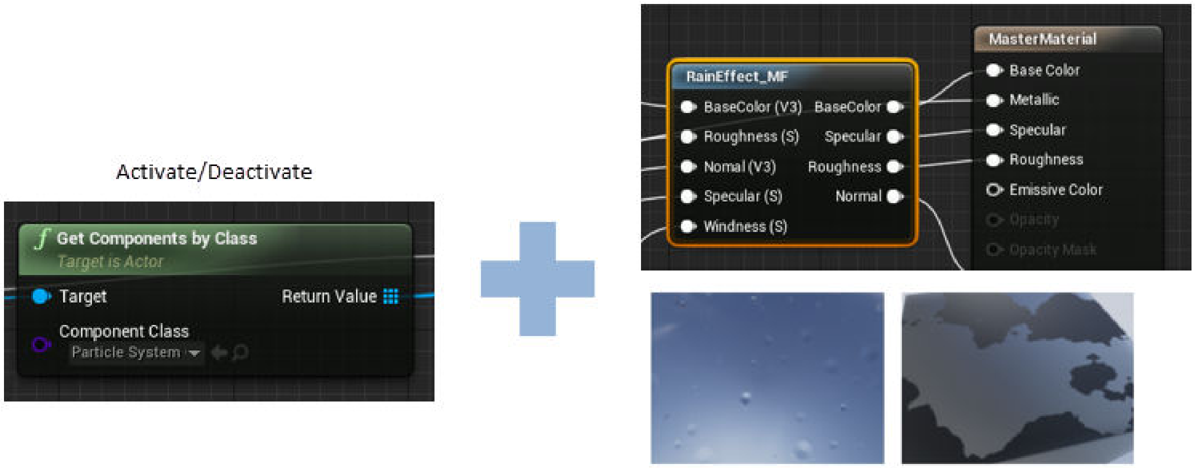
This table summarizes settings for specific fog conditions.

Fog Condition	Settings	Unreal Editor Environment
None	**Fog density**: 0	
Heavy	**Fog density**: 100	

Rain

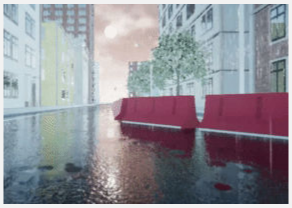
Use **Cloud opacity** and **Rain density** to control rain in the scene.

- **Cloud opacity** — Unreal Editor **Cloud Opacity** global actor target value.
- **Rain density** — Unreal Editor local actor that controls rain density, wetness, rain puddles, and ripples.



Wetness, rain puddles, and ripples

This table summarizes settings for specific rain conditions.

Rain Condition	Settings	Unreal Editor Environment
Light	**Cloud opacity**: 10 **Rain density**: 25	
Heavy	**Cloud opacity**: 10 **Rain density**: 80	

Version History

Introduced in R2018a

See Also

Simulation 3D Vehicle with Ground Following | Simulation 3D Vehicle

Topics

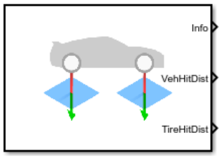
"How 3D Simulation for Vehicle Dynamics Blockset Works"

“Scene Interrogation in 3D Environment”
“Unreal Engine Simulation Environment Requirements and Limitations”
“Customize 3D Scenes for Vehicle Dynamics Simulations”
“Prepare Custom Vehicle Mesh for the Unreal Editor”

Vehicle Terrain Sensor

Vehicle and tire distances to objects

Library:	Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Vehicle Terrain Sensor block implements ray tracing to detect the terrain below the tires and objects in front of the vehicle. Specifically, for these actor components, the block returns the hit location (in the world coordinate system) and the distance to an object.

- Vehicle body
- Left front wheel
- Right front wheel
- Left rear wheel
- Right rear wheel

Tip Verify that the Vehicle Terrain Sensor block executes before the Simulation 3D Fisheye Camera block. That way, the Unreal Engine 3D visualization environment prepares the data before the Vehicle Terrain Sensor block receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Vehicle Terrain Sensor — `1`

For more information about execution order, see “Control and Display Execution Order”.

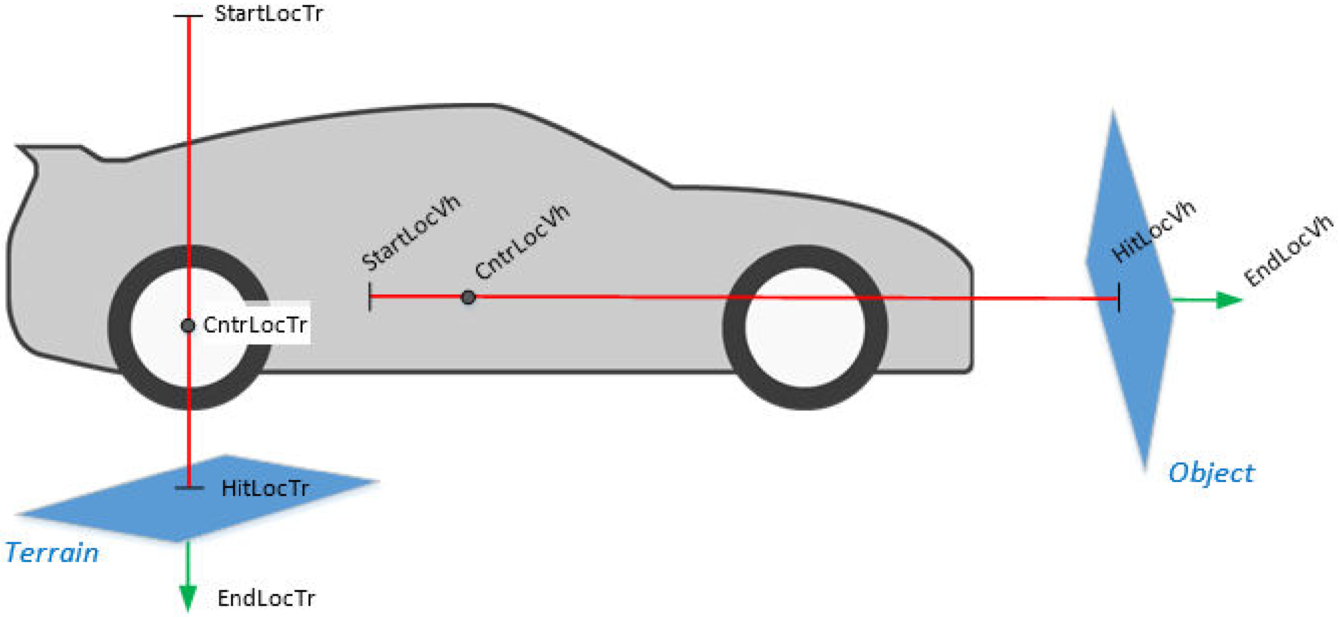
Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor.

Hit Distance

To calculate the hit distances shown in the illustration, the block implements these equations.

Front of vehicle to object, *DistToHitVhAdjust*	`DistToHitVh = GetLength(CntrLocVh,HitLocVh)`
	`DistToHitVhAdjust = DistToHitVh - VehCntrLngthVal`
	
	`EndLocVh = CntrLocVh + VehRayLngth - VehRayOffset`
	`VehRayOffset = CntrLocVh - StartLocVh`
	`VehRayLngth = StartLocVh - EndLocVh`

Tires to terrain, *DistToHitTrAdjust*	`DistToHitTr = GetLength(CntrLocTr, HitLocTr)`
	`DistToHitTrAdjust = DistToHitTr - TireRadiiVal`
	
	`EndLocTr = CntrLocTr + LengthTr - OffsetTr`
	`OffsetTr = CntrLocTr - StartLocTr`
	`LengthTr = StartLocTr - EndLocTr`



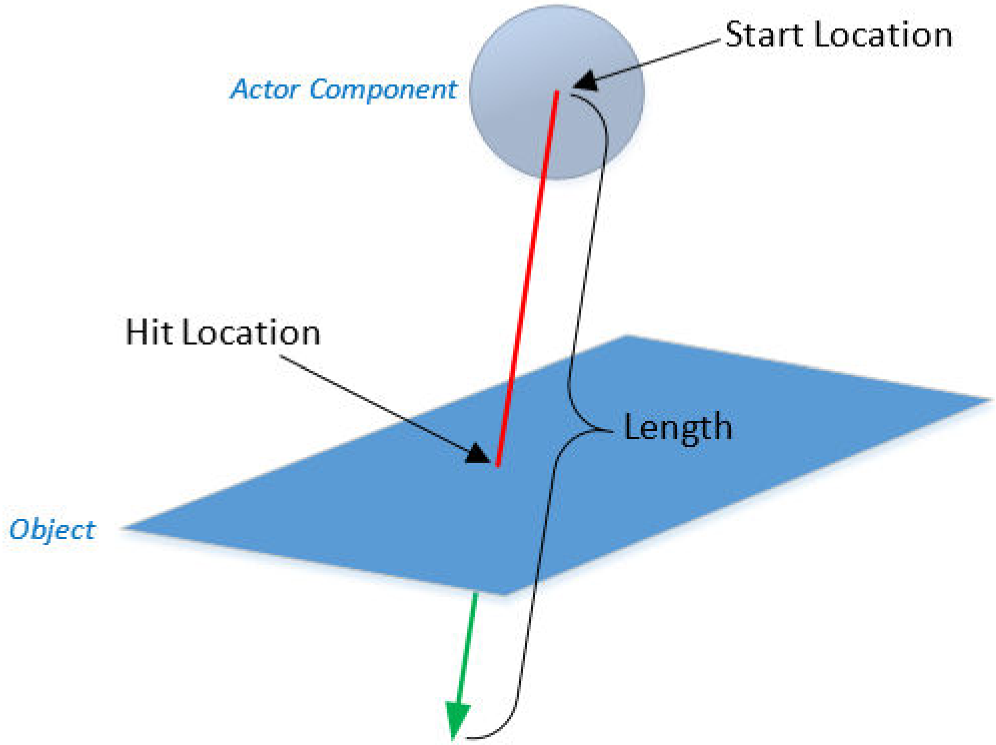
This illustration and equations use these variables.

CntrLocVh	Vehicle center location
DistToHitVh	Distance from vehicle center location to object
DistToHitVhAdjust	Distance from the front of the vehicle to object
EndLocVh	Vehicle ray trace end
HitLocVh	Vehicle hit location
OffsetVh	Vehicle trace offset
StartLocVh	Vehicle ray trace start
VehRayLngth	Vehicle trace length
VehCntrLngthVal	Distance from vehicle center to front
CntrLocTr	Tire center location
DistToHitTr	Distance from tire center location to terrain
DistToHitTrAdjust	Distance from tire to terrain
HitLocTr	Tire hit location
EndLocTr	Tire ray trace end
OffsetTr	Tire trace offset
StartLocTr	Tire ray trace start

LengthTr	Tire trace length
TireRadiiVal	Tire radius

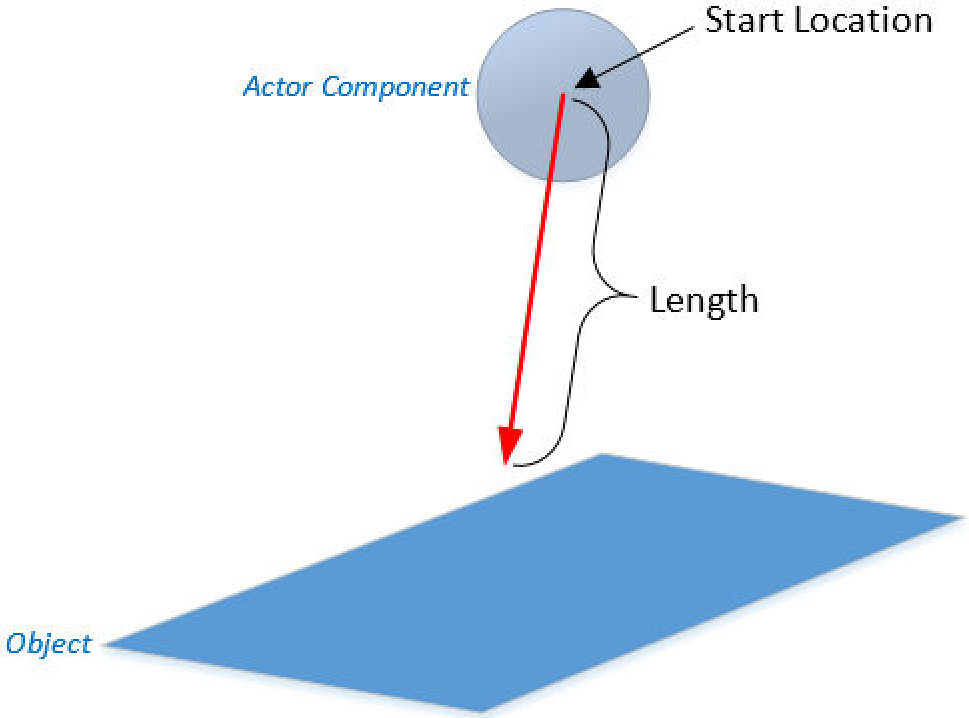
Hit Event

To determine a hit event, the block uses the ray trace. The block provides the hit location in the world coordinate system.



Miss Event

To determine a miss event, the block uses the ray trace.



Ports

Input

`VehCntr` — Vehicle distance from center to front
`scalar`

Distance from the vehicle center to front, *VehCntrLngthVal*, in m.

Dependencies

Distance to vehicle center	Creates Port	Creates Parameter
`Constant`	None	**Distance from vehicle center to front, VehCntrLngthVal**
`External input`	`VehCntr`	*None*

`TireRadii` — Tire radii
`array`

Tire radii, *TireRadiiVal*, in m.

Dependencies

Distance to tire center Setting	Creates Port	Creates Parameter
`Constant`	None	**Distance from tire center to ground, TireRadiiVal**
`External input`	`TireRadii`	None

Output

`Info` — Bus signal
bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

Signal	Description	Variable	Units
`HitFlg`	Vehicle and wheel hit flag: • Hit an object – `1` • Miss an object – `0`	$\begin{bmatrix} Vehicle \\ FrontLeft \\ FrontRight \\ RearLeft \\ RearRight \end{bmatrix}$	NA
`HitLoc`	Vehicle, *HitLocVh*, and tire, *HitLocTr*, hit locations, in world coordinate system *X*-, *Y*, and *Z*- axes, respectively	$\begin{bmatrix} Vehicle_X & Vehicle_Y & Vehicle_Z \\ FrontLeft_X & FrontLeft_Y & FrontLeft_Z \\ FrontRight_X & FrontRight_Y & FrontRight_Z \\ RearLeft_X & RearLeft_Y & RearLeft_Z \\ RearRear_X & RearRear_Y & RearRear_Z \end{bmatrix}$	m
`StartLoc`	Vehicle, *StartLocVh*, and tire, *StartLocTr*, ray trace start locations, in world coordinate system *X*-, *Y*, and *Z*- axes, respectively		m

`VehHitDist` — Front of vehicle distance to object
`scalar`

Distance from the front of the vehicle to object, *DistToHitVhAdjust*, in m.

`TireHitDist` — Tire distance to terrain
`vector`

Distance from tire to terrain, *DistToHitTrAdjust*, in m.

$DistToHitTrAdjust = [FrontLeft\ \ FrontRight\ \ RearLef\ \ RearRight]$

Parameters

Actor Setup

`Tag for actor in 3D scene, ActorTag` — Name
`SimulinVehicle1` (default) | character vector

Actor name.

Actors are scene objects that support 3D translation, rotation, and scale. Parts are actor components. Components do not exist by themselves; they are associated with an actor.

The block does not support multiple instances of the same actor tag. To refer to the same scene actor when you use the 3D block pairs (e.g. Simulation 3D Actor Transform Get and Simulation 3D Actor Transform Set), specify the same **Tag for actor in 3D scene, ActorTag** parameter.

`Distance to vehicle center` — Selection

`Constant` (default) | `External input`

Configure how to provide the distance to the vehicle center.

Dependencies

Distance to vehicle center	Creates Port	Creates Parameter
`Constant`	None	**Distance from vehicle center to front, VehCntrLngthVal**
`External input`	`VehCntr`	*None*

`Distance to tire center` — Selection

`Constant` (default) | `External input`

Configure how to provide the distance to the tire center.

Dependencies

Distance to tire center Setting	Creates Port	Creates Parameter
`Constant`	None	**Distance from tire center to ground, TireRadiiVal**
`External input`	`TireRadii`	None

`Distance from vehicle center to front, VehCntrLngthVal` — Vehicle center

`0` (default) | `scalar`

Distance from the vehicle center to front, *VehCntrLngthVal*, in m.

Dependencies

Distance to vehicle center	Creates Port	Creates Parameter
`Constant`	None	**Distance from vehicle center to front, VehCntrLngthVal**
`External input`	`VehCntr`	*None*

`Distance from tire center to ground, TireRadiiVal` — Tire radii

`0` (default) | `scalar`

Tire radius, *TireRadiiVal*, in m.

Dependencies

Distance to tire center Setting	Creates Port	Creates Parameter
`Constant`	None	**Distance from tire center to ground, TireRadiiVal**
`External input`	`TireRadii`	None

Trace Lengths

`Vehicle body x-axis trace length, VehRayLngth` — Trace length

`5` (default) | `scalar`

Vehicle body trace length, *VehRayLngth*, in m.

`Left front wheel z-axis trace length, LfRayLngth` — Trace length

`5` (default) | `scalar`

Left front wheel trace length, *LfRayLngth* and *LengthTr*, in m.

`Right front wheel z-axis trace length, RfRayLngth` — Trace length

`5` (default) | `scalar`

Right front wheel trace length, *RfRayLngth* and *LengthTr*, in m.

`Left rear wheel z-axis trace length, LrRayLngth` — Trace length

`5` (default) | `scalar`

Left rear wheel trace length, *LrRayLngth* and *LengthTr*, in m.

`Right rear wheel z-axis trace length, RrRayLngth` — Trace length

`5` (default) | `scalar`

Right rear wheel trace length, *RrRayLngth* and *LengthTr*, in m.

Starting Point Offsets

`Vehicle body x-axis trace offset, VehRayOffset` — Offset the vehicle ray trace

`0` (default) | `scalar`

Vehicle body trace offset, *OffsetVh*, in m.

`Left front wheel z-axis trace offset, LfRayOffset` — Offset the left front wheel ray trace

`0` (default) | `scalar`

Left front wheel trace offset, *LfRayOffset* and *OffsetTr*, in m.

`Right front wheel z-axis trace offset, RfRayOffset` — Offset the right front wheel ray trace

`0` (default) | `scalar`

Right front wheel trace offset, *RfRayOffset* and *OffsetTr*, in m.

`Left rear wheel z-axis trace offset, LrRayOffset` — Offset the left rear wheel ray trace
`0` (default) | `scalar`

Left rear wheel trace offset, *LrRayOffset* and *OffsetTr*, in m.

`Right rear wheel z-axis trace offset, RrRayOffset` — Offset the right rear wheel ray trace
`0` (default) | `scalar`

Right rear wheel trace offset, *RrRayOffset* and *OffsetTr*, in m.

Enable Traces

`Vehicle body` — Enable vehicle body ray tracing
on (default) | off

Enable vehicle body ray tracing.

`Left front tire` — Enable left front tire ray tracing
on (default) | off

Enable left front tire ray tracing.

`Right front tire` — Enable right front tire ray tracing
on (default) | off

Enable right front tire ray tracing.

`Left rear tire` — Enable left rear tire ray tracing
on (default) | off

Enable left rear tire ray tracing.

`Right rear tire` — Enable right rear tire ray tracing
on (default) | off

Enable right rear tire ray tracing.

`Trace line visualization` — Visualize ray traces
on (default) | off

Enable trace line visualization.

`Sample time` — Sample time
`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Version History

Introduced in R2018a

See Also

Simulation 3D Camera Get | Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

"Scene Interrogation in 3D Environment"

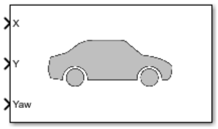
External Websites

Unreal Engine

Simulation 3D Vehicle with Ground Following

Implement vehicle that follows ground in 3D environment

Library: Automated Driving Toolbox / Simulation 3D
Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Vehicle with Ground Following block implements a vehicle with four wheels in a 3D simulation environment. This environment is rendered using the Unreal Engine from Epic Games. The block uses the input (*X*, *Y*) position and yaw angle of the vehicle to adjust the elevation, roll angle, and pitch angle of the vehicle so that it follows the ground terrain. The block determines the vehicle velocity and heading and adjusts the steering angle and rotation for each wheel. Use this block for automated driving applications.

To use this block, ensure that the Simulation 3D Scene Configuration block is in your model. If you set the **Sample time** parameter of the Simulation 3D Vehicle with Ground Following block to `-1`, the block inherits the sample time specified in the Simulation 3D Scene Configuration block.

The block input uses the vehicle Z-down *right-handed* (RH) *Cartesian* coordinate system defined in SAE J670[1]. The coordinate system is inertial and initially aligned with the vehicle geometric center:

- *X*-axis — Along vehicle longitudinal axis, points forward
- *Y*-axis — Along vehicle lateral axis, points to the right
- *Z*-axis — Points downward

Note The Simulation 3D Vehicle with Ground Following block must execute before the Simulation 3D Scene Configuration block. That way, the Simulation 3D Vehicle with Ground Following block prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Vehicle with Ground Following — `-1`

For more information about execution order, see “Control and Display Execution Order”.

You can configure the Simulation 3D Vehicle with Ground Following block to import custom meshes on page 7-57 and control vehicle lights on page 7-58.

Ports

Input

`X` — Longitudinal position of vehicle

scalar

Longitudinal position of the vehicle along the *X*-axis of the scene. **X** is in the inertial *Z*-down coordinate system. Units are in meters.

`Y` — Lateral position of vehicle

scalar

Lateral position of the vehicle along the *Y*-axis of the scene. **Y** is in the inertial *Z*-down coordinate system. Units are in meters.

`Yaw` — Yaw orientation angle of vehicle

scalar

Yaw orientation angle of the vehicle along the *Z*-axis of the scene. **Yaw** is in the *Z*-down coordinate system. Units are in radians.

`Light controls` — Vehicle lights on or off

1-by-6 vector

Light controls input signal, specified as a 1-by-6 Boolean vector. Each element of the vector turns a specific vehicle light on or off, as indicated in this table. A value of 1 turns the light on; a value of 0 turns the light off

Vector Element	Vehicle Light
(1,1)	Headlight high beam
(1,2)	Headlight low beam
(1,3)	Brake
(1,4)	Reverse
(1,5)	Left signal
(1,6)	Right signal

Dependencies

To create this port, on the **Light Controls** tab, select **Enable light controls**.

Data Types: `Boolean`

Parameters

Vehicle Parameters

Type — Type of vehicle

`Muscle car` (default) | `Sedan` | `Sport utility vehicle` | `Small pickup truck` | `Hatchback` | `Box truck` | `Custom`

Select the type of vehicle. To obtain the dimensions of each vehicle type, see these reference pages:

- `Muscle car` — **Muscle Car**
- `Sedan` — **Sedan**
- `Sport utility vehicle` — **Sport Utility Vehicle**
- `Small pickup truck` — **Small Pickup Truck**
- `Hatchback` — **Hatchback**
- `Box truck` — **Box Truck**

Dependencies

Selecting `Custom` enables parameters that allow you to import a custom mesh for your vehicle.

`Path to custom mesh, MeshPath` — Path to custom mesh

`/MathWorksSimulation/Vehicles/Muscle/Meshes/SK_MuscleCar.SK_MuscleCar` (default) | valid path

Path to custom mesh.

To create a custom vehicle mesh, see "Prepare Custom Vehicle Mesh for the Unreal Editor".

Example: `/MathWorksSimulation/Vehicles/Muscle/Meshes/SK_Sedan.SK_Sedan`

Dependencies

To enable this parameter, set **Type** to `Custom`.

`Track width in custom mesh, TrackWidth` — Track width

`1.9` (default) | scalar

Track width in custom mesh, in m.

Dependencies

To enable this parameter, set **Type** to `Custom`.

`Wheel base in custom mesh, WheelBase` — Wheel base

`3` (default) | scalar

Wheel base in custom mesh, in m.

Dependencies

To enable this parameter, set **Type** to `Custom`.

`Wheel radius in custom mesh, WheelRadius` — Wheel radius

`0.35` (default) | scalar

Wheel radius in custom mesh, in m.

Dependencies

To enable this parameter, set **Type** to `Custom`.

`Color` — Color of vehicle

`Red` (default) | `Orange` | `Yellow` | `Green` | `Blue` | `Black` | `White` | `Silver`

Select the color of the vehicle.

`Initial position [X, Y, Z]`, `InitialPos (m)` — Initial vehicle position
`[0, 0, 0]` (default) | real-valued 1-by-3 vector

Initial vehicle position along the *X*-axis, *Y*-axis, and *Z*-axis in the inertial *Z*-down coordinate system, in m.

`Initial rotation [Roll, Pitch, Yaw]`, `InitialRot (rad)` — Initial angle of vehicle rotation
`[0, 0, 0]` (default) | real-valued 1-by-3 vector

Initial angle of vehicle rotation, in rad. The angle of rotation is defined by the roll, pitch, and yaw of the vehicle.

`Name`, `ActorName` — Name of vehicle
`SimulinkVehicle1` (default) | vehicle name

Name of vehicle. By default, when you use the block in your model, the block sets the **Name** parameter to `SimulinkVehicle`*X*. The value of *X* depends on the number of Simulation 3D Vehicle with Ground Following blocks that you have in your model.

`Sample time`, `SampleTime` — Sample time
`-1` (default) | positive scalar

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

If you set the sample time to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

Light Controls

`Enable light controls`, `VehLightsControl` — Control vehicle lights
`off` (default) | `on`

Select whether to control the vehicle headlights. Use the enabled parameters to set the light parameters, including headlight intensity.

Dependencies

Selecting this parameter:

- Creates the input port `Light controls`
- Enables these light parameters.

Lights	Light Parameters
Headlights	• **Headlight color** • **High beam intensity** • **Low beam intensity** • **High beam cone half angle** • **Low beam cone half angle** • **Left headlight beam orientation** • **Right headlight beam orientation**
Brake lights	**Brake light intensity**
Reverse lights	**Reverse light intensity**
Turn signal lights	• **Turn signal light intensity** • **Period** • **Pulse width**

Headlights

`Headlight color [R,G,B]`, `HeadlightColor` — Headlight color

`[1,1,1]` (default) | 1-by-3 vector of RGB triplet values

Headlight color, specified as a normalized 1-by-3 vector of RGB triplet values.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `int8` | `uint8`

`High beam intensity`, `HighBeamIntensity` — High beam intensity

`100000` (default) | positive scalar

High beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam intensity`, `LowBeamIntensity` — Low beam intensity

`60000` (default) | positive scalar

Low beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`High beam cone half angle`, `HighBeamConeAngle` — High beam cone half angle

`1.22` (default) | positive scalar less than pi/2

High beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam cone half angle, LowBeamConeAngle` — Low beam cone half angle

`1.22` (default) | positive scalar less than pi/2

Low beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Left headlight beam orientation [Pitch, Yaw], LeftHeadlightOrientation` — Left headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the left headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Right headlight beam orientation [Pitch, Yaw], RightHeadlightOrientation` — Right headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the right headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Brake Lights

`Brake light intensity, BrakelightIntensity` — Intensity

`500` (default) | positive scalar

Brake light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Reverse Lights

`Reverse light intensity, ReverselightIntensity` — Intensity

`500` (default) | positive scalar

Reverse light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Turn Signal Lights

`Turn signal light intensity, SignallightIntensity` — Intensity

`500` (default) | positive scalar

Turn signal light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Period, SignallightPeriod` — Turn signal light period

`1` (default) | positive scalar

Turn signal light period, in s.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Pulse width, SignalPulseWidth` — Pulse width

`50` (default) | positive scalar less than 100

Turn signal light pulse width, as a percent of the period.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

More About

Import Custom Meshes

To import custom meshes for defining custom vehicles, follow these steps:

1. Install the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package. See “Customize 3D Scenes for Vehicle Dynamics Simulations”.
2. On the block **Parameters** tab, set **Type** to `Custom`.
3. In the **Path to custom mesh** field, enter the path to the vehicle mesh in the Unreal Engine project. For example, enter `/MathWorksSimulation/Vehicles/Muscle/Meshes/SK_MuscleCar.SK_MuscleCar`.

   To create a custom vehicle mesh, see “Prepare Custom Vehicle Mesh for the Unreal Editor”.

4. Use the vehicle dimensions in the custom mesh to enter the dimensions in the corresponding block parameter fields.

Control Vehicle Lights

To control the lights of vehicles in a scene, follow these steps:

1. Install the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package. See “Customize 3D Scenes for Vehicle Dynamics Simulations”.
2. On the block **Light Controls** tab, select **Enable light controls**.
3. Use the enabled parameters to specify the vehicle light for:

   - Headlights
   - Brake lights
   - Reverse lights
   - Turn signal lights
4. Connect Boolean light control signals to the `Signal lights` input port.

Version History

Introduced in R2019b

References

[1] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[2] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle

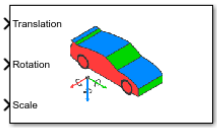
Topics

“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Prepare Custom Vehicle Mesh for the Unreal Editor”
“Scene Interrogation in 3D Environment”
“Unreal Engine Simulation Environment Requirements and Limitations”

Simulation 3D Vehicle

Implement vehicle in 3D environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Vehicle block implements a vehicle with four wheels in the 3D simulation environment.

To use this block, ensure that the Simulation 3D Scene Configuration block is in your model. If you set the **Sample time** parameter of this block to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

The block input uses the vehicle Z-down *right-handed* (RH) *Cartesian* coordinate system defined in SAE J670[1]. The coordinate system is inertial and initially aligned with the vehicle geometric center:

- *X*-axis — Along vehicle longitudinal axis, points forward
- *Y*-axis — Along vehicle lateral axis, points to the right
- *Z*-axis — Points downward

Tip Verify that the Simulation 3D Vehicle block executes before the Simulation 3D Scene Configuration block. That way, Simulation 3D Vehicle prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Vehicle — `-1`

For more information about execution order, see “Control and Display Execution Order”.

You can configure the Simulation 3D Vehicle with Ground Following block to import custom meshes on page 7-69 and control vehicle lights on page 7-69.

Ports

Input

`Translation` — Vehicle translation

5-by-3 array

Vehicle and wheel translation, in m. Array dimensions are 5-by-3.

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Vehicle translation along the inertial vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Wheel translation relative to vehicle, along the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The signal contains translation information according to the axle and wheel locations.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element	Translation Axis
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down *Y*-axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down *Z*-axis
Rear left wheel, X_{RL}	`Translation(4,1)`	Vehicle Z-down *X*-axis
Rear left wheel, Y_{RL}	`Translation(4,2)`	Vehicle Z-down *Y*-axis
Rear left wheel, Z_{RL}	`Translation(4,3)`	Vehicle Z-down *Z*-axis
Rear right wheel, X_{RR}	`Translation(5,1)`	Vehicle Z-down *X*-axis
Rear right wheel, Y_{RR}	`Translation(5,2)`	Vehicle Z-down *Y*-axis
Rear right wheel, Z_{RR}	`Translation(5,3)`	Vehicle Z-down *Z*-axis

`Rotation` — Vehicle rotation
5-by-3 array

Vehicle and wheel rotation, in rad. Array dimensions are 5-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Vehicle rotation about the inertial vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Wheel rotation relative to vehicle, about the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The signal contains rotation information according to the axle and wheel locations.

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	**Array Element**	**Rotation Axis**
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down *Y*-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down *Z*-axis
Rear left wheel, $Roll_{RL}$	`Rotation(4,1)`	Vehicle Z-down *X*-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(4,2)`	Vehicle Z-down *Y*-axis
Rear left wheel, Yaw_{RL}	`Rotation(4,3)`	Vehicle Z-down *Z*-axis
Rear right wheel, $Roll_{RR}$	`Rotation(5,1)`	Vehicle Z-down *X*-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(5,2)`	Vehicle Z-down *Y*-axis
Rear right wheel, Yaw_{RR}	`Rotation(5,3)`	Vehicle Z-down *Z*-axis

`Scale` — Vehicle scale

5-by-3

Vehicle and wheel scale, dimensionless. Array dimensions are 5-by-3.

- `Scale(1,1)`, `Scale(1,2)`, and `Scale(1,3)` — Vehicle scale along the inertial vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.
- `Scale(...,1)`, `Scale(...,2)`, and `Scale(...,3)` — Wheel scale relative to vehicle, along vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The signal contains scale information according to the axle and wheel locations.

$$Scale = \begin{bmatrix} X_{V_{scale}} & Y_{V_{scale}} & Z_{V_{scale}} \\ X_{FL_{scale}} & Y_{FL_{scale}} & Z_{FL_{scale}} \\ X_{FR_{scale}} & Y_{FR_{scale}} & Z_{FR_{scale}} \\ X_{RL_{scale}} & Y_{RL_{scale}} & Z_{RL_{scale}} \\ X_{RR_{scale}} & Y_{RR_{scale}} & Z_{RR_{scale}} \end{bmatrix}$$

Scale	Array Element	Scale Axis
Vehicle, $X_{v_{scale}}$	`Scale(1,1)`	Vehicle Z-down X-axis
Vehicle, $Y_{v_{scale}}$	`Scale(1,2)`	Vehicle Z-down Y-axis
Vehicle, $Z_{v_{scale}}$	`Scale(1,3)`	Vehicle Z-down Z-axis
Front left wheel, $X_{FL_{scale}}$	`Scale(2,1)`	Vehicle Z-down X-axis
Front left wheel, $Y_{FL_{scale}}$	`Scale(2,2)`	Vehicle Z-down Y-axis
Front left wheel, $Z_{FL_{scale}}$	`Scale(2,3)`	Vehicle Z-down Z-axis
Front right wheel, $X_{FR_{scale}}$	`Scale(3,1)`	Vehicle Z-down X-axis
Front right wheel, $Y_{FR_{scale}}$	`Scale(3,2)`	Vehicle Z-down Y-axis
Front right wheel, $Z_{FR_{scale}}$	`Scale(3,3)`	Vehicle Z-down Z-axis
Rear left wheel, $X_{RL_{scale}}$	`Scale(4,1)`	Vehicle Z-down X-axis
Rear left wheel, $Y_{RL_{scale}}$	`Scale(4,2)`	Vehicle Z-down Y-axis
Rear left wheel, $Z_{RL_{scale}}$	`Scale(4,3)`	Vehicle Z-down Z-axis
Rear right wheel, $X_{RR_{scale}}$	`Scale(5,1)`	Vehicle Z-down X-axis
Rear right wheel, $Y_{RR_{scale}}$	`Scale(5,2)`	Vehicle Z-down Y-axis
Rear right wheel, $Z_{RR_{scale}}$	`Scale(5,3)`	Vehicle Z-down Z-axis

`Light controls` — Vehicle lights on or off
1-by-6 vector

Light controls input signal, specified as a 1-by-6 Boolean vector. Each element of the vector turns a specific vehicle light on or off, as indicated in this table. A value of 1 turns the light on; a value of 0 turns the light off

Vector Element	Vehicle Light
(1,1)	Headlight high beam
(1,2)	Headlight low beam
(1,3)	Brake
(1,4)	Reverse
(1,5)	Left signal
(1,6)	Right signal

Dependencies

To create this port, on the **Light Controls** tab, select **Enable light controls**.

Data Types: `Boolean`

Parameters

Vehicle Parameters

Type — Type
`Muscle car` (default) | `Sedan` | `Sport utility vehicle` | `Small pickup truck` | `Hatchback` | `Box truck`

If you set **Actor type** to `Passenger vehicle`, use the **Vehicle type** parameter to specify the vehicle. This table provides links to the vehicle dimensions.

Vehicle type Setting	Vehicle Dimensions
`Muscle car`	**Muscle Car**
`Sedan`	**Sedan**
`Sport utility vehicle`	**Sport Utility Vehicle**
`Small pickup truck`	**Small Pickup Truck**
`Hatchback`	**Hatchback**
`Box truck`	**Box Truck**

Dependencies

Selecting `Custom` enables parameters that allow you to import a custom mesh for your vehicle.

`Path to custom mesh, MeshPath` — Path to custom mesh

`/MathWorksSimulation/Vehicles/Muscle/Meshes/SK_MuscleCar.SK_MuscleCar` (default) | valid path

Path to custom mesh.

To create a custom vehicle mesh, see "Prepare Custom Vehicle Mesh for the Unreal Editor".

Example: `/MathWorksSimulation/Vehicles/Muscle/Meshes/SK_Sedan.SK_Sedan`

Dependencies

To enable this parameter, set **Type** to `Custom`.

`Color` — Color of vehicle

`Red` (default) | `Orange` | `Yellow` | `Green` | `Blue` | `Black` | `White` | `Silver`

Select the color of the vehicle.

`Name` — Name of vehicle

`SimulinkVehicle1` (default) | character vector

Name of vehicle. By default, when you use the block in your model, the block sets the **Name** parameter to `SimulinkVehicle`*X*. The value of *X* depends on the number of Simulation 3D Vehicle with Ground Following and Simulation 3D Vehicle blocks that you have in your model.

`Sample time` — Sample time

`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Light Controls

`Enable light controls, VehLightsControl` — Control vehicle lights

`off` (default) | `on`

Select whether to control the vehicle headlights. Use the enabled parameters to set the light parameters, including headlight intensity.

Dependencies

Selecting this parameter:

- Creates the input port `Light controls`
- Enables these light parameters.

Lights	Light Parameters
Headlights	• **Headlight color** • **High beam intensity** • **Low beam intensity** • **High beam cone half angle** • **Low beam cone half angle** • **Left headlight beam orientation** • **Right headlight beam orientation**
Brake lights	**Brake light intensity**
Reverse lights	**Reverse light intensity**
Turn signal lights	• **Turn signal light intensity** • **Period** • **Pulse width**

Headlights

`Headlight color [R,G,B]`, `HeadlightColor` — Headlight color
`[1,1,1]` (default) | 1-by-3 vector of RGB triplet values

Headlight color, specified as a normalized 1-by-3 vector of RGB triplet values.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `int8` | `uint8`

`High beam intensity`, `HighBeamIntensity` — High beam intensity
`100000` (default) | positive scalar

High beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam intensity`, `LowBeamIntensity` — Low beam intensity
`60000` (default) | positive scalar

Low beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`High beam cone half angle, HighBeamConeAngle` — High beam cone half angle

`1.22` (default) | positive scalar less than pi/2

High beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam cone half angle, LowBeamConeAngle` — Low beam cone half angle

`1.22` (default) | positive scalar less than pi/2

Low beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Left headlight beam orientation [Pitch, Yaw], LeftHeadlightOrientation` — Left headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the left headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Right headlight beam orientation [Pitch, Yaw], RightHeadlightOrientation` — Right headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the right headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Brake Lights

`Brake light intensity, BrakelightIntensity` — Intensity

`500` (default) | positive scalar

Brake light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Reverse Lights

`Reverse light intensity, ReverselightIntensity` — Intensity

`500` (default) | positive scalar

Reverse light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Turn Signal Lights

`Turn signal light intensity, SignallightIntensity` — Intensity

`500` (default) | positive scalar

Turn signal light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Period, SignallightPeriod` — Turn signal light period

`1` (default) | positive scalar

Turn signal light period, in s.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Pulse width, SignalPulseWidth` — Pulse width

`50` (default) | positive scalar less than 100

Turn signal light pulse width, as a percent of the period.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Initial Values

`Initial array values to translate vehicle per part, Translation` — Vehicle initial translation

zeros(5, 3) (default) | 5-by-3 array

Initial vehicle and wheel translation, in m. Array dimensions are 5-by-3.

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Initial vehicle translation along the inertial vehicle Z-down coordinate system *X*-, *Y*-, and *Z*- axes, respectively.

- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Initial wheel translation relative to vehicle, along the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The parameter contains translation information according to the axle and wheel locations.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element	Translation Axis
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down *Y*-axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down *Z*-axis
Rear left wheel, X_{RL}	`Translation(4,1)`	Vehicle Z-down *X*-axis
Rear left wheel, Y_{RL}	`Translation(4,2)`	Vehicle Z-down *Y*-axis
Rear left wheel, Z_{RL}	`Translation(4,3)`	Vehicle Z-down *Z*-axis
Rear right wheel, X_{RR}	`Translation(5,1)`	Vehicle Z-down *X*-axis
Rear right wheel, Y_{RR}	`Translation(5,2)`	Vehicle Z-down *Y*-axis
Rear right wheel, Z_{RR}	`Translation(5,3)`	Vehicle Z-down *Z*-axis

`Initial array values to rotate vehicle per part, Rotation` — Vehicle initial rotation

zeros(5, 3) (default) | 5-by-3 array

Initial vehicle and wheel rotation, about the vehicle Z-down *X*-, *Y*-, and *Z*- axes.

Array dimensions are 5-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Initial vehicle rotation about the inertial vehicle Z-down coordinate system*X*-, *Y*-, and *Z*- axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Initial wheel rotation relative to vehicle, about the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The parameter contains rotation information according to the axle and wheel locations.

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down *Y*-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down *Z*-axis
Rear left wheel, $Roll_{RL}$	`Rotation(4,1)`	Vehicle Z-down *X*-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(4,2)`	Vehicle Z-down *Y*-axis
Rear left wheel, Yaw_{RL}	`Rotation(4,3)`	Vehicle Z-down *Z*-axis
Rear right wheel, $Roll_{RR}$	`Rotation(5,1)`	Vehicle Z-down *X*-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(5,2)`	Vehicle Z-down *Y*-axis
Rear right wheel, Yaw_{RR}	`Rotation(5,3)`	Vehicle Z-down *Z*-axis

`Initial array values to scale vehicle per part, Scale` — Vehicle initial scale

ones(5, 3) (default) | 5-by-3 array

Initial vehicle and wheel scale, dimensionless. Array dimensions are 5-by-3.

- `Scale(1,1)`, `Scale(1,2)`, and `Scale(1,3)` — Initial vehicle scale along the inertial vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.
- `Scale(...,1)`, `Scale(...,2)`, and `Scale(...,3)` — Initial wheel scale relative to vehicle, along vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The parameter contains scale information according to the axle and wheel locations.

$$Scale = \begin{bmatrix} X_{V_{scale}} & Y_{V_{scale}} & Z_{V_{scale}} \\ X_{FL_{scale}} & Y_{FL_{scale}} & Z_{FL_{scale}} \\ X_{FR_{scale}} & Y_{FR_{scale}} & Z_{FR_{scale}} \\ X_{RL_{scale}} & Y_{RL_{scale}} & Z_{RL_{scale}} \\ X_{RR_{scale}} & Y_{RR_{scale}} & Z_{RR_{scale}} \end{bmatrix}$$

Scale	**Array Element**	**Scale Axis**
Vehicle, $X_{v_{scale}}$	`Scale(1,1)`	Vehicle Z-down X-axis
Vehicle, $Y_{v_{scale}}$	`Scale(1,2)`	Vehicle Z-down Y-axis
Vehicle, $Z_{v_{scale}}$	`Scale(1,3)`	Vehicle Z-down Z-axis
Front left wheel, $X_{FL_{scale}}$	`Scale(2,1)`	Vehicle Z-down X-axis
Front left wheel, $Y_{FL_{scale}}$	`Scale(2,2)`	Vehicle Z-down Y-axis
Front left wheel, $Z_{FL_{scale}}$	`Scale(2,3)`	Vehicle Z-down Z-axis
Front right wheel, $X_{FR_{scale}}$	`Scale(3,1)`	Vehicle Z-down X-axis
Front right wheel, $Y_{FR_{scale}}$	`Scale(3,2)`	Vehicle Z-down Y-axis
Front right wheel, $Z_{FR_{scale}}$	`Scale(3,3)`	Vehicle Z-down Z-axis
Rear left wheel, $X_{RL_{scale}}$	`Scale(4,1)`	Vehicle Z-down X-axis
Rear left wheel, $Y_{RL_{scale}}$	`Scale(4,2)`	Vehicle Z-down Y-axis
Rear left wheel, $Z_{RL_{scale}}$	`Scale(4,3)`	Vehicle Z-down Z-axis
Rear right wheel, $X_{RR_{scale}}$	`Scale(5,1)`	Vehicle Z-down X-axis
Rear right wheel, $Y_{RR_{scale}}$	`Scale(5,2)`	Vehicle Z-down Y-axis
Rear right wheel, $Z_{RR_{scale}}$	`Scale(5,3)`	Vehicle Z-down Z-axis

More About

Import Custom Meshes

To import custom meshes for defining custom vehicles, follow these steps:

1. Install the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package. See “Customize 3D Scenes for Vehicle Dynamics Simulations”.
2. On the block **Parameters** tab, set **Type** to `Custom`.
3. In the **Path to custom mesh** field, enter the path to the vehicle mesh in the Unreal Engine project. For example, enter `/MathWorksSimulation/Vehicles/Muscle/Meshes/SK_MuscleCar.SK_MuscleCar`.

   To create a custom vehicle mesh, see “Prepare Custom Vehicle Mesh for the Unreal Editor”.
4. Use the vehicle dimensions in the custom mesh to enter the dimensions in the corresponding block parameter fields.

Control Vehicle Lights

To control the lights of vehicles in a scene, follow these steps:

1. Install the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package. See “Customize 3D Scenes for Vehicle Dynamics Simulations”.
2. On the block **Light Controls** tab, select **Enable light controls**.
3. Use the enabled parameters to specify the vehicle lights for:

   - Headlights
   - Brake lights

  - Reverse lights
  - Turn signal lights

4. Connect Boolean light control signals to the `Signal lights` input port.

Version History

Introduced in R2019b

References

[1] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[2] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

See Also

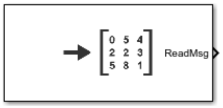
Simulation 3D Vehicle with Ground Following | Simulation 3D Scene Configuration

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Prepare Custom Vehicle Mesh for the Unreal Editor”
“Unreal Engine Simulation Environment Requirements and Limitations”

Simulation 3D Message Get

Retrieve data from Unreal Engine visualization environment
Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Core
Aerospace Blockset / Animation / Simulation 3D



Description

The Simulation 3D Message Get block retrieves data from the Unreal Engine 3D visualization environment. In your model, ensure that the Simulation 3D Scene Configuration block is at the same level as the Simulation 3D Message Get block.

Tip Verify that the Simulation 3D Scene Configuration block executes before the Simulation 3D Message Get block. That way, the Unreal Engine 3D visualization environment prepares the data before the Simulation 3D Message Get block receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

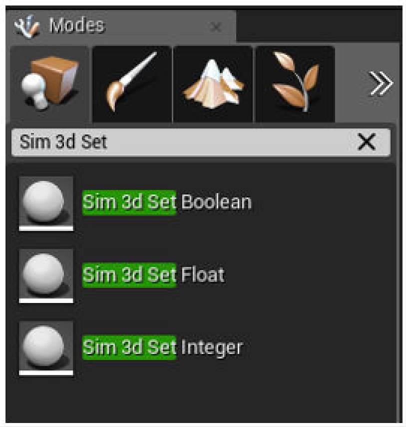
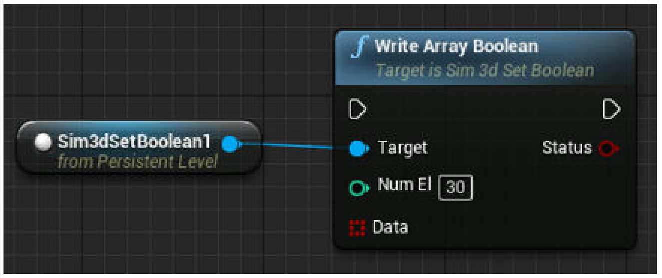
- Simulation 3D Scene Configuration — `0`
- Simulation 3D Message Get — `1`

For more information about execution order, see “Control and Display Execution Order”.

Configure Scenes to Send Data

To use the block, you must configure scenes in the Unreal Engine environment to send data to the Simulink model:

1. Install the “Customize 3D Scenes for Vehicle Dynamics Simulations”.
2. In the Unreal Editor, follow these general workflows to send data to Simulink. For detailed information, see “Get Started Communicating with the Unreal Engine Visualization Environment”.

Unreal Engine User	**Workflow**
Blueprint	**a** Instantiate the `Sim3DSet` actor that corresponds to the data type you want to send to the Simulink model. This example shows the Unreal Editor `Sim3DSet` data types.  **b** Specify an actor tag name that matches the Simulation 3D Message Get block **Signal name** parameter. **c** Navigate to the Level Blueprint. **d** Find the blueprint method for the `Sim3DSet` actor class based on the data type and size specified by the Simulation 3D Message Get block **Data type** and **Message size** parameters. For example, in Unreal Editor, this diagram shows that `Write Array Boolean` is the method for the `Sim3DSetBoolean` actor class that sends Boolean data type of array size 30.  **e** Compile and save the scene. **Note** By default, the Double Lane Change scene has a `Sim3DSetBoolean` actor with tag name `NumOfConesHit`.

Unreal Engine User	**Workflow**
C++ class	**a** Create a new actor class for the mesh or asset that you want the Simulink model to interact with. Derive it from `ASim3dActor`. **b** In the new actor class: • Declare a pointer to the signal name as a class field. • Get the class tag. • Create a signal writer and assign the pointer in the method `Sim3dSetup`. • In the method `Sim3dStep`, invoke the `WriteSimulation3DMessage` function to write the data to the Simulink model. • Delete the signal writer in the method `Sim3dRelease` of the actor.

For more information about the Unreal Editor, see the Unreal Engine 4 Documentation.

Ports

Output

`ReadMsg` — Data retrieved from scene
`scalar | array`

Data retrieved from the 3D visualization environment scene data. In the Unreal Engine environment, you can use the `Sim3DSet` class to configure scene actors to send data to the Simulink model.

For example, in the Unreal Editor, the Double Lane Change scene has a `Sim3DSetBoolean` actor with tag name `NumOfConesHit`. Use it to retrieve the number of cones the vehicle hits during a double-lane change maneuver.

This table provides the Double Lane Change scene cone name that corresponds to the `ReadMsg` array element.

Simulation 3D Message Get Block ReadMsg Value	Unreal Editor Cone Name	Simulation 3D Message Get Block Array Element	Unreal Editor Cone Name
`ReadMsg(1,1)`	`SM_Cone5`	`ReadMsg(2,1)`	`SM_Cone10`
`ReadMsg(1,2)`	`SM_Cone4`	`ReadMsg(2,2)`	`SM_Cone09`
`ReadMsg(1,3)`	`SM_Cone3`	`ReadMsg(2,3)`	`SM_Cone08`
`ReadMsg(1,4)`	`SM_Cone2`	`ReadMsg(2,4)`	`SM_Cone07`
`ReadMsg(1,5)`	`SM_Cone01`	`ReadMsg(2,5)`	`SM_Cone06`
`ReadMsg(1,6)`	`SM_Cone15`	`ReadMsg(2,6)`	`SM_Cone20`
`ReadMsg(1,7)`	`SM_Cone14`	`ReadMsg(2,7)`	`SM_Cone19`
`ReadMsg(1,8)`	`SM_Cone13`	`ReadMsg(2,8)`	`SM_Cone18`

Simulation 3D Message Get Block ReadMsg Value	Unreal Editor Cone Name	Simulation 3D Message Get Block Array Element	Unreal Editor Cone Name
`ReadMsg(1,9)`	`SM_Cone12`	`ReadMsg(2,9)`	`SM_Cone17`
`ReadMsg(1,10)`	`SM_Cone11`	`ReadMsg(2,10)`	`SM_Cone16`
`ReadMsg(1,11)`	`SM_Cone25`	`ReadMsg(2,11)`	`SM_Cone30`
`ReadMsg(1,12)`	`SM_Cone24`	`ReadMsg(2,12)`	`SM_Cone29`
`ReadMsg(1,13)`	`SM_Cone23`	`ReadMsg(2,13)`	`SM_Cone28`
`ReadMsg(1,14)`	`SM_Cone22`	`ReadMsg(2,14)`	`SM_Cone27`
`ReadMsg(1,15)`	`SM_Cone21`	`ReadMsg(2,15)`	`SM_Cone26`

Parameters

`Signal name, SigName` — Message signal name

`mySignal` (default)

Specifies the signal name in the 3D visualization environment. In the Unreal Engine environment, use the `Sim3DSet` actor class 'Tags' property located in the 'Details' pane.

For example, you can retrieve data from the double-lane change scene that indicates if cones are hit during a double-lane change maneuver. To retrieve cone hit data from the double-lane change scene, set this parameter to `NumOfConesHit`. In the double-lane change scene, the `Sim3DSet` actor class 'Tags' property is set to `NumOfConesHit`.

`Data type, DataType` — Message data type

`double*` | `single` | `int8*` | `uint8*` | `int16*` | `uint16*` | `int32` | `uint32*` | `boolean`

3D visualization environment signal data type. The supported data types depend on the Unreal Engine workflow.

Workflow	Supported Data Types

Blueprint	`single`
	`int32`
	`Boolean`

Workflow	**Supported Data Types**

*C++ class	`double`
	`single`
	`int8`
	`uint8`
	`int16`
	`uint16`
	`int32`
	`uint32`
	`Boolean`

In the Unreal Engine environment, instantiate the `Sim3DSet` actor class for the data type that you want to send to the Simulink model. For example, you can retrieve data from the double-lane change scene that indicates if cones are hit during a double-lane change maneuver. To retrieve cone hit data from the double-lane change scene, set this parameter to `boolean`. In the double-lane change scene, the `Sim3DSetBoolean` actor class is instantiated to send the cone hit or miss boolean data.

`Message size, MsgSize` — Message dimension
`[1 1]` (default) | `scalar` | `array`

3D visualization environment signal dimension. In the Unreal Engine environment blueprint, set the input to the node of the `Sim3DSet` actor class to specify the dimensions of data that you want to send to the Simulink model.

For example, you can retrieve data from the double-lane change scene that indicates if cones are hit during a double-lane change maneuver. To retrieve cone hit data from the double-lane change scene, set this parameter to `[2 15]`. In the double-lane change scene, the input to the blueprint node for the `Sim3DSetBoolean` actor class is set to 30, the number of cones in the scene.

`Sample time` — Sample time
`0.02` (default) | `-1` | `scalar`

Sample time, in s. The graphics frame rate is the inverse of the sample time. If you set the sample time to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

Version History

Introduced in R2019b

See Also

Double Lane Change | Simulation 3D Scene Configuration | Simulation 3D Message Set

Topics

"Get Started Communicating with the Unreal Engine Visualization Environment"
"Send Double-Lane Change Scene Data"

"Customize 3D Scenes for Vehicle Dynamics Simulations"

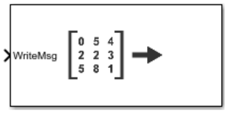
External Websites

Unreal Engine

Simulation 3D Message Set

Send data to Unreal Engine visualization environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Core
Aerospace Blockset / Animation / Simulation 3D
Simulink 3D Animation / Simulation 3D



Description

The Simulation 3D Message Set block sends data to the Unreal Engine 3D visualization environment. In your model, ensure that the Simulation 3D Scene Configuration block is at the same level as the Simulation 3D Message Set block.

Tip Verify that the Simulation 3D Message Set block executes before the Simulation 3D Scene Configuration block. That way, Simulation 3D Message Set prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

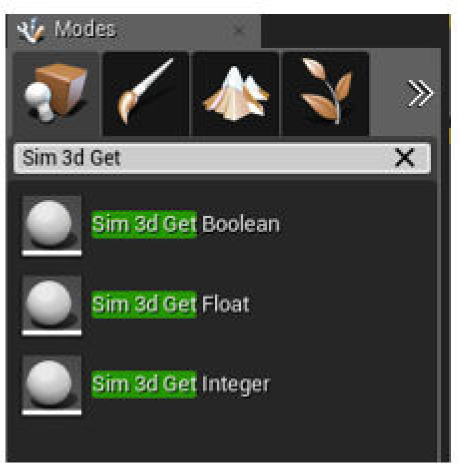
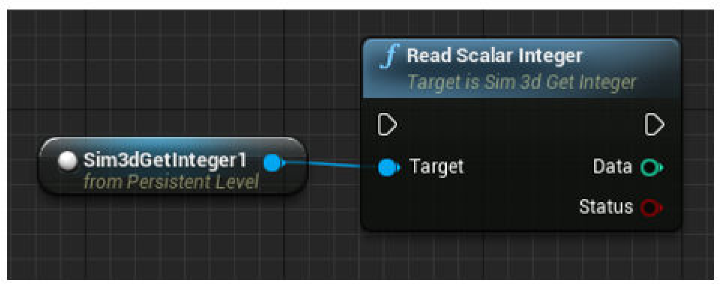
- Simulation 3D Scene Configuration — `0`
- Simulation 3D Message Set — `-1`

For more information about execution order, see “Control and Display Execution Order”.

Configure Scenes to Receive Data

To use the block, you must configure scenes in the Unreal Engine environment to receive data from the Simulink model:

1. Install the “Customize 3D Scenes for Vehicle Dynamics Simulations”.
2. In the Unreal Editor, follow these general workflows to receive data from Simulink. For detailed information, see “Get Started Communicating with the Unreal Engine Visualization Environment”.

Unreal Engine User	**Workflow**
Blueprint	**a** Instantiate the `Sim3DGet` actor that corresponds to the data type you want to receive from the Simulink model. This example shows the Unreal Editor `Sim3DGet` data types.  **b** Specify an actor tag name that matches the Simulation 3D Message Set block **Signal name** parameter. **c** Navigate to the Level Blueprint. **d** Find the blueprint method for the `Sim3DGet` actor class based on the data type and size that you want to receive from the Simulink model. For example, in Unreal Editor, this diagram shows that `Read Scalar Integer` is the method for `Sim3DGetInteger` actor class to receive `int32` data type of size scalar.  **e** Compile and save the scene. **Note** By default, the Double Lane Change scene has a `Sim3DGetInteger` actor with tag name `TrafficLight1`.

Unreal Engine User	Workflow
C++ class	**a** Create a new actor class for the mesh or asset that you want the Simulink model to interact with. Derive it from `ASim3dActor`. **b** In the new actor class: • Declare a pointer to the signal name as a class field. • Get the class tag. • Create a signal reader and assign the pointer in the method `Sim3dSetup`. • In the method `Sim3dStep`, invoke the `ReadSimulation3DMessage` function to read the data from a Simulink model. • Delete the signal reader in the method `Sim3dRelease` of the actor.

For more information about the Unreal Editor, see the Unreal Engine 4 Documentation.

Ports

Input

`WriteMsg` — Data sent to scene
`scalar` | `array`

Data sent to the 3D visualization environment scene. In the Unreal Engine environment, you can configure the `Sim3DGet` class to receive the data from the Simulink model.

For example, in the Unreal Editor, the Double Lane Change scene has a `Sim3DGetInteger` integer actor with tag name `TrafficLight1`. The integer actor reads `int32` data type from the Simulink model. You can use it to control the traffic signal light color.

This table provides the scene traffic signal light color that corresponds to the `WriteMsg` value in the Double Lane Change scene.

Simulation 3D Message Set Block `WriteMsg` Value	`TrafficLight1` Color
`0`	`Red`
`1`	`Yellow`
`2`	`Green`

Parameters

`Signal name, SigName` — Message signal name
`mySignal` (default)

Specifies the signal name in the 3D visualization environment. In the Unreal Engine environment, use the `Sim3Get` actor class 'Tags' property located in the 'Details' pane.

For example, you can send data to the double lane change scene that changes the traffic signal light color to red, yellow, or green. To send data to the traffic signal light, set this parameter to `TrafficLight1`. In the double lane change scene, the 'Tags' property value for `Sim3dGetInteger` actor class is set to TrafficLight1.

`Sample time` — Sample time
`0.02` (default) | `-1` | `scalar`

Sample time, in s. The graphics frame rate is the inverse of the sample time. If you set the sample time to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

Version History

Introduced in R2019b

See Also

Simulation 3D Scene Configuration | Simulation 3D Message Get

Topics

“Get Started Communicating with the Unreal Engine Visualization Environment”
“Send Double-Lane Change Scene Data”
“Customize 3D Scenes for Vehicle Dynamics Simulations”

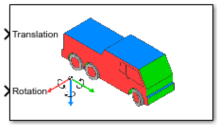
External Websites

Unreal Engine

Simulation 3D Tractor

Implement tractor in 3D environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Tractor block implements a tree-axle tractor in the 3D simulation environment.

To use the Simulation 3D Tractor block, ensure that the Simulation 3D Scene Configuration block is in your model. If you set the **Sample time** parameter of the Simulation 3D Tractor block to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

The block input uses the vehicle Z-down *right-handed* (RH) *Cartesian* coordinate system defined in SAE J670[1]. The coordinate system is inertial and initially aligned with the vehicle geometric center:

- *X*-axis — Points forward along vehicle longitudinal axis
- *Y*-axis — Points to the right along vehicle lateral axis
- *Z*-axis — Points downward

Tip Verify that the Simulation 3D Tractor block executes before the Simulation 3D Scene Configuration block. That way, Simulation 3D Vehicle prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Tractor — `-1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Input

`Translation` — Vehicle translation
7-by-3 array

Vehicle and wheel translation, in m. The array dimensions are 7-by-3, where:

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Vehicle translation along the inertial vehicle Z-down *X*-, *Y*-, and *Z*-axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Wheel translation relative to vehicle, along the vehicle Z-down *X*-, *Y*-, and *Z*-axes, respectively.

The signal contains translation information according to the axle and wheel locations.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{ML} & Y_{ML} & Z_{ML} \\ X_{MR} & Y_{MR} & Z_{MR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element	Translation Axis
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down Z-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down X-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down Y-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down Z-axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down X-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down Z-axis
Middle left wheel, X_{ML}	`Translation(4,1)`	Vehicle Z-down X-axis
Middle left wheel, Y_{ML}	`Translation(4,2)`	Vehicle Z-down Y-axis
Middle left wheel, Z_{ML}	`Translation(4,3)`	Vehicle Z-down Z-axis
Middle right wheel, X_{MR}	`Translation(5,1)`	Vehicle Z-down X-axis
Middle right wheel, Y_{MR}	`Translation(5,2)`	Vehicle Z-down Y-axis
Middle right wheel, Z_{MR}	`Translation(5,3)`	Vehicle Z-down Z-axis
Rear left wheel, X_{RL}	`Translation(6,1)`	Vehicle Z-down X-axis
Rear left wheel, Y_{RL}	`Translation(6,2)`	Vehicle Z-down Y-axis
Rear left wheel, Z_{RL}	`Translation(6,3)`	Vehicle Z-down Z-axis
Rear right wheel, X_{RR}	`Translation(7,1)`	Vehicle Z-down X-axis
Rear right wheel, Y_{RR}	`Translation(7,2)`	Vehicle Z-down Y-axis
Rear right wheel, Z_{RR}	`Translation(7,3)`	Vehicle Z-down Z-axis

`Rotation` — Vehicle rotation

7-by-3 array

Vehicle and wheel rotation, in rad. The array dimensions are 7-by-3, where:

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Vehicle rotation about the inertial vehicle Z-down X-, Y-, and Z-axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Wheel rotation relative to vehicle, about the vehicle Z-down X-, Y-, and Z-axes, respectively.

The signal contains rotation information according to the axle and wheel locations.

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{ML} & Pitch_{ML} & Yaw_{ML} \\ Roll_{MR} & Pitch_{MR} & Yaw_{MR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down *Y*-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down *Z*-axis
Middle left wheel, $Roll_{ML}$	`Rotation(4,1)`	Vehicle Z-down *X*-axis
Middle left wheel, $Pitch_{ML}$	`Rotation(4,2)`	Vehicle Z-down *Y*-axis
Middle left wheel, Yaw_{ML}	`Rotation(4,3)`	Vehicle Z-down *Z*-axis
Middle right wheel, $Roll_{MR}$	`Rotation(5,1)`	Vehicle Z-down *X*-axis
Middle right wheel, $Pitch_{MR}$	`Rotation(5,2)`	Vehicle Z-down *Y*-axis
Middle right wheel, Yaw_{MR}	`Rotation(5,3)`	Vehicle Z-down *Z*-axis
Rear left wheel, $Roll_{RL}$	`Rotation(6,1)`	Vehicle Z-down *X*-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(6,2)`	Vehicle Z-down *Y*-axis
Rear left wheel, Yaw_{RL}	`Rotation(6,3)`	Vehicle Z-down *Z*-axis
Rear right wheel, $Roll_{RR}$	`Rotation(7,1)`	Vehicle Z-down *X*-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(7,2)`	Vehicle Z-down *Y*-axis
Rear right wheel, Yaw_{RR}	`Rotation(7,3)`	Vehicle Z-down *Z*-axis

Parameters

Vehicle Parameters

Type — Tractor type

`Conventional tractor` (default) | `Cab-over tractor`

Type of tractor. For the dimensions, see:

- **Cab-Over Tractor**
- **Conventional Tractor**

`Color` — Vehicle color

`Red` (default) | `Orange` | `Yellow` | `Green` | `Blue` | `Black` | `White` | `Silver`

Specify the vehicle color.

`Name` — Name of vehicle

`SimulinkVehicle1` (default) | character vector

Name of the vehicle. By default, when you use the block in your model, the block sets the **Name** parameter to `SimulinkVehicleX`. The value of *X* depends on the number of Simulation 3D Vehicle with Ground Following and Simulation 3D Vehicle blocks that you have in your model.

Initial Values

`Initial array values to translate vehicle per part, Translation` — Vehicle initial translation

zeros(7, 3) (default) | 7-by-3 array

Initial vehicle and wheel translation, in m. The array dimensions are 7-by-3, where:

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Initial vehicle translation along the inertial vehicle Z-down coordinate system *X*-, *Y*-, and *Z*-axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Initial wheel translation relative to the vehicle, along the vehicle Z-down *X*-, *Y*-, and *Z*-axes, respectively.

The parameter contains translation information according to the axle and wheel locations.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{ML} & Y_{ML} & Z_{ML} \\ X_{MR} & Y_{MR} & Z_{MR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element	Translation Axis
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down *Y*-axis

Translation	Array Element	Translation Axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down Z-axis
Middle left wheel, X_{ML}	`Translation(4,1)`	Vehicle Z-down X-axis
Middle left wheel, Y_{ML}	`Translation(4,2)`	Vehicle Z-down Y-axis
Middle left wheel, Z_{ML}	`Translation(4,3)`	Vehicle Z-down Z-axis
Middle right wheel, X_{MR}	`Translation(5,1)`	Vehicle Z-down X-axis
Middle right wheel, Y_{MR}	`Translation(5,2)`	Vehicle Z-down Y-axis
Middle right wheel, Z_{MR}	`Translation(5,3)`	Vehicle Z-down Z-axis
Rear left wheel, X_{RL}	`Translation(6,1)`	Vehicle Z-down X-axis
Rear left wheel, Y_{RL}	`Translation(6,2)`	Vehicle Z-down Y-axis
Rear left wheel, Z_{RL}	`Translation(6,3)`	Vehicle Z-down Z-axis
Rear right wheel, X_{RR}	`Translation(7,1)`	Vehicle Z-down X-axis
Rear right wheel, Y_{RR}	`Translation(7,2)`	Vehicle Z-down Y-axis
Rear right wheel, Z_{RR}	`Translation(7,3)`	Vehicle Z-down Z-axis

`Initial array values to rotate vehicle per part, Rotation` — Vehicle initial rotation

zeros(7, 3) (default) | 7-by-3 array

Initial vehicle and wheel rotation, about the vehicle Z-down X-, Y-, and Z-axes, in rad.

The array dimensions are 7-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Initial vehicle rotation about the inertial vehicle Z-down coordinate system X-, Y-, and Z-axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Initial wheel rotation relative to the vehicle, about the vehicle Z-down X-, Y-, and Z-axes, respectively.

The parameter contains rotation information according to the axle and wheel locations.

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{ML} & Pitch_{ML} & Yaw_{ML} \\ Roll_{MR} & Pitch_{MR} & Yaw_{MR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down Z-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down X-axis

Rotation	Array Element	Rotation Axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down Y-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down Z-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down X-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down Z-axis
Middle left wheel, $Roll_{ML}$	`Rotation(4,1)`	Vehicle Z-down X-axis
Middle left wheel, $Pitch_{ML}$	`Rotation(4,2)`	Vehicle Z-down Y-axis
Middle left wheel, Yaw_{ML}	`Rotation(4,3)`	Vehicle Z-down Z-axis
Middle right wheel, $Roll_{MR}$	`Rotation(5,1)`	Vehicle Z-down X-axis
Middle right wheel, $Pitch_{MR}$	`Rotation(5,2)`	Vehicle Z-down Y-axis
Middle right wheel, Yaw_{MR}	`Rotation(5,3)`	Vehicle Z-down Z-axis
Rear left wheel, $Roll_{RL}$	`Rotation(6,1)`	Vehicle Z-down X-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(6,2)`	Vehicle Z-down Y-axis
Rear left wheel, Yaw_{RL}	`Rotation(6,3)`	Vehicle Z-down Z-axis
Rear right wheel, $Roll_{RR}$	`Rotation(7,1)`	Vehicle Z-down X-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(7,2)`	Vehicle Z-down Y-axis
Rear right wheel, Yaw_{RR}	`Rotation(7,3)`	Vehicle Z-down Z-axis

`Sample time` — Sample time
`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Version History

Introduced in R2020b

References

[1] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[2] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

See Also

Vehicle Body 3DOF Three Axles | Simulation 3D Trailer | Vehicle Body 6DOF Three Axles | Vehicle Body 3DOF | Vehicle Body 6DOF

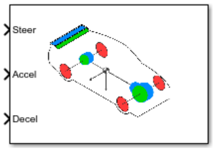
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”

Simulation 3D Physics Vehicle

Implement controllable 6DOF vehicle 3D environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Physics Vehicle block implements a controllable 10DOF vehicle in the 3D simulation environment, with a vertical DOF for each vehicle and 6DOF for the chassis.

To use the Simulation 3D Physics Vehicle block, ensure that the Simulation 3D Scene Configuration block is in your model. If you set the **Sample time** parameter of the Simulation 3D Physics Vehicle block to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

The block input uses the vehicle Z-down *right-handed* (RH) *Cartesian* coordinate system defined in SAE J670[1]. The coordinate system is inertial and initially aligned with the vehicle geometric center:

- *X*-axis — Along vehicle longitudinal axis, points forward
- *Y*-axis — Along vehicle lateral axis, points to the right
- *Z*-axis — Points downward

Tip Verify that the Simulation 3D Scene Configuration block executes before the Simulation 3D Physics Vehicle block. That way, the Unreal Engine 3D visualization environment prepares the data before the Simulation 3D Physics Vehicle block receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Physics Vehicle — `-1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Input

`SteerCmd` — Normalized steer angle
scalar

Normalized steer angle, specified as a scalar. `SteerCmd` corresponds to the minimum and maximum range of the steering angle as determined by the`Front wheel max steer angle` and `Rear wheel max steer angle` parameters, respectively

`AccelCmd` — Normalized vehicle acceleration
scalar

Normalized acceleration torque request to the vehicle powertrain, specified as a scalar. The exact response will be characterized by the engine, transmission and other vehicle parameters.

`DecelCmd` — Normalized vehicle deceleration
`scalar`

Normalized deceleration torque request to the vehicle braking system, specified as a scalar. The exact braking response will be characterized by the engine, transmission and other vehicle parameters.

`GearCmd` — Gear input
`1 | -1 | 0`

Gear input, specified as either `1`, `-1`, or `0`, with:

- `1` – Forward shift gear.
- `-1` – Reverse gear.
- `0` – Neutral gear.

If manual shift mode is selected, then the vehicle will shift according to what the signal is, but the values listed will still apply. Any input set that doesn't correspond to a valid gear will be ignored.

Output

`Info` — Bus signal
bus

Bus signal containing these block values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CG displacement along the earth-fixed *X*-axis	Computed	m
			`Y`	Vehicle CG displacement along the earth-fixed *Y*-axis	Computed	m
			`Z`	Vehicle CG displacement along the earth-fixed *Z*-axis	`0`	m
		`Vel`	`Xdot`	Vehicle CG velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Vehicle CG velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Vehicle CG velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Ang`	`phi`	Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	`0`	rad

Signal				**Description**	**Value**	**Units**
			`theta`	Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	`0`	rad
			`psi`	Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad
`BdyFrm`	`Cg`	`Vel`	`xdot`	Vehicle CG velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle CG velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle CG velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	`0`	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	`0`	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s
		`Acc`	`ax`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	gn
			`xddot`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2
			`zddot`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	m/s^2

Signal						Description	Value	Units
		AngAcc	pdot			Vehicle angular acceleration about the vehicle-fixed *x*-axis	0	rad/s
			qdot			Vehicle angular acceleration about the vehicle-fixed *y*-axis	0	rad/s
			rdot			Vehicle angular acceleration about the vehicle-fixed *z*-axis	Computed	rad/s
		DCM				Direction cosine matrix	Computed	rad
	Forces	Tires	FrntTires	Lft	Fx	Front left tire force, along the vehicle-fixed *x*-axis	Computed	N
					Fy	Front left tire force, along the vehicle-fixed *y*-axis	Computed	N
					Fz	Front left tire force, along the vehicle-fixed *z*-axis	Computed	N
				Rght	Fx	Front right tire force, along the vehicle-fixed *x*-axis	Computed	N
					Fy	Front right tire force, along the vehicle-fixed *y*-axis	Computed	N
					Fz	Front right tire force, along the vehicle-fixed *z*-axis	Computed	N
			RearTires	Lft	Fx	Rear left tire force, along the vehicle-fixed *x*-axis	Computed	N
					Fy	Rear left tire force, along the vehicle-fixed *y*-axis	Computed	N
					Fz	Rear left tire force, along the vehicle-fixed *z*-axis	Computed	N
				Rght	Fx	Rear right tire force, along the vehicle-fixed *x*-axis	Computed	N
					Fy	Rear right tire force, along the vehicle-fixed *y*-axis	Computed	N

Signal		Description	Variable	Units
Mtr	MtrSpd	Applied drive shaft angular speed input	ω_i	RPM
Trans	TransGearCmd	Commanded gear	N_{cmd}	N/A

Signal		Description	Variable	Units
	`TransGear`	Engaged gear	*N*	N/A

The `Info` output parameter is optional.

`xdot` — Vehicle longitudinal velocity

`scalar`

Vehicle CG velocity along the vehicle-fixed *x*-axis, in m/s.

`ydot` — Vehicle lateral velocity

`scalar`

Vehicle CG velocity along the vehicle-fixed *y*-axis, in m/s.

`psi` — Yaw

`scalar`

Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw), in rad.

`r` — Yaw rate

`scalar`

Vehicle angular velocity, `r`, about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

Parameters

Chassis

Type — Type

`Muscle car` (default) | `Sedan` | `Sport utility vehicle` | `Small pickup truck` | `Hatchback` | `Box truck`

Specify the vehicle type. This table provides links to the vehicle dimensions.

Vehicle type Setting	Vehicle Dimensions
`Muscle car`	**Muscle Car**
`Sedan`	**Sedan**
`Sport utility vehicle`	**Sport Utility Vehicle**
`Small pickup truck`	**Small Pickup Truck**
`Hatchback`	**Hatchback**
`Box truck`	**Box Truck**

Dependencies

Selecting `Custom` enables parameters that allow you to import a custom mesh for your vehicle.

`Color` — Color of vehicle

`Red` (default) | `Orange` | `Yellow` | `Green` | `Blue` | `Black` | `White` | `Silver`

Select the color of the vehicle.

`Name` — Name of vehicle
`SimulinkVehicle1` (default) | character vector

Name of vehicle. By default, when you use the block in your model, the block sets the **Name** parameter to `SimulinkVehicle`*X*. The value of *X* depends on the number of Simulation 3D Physics Vehicle and Simulation 3D Vehicle blocks that you have in your model.

`Initial position` — Vehicle initial position
[0, 0, -0.5] (default) | 1-by-3 array

Initial vehicle position specified by a 1-by-3 array, in m. Array elements are values along the **Coordinate system** parameter *X*-, *Y*-, and *Z*- axes, respectively.

`Initial rotation` — Vehicle initial rotation
[0, 0, 0] (default) | 1-by-3 array

Initial vehicle rotation specified by a 1-by-3 array, in rad. Array elements are values about the **Coordinate system** parameter *X*-, *Y*-, and *Z*- axes, respectively.

`Mass` — Vehicle mass
1500 (default) | scalar

Vehicle mass, in kg. This value does not include the wheel masses.

`Drag Coefficient` — Vehicle drag coefficient
0.3 (default) | scalar

Vehicle drag coefficient, dimensionless.

`Track width` — Distance between wheels
1.9 (default) | scalar

The vehicle track width refers to the distance between the wheels, or the axle length, specified in meters. This parameter is only used for custom mesh options.

`Chassis height` — Height of chassis
1.5 (default) | scalar

Height of chassis used to calculate drag force, specified in meters.

`Center of mass offset` — Offset in center of mass
[0, 0, 0] (default) | three element vector

Offset in center of mass, specified as a three element vector, in meters.

`Inertia tensor scaling vector` — Scaling of inertia tensor
[1, 1, 1] (default) | three element vector

Scaling of inertia tensor, specified as a three element dimensionless vector.

Powertrain and Driveline

Powertrain

`Motor torque indices` — Motor torque indices
`[ 0, 300, 400, 0 ]` (default) | `vector`

Motor torque indices, in N·m. You can use these pre-transmission values to represent either an electric motor or a conventional engine.

Data Types: `double`

`Motor speed breakpoints` — Motor speed breakpoints
`[ 0, 1000, 5500, 8000 ]` (default) | `vector`

Motor speed breakpoints, in rpm.

Data Types: `double`

`Max powertrain speed` — Max powertrain speed
`8500` (default) | `scalar`

Max powertrain speed, in rpm. If you select an automatic transmission option, this value also corresponds to the normalized shift points used in the up and downshift logic.

Data Types: `double`

`Powertrain rotational inertia` — Powertrain rotational inertia
`1` (default) | `scalar`

Powertrain rotational inertia, in kg·m^2.

Data Types: `double`

`Powertrain damping at full max torque request` — Powertrain damping at full max torque request
`0.15` (default) | `scalar`

Powertrain damping at full max torque request, in kg·m^2/s.

Data Types: `double`

`Powertrain damping at zero torque request, in gear` — Powertrain damping at zero torque request, in gear
`2` (default) | `scalar`

Powertrain damping at zero torque request, in gear, in kg·m^2/s.

Data Types: `double`

`Powertrain damping at zero torque request, in neutral` — Powertrain damping at zero torque request, in neutral
`0.35` (default) | `scalar`

Powertrain damping at zero torque request, in neutral, in kg·m^2/s.

Data Types: `double`

Driveline

`Differential type` — Differential
`Limited Slip` (default) | `Open`

For both `Limited Slip` and `Open` differentials, the block implements a differential as a planetary bevel gear train. The block matches the driveshaft bevel gear to the crown (ring) bevel gear.

If you select `Limited Slip`, the block prevents one of the wheels from slipping by splitting the torque applied to the left and right axles. With different torque applied to the axles, the wheels can move at different angular velocities, preventing slip.

`Drivetrain type` — Drivetrain

`Rear Wheel Drive` (default) | `Front Wheel Drive` | `All Wheel Drive`

Implement rear wheel, front wheel, or all wheel drive.

`Transmission type` — Transmission

`Automatic` (default) | `Manual`

Implement an automatic or manual transmission.

Note A response is required for the `GearCmd` input even if `Transmission type` is set to `Automatic`.

`Clutch slip torque` — Clutch slip torque

`10` (default) | `scalar`

Clutch slip torque, specified as a scalar in N·m.

Data Types: `double`

`Shift time` — Time taken to complete a shift

`0.25` (default) | `scalar`

Time taken to complete a shift, specified as a scalar in s.

Data Types: `double`

`Minimum shift latency` — Minimum time transmission will stay in newly selected gear

`1.0` (default) | `scalar`

Minimum time the transmission will stay in a newly selected gear to mitigate shift hunting, specified as a scalar in s.

Data Types: `double`

`Shift up indices` — Normalized engine speeds at which a shift up for forward gears begins

`[ 0.15, 0.65, 0.65, 0.65, 0.65 ]` (default) | `vector`

Normalized engine speeds with respect to the `Max powertrain speed` parameter, at which a shift up for forward gears will be initiated, specified as a scalar in s.

Data Types: `double`

`Shift down indices` — Normalized engine speeds at which a shift down for forward gears begins

`[ 0.15, 0.5, 0.5, 0.5, 0.5 ]` (default) | `vector`

Normalized engine speeds with respect to the `Max powertrain speed` parameter, at which a shift down for forward gears will be initiated, specified as a scalar in s.

Data Types: `double`

`Gear ratio vector` — Gear ratios
`[ -4, 4, 2, 1.5, 1.1, 1.0 ]` (default) | `vector`

Gear ratios, dimensionless.

Note At least one negative ratio is required for reverse gear. A neutral ratio is also required such that the length of the array should correspond to the number of forward gears plus two one for reverse and one for neutral.

Data Types: `double`

`Gear number vector` — Gear ratios
`[-1, 0, 1, 2, 3, 4, 5, 6, 7, 8]` (default) | `vector`

Gear number vector, dimensionless.

Data Types: `double`

`Front to rear torque split ratio` — Front to rear torque split ratio
0.5 (default) | scalar

Front to rear torque split ratio, dimensionless.

`1` indicates 100% torque to the front, whereas `0` indicates 100% to the rear.

`Final drive ratio` — Final drive ratio
4 (default) | `scalar`

Final drive ratio, dimensionless. This is the post transmission ratio, typically found in a differential or final drive gearbox.

Data Types: `double`

Steering and Brakes

Steering

`Front wheel max steer angle` — Front wheel max steer angle
45*pi/180 (default) | `scalar`

Front wheel max steer angle, in radians. This is the absolute angle which the front wheels will turn with a `-1` or `1` steer command input signal

Data Types: `double`

`Rear wheel max steer angle` — Rear wheel max steer angle
0 (default) | `scalar`

Rear wheel max steer angle, in radians. This is the absolute angle which the rear wheels will turn with a `-1` or `1` steer command input signal

Data Types: `double`

`Percent Ackerman, PctAck` — Percent Ackerman constant
`100` (default) | `scalar`

Constant value of percent Ackerman, in percent. A value of `100` indicates an ideal Ackermann inside or outside steering adjustment, while `0` indicates a pure parallel steer adjustment.

Data Types: `double`

`Maximum steering ratio breakpoints` — Maximum steering ratio
`[ 1, 0.8, 0.7 ]` (default) | `vector`

Maximum steering ratio breakpoints, dimensionless. This is the gain by which the steering command is affected by the vehicle speed brake points.

Data Types: `double`

`Steering ratio speed breakpoints` — Steering ratio speed breakpoints
`[ 0, 60, 120 ]./3.6` (default) | `vector`

Steering ratio speed breakpoints, in m/s. This is the vehicle forward speed break points used by the steer ratio gains.

Data Types: `double`

Brakes

`Maximum front wheel torque` — Maximum front wheel torque
`1500` (default) | `scalar`

Maximum front wheel torque, in N·m. This is the maximum braking torque applied to the front wheels corresponding to the normalized `DecelCmd` input.

Data Types: `double`

`Maximum rear wheel torque` — Maximum rear wheel torque
`1500` (default) | `scalar`

Maximum rear wheel torque, in N·m. This is the maximum braking torque applied to the rear wheels corresponding to the normalized `DecelCmd` input.

Data Types: `double`

`Front wheels affected by handbrake` — Selection
`off` (default) | `on`

Front wheels affected by handbrake.

Data Types: `Boolean`

`Rear wheels affected by handbrake` — Selection
`off` (default) | `on`

Rear wheels affected by handbrake.

Data Types: `Boolean`

`Enable handbrake input` — Enable handbrake input
`off` (default) | `on`

Enable handbrake input.

Data Types: `Boolean`

Suspension, Wheels and Tires

Suspension

`Front suspension force offset` — Front suspension force offset
`0` (default) | scalar

Front suspension force offset, specified as a scalar in meters.

`Maximum front suspension compression` — Maximum front suspension compression
`.01` (default) | scalar

Maximum front suspension compression or jounce, specified as a scalar in meters. Jounce is the upward movement or compression of suspension components.

`Maximum front suspension extension` — Maximum front suspension extension
`.01` (default) | scalar

Maximum front suspension extension or rebound, specified as a scalar in meters. Rebound is the downward movement or extension of suspension components.

`Front suspension natural frequency` — Natural frequency of front suspension
`7` (default) | scalar

Natural frequency of front suspension, in Hz. Suspension frequencies are the rate that a spring oscillates after applying a load (or hitting a bump).

`Front suspension damping ratio` — Damping ratio of front suspension
`1` (default) | scalar

Damping ratio of front suspension, dimensionless. Damping ratio is the coefficient of the damper at its peak level, where the vehicle will be in a completely stable state.

`Rear suspension force offset` — Rear suspension force offset
`0` (default) | scalar

Rear suspension force offset, specified as a scalar in meters.

`Maximum rear suspension compression` — Maximum rear suspension compression
`.01` (default) | scalar

Maximum rear suspension compression or jounce, specified as a scalar in meters. Jounce is the upward movement or compression of suspension components.

`Maximum rear suspension extension` — Maximum rear suspension extension
`.01` (default) | scalar

Maximum rear suspension extension or rebound, specified as a scalar in meters. Rebound is the downward movement or extension of suspension components.

`Rear suspension natural frequency` — Natural frequency of rear suspension
`7` (default) | scalar

Natural frequency of rear suspension, in Hz. Suspension frequencies are the rate that a spring oscillates after applying a load (or hitting a bump).

Wheels

`Front wheel mass` — Front wheel mass
`10` (default) | `scalar`

Front wheel mass, in kg.

Data Types: `double`

`Front wheel damping` — Front wheel damping
`0.25` (default) | `scalar`

Front wheel damping, in N·m/s.

Data Types: `double`

`Rear wheel mass` — Rear wheel mass
`20` (default) | `scalar`

Rear wheel mass, in kg.

Data Types: `double`

`Rear wheel damping` — Rear wheel damping
`0.25` (default) | `scalar`

Rear wheel damping, in N·m/s.

Data Types: `double`

Tires

`Front tire max lateral stiffness factor` — Front tire max lateral stiffness factor
`2.0` (default) | `scalar`

Front tire max lateral stiffness factor, dimensionless.

Data Types: `double`

`Front tire lateral stiffness` — Front tire lateral stiffness
`17` (default) | `scalar`

Front tire lateral stiffness, dimensionless.

Data Types: `double`

`Front tire longitudinal stiffness` — Front tire longitudinal stiffness
`1000` (default) | `scalar`

Front tire longitudinal stiffness, dimensionless.

Data Types: `double`

`Rear tire max lateral stiffness factor` — Front tire max lateral stiffness factor
`2.0` (default) | `scalar`

Front tire max lateral stiffness factor, dimensionless.

Data Types: `double`

`Rear tire lateral stiffness` — Front tire lateral stiffness

`17` (default) | `scalar`

Rear tire lateral stiffness, dimensionless.

Data Types: `double`

`Rear tire longitudinal stiffness` — Front tire longitudinal stiffness

`1000` (default) | `scalar`

Front tire longitudinal stiffness, dimensionless.

Data Types: `double`

`Friction scaling factor` — Friction scaling

`1.0` (default) | `scalar`

Nominal friction scale, dimensionless.

Data Types: `double`

Light Controls

`Enable light controls, VehLightsControl` — Control vehicle lights

`off` (default) | `on`

Select whether to control the vehicle headlights. Use the enabled parameters to set the light parameters, including headlight intensity.

Dependencies

Selecting this parameter:

- Creates the input port `Light controls`
- Enables these light parameters.

Lights	Light Parameters
Headlights	• **Headlight color** • **High beam intensity** • **Low beam intensity** • **High beam cone half angle** • **Low beam cone half angle** • **Left headlight beam orientation** • **Right headlight beam orientation**
Brake lights	**Brake light intensity**
Reverse lights	**Reverse light intensity**
Turn signal lights	• **Turn signal light intensity** • **Period** • **Pulse width**

Headlights

`Headlight color [R,G,B]`, `HeadlightColor` — Headlight color

`[1,1,1]` (default) | 1-by-3 vector of RGB triplet values

Headlight color, specified as a normalized 1-by-3 vector of RGB triplet values.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `int8` | `uint8`

`High beam intensity`, `HighBeamIntensity` — High beam intensity

`100000` (default) | positive scalar

High beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam intensity`, `LowBeamIntensity` — Low beam intensity

`60000` (default) | positive scalar

Low beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`High beam cone half angle`, `HighBeamConeAngle` — High beam cone half angle

`1.22` (default) | positive scalar less than pi/2

High beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam cone half angle`, `LowBeamConeAngle` — Low beam cone half angle

`1.22` (default) | positive scalar less than pi/2

Low beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Left headlight beam orientation [Pitch, Yaw]`, `LeftHeadlightOrientation` — Left headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the left headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Right headlight beam orientation [Pitch, Yaw], RightHeadlightOrientation` — Right headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the right headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Brake Lights

`Brake light intensity, BrakelightIntensity` — Intensity

`500` (default) | positive scalar

Brake light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Reverse Lights

`Reverse light intensity, ReverselightIntensity` — Intensity

`500` (default) | positive scalar

Reverse light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Turn Signal Lights

`Turn signal light intensity, SignallightIntensity` — Intensity

`500` (default) | positive scalar

Turn signal light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Period, SignallightPeriod` — Turn signal light period

`1` (default) | positive scalar

Turn signal light period, in s.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Pulse width, SignalPulseWidth` — Pulse width

`50` (default) | positive scalar less than 100

Turn signal light pulse width, as a percent of the period.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Sample Time

`Sample time` — Sample time

`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Ground Truth

`Output location and orientation` — Select to return location and orientation

`on` (default) | `off`

Select to return location and orientation.

Data Types: `Boolean`

`Output nominal vehicle state feedback` — Select to return nominal vehicle state feedback

`on` (default) | `off`

Select to return nominal vehicle state feedback

Data Types: `Boolean`

Version History

Introduced in R2022b

References

[1] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[2] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

See Also

Simulation 3D Scene Configuration

Topics

“Scene Interrogation in 3D Environment”

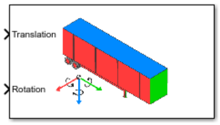
External Websites

Unreal Engine
UWheeledVehicleMovementComponent

Simulation 3D Trailer

Implement trailer in 3D environment

Library:	Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Trailer block implements a trailer with two or three axles in the 3D simulation environment.

To use the Simulation 3D Trailer block, ensure that the Simulation 3D Scene Configuration block is in your model. If you set the **Sample time** parameter of the Simulation 3D Trailer block to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

The block input uses the vehicle Z-down *right-handed* (RH) *Cartesian* coordinate system defined in SAE J670[1]. The coordinate system is inertial and initially aligned with the vehicle geometric center:

- *X*-axis — Points forward along vehicle longitudinal axis
- *Y*-axis — Points to the right along vehicle lateral axis
- *Z*-axis — Points downward

Tip Verify that the Simulation 3D Trailer block executes before the Simulation 3D Scene Configuration block. That way, Simulation 3D Vehicle prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Trailer — `-1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Input

`Translation` — Vehicle translation

5-by-3 array (default) | 7-by-3 array

Vehicle and wheel translation, in m. The array dimensions are `5`-by-`3` for a two-axle trailer and `7`-by-`3` for a three-axle trailer, where:

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Vehicle translation along the inertial vehicle Z-down *X*-, *Y*-, and *Z*-axes, respectively.

- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Wheel translation relative to vehicle, along the vehicle Z-down *X*-, *Y*-, and *Z*-axes, respectively.

The signal contains translation information according to the axle and wheel locations.

For a two-axle trailer:

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element	Translation Axis
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down *Y*-axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down *Z*-axis
Rear left wheel, X_{RL}	`Translation(4,1)`	Vehicle Z-down *X*-axis
Rear left wheel, Y_{RL}	`Translation(4,2)`	Vehicle Z-down *Y*-axis
Rear left wheel, Z_{RL}	`Translation(4,3)`	Vehicle Z-down *Z*-axis
Rear right wheel, X_{RR}	`Translation(5,1)`	Vehicle Z-down *X*-axis
Rear right wheel, Y_{RR}	`Translation(5,2)`	Vehicle Z-down *Y*-axis
Rear right wheel, Z_{RR}	`Translation(5,3)`	Vehicle Z-down *Z*-axis

For a three-axle trailer:

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{ML} & Y_{ML} & Z_{ML} \\ X_{MR} & Y_{MR} & Z_{MR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	Array Element	Translation Axis
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis

Translation	Array Element	Translation Axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down Z-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down X-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down Y-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down Z-axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down X-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down Z-axis
Middle left wheel, X_{ML} (for three-axle trailer)	`Translation(4,1)`	Vehicle Z-down X-axis
Middle left wheel, Y_{ML}	`Translation(4,2)`	Vehicle Z-down Y-axis
Middle left wheel, Z_{ML}	`Translation(4,3)`	Vehicle Z-down Z-axis
Middle right wheel, X_{MR}	`Translation(5,1)`	Vehicle Z-down X-axis
Middle right wheel, Y_{MR}	`Translation(5,2)`	Vehicle Z-down Y-axis
Middle right wheel, Z_{MR}	`Translation(5,3)`	Vehicle Z-down Z-axis
Rear left wheel, X_{RL}	`Translation(6,1)`	Vehicle Z-down X-axis
Rear left wheel, Y_{RL}	`Translation(6,2)`	Vehicle Z-down Y-axis
Rear left wheel, Z_{RL}	`Translation(6,3)`	Vehicle Z-down Z-axis
Rear right wheel, X_{RR}	`Translation(7,1)`	Vehicle Z-down X-axis
Rear right wheel, Y_{RR}	`Translation(7,2)`	Vehicle Z-down Y-axis
Rear right wheel, Z_{RR}	`Translation(7,3)`	Vehicle Z-down Z-axis

`Rotation` — Vehicle rotation

5-by-3 array (default) | 7-by-3 array

Vehicle and wheel rotation, in rad. The array dimensions are 5-by-3 for a two-axle trailer and 7-by-3 for a three-axle trailer, where:

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Vehicle rotation about the inertial vehicle Z-down X-, Y-, and Z-axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Wheel rotation relative to vehicle, about the vehicle Z-down X-, Y-, and Z-axes, respectively.

The signal contains rotation information according to the axle and wheel locations.

For a two-axle trailer:

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down Z-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down X-axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down Y-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down Z-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down X-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down Z-axis
Rear left wheel, $Roll_{RL}$	`Rotation(4,1)`	Vehicle Z-down X-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(4,2)`	Vehicle Z-down Y-axis
Rear left wheel, Yaw_{RL}	`Rotation(4,3)`	Vehicle Z-down Z-axis
Rear right wheel, $Roll_{RR}$	`Rotation(5,1)`	Vehicle Z-down X-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(5,2)`	Vehicle Z-down Y-axis
Rear right wheel, Yaw_{RR}	`Rotation(5,3)`	Vehicle Z-down Z-axis

For a three-axle trailer:

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{ML} & Pitch_{ML} & Yaw_{ML} \\ Roll_{MR} & Pitch_{MR} & Yaw_{MR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down Z-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down X-axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down Y-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down Z-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down X-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down Z-axis
Middle left wheel, $Roll_{ML}$	`Rotation(4,1)`	Vehicle Z-down X-axis
Middle left wheel, $Pitch_{ML}$	`Rotation(4,2)`	Vehicle Z-down Y-axis

Rotation	Array Element	Rotation Axis
Middle left wheel, Yaw_{ML}	`Rotation(4,3)`	Vehicle Z-down Z-axis
Middle right wheel, $Roll_{MR}$	`Rotation(5,1)`	Vehicle Z-down X-axis
Middle right wheel, $Pitch_{MR}$	`Rotation(5,2)`	Vehicle Z-down Y-axis
Middle right wheel, Yaw_{MR}	`Rotation(5,3)`	Vehicle Z-down Z-axis
Rear left wheel, $Roll_{RL}$	`Rotation(6,1)`	Vehicle Z-down X-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(6,2)`	Vehicle Z-down Y-axis
Rear left wheel, Yaw_{RL}	`Rotation(6,3)`	Vehicle Z-down Z-axis
Rear right wheel, $Roll_{RR}$	`Rotation(7,1)`	Vehicle Z-down X-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(7,2)`	Vehicle Z-down Y-axis
Rear right wheel, Yaw_{RR}	`Rotation(7,3)`	Vehicle Z-down Z-axis

Parameters

Vehicle Parameters

Type — Trailer type

`Two-axle trailer` (default) | `Three-axle trailer`

Trailer type. For the trailer dimensions, see:

- **Two-Axle Trailer**
- **Three-Axle Trailer**

`Name` — Name of vehicle

`SimulinkVehicle1` (default) | character vector

Name of vehicle. By default, when you use the block in your model, the block sets the **Name** parameter to `SimulinkVehicle`*X*. The value of *X* depends on the number of Simulation 3D Vehicle with Ground Following and Simulation 3D Vehicle blocks that you have in your model.

Initial Values

`Initial array values to translate vehicle per part, Translation` — Vehicle initial translation

zeros(5, 3) (default) | zeros(7, 3)

Initial vehicle and wheel translation, in m. The array dimensions are 5-by-3 for a two-axle trailer and 7-by-3 for a three-axle trailer, where:

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Initial vehicle translation along the inertial vehicle Z-down coordinate system X-, Y-, and Z-axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Initial wheel translation relative to vehicle, along the vehicle Z-down X-, Y-, and Z-axes, respectively.

The signal contains translation information according to the axle and wheel locations.

For a two-axle trailer:

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	**Array Element**	**Translation Axis**
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down *Z*-axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down *X*-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down *Y*-axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down *Z*-axis
Rear left wheel, X_{RL}	`Translation(4,1)`	Vehicle Z-down *X*-axis
Rear left wheel, Y_{RL}	`Translation(4,2)`	Vehicle Z-down *Y*-axis
Rear left wheel, Z_{RL}	`Translation(4,3)`	Vehicle Z-down *Z*-axis
Rear right wheel, X_{RR}	`Translation(5,1)`	Vehicle Z-down *X*-axis
Rear right wheel, Y_{RR}	`Translation(5,2)`	Vehicle Z-down *Y*-axis
Rear right wheel, Z_{RR}	`Translation(5,3)`	Vehicle Z-down *Z*-axis

For a three-axle trailer:

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_{FL} & Y_{FL} & Z_{FL} \\ X_{FR} & Y_{FR} & Z_{FR} \\ X_{ML} & Y_{ML} & Z_{ML} \\ X_{MR} & Y_{MR} & Z_{MR} \\ X_{RL} & Y_{RL} & Z_{RL} \\ X_{RR} & Y_{RR} & Z_{RR} \end{bmatrix}$$

Translation	**Array Element**	**Translation Axis**
Vehicle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis
Vehicle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down *Y*-axis
Vehicle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down *Z*-axis
Front left wheel, X_{FL}	`Translation(2,1)`	Vehicle Z-down *X*-axis
Front left wheel, Y_{FL}	`Translation(2,2)`	Vehicle Z-down *Y*-axis
Front left wheel, Z_{FL}	`Translation(2,3)`	Vehicle Z-down *Z*-axis

Translation	Array Element	Translation Axis
Front right wheel, X_{FR}	`Translation(3,1)`	Vehicle Z-down X-axis
Front right wheel, Y_{FR}	`Translation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Z_{FR}	`Translation(3,3)`	Vehicle Z-down Z-axis
Middle left wheel, X_{ML} (for three-axle trailer)	`Translation(4,1)`	Vehicle Z-down X-axis
Middle left wheel, Y_{ML}	`Translation(4,2)`	Vehicle Z-down Y-axis
Middle left wheel, Z_{ML}	`Translation(4,3)`	Vehicle Z-down Z-axis
Middle right wheel, X_{MR}	`Translation(5,1)`	Vehicle Z-down X-axis
Middle right wheel, Y_{MR}	`Translation(5,2)`	Vehicle Z-down Y-axis
Middle right wheel, Z_{MR}	`Translation(5,3)`	Vehicle Z-down Z-axis
Rear left wheel, X_{RL}	`Translation(6,1)`	Vehicle Z-down X-axis
Rear left wheel, Y_{RL}	`Translation(6,2)`	Vehicle Z-down Y-axis
Rear left wheel, Z_{RL}	`Translation(6,3)`	Vehicle Z-down Z-axis
Rear right wheel, X_{RR}	`Translation(7,1)`	Vehicle Z-down X-axis
Rear right wheel, Y_{RR}	`Translation(7,2)`	Vehicle Z-down Y-axis
Rear right wheel, Z_{RR}	`Translation(7,3)`	Vehicle Z-down Z-axis

`Initial array values to rotate vehicle per part, Rotation` — Vehicle initial rotation

zeros(5, 3) (default) | zeros(7, 3)

Initial vehicle and wheel rotation, about the vehicle Z-down X-, Y-, and Z-axes, in rad.

The array dimensions are 5-by-3 for a two-axle trailer and 7-by-3 for a three-axle trailer, where:

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Initial vehicle rotation about the inertial vehicle Z-down coordinate system X-, Y-, and Z-axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Initial wheel rotation relative to the vehicle, about the vehicle Z-down X-, Y-, and Z-axes, respectively.

The signal contains translation information according to the axle and wheel locations.

For a two-axle trailer:

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down Y-axis

Rotation	Array Element	Rotation Axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down Z-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down X-axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down Y-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down Z-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down X-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down Z-axis
Rear left wheel, $Roll_{RL}$	`Rotation(4,1)`	Vehicle Z-down X-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(4,2)`	Vehicle Z-down Y-axis
Rear left wheel, Yaw_{RL}	`Rotation(4,3)`	Vehicle Z-down Z-axis
Rear right wheel, $Roll_{RR}$	`Rotation(5,1)`	Vehicle Z-down X-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(5,2)`	Vehicle Z-down Y-axis
Rear right wheel, Yaw_{RR}	`Rotation(5,3)`	Vehicle Z-down Z-axis

For a three-axle trailer:

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{ML} & Pitch_{ML} & Yaw_{ML} \\ Roll_{MR} & Pitch_{MR} & Yaw_{MR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down Z-axis
Front left wheel, $Roll_{FL}$	`Rotation(2,1)`	Vehicle Z-down X-axis
Front left wheel, $Pitch_{FL}$	`Rotation(2,2)`	Vehicle Z-down Y-axis
Front left wheel, Yaw_{FL}	`Rotation(2,3)`	Vehicle Z-down Z-axis
Front right wheel, $Roll_{FR}$	`Rotation(3,1)`	Vehicle Z-down X-axis
Front right wheel, $Pitch_{FR}$	`Rotation(3,2)`	Vehicle Z-down Y-axis
Front right wheel, Yaw_{FR}	`Rotation(3,3)`	Vehicle Z-down Z-axis
Middle left wheel, $Roll_{ML}$	`Rotation(4,1)`	Vehicle Z-down X-axis
Middle left wheel, $Pitch_{ML}$	`Rotation(4,2)`	Vehicle Z-down Y-axis
Middle left wheel, Yaw_{ML}	`Rotation(4,3)`	Vehicle Z-down Z-axis
Middle right wheel, $Roll_{MR}$	`Rotation(5,1)`	Vehicle Z-down X-axis

Rotation	Array Element	Rotation Axis
Middle right wheel, $Pitch_{MR}$	`Rotation(5,2)`	Vehicle Z-down Y-axis
Middle right wheel, Yaw_{MR}	`Rotation(5,3)`	Vehicle Z-down Z-axis
Rear left wheel, $Roll_{RL}$	`Rotation(6,1)`	Vehicle Z-down X-axis
Rear left wheel, $Pitch_{RL}$	`Rotation(6,2)`	Vehicle Z-down Y-axis
Rear left wheel, Yaw_{RL}	`Rotation(6,3)`	Vehicle Z-down Z-axis
Rear right wheel, $Roll_{RR}$	`Rotation(7,1)`	Vehicle Z-down X-axis
Rear right wheel, $Pitch_{RR}$	`Rotation(7,2)`	Vehicle Z-down Y-axis
Rear right wheel, Yaw_{RR}	`Rotation(7,3)`	Vehicle Z-down Z-axis

`Sample time` — Sample time
`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Version History

Introduced in R2020b

References

[1] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology*. SAE J670. Warrendale, PA: Society of Automotive Engineers, 2008.

[2] Technical Committee. *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*. ISO 8855:2011. Geneva, Switzerland: International Organization for Standardization, 2011.

See Also

Vehicle Body 3DOF Three Axles | Simulation 3D Tractor | Trailer Body 3DOF | Trailer Body 6DOF

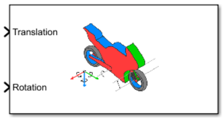
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”

Simulation 3D Motorcycle

Implement motorcycle in 3D environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Motorcycle block implements a motorcycle with two wheels in the 3D simulation environment.

To use this block, ensure that the Simulation 3D Scene Configuration block is in your model. If you set the **Sample time** parameter of this block to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

The block input uses the vehicle Z-down *right-handed* (RH) *Cartesian* coordinate system defined in SAE J670[1]. The coordinate system is inertial and initially aligned with the vehicle geometric center:

- *X*-axis — Along vehicle longitudinal axis, points forward
- *Y*-axis — Along vehicle lateral axis, points to the right
- *Z*-axis — Points downward

Tip Verify that the Simulation 3D Motorcycle block executes before the Simulation 3D Scene Configuration block. That way, Simulation 3D Motorcycle prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click each block and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Motorcycle — `-1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Input

`Translation` — Motorcycle translation

5-by-3 array

Motorcycle and component translation, in m. Array dimensions are 5-by-3.

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Motorcycle translation along the inertial vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Motorcycle component translation relative to vehicle, along the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The signal contains translation information according to the locations.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_H & Y_H & Z_H \\ X_{SA} & Y_{SA} & Z_{SA} \\ X_F & Y_F & Z_F \\ X_R & Y_R & Z_R \end{bmatrix}$$

Translation	Array Element	Translation Axis
Motorcycle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis
Motorcycle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down *Y*-axis
Motorcycle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down *Z*-axis
Handlebars, X_H	`Translation(2,1)`	Vehicle Z-down *X*-axis
Handlebars, Y_H	`Translation(2,2)`	Vehicle Z-down *Y*-axis
Handlebars, Z_H	`Translation(2,3)`	Vehicle Z-down *Z*-axis
Swing arm, X_{SA}	`Translation(3,1)`	Vehicle Z-down *X*-axis
Swing arm, Y_{SA}	`Translation(3,2)`	Vehicle Z-down *Y*-axis
Swing arm, Z_{SA}	`Translation(3,3)`	Vehicle Z-down *Z*-axis
Front wheel, X_F	`Translation(4,1)`	Vehicle Z-down *X*-axis
Front wheel, Y_F	`Translation(4,2)`	Vehicle Z-down *Y*-axis
Front wheel, Z_F	`Translation(4,3)`	Vehicle Z-down *Z*-axis
Rear wheel, X_R	`Translation(5,1)`	Vehicle Z-down *X*-axis
Rear wheel, Y_R	`Translation(5,2)`	Vehicle Z-down *Y*-axis
Rear wheel, Z_R	`Translation(5,3)`	Vehicle Z-down *Z*-axis

`Rotation` — Motorcycle rotation

5-by-3 array

Vehicle and component rotation, in rad. Array dimensions are 5-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Motorcycle rotation about the inertial vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Motorcycle component rotation relative to vehicle, about the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The signal contains rotation information according to the locations.

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_H & Pitch_H & Yaw_H \\ Roll_{SA} & Pitch_{SA} & Yaw_{SA} \\ Roll_F & Pitch_F & Yaw_F \\ Roll_R & Pitch_R & Yaw_R \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down Z-axis
Handlebar, $Roll_H$	`Rotation(2,1)`	Vehicle Z-down X-axis
Handlebar, $Pitch_H$	`Rotation(2,2)`	Vehicle Z-down Y-axis
Handlebar, Yaw_H	`Rotation(2,3)`	Vehicle Z-down Z-axis
Swing arm, $Roll_{SA}$	`Rotation(3,1)`	Vehicle Z-down X-axis
Swing arm, $Pitch_{SA}$	`Rotation(3,2)`	Vehicle Z-down Y-axis
Swing arm, Yaw_{SA}	`Rotation(3,3)`	Vehicle Z-down Z-axis
Front wheel, $Roll_F$	`Rotation(4,1)`	Vehicle Z-down X-axis
Front wheel, $Pitch_F$	`Rotation(4,2)`	Vehicle Z-down Y-axis
Front wheel, Yaw_F	`Rotation(4,3)`	Vehicle Z-down Z-axis
Rear wheel, $Roll_R$	`Rotation(5,1)`	Vehicle Z-down X-axis
Rear wheel, $Pitch_R$	`Rotation(5,2)`	Vehicle Z-down Y-axis
Rear wheel, Yaw_R	`Rotation(5,3)`	Vehicle Z-down Z-axis

`Light controls` — Vehicle lights on or off

1-by-5 vector

Light controls input signal, specified as a 1-by-5 Boolean vector. Each element of the vector turns a specific vehicle light on or off, as indicated in this table. A value of 1 turns the light on; a value of 0 turns the light off

Vector Element	Vehicle Light
(1,1)	Headlight high beam
(1,2)	Headlight low beam
(1,3)	Brake
(1,4)	Left signal
(1,5)	Right signal

Dependencies

To create this port, on the **Light Controls** tab, select **Enable light controls**.

Data Types: `Boolean`

Parameters

Vehicle Parameters

Type — Type
`Sports bike` (default) | `Motor bike` | `Scooter`

Use the **Type** parameter to specify the motorcycle type. This table provides links to the motorcycle dimensions.

Vehicle Type Setting	Vehicle Dimensions
`Sports bike`	**Sports Bike**
`Motor bike`	**Motor Bike**
`Scooter`	**Scooter**

`Color` — Color of vehicle

`Red` (default) | `Orange` | `Yellow` | `Green` | `Blue` | `Black` | `White` | `Silver`

Select the color of the vehicle.

Name — Name of motorcycle
`SimulinkVehicle1` (default) | character vector

Name of motorcycle. By default, when you use the block in your model, the block sets the **Name** parameter to `SimulinkVehicle`*X*. The value of *X* depends on the number of 3D simulation blocks that you have in your model.

`Sample time` — Sample time
`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Light Controls

`Enable light controls, VehLightsControl` — Control vehicle lights
`off` (default) | `on`

Select whether to control the vehicle headlights. Use the enabled parameters to set the light parameters, including headlight intensity.

Dependencies

Selecting this parameter:

- Creates the input port `Light controls`
- Enables these light parameters.

Lights	Light Parameters
Headlights	• **Headlight color** • **High beam intensity** • **Low beam intensity** • **High beam cone half angle** • **Low beam cone half angle** • **Left headlight beam orientation** • **Right headlight beam orientation**
Brake lights	**Brake light intensity**
Turn signal lights	• **Turn signal light intensity** • **Period** • **Pulse width**

Headlights

`Headlight color [R,G,B]`, `HeadlightColor` — Headlight color

`[1,1,1]` (default) | 1-by-3 vector of RGB triplet values

Headlight color, specified as a normalized 1-by-3 vector of RGB triplet values.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `int8` | `uint8`

`High beam intensity`, `HighBeamIntensity` — High beam intensity

`100000` (default) | positive scalar

High beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam intensity`, `LowBeamIntensity` — Low beam intensity

`60000` (default) | positive scalar

Low beam intensity, in cd.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`High beam cone half angle`, `HighBeamConeAngle` — High beam cone half angle

`1.22` (default) | positive scalar less than pi/2

High beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Low beam cone half angle, LowBeamConeAngle` — Low beam cone half angle

`1.22` (default) | positive scalar less than pi/2

Low beam cone half angle, in rad.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Left headlight beam orientation [Pitch, Yaw], LeftHeadlightOrientation` — Left headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the left headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Right headlight beam orientation [Pitch, Yaw], RightHeadlightOrientation` — Right headlight beam orientation

`[0,0]` (default) | 1-by-2 vector greater with values between -pi and pi

Pitch and yaw orientation of the right headlight beam orientation in the *Z*-down coordinate system, specified as a 1-by-2 vector, in rad. The first element of the vector, `[1,1]`, is the pitch angle. The second element of the vector, `[1,2]` is the yaw angle.

Dependencies

To enable this parameter, select **Enable light controls**.

Brake Lights

`Brake light intensity, BrakelightIntensity` — Intensity

`500` (default) | positive scalar

Brake light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Turn Signal Lights

`Turn signal light intensity, SignallightIntensity` — Intensity

`500` (default) | positive scalar

Turn signal light intensity, in cd/m^2.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Period, SignallightPeriod` — Turn signal light period

`1` (default) | positive scalar

Turn signal light period, in s.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

`Pulse width, SignalPulseWidth` — Pulse width

`50` (default) | positive scalar less than 100

Turn signal light pulse width, as a percent of the period.

Dependencies

To enable this parameter, select **Enable light controls**.

Data Types: `double`

Initial Values

`Initial array values to translate vehicle per part, Translation` — Motorcycle initial translation

zeros(3, 3) (default) | 3-by-3 array

Initial motorcycle and component translation, in m. Array dimensions are 5-by-3.

- `Translation(1,1)`, `Translation(1,2)`, and `Translation(1,3)` — Initial vehicle translation along the inertial vehicle Z-down coordinate system *X*-, *Y*-, and *Z*- axes, respectively.
- `Translation(...,1)`, `Translation(...,2)`, and `Translation(...,3)` — Initial motorcycle component translation relative to vehicle, along the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively.

The parameter contains translation information according to the locations.

$$Translation = \begin{bmatrix} X_v & Y_v & Z_v \\ X_H & Y_H & Z_H \\ X_{SA} & Y_{SA} & Z_{SA} \\ X_F & Y_F & Z_F \\ X_R & Y_R & Z_R \end{bmatrix}$$

Translation	Array Element	Translation Axis
Motorcycle, X_v	`Translation(1,1)`	Inertial vehicle Z-down *X*-axis

Translation	Array Element	Translation Axis
Motorcycle, Y_v	`Translation(1,2)`	Inertial vehicle Z-down Y-axis
Motorcycle, Z_v	`Translation(1,3)`	Inertial vehicle Z-down Z-axis
Handlebars, X_H	`Translation(2,1)`	Vehicle Z-down X-axis
Handlebars, Y_H	`Translation(2,2)`	Vehicle Z-down Y-axis
Handlebars, Z_H	`Translation(2,3)`	Vehicle Z-down Z-axis
Swing arm, X_{SA}	`Translation(3,1)`	Vehicle Z-down X-axis
Swing arm, Y_{SA}	`Translation(3,2)`	Vehicle Z-down Y-axis
Swing arm, Z_{SA}	`Translation(3,3)`	Vehicle Z-down Z-axis
Front wheel, X_F	`Translation(4,1)`	Vehicle Z-down X-axis
Front wheel, Y_F	`Translation(4,2)`	Vehicle Z-down Y-axis
Front wheel, Z_F	`Translation(4,3)`	Vehicle Z-down Z-axis
Rear wheel, X_R	`Translation(5,1)`	Vehicle Z-down X-axis
Rear wheel, Y_R	`Translation(5,2)`	Vehicle Z-down Y-axis
Rear wheel, Z_R	`Translation(5,3)`	Vehicle Z-down Z-axis

`Initial array values to rotate vehicle per part, Rotation` — Motorcycle initial rotation

zeros(5, 3) (default) | 5-by-3 array

Initial motorcycle and component rotation, about the vehicle Z-down X-, Y-, and Z- axes.

Array dimensions are 5-by-3.

- `Rotation(1,1)`, `Rotation(1,2)`, and `Rotation(1,3)` — Initial motorcycle rotation about the inertial vehicle Z-down coordinate system$X$-, Y-, and Z- axes, respectively.
- `Rotation(...,1)`, `Rotation(...,2)`, and `Rotation(...,3)` — Initial motorcycle component rotation relative to vehicle, about the vehicle Z-down X-, Y-, and Z- axes, respectively.

The parameter contains rotation information according to the location.

$$Rotation = \begin{bmatrix} Roll_v & Pitch_v & Yaw_v \\ Roll_{FL} & Pitch_{FL} & Yaw_{FL} \\ Roll_{FR} & Pitch_{FR} & Yaw_{FR} \\ Roll_{RL} & Pitch_{RL} & Yaw_{RL} \\ Roll_{RR} & Pitch_{RR} & Yaw_{RR} \end{bmatrix}$$

Rotation	Array Element	Rotation Axis
Vehicle, $Roll_v$	`Rotation(1,1)`	Inertial vehicle Z-down X-axis
Vehicle, $Pitch_v$	`Rotation(1,2)`	Inertial vehicle Z-down Y-axis
Vehicle, Yaw_v	`Rotation(1,3)`	Inertial vehicle Z-down Z-axis
Handlebar, $Roll_H$	`Rotation(2,1)`	Vehicle Z-down X-axis
Handlebar, $Pitch_H$	`Rotation(2,2)`	Vehicle Z-down Y-axis

Rotation	**Array Element**	**Rotation Axis**
Handlebar, Yaw_H	`Rotation(2,3)`	Vehicle Z-down Z-axis
Swing arm, $Roll_{SA}$	`Rotation(3,1)`	Vehicle Z-down X-axis
Swing arm, $Pitch_{SA}$	`Rotation(3,2)`	Vehicle Z-down Y-axis
Swing arm, Yaw_{SA}	`Rotation(3,3)`	Vehicle Z-down Z-axis
Front wheel, $Roll_F$	`Rotation(4,1)`	Vehicle Z-down X-axis
Front wheel, $Pitch_F$	`Rotation(4,2)`	Vehicle Z-down Y-axis
Front wheel, Yaw_F	`Rotation(4,3)`	Vehicle Z-down Z-axis
Rear wheel, $Roll_R$	`Rotation(5,1)`	Vehicle Z-down X-axis
Rear wheel, $Pitch_R$	`Rotation(5,2)`	Vehicle Z-down Y-axis
Rear wheel, Yaw_R	`Rotation(5,3)`	Vehicle Z-down Z-axis

Version History

Introduced in R2021b

References

[1] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology J670*. Warrendale, PA: SAE International, 2008.

See Also

Motorcycle Body Longitudinal In-Plane | Motorcycle Chain | Simulation 3D Scene Configuration

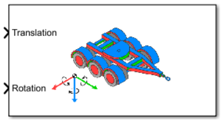
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Prepare Custom Vehicle Mesh for the Unreal Editor”
“Unreal Engine Simulation Environment Requirements and Limitations”

Simulation 3D Dolly

Implement dolly in 3D environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Dolly block implements a dolly in the 3D simulation environment.

To use this block, ensure that the Simulation 3D Scene Configuration block is in your model. If you set the **Sample time** parameter of this block to `-1`, the block uses the sample time specified in the Simulation 3D Scene Configuration block.

The block input uses the vehicle Z-down *right-handed* (RH) *Cartesian* coordinate system defined in SAE J670[1]. The coordinate system is inertial and initially aligned with the vehicle geometric center:

- *X*-axis — Along vehicle longitudinal axis, points forward
- *Y*-axis — Along vehicle lateral axis, points to the right
- *Z*-axis — Points downward

Tip Verify that the Simulation 3D Dolly block executes before the Simulation 3D Scene Configuration block. That way, Simulation 3D Dolly prepares the signal data before the Unreal Engine 3D visualization environment receives it. To check the block execution order, right-click each block and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Dolly — `-1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Input

`Translation` — Dolly translation

5-by-3 array (default) | 8-by-3 array | 11-by-3 array

Dolly, axle, and wheel translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively, in m. Array dimensions depend on the **Type** parameter.

Type Parameter	Array Dimension
`One-axle dolly` (default)	5-by-3 array

Type Parameter	Array Dimension
`Two-axle dolly`	8-by-3 array
`Three-axle dolly`	11-by-3 array

The signal contains translation information according to the dolly, axle, and wheel locations.

Signal Index	Description

`Translation(1,1)`
`Translation(1,2)`
`Translation(1,3)`
	Dolly translation, `Vehicle`, along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(2,1)`
`Translation(2,2)`
`Translation(2,3)`
	Hitch socket, `HitchSocket`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(3,1)`
`Translation(3,2)`
`Translation(3,3)`
	Axle one, `Axle1`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(4,1)`
`Translation(4,2)`
`Translation(4,3)`
	Axle one left wheel, `Wheel_L1`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(5,1)`
`Translation(5,2)`
`Translation(5,3)`
	Axle one right wheel, `Wheel_R1`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(6,1)`
`Translation(6,2)`
`Translation(6,3)`
	Axle two, `Axle2`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(7,1)`
`Translation(7,2)`
`Translation(7,3)`
	Axle two left wheel, `Wheel_L2`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(8,1)`
`Translation(8,2)`
`Translation(8,3)`
	Axle two right wheel, `Wheel_R2`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

Signal Index	Description

`Translation(9,1)`
`Translation(9,2)`
`Translation(9,3)`
	Axle three, `Axle3`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(10,1)`
`Translation(10,2)`
`Translation(10,3)`
	Axle three left wheel, `Wheel_L3`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(11,1)`
`Translation(11,2)`
`Translation(11,3)`
	Axle three right wheel, `Wheel_R3`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation` — Dolly rotation

5-by-3 array (default) | 8-by-3 array | 11-by-3 array

Dolly, axle, and wheel rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively, in m. Array dimensions depend on the **Type** parameter.

Type Parameter	Array Dimension
`One-axle dolly` (default)	5-by-3 array
`Two-axle dolly`	8-by-3 array
`Three-axle dolly`	11-by-3 array

The signal contains rotation information according to the dolly, axle, and wheel locations.

Signal Index	Description

`Rotation(1,1)`
`Rotation(1,2)`
`Rotation(1,3)`
	Dolly rotation, `Vehicle`, about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(2,1)`
`Rotation(2,2)`
`Rotation(2,3)`
	Hitch socket, `HitchSocket`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(3,1)`
`Rotation(3,2)`
`Rotation(3,3)`
	Axle one, `Axle1`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

Signal Index	Description

`Rotation(4,1)`
`Rotation(4,2)`
`Rotation(4,3)`
	Axle one left wheel, `Wheel_L1`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(5,1)`
`Rotation(5,2)`
`Rotation(5,3)`
	Axle one right wheel, `Wheel_R1`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(6,1)`
`Rotation(6,2)`
`Rotation(6,3)`
	Axle two, `Axle2`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(7,1)`
`Rotation(7,2)`
`Rotation(7,3)`
	Axle two left wheel, `Wheel_L2`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(8,1)`
`Rotation(8,2)`
`Rotation(8,3)`
	Axle two right wheel, `Wheel_R2`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(9,1)`
`Rotation(9,2)`
`Rotation(9,3)`
	Axle three, `Axle3`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(10,1)`
`Rotation(10,2)`
`Rotation(10,3)`
	Axle three left wheel, `Wheel_L3`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(11,1)`
`Rotation(11,2)`
`Rotation(11,3)`
	Axle three right wheel, `Wheel_R3`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

Parameters

Vehicle Parameters

Type — Type

`One-axle dolly` (default) | `Two-axle dolly` | `Three-axle dolly`

Use the **Type** parameter to specify the number of axles on the dolly. This table provides links to the dolly dimensions.

Type Setting	Dolly Dimensions
`One-axle dolly`	**One-Axle Dolly**
`Two-axle dolly`	**Two-Axle Dolly**
`Three-axle dolly`	**Three-Axle Dolly**

Name — Name of dolly

`SimulinkVehicle1` (default) | character vector

Name of dolly. By default, when you use the block in your model, the block sets the **Name** parameter to `SimulinkVehicle`*X*. The value of *X* depends on the number of simulation 3D vehicle blocks that you have in your model.

`Sample time` — Sample time

`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Initial Values

`Initial array values to translate vehicle per part, Translation` — Vehicle initial translation

zeros(5, 3) (default) | zeros(8, 3) | zeros(11, 3)

Initial dolly, axle, and wheel translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively, in m. Array dimensions depend on the **Type** parameter.

Type Parameter	Array Dimension
`One-axle dolly` (default)	5-by-3 array
`Two-axle dolly`	8-by-3 array
`Three-axle dolly`	11-by-3 array

The parameter contains the initial translation values according to the dolly, axle, and wheel locations.

Signal Index	Description

`Translation(1,1)`
`Translation(1,2)`
`Translation(1,3)`
	Dolly translation, `Vehicle`, along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(2,1)`
`Translation(2,2)`
`Translation(2,3)`
	Hitch socket, `HitchSocket`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(3,1)`
`Translation(3,2)`
`Translation(3,3)`
	Axle one, `Axle1`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

Signal Index	Description

`Translation(4,1)`
`Translation(4,2)`
`Translation(4,3)`
	Axle one left wheel, `Wheel_L1`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(5,1)`
`Translation(5,2)`
`Translation(5,3)`
	Axle one right wheel, `Wheel_R1`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(6,1)`
`Translation(6,2)`
`Translation(6,3)`
	Axle two, `Axle2`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(7,1)`
`Translation(7,2)`
`Translation(7,3)`
	Axle two left wheel, `Wheel_L2`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(8,1)`
`Translation(8,2)`
`Translation(8,3)`
	Axle two right wheel, `Wheel_R2`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(9,1)`
`Translation(9,2)`
`Translation(9,3)`
	Axle three, `Axle3`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(10,1)`
`Translation(10,2)`
`Translation(10,3)`
	Axle three left wheel, `Wheel_L3`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Translation(11,1)`
`Translation(11,2)`
`Translation(11,3)`
	Axle three right wheel, `Wheel_R3`, translation along the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Initial array values to rotate vehicle per part, Rotation` — Initial rotation
zeros(5, 3) (default) | zeros(8, 3) | zeros(11, 3)

Initial dolly, axle, and wheel rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes, respectively, in m. Array dimensions depend on the **Type** parameter.

Type Parameter	Array Dimension
`One-axle dolly` (default)	5-by-3 array

Type Parameter	**Array Dimension**
`Two-axle dolly`	8-by-3 array
`Three-axle dolly`	11-by-3 array

The parameter contains the initial rotation values according to the dolly, axle, and wheel locations.

Signal Index	**Description**

`Rotation(1,1)`
`Rotation(1,2)`
`Rotation(1,3)`
	Dolly rotation, `Vehicle`, about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(2,1)`
`Rotation(2,2)`
`Rotation(2,3)`
	Hitch socket, `HitchSocket`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(3,1)`
`Rotation(3,2)`
`Rotation(3,3)`
	Axle one, `Axle1`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(4,1)`
`Rotation(4,2)`
`Rotation(4,3)`
	Axle one left wheel, `Wheel_L1`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(5,1)`
`Rotation(5,2)`
`Rotation(5,3)`
	Axle one right wheel, `Wheel_R1`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(6,1)`
`Rotation(6,2)`
`Rotation(6,3)`
	Axle two, `Axle2`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(7,1)`
`Rotation(7,2)`
`Rotation(7,3)`
	Axle two left wheel, `Wheel_L2`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(8,1)`
`Rotation(8,2)`
`Rotation(8,3)`
	Axle two right wheel, `Wheel_R2`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

Signal Index	Description

`Rotation(9,1)`
`Rotation(9,2)`
`Rotation(9,3)`
	Axle three, `Axle3`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(10,1)`
`Rotation(10,2)`
`Rotation(10,3)`
	Axle three left wheel, `Wheel_L3`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

`Rotation(11,1)`
`Rotation(11,2)`
`Rotation(11,3)`
	Axle three right wheel, `Wheel_R3`, rotation about the vehicle Z-down *X*-, *Y*-, and *Z*- axes

Version History

Introduced in R2021b

References

[1] Vehicle Dynamics Standards Committee. *Vehicle Dynamics Terminology J670*. Warrendale, PA: SAE International, 2008.

See Also

Simulation 3D Scene Configuration

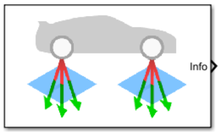
Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Prepare Custom Vehicle Mesh for the Unreal Editor”
“Unreal Engine Simulation Environment Requirements and Limitations”

Simulation 3D Terrain Sensor

Implement multipoint terrain sensor in 3D environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components

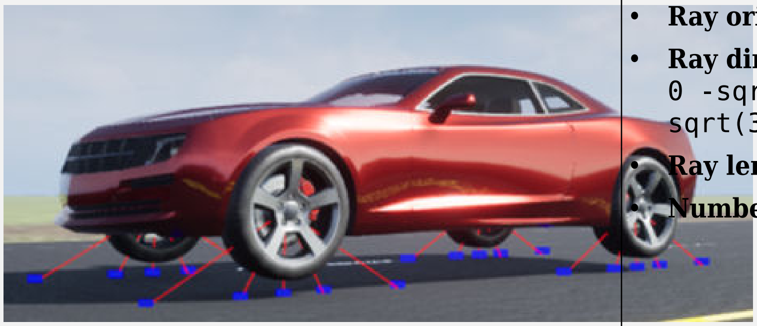


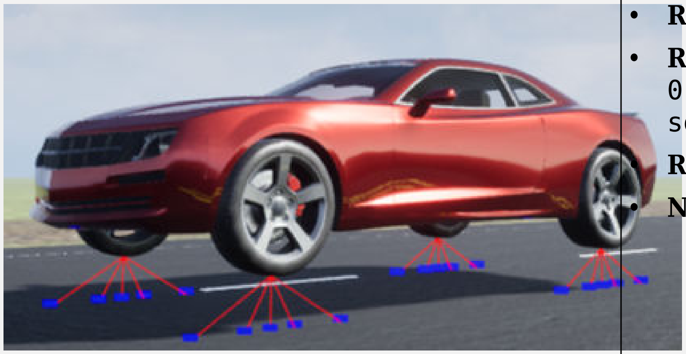
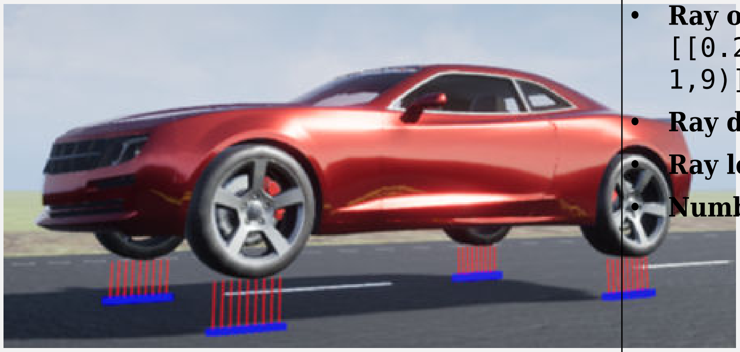
Description

The Simulation 3D Terrain Sensor block implements a multipoint terrain sensor in Unreal Engine. Use the block for contact modeling at high vehicle velocities over terrain changes, including speed bumps. The block implements ray tracing to detect the terrain below the tires. Use the block parameters to:

- Sense the terrain under any simulation 3D vehicle actor in the scene, including actors created by the Simulation 3D Vehicle and Simulation 3D Motorcycle blocks.
- Configure the ray origins, directions, and lengths to adjust the terrain sensor pattern for your scene and test scenario.

The block creates a terrain sensor pattern for each of the wheels on the vehicle actor. For specific patterns, this table provides the corresponding parameter settings.

Pattern	Parameter Settings
 • Five rays per wheel • Rays originate at point specified by wheel spin axis • Rays extend downward at 15° intervals • Rays length is 6 m	• **Ray origins** – `zeros(5,3)` • **Ray directions** – `[sqrt(3)/2 0 -1/2;1/2 0 -sqrt(3)/2; 0 0 -1; -1/2 0 -sqrt(3)/2; -sqrt(3)/2 0 -1/2]` • **Ray lengths** – `ones(5,1)*6` • **Number of wheels on parent vehicle** – 4

Pattern	Parameter Settings
 - Five rays per wheel - Rays originate at point specified by .37 m wheel radius - Rays extend downward at 15° intervals - Rays length is 4 m	- **Ray origins** – `zeros(5,3)+[0 0 -.37]` - **Ray directions** – `[sqrt(3)/2 0 -1/2;1/2 0 -sqrt(3)/2; 0 0 -1; -1/2 0 -sqrt(3)/2; -sqrt(3)/2 0 -1/2]` - **Ray lengths** – `ones(5,1)*4` - **Number of wheels on parent vehicle** – 4
 - Nine rays per wheel - Rays originate from points specified by .37 m wheel radius, along *Y*-axis of Z-up vehicle coordinate system - Rays extend downward, along *Z*-axis of Z-up vehicle coordinate system - Rays length is 2 m	- **Ray origins** – `[[0.2:-0.05:-0.2];zeros(1,9);zeros(1,9)]'+[0 0 -.37]` - **Ray directions** – `zeros(9,3)+[0 0 -1]` - **Ray lengths** – `ones(9,1)*2` - **Number of wheels on parent vehicle** – 4

Tip Verify that the Simulation 3D Scene Configuration block executes before the Simulation 3D Terrain Sensor block. That way, the Unreal Engine 3D visualization environment prepares the data before the Simulation 3D Terrain Sensor block receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Terrain Sensor — `1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Output

`Info` — Bus signal

bus

Bus signal containing block values. The signals are arrays that depend on the wheel location.

Signal	Description	Units
`Wheel`*`W`*`Positions`	Wheel *W* ray hit location relative to ray origin, specified as a real-valued *N*-by-3 array of the form [*X*, *Y*, *Z*] in the 3D visualization engine world coordinate system. *N* is the number of rays per wheel.	m
`Wheel`*`W`*`Status`	Wheel *W* ray hit status, specified as a *N*-by-1 array. *N* is the number of rays per wheel. • Hit an object – `1` • Miss an object – `0`	NA

Parameters

Mounting

`Sensor identifier, sensorId` — Unique sensor identifier

`0` (default) | positive integer

Unique sensor identifier, specified as a positive integer. In a multisensor system, the sensor identifier distinguishes between sensors. When you add a new sensor block to your model, the **Sensor identifier** of that block is *N* + 1. *N* is the highest **Sensor identifier** value among existing sensor blocks in the model.

Example: 2

`Parent name, VehicleIdentifier` — Name of parent to which sensor is mounted

`SimulinkVehicle1` (default) | vehicle name

Name of the parent to which the sensor is mounted, specified as the name of a vehicle in your model. The vehicle names that you can select correspond to the **Name** parameters of the simulation 3D vehicle blocks in your model.

Example: `SimulinkVehicle2`

Parameters

`Ray origins, RayOrigins` — Ray origin

`[0 0 1]` (default) | real-valued *N*-by-3 array

Ray origin relative to the wheel spin axis, specified as a real-valued *N*-by-3 array of the form [*X*, *Y*, *Z*]. *N* is the number of rays. Units are in meters.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the 3D visualization engine coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the right of the vehicle, as viewed when looking in the forward direction of the vehicle.
- The *Z*-axis points up.

Example: `zeros(10,3)`

`Ray directions, RayDirections` — Normalized ray direction
`[0 0 -1]` (default) | real-valued *N*-by-3 array

Normalized ray direction relative to wheel, specified as a real-valued *N*-by-3 array of the form [*X*, *Y*, *Z*]. *N* is the number of rays. Units are in dimensionless.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the 3D visualization engine coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the right of the vehicle, as viewed when looking in the forward direction of the vehicle.
- The *Z*-axis points up.

Example: `ones(10,3)`

`Ray lengths, RayLengths` — Length
`20` (default) | real-valued *N*-by-1 vector

Ray length, specified as a real-valued *N*-by-1 vector *N*, *N* is the number of rays. Units are in meters.

Example: `ones(10,1)*10`

`Number of wheels on parent vehicle` — Number of wheels
`4` (default) | positive integer

Name of wheels the parent to which the sensor is mounted. The vehicle name corresponds to the **Name** parameters of the simulation 3D vehicle blocks in your model.

Example: `6`

`Visualize trace line` — Visualize ray traces
off (default) | on

Enable trace line visualization.

`Sample time` — Sample time
`-1` (default) | `scalar`

Sample time, T_s. The graphics frame rate is the inverse of the sample time.

Version History

Introduced in R2022a

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle

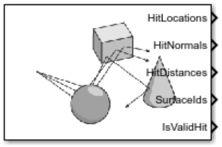
Topics
“Coordinate Systems in Vehicle Dynamics Blockset”
“Scene Interrogation in 3D Environment”

External Websites
Unreal Engine

Simulation 3D Ray Tracer

Implement ray tracing in 3D environment

Library: Vehicle Dynamics Blockset / Vehicle Scenarios / Sim3D / Sim3D Vehicle / Components



Description

The Simulation 3D Ray Tracer block implements ray tracing to get the positions, surface normals, surface identifiers, and distances for objects in the scene. You can specify block parameters that configure the ray origins, directions, and lengths to adjust the ray trace sensor pattern for your scene and test scenario.

Tip Verify that the Simulation 3D Scene Configuration block executes before the Simulation 3D Ray Tracer block. That way, the Unreal Engine 3D visualization environment prepares the data before the Simulation 3D Ray Tracer block receives it. To check the block execution order, right-click the blocks and select **Properties**. On the **General** tab, confirm these **Priority** settings:

- Simulation 3D Scene Configuration — `0`
- Simulation 3D Terrain Sensor — `1`

For more information about execution order, see “Control and Display Execution Order”.

Ports

Output

`HitLocations` — Hit locations

real-valued *N(B+1)*-by-3 array

Hit locations, returned as a real-valued *N(B+1)*-by-3 array of the form [*X*, *Y*, *Z*], in meters. *N* is the number of rays and *B* is the number of bounces per ray.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the 3D visualization engine coordinate system, where:

- The *X*-axis points forward from the vehicle
- The *Y*-axis points to the right of the vehicle, as viewed when looking in the forward direction of the vehicle
- The *Z*-axis points up

Data Types: `double`

`HitNormals` — Ray normal to hit location

real-valued *N(B+1)*-by-3 array

Ray normal to the hit location, returned as a real-valued *N(B+1)*-by-3 array of the form [*X*, *Y*, *Z*], in meters. *N* is the number of rays and *B* is the number of bounces per ray.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the 3D visualization engine coordinate system, where:

- The *X*-axis points forward from the vehicle
- The *Y*-axis points to the right of the vehicle, as viewed when looking in the forward direction of the vehicle
- The *Z*-axis points up

Data Types: `double`

`HitDistances` — Ray distance to hit location

real-valued *N(B+1)*-by-1 array

Ray distance to hit location, returned as a real-valued *N(B+1)*-by-1 vector *N*, in meters. *N* is the number of rays and *B* is the number of bounces per ray.

Data Types: `double`

`SurfaceIds` — Object IDs of hit surfaces

integer-valued *N(B+1)*-by-1 vector | `0`

Object identifier of the surfaces hit by the ray, returned as an integer-valued *N(B+1)*-by-1 vector *N*. *N* is the number of rays and *B* is the number of bounces per ray.

The returned surface identifiers are the object values specified when creating custom surfaces in the Unreal Editor. If a surface identifier is unknown, the block assigns it an ID of `0`. For information about adding surfaces, see Add a Surface Type in the Unreal Engine documentation.

Data Types: `uint8`

`IsValidHit` — Hit flag

N-by-1 vector

Hit flag, returned as a *N*-by-1 Boolean vector. *N* is the number of rays. A value of 1 indicates the ray hit a surface.

Data Types: `Boolean`

Parameters

Mounting

`Sensor identifier` — Unique sensor identifier

`1` (default) | positive integer

Unique sensor identifier, specified as a positive integer. In a multisensor system, the sensor identifier distinguishes between sensors. When you add a new sensor block to your model, the **Sensor identifier** of that block is *N* + 1. *N* is the highest **Sensor identifier** value among existing sensor blocks in the model.

Example: `2`

`Parent name` — Name of parent

`Scene Origin` (default)

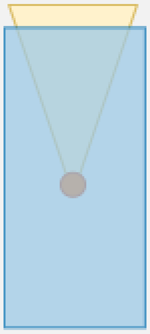
Name of parent to which the sensor is mounted, specified as the name of a vehicle in your model, or `Scene Origin`. The vehicle names that you can select correspond to the **Name** parameters of the simulation 3D vehicle blocks in your model.

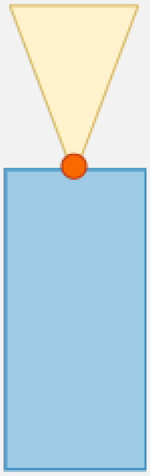
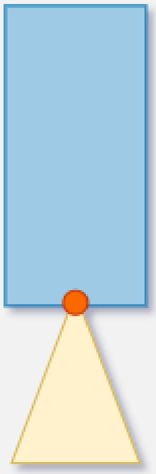
`Mounting location` — Sensor mounting location

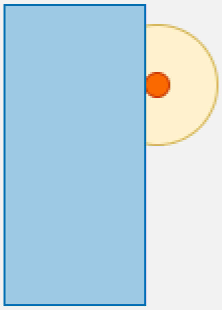
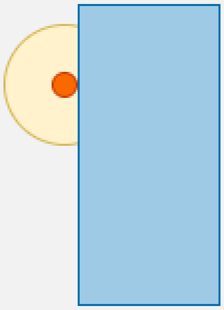
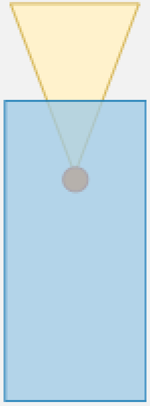
`Origin` (default) | `Front bumper` | `Rear bumper` | `Right mirror` | `Left mirror` | `Rearview mirror` | `Hood center` | `Roof center`

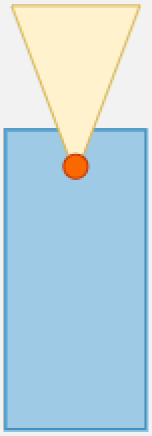
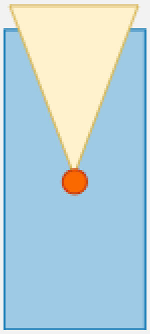
Sensor mounting location.

- When **Parent name** is `Scene Origin`, the block mounts the sensor to the origin of the scene. You can set the **Mounting location** to `Origin` only. During simulation, the sensor remains stationary.
- When **Parent name** is the name of a vehicle, the block mounts the sensor to one of the predefined mounting locations described in the table. During simulation, the sensor travels with the vehicle.

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Origin`	Forward-facing sensor mounted to the vehicle origin, which is on the ground and at the geometric center of the vehicle (see "Coordinate Systems in Vehicle Dynamics Blockset") 	[0, 0, 0]

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Front bumper`	Forward-facing sensor mounted to the front bumper 	[0, 0, 0]
`Rear bumper`	Backward-facing sensor mounted to the rear bumper 	[0, 0, 180]

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Right mirror`	Downward-facing sensor mounted to the right side-view mirror 	[0, –90, 0]
`Left mirror`	Downward-facing sensor mounted to the left side-view mirror 	[0, –90, 0]
`Rearview mirror`	Forward-facing sensor mounted to the rearview mirror, inside the vehicle 	[0, 0, 0]

Vehicle Mounting Location	Description	Orientation Relative to Vehicle Origin [Roll, Pitch, Yaw] (deg)
`Hood center`	Forward-facing sensor mounted to the center of the hood 	[0, 0, 0]
`Roof center`	Forward-facing sensor mounted to the center of the roof 	[0, 0, 0]

Roll, pitch, and yaw are clockwise-positive when looking in the positive direction of the *X*-axis, *Y*-axis, and *Z*-axis, respectively. When looking at a vehicle from the top down, the yaw angle (that is, the orientation angle) is counterclockwise-positive because you are looking in the negative direction of the axis.

The *X*-*Y*-*Z* mounting location of the sensor relative to the vehicle depends on the vehicle type. To specify the vehicle type, use the **Type** parameter of the Simulation 3D Vehicle block to which you mount the sensor. To obtain the *X*-*Y*-*Z* mounting locations for a vehicle type, see the reference page for that vehicle.

To determine the location of the sensor in world coordinates, open the sensor block. Then, on the **Ground Truth** tab, select the **Output location (m) and orientation (rad)** parameter and inspect the data from the **Location** output port.

`Specify offset` — Specify offset from mounting location

`off` (default) | `on`

Select this parameter to specify an offset from the mounting location by using the **Relative translation [X, Y, Z] (m)** and **Relative rotation [Roll, Pitch, Yaw] (deg)** parameters.

`Relative translation [X, Y, Z] (m)` — Translation offset relative to mounting location

`[0, 0, 0]` (default) | real-valued 1-by-3 vector

Translation offset relative to the mounting location of the sensor, specified as a real-valued 1-by-3 vector of the form [*X*, *Y*, *Z*], in meters.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle
- The *Y*-axis points to the left of the vehicle, as viewed when looking in the forward direction of the vehicle
- The *Z*-axis points up

The origin is the mounting location specified in the **Mounting location** parameter. This origin is different from the vehicle origin, which is the geometric center of the vehicle.

If you mount the sensor to the scene origin by setting **Parent name** to `Scene Origin`, then *X*, *Y*, and *Z* are in the world coordinates of the scene.

For more details about the vehicle and world coordinate systems, see “Coordinate Systems in Vehicle Dynamics Blockset”.

Example: `[0,0,0.01]`

Dependencies

To enable this parameter, select **Specify offset**.

`Relative rotation [Roll, Pitch, Yaw] (deg)` — Rotational offset relative to mounting location

`[0, 0, 0]` (default) | real-valued 1-by-3 vector

Rotational offset relative to the mounting location of the sensor, specified as a real-valued 1-by-3 vector of the form [*Roll*, *Pitch*, *Yaw*], in degrees. Roll, pitch, and yaw are the angles of rotation about the *X*-, *Y*-, and *Z*-axes, respectively.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when looking in the forward direction of the vehicle.
- The *Z*-axis points up.
- Roll, pitch, and yaw are clockwise-positive when looking in the forward direction of the *X*-axis, *Y*-axis, and *Z*-axis, respectively. If you view a scene from a 2D top-down perspective, then the yaw angle (also called the orientation angle) is counterclockwise-positive because you are viewing the scene in the negative direction of the *Z*-axis.

The origin is the mounting location specified in the **Mounting location** parameter. This origin is different from the vehicle origin, which is the geometric center of the vehicle.

If you mount the sensor to the scene origin by setting **Parent name** to `Scene Origin`, then *X*, *Y*, and *Z* are in the world coordinates of the scene.

For more details about the vehicle and world coordinate systems, see “Coordinate Systems in Vehicle Dynamics Blockset”.

Example: `[0,0,10]`

Dependencies

To enable this parameter, select **Specify offset**.

Parameters

`Ray origins, RayOrigins` — Ray origin

`zeros(10,3)` (default) | real-valued *N*-by-3 array

Ray origin relative to sensor mounting location, specified as a real-valued *N*-by-3 array of the form [*X*, *Y*, *Z*], in meters. *N* is the number of rays.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the 3D visualization engine coordinate system, where:

- The *X*-axis points forward from the vehicle
- The *Y*-axis points to the right of the vehicle, as viewed when looking in the forward direction of the vehicle
- The *Z*-axis points up

Example: `zeros(10,3)`

`Ray directions, RayDirections` — Normalized ray direction

`ones(10,3)` (default) | real-valued *N*-by-3 array

Normalized ray direction relative to sensor mounting location, specified as a real-valued *N*-by-3 array of the form [*X*, *Y*, *Z*]. *N* is the number of rays. The units are dimensionless.

If you mount the sensor to a vehicle by setting **Parent name** to the name of that vehicle, then *X*, *Y*, and *Z* are in the 3D visualization engine coordinate system, where:

- The *X*-axis points forward from the vehicle
- The *Y*-axis points to the right of the vehicle, as viewed when looking in the forward direction of the vehicle
- The *Z*-axis points up

Example: `ones(10,3)`

`Max ray lengths, RayLengths` — Maximum total ray length

`ones(10,1)*10` (default) | real-valued *N*-by-1 vector

Maximum total ray length of a multi-bounce trace path, specified as a real-valued *N*-by-1 vector, in meters. *N* is the number of rays.

Example: `ones(10,1)*10`

`Number of bounces` — Number of bounces per ray

`2` (default) | positive integer

Number of bounces that a trace may have before terminating, *B*, specified as an integer.

Example: `0`

`Visualize trace line` — Visualize ray traces
on (default) | off

Whether to enable Unreal Engine trace line visualization for the ray tracer.

`Enable optimization` — Enable optimization
on (default) | off

Whether to enable optimization of the ray tracer. Enabling this parameter allows the block to perform concurrent traces. Enable this parameter when the number of traces is large and your machine has multiple cores.

`Sample time` — Sample time

`-1` (default) | positive scalar

Sample time of the block, in seconds, specified as a positive scalar. The 3D simulation environment frame rate is the inverse of the sample time.

If you set the sample time to `-1`, the block inherits its sample time from the Simulation 3D Scene Configuration block.

Version History

Introduced in R2022b

See Also

Simulation 3D Camera Get | Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

"Scene Interrogation in 3D Environment"

External Websites

Unreal Engine

8

Scenes

Straight Road

Straight road 3D environment

Description

The **Straight Road** scene is a 3D environment of a straight four-lane divided highway. The scene is rendered using RoadRunner.

Setup

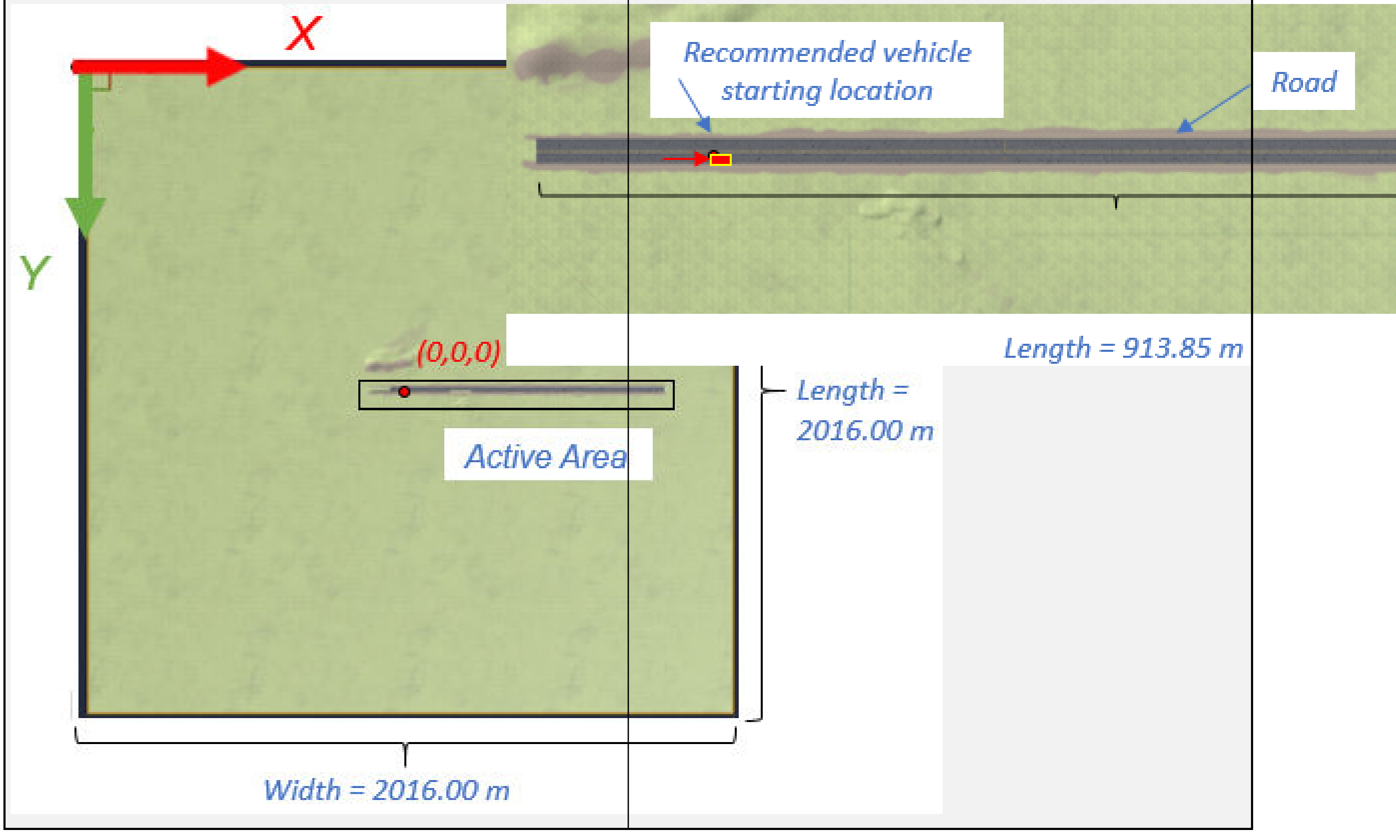
To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `Straight road`.

Layout

The scene uses the world coordinate system to locate objects.

The active area of the scene contains the road.

Overall	Active Area
	

Scene Dimensions

This table provides the scene area corner locations in the world coordinate system. Dimensions are in m.

Locations	X (m)	Y (m)	Z (m)
Scene — Top left	`-1008`	`-1008`	`0`
Scene — Bottom right	`1008`	`1008`	`0`
Active area — Bottom left	`-800`	`8.35`	`0`

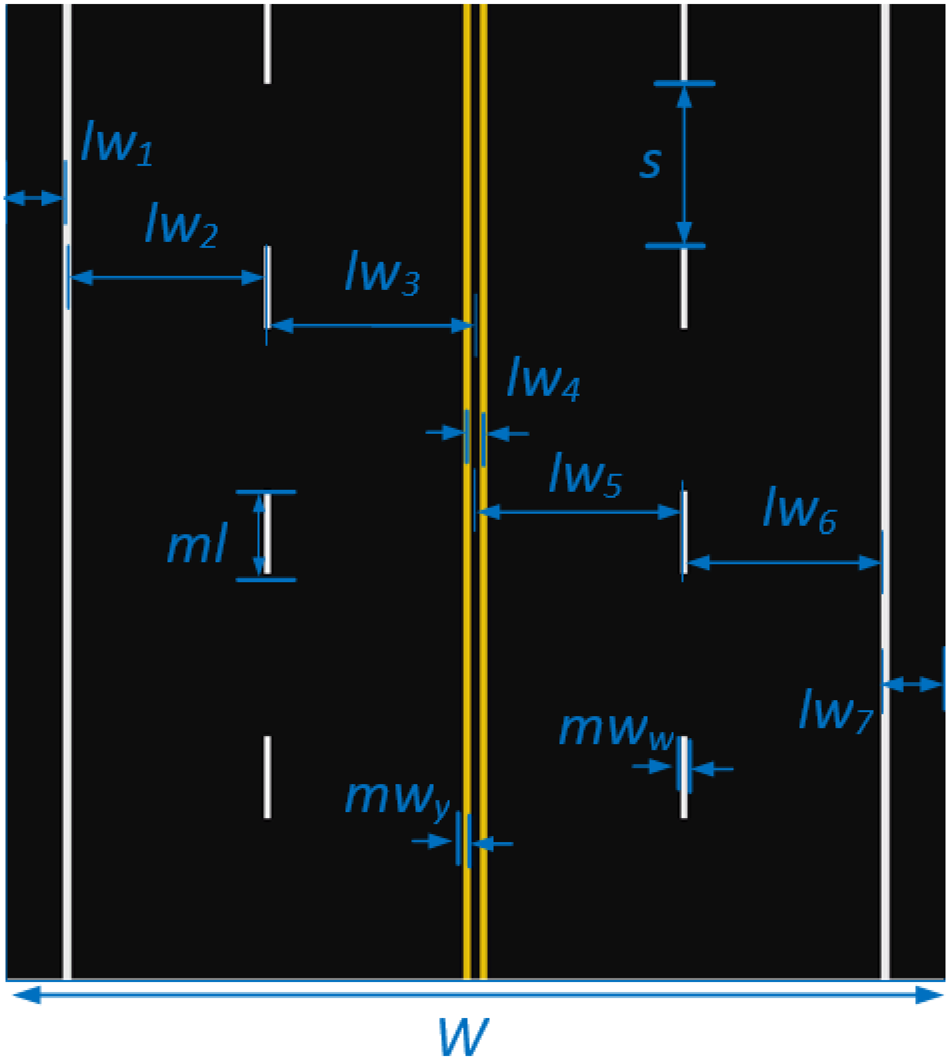
Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
`-118`	`5.7`	`0`	`0`	`0`	`0`

Lane Dimensions

This figure and table provides the lane dimensions, in m.

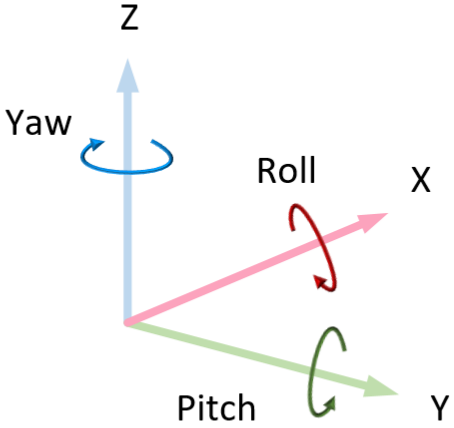


Variable	Dimension (m)
lw_1	0.625
lw_2	3.85
lw_3	3.85
lw_4	0.34
lw_5	3.85
lw_6	3.85
lw_7	0.625
ml	1.5
s	4.5

Variable	Dimension (m)
mw_w	`0.125`
mw_y	`0.125`
W	`16.70`

World Coordinate System

The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about X-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about Y-axis
Z	Extends upwards Yaw — Left-handed rotation about Z-axis

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `HwStrght`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner
Behavior changed in R2022b

Starting from R2022b, the Straight Road scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022b locations.

See Also

Simulation 3D Scene Configuration | Curved Road | Double Lane Change | Open Surface | Large Parking Lot | Parking Lot | US City Block | US Highway | Virtual Mcity

Topics

"Unreal Engine Simulation Environment Requirements and Limitations"
"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Customize 3D Scenes for Vehicle Dynamics Simulations"

Curved Road

Curved road 3D environment

Description

The **Curved Road** scene is a 3D environment of a curved highway loop. The scene is rendered using RoadRunner.

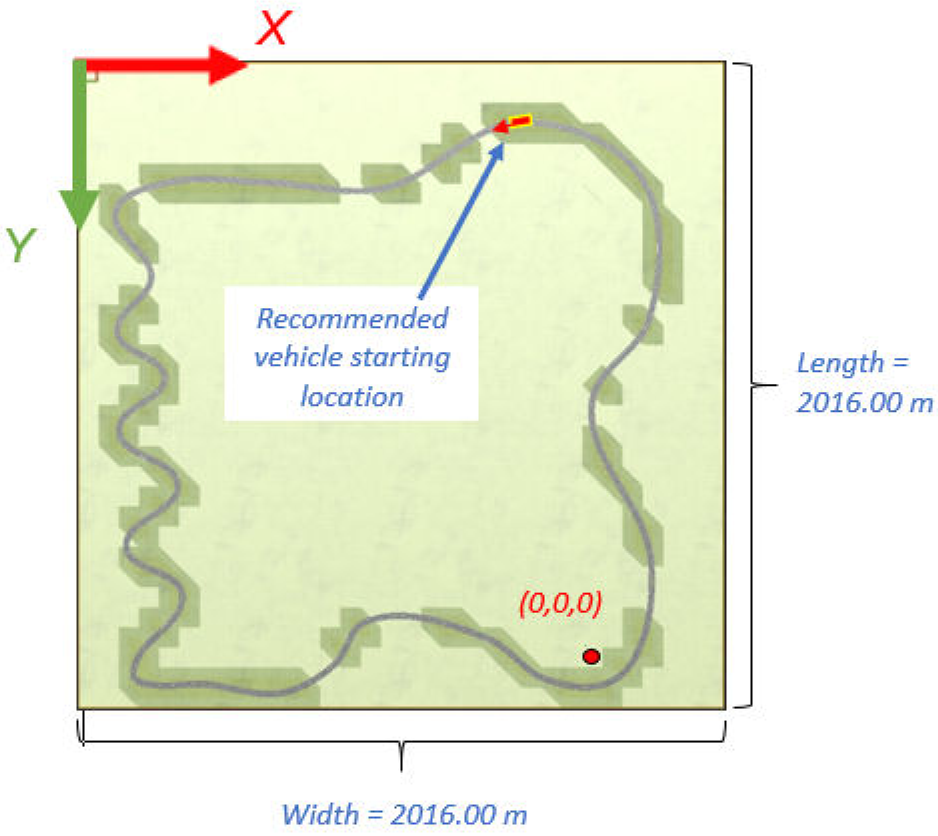
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `Curved road`.

Layout

The scene uses the world coordinate system to locate objects.



Scene Dimensions

This table provides the scene corner locations in the world coordinate system. Dimensions are in m.

Location	X (m)	Y (m)	Z (m)
Scene — Bottom left	-1587.75	195.39	0
Scene — Top right	428.26	-1820.60	0

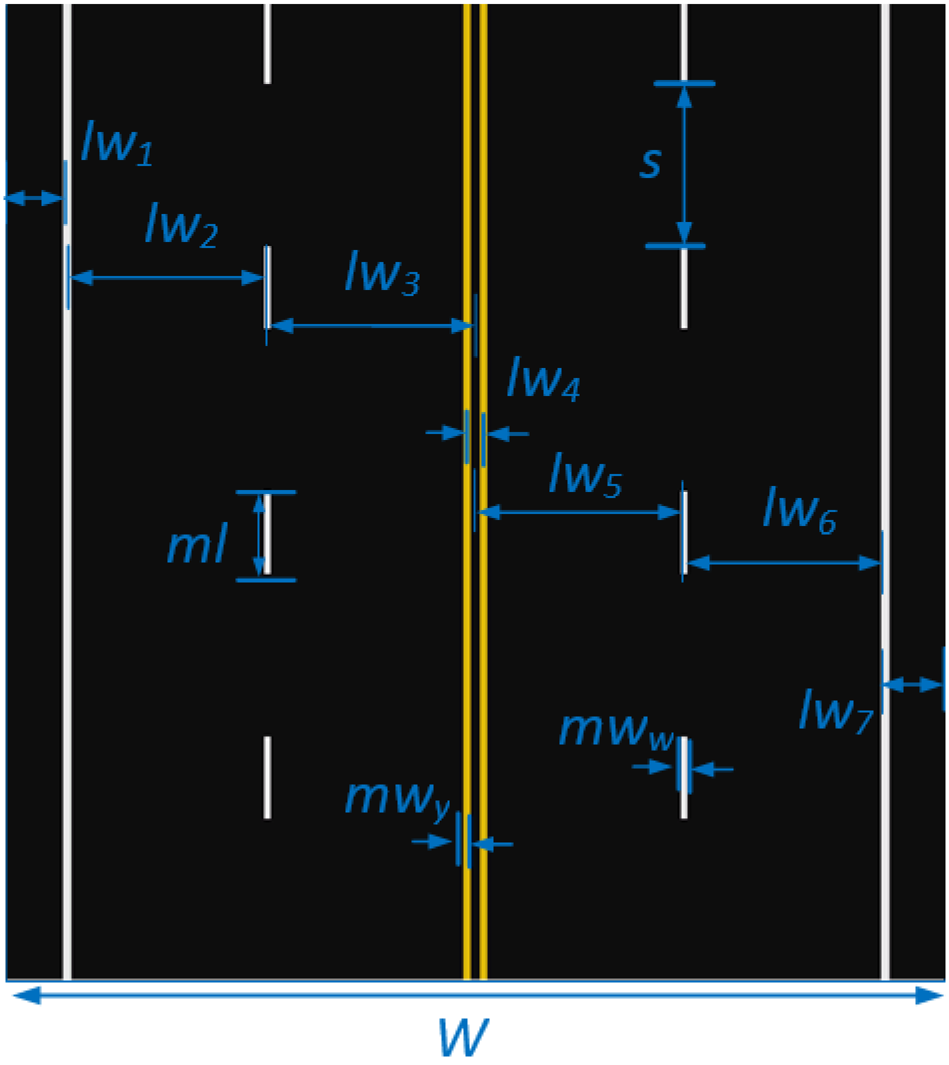
Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
0.2	-1605.00	0	0	0	–156°

Lane Dimensions

This figure and table provides the lane dimensions, in m.

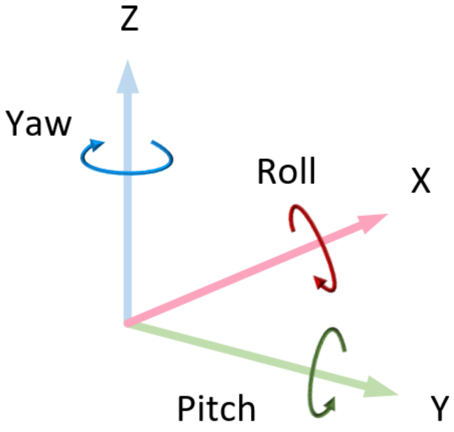


Variable	Dimension (m)
lw_1	`0.625`
lw_2	`3.85`
lw_3	`3.85`
lw_4	`0.34`
lw_5	`3.85`
lw_6	`3.85`
lw_7	`0.625`
ml	`1.5`
s	`4.5`
mw_w	`0.125`
mw_y	`0.125`

Variable	Dimension (m)
W	`16.65`

World Coordinate System

The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `HwCurve`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner

Behavior changed in R2022b

Starting from R2022b, the Curved Road scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022b locations.

See Also

Simulation 3D Scene Configuration | Double Lane Change | Open Surface | Large Parking Lot | Parking Lot | Straight Road | US City Block | US Highway | Virtual Mcity

Topics

"Unreal Engine Simulation Environment Requirements and Limitations"
"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Customize 3D Scenes for Vehicle Dynamics Simulations"

Parking Lot

Parking lot 3D environment

Description

The **Parking Lot** scene is a 3D environment of a parking lot. The scene is rendered using RoadRunner.

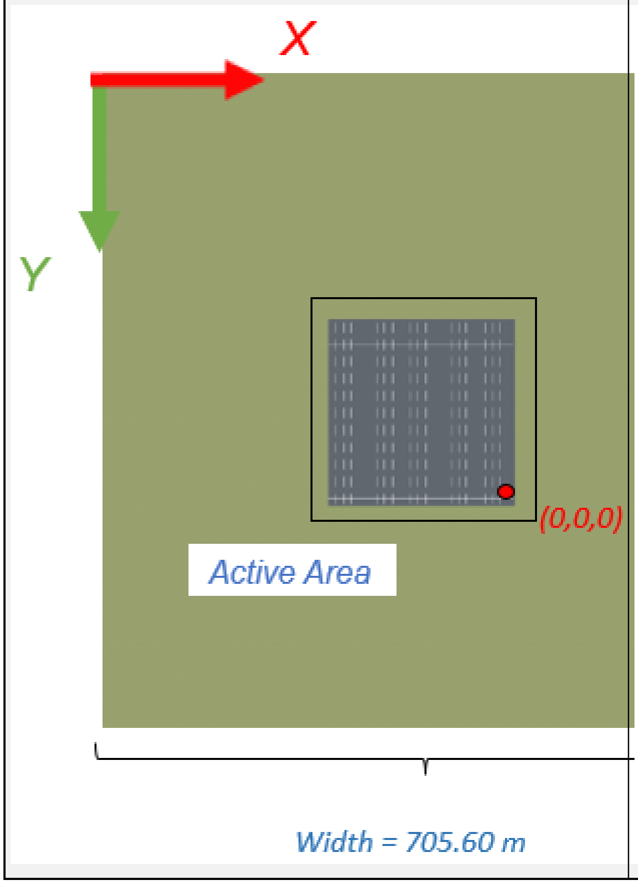
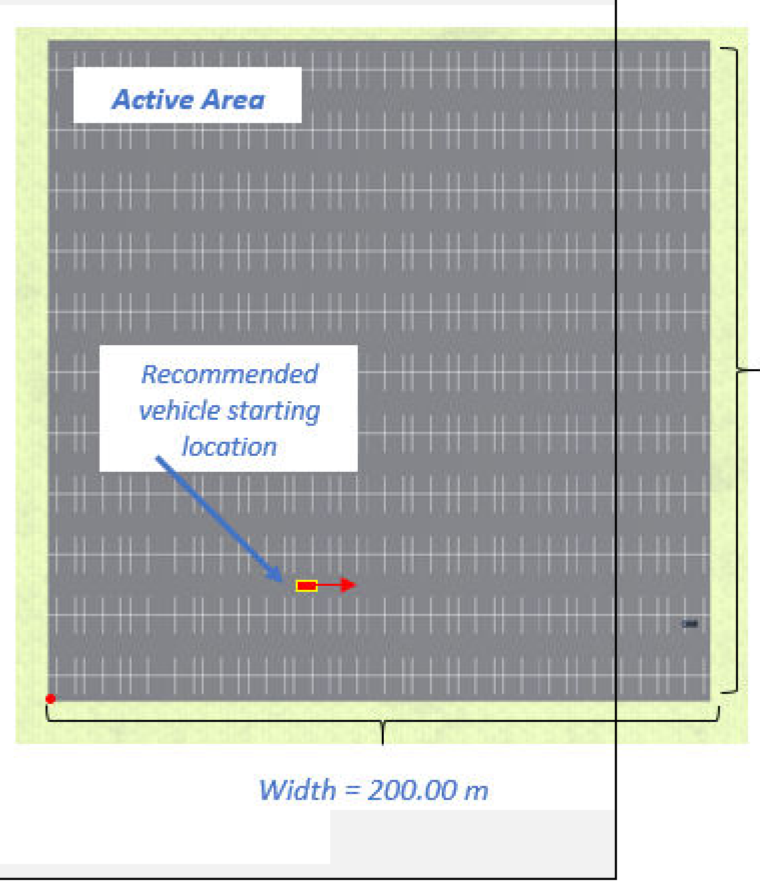
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `Parking lot`.

Layout

The scene uses the world coordinate system to locate objects. The active area of the scene contains the parking lot.

Overall	Active Area
	

Scene Dimensions

This table provides the scene and active area corner locations in the world coordinate system. Dimensions are in m.

Locations	X (m)	Y (m)	Z (m)
Scene — Bottom left	-437.32	262.79	0
Scene — Top right	268.28	-442.81	0
Active area — Bottom left	-193.86	23.43	0

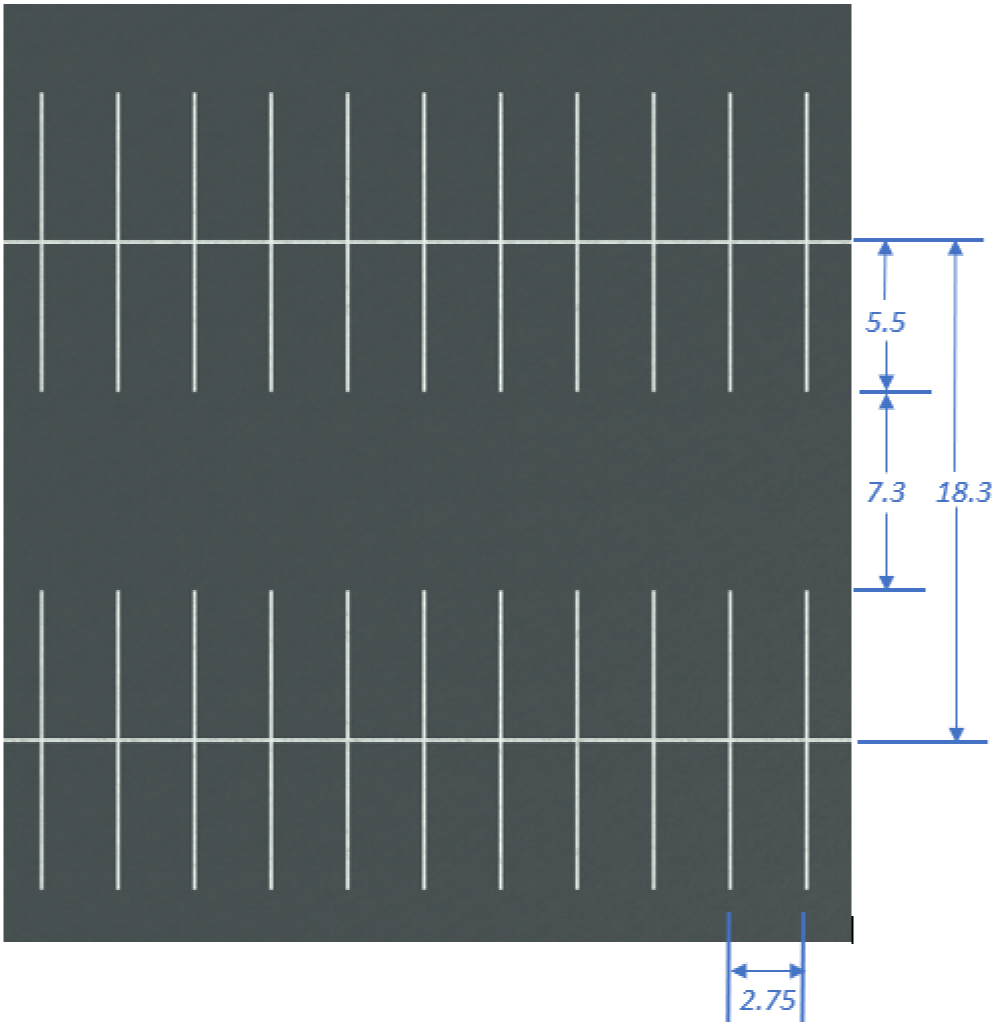
Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X **(m)**	**Y** **(m)**	**Z** **(m)**	**Roll** **(deg)**	**Pitch** **(deg)**	**Yaw** **(deg)**
`-104.0`	`-9.7`	`0`	`0`	`0`	`0`

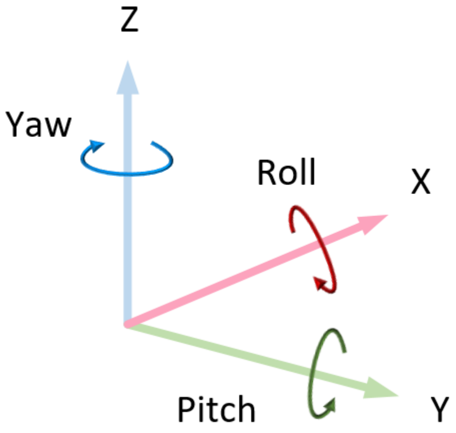
Parking Space Dimensions

This figure shows the parking space dimensions, in m.



World Coordinate System

The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `SimpleLot`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner

Behavior changed in R2022b

Starting from R2022b, the Parking Lot scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022b locations.

See Also

Simulation 3D Scene Configuration | Curved Road | Double Lane Change | Open Surface | Large Parking Lot | Straight Road | US City Block | US Highway | Virtual Mcity

Topics
"Unreal Engine Simulation Environment Requirements and Limitations"
"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Customize 3D Scenes for Vehicle Dynamics Simulations"

Large Parking Lot

Large parking lot 3D environment

Description

The **Large Parking Lot** scene is a 3D environment of a large parking lot that contains cones, curbs, traffic signs, and parked vehicles. The scene is rendered using RoadRunner.

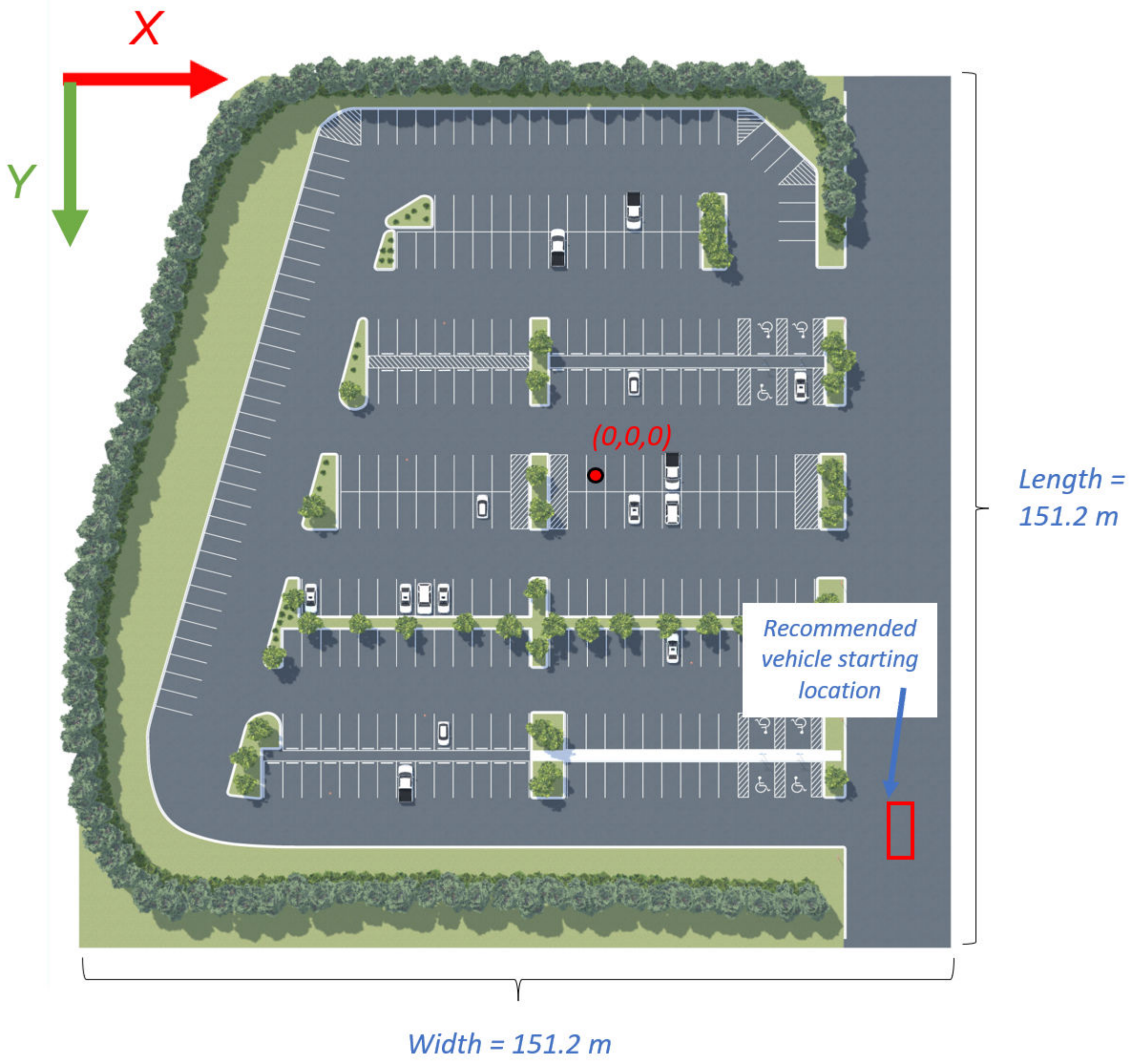
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `Large parking lot`.

Layout

The scene uses the world coordinate system to locate objects.



Scene Dimensions

This table provides the scene area corner locations in the world coordinate system. Dimensions are in m and deg.

Locations	X (m)	Y (m)	Z (m)
Scene — Top left	`-78.6`	`-73.5`	`0`
Scene — Bottom right	`72.6`	`77.7`	`0`

Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

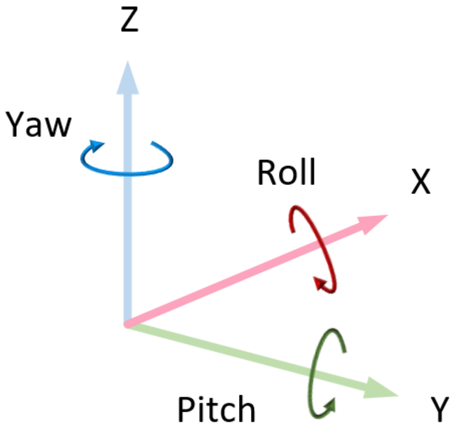
Recommended Starting Location					
X (m)	**Y (m)**	**Z (m)**	**Roll (deg)**	**Pitch (deg)**	**Yaw (deg)**
`45.0`	`54.7`	`0`	`0`	`0`	`-90`

Parking Space Dimensions

This figure shows the parking space dimensions, in m.

World Coordinate System

The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Vehicles

Hatchback, Pickups, and Sedans

This table provides the vehicle tag names and initial locations for other vehicles in the scene, in the world coordinate system. Dimensions are in m and deg.

Object	Unreal Engine Editor Name	Locations					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Vehicle	`CompactCarNode`	-21.69	38.90	0.00	0	0	180
	`CompactCarNode445`	-16.11	4.40	0.00	0	0	0
	`CompactCarNode450`	5.63	-14.25	0.00	0	0	0
	`PickupTruckNode`	5.61	-40.40	0.00	0	0	180
	`PickupTruckNode396`	-5.27	-34.87	0.00	0	0	0

Object	Unreal Engine Editor Name	Locations					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
	PickupTruckNode443	-27.13	46.40	0.00	0	0	0
	PickupTruckNode444	11.14	-0.90	0.00	0	0	180
	SedanNode	-40.71	18.40	0.00	0	0	180
	SedanNode446	-21.68	18.40	0.00	0	0	180
	SedanNode447	-27.12	18.40	0.00	0	0	180
	SedanNode449	5.70	4.80	0.00	0	0	0
	SedanNode451	29.55	-13.80	0.00	0	0	0
	SedanNode452	11.20	25.90	0.00	0	0	0
	SuvNode	-24.40	18.40	0.00	0	0	180
	SuvNode448	11.14	4.80	0.00	0	0	0

Objects

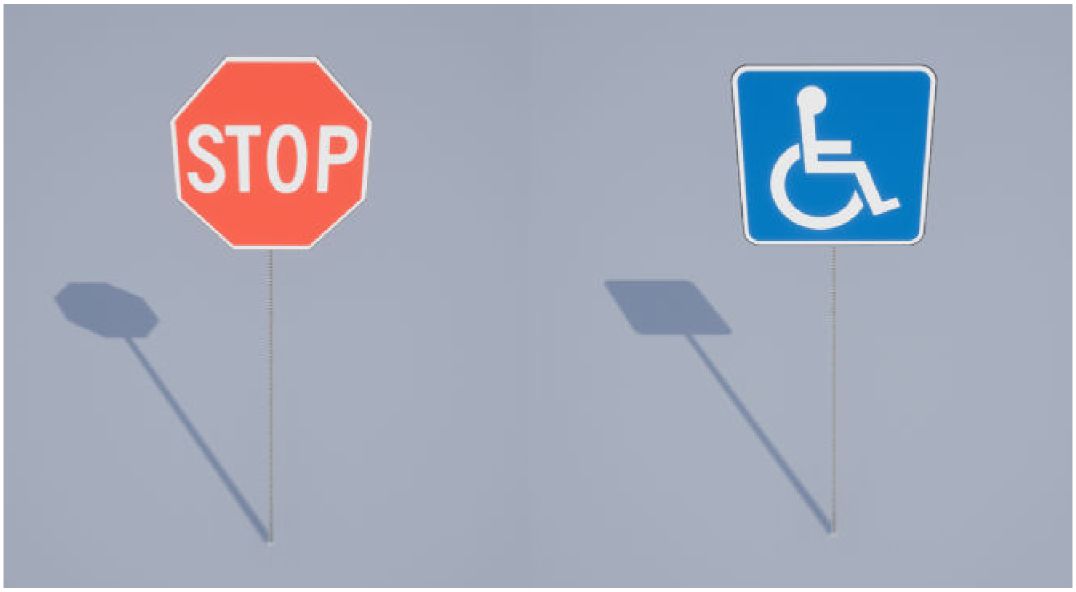
Cones

Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m and deg.

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Cone	TrafficCone01_PropNode	-21.60	-23.41	0.00	0	0	0
	TrafficCone01_PropNode453	-24.41	36.19	0.00	0	0	0
	TrafficCone01_PropNode454	-27.00	-2.68	0.00	0	0	0
	TrafficCone01_PropNode455	13.92	28.21	0.00	0	0	0
	TrafficCone01_PropNode475	-38.02	48.02	0.00	0	0	0

Traffic Signs



Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m and deg.

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Traffic signs	`SignPost_10ftNode`	`34.78`	`57.38`	`0.00`	`0`	`0`	`90`
	`SignPost_10ftNode456`	`35.30`	`36.38`	`0.00`	`0`	`0`	`90`
	`SignPost_10ftNode457`	`35.28`	`15.95`	`0.00`	`0`	`0`	`90`
	`SignPost_10ftNode458`	`35.35`	`-2.92`	`0.00`	`0`	`0`	`90`
	`SignPost_10ftNode459`	`35.69`	`-23.64`	`0.00`	`0`	`0`	`90`
	`SignPost_10ftNode460`	`24.01`	`42.80`	`0.00`	`0`	`0`	`0`
	`SignPost_10ftNode461`	`24.29`	`-18.12`	`0.00`	`0`	`0`	`0`
	`SignPost_10ftNode462`	`29.56`	`-18.12`	`0.00`	`0`	`0`	`0`
	`SignPost_10ftNode463`	`29.27`	`41.80`	`0.00`	`0`	`0`	`180`
	`SignPost_10ftNode464`	`29.27`	`42.80`	`0.00`	`0`	`0`	`0`
	`SignPost_10ftNode465`	`24.29`	`-17.01`	`0.00`	`0`	`0`	`0`
	`SignPost_10ftNode466`	`25.01`	`41.80`	`0.00`	`0`	`0`	`180`
	`SignPost_10ftNode474`	`29.56`	`-17.01`	`0.00`	`0`	`0`	`180`

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `LargeParkingLot`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner

Behavior changed in R2022a

Starting from R2022a, the Large Parking Lot scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022a locations.

See Also

Simulation 3D Scene Configuration | Curved Road | Double Lane Change | Open Surface | Parking Lot | Straight Road | US City Block | US Highway | Virtual Mcity

Topics

"Unreal Engine Simulation Environment Requirements and Limitations"
"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Customize 3D Scenes for Vehicle Dynamics Simulations"

Open Surface

Open surface 3D environment

Description

The **Open Surface** scene contains a 3D environment of an open, black road surface. The scene is rendered using RoadRunner.

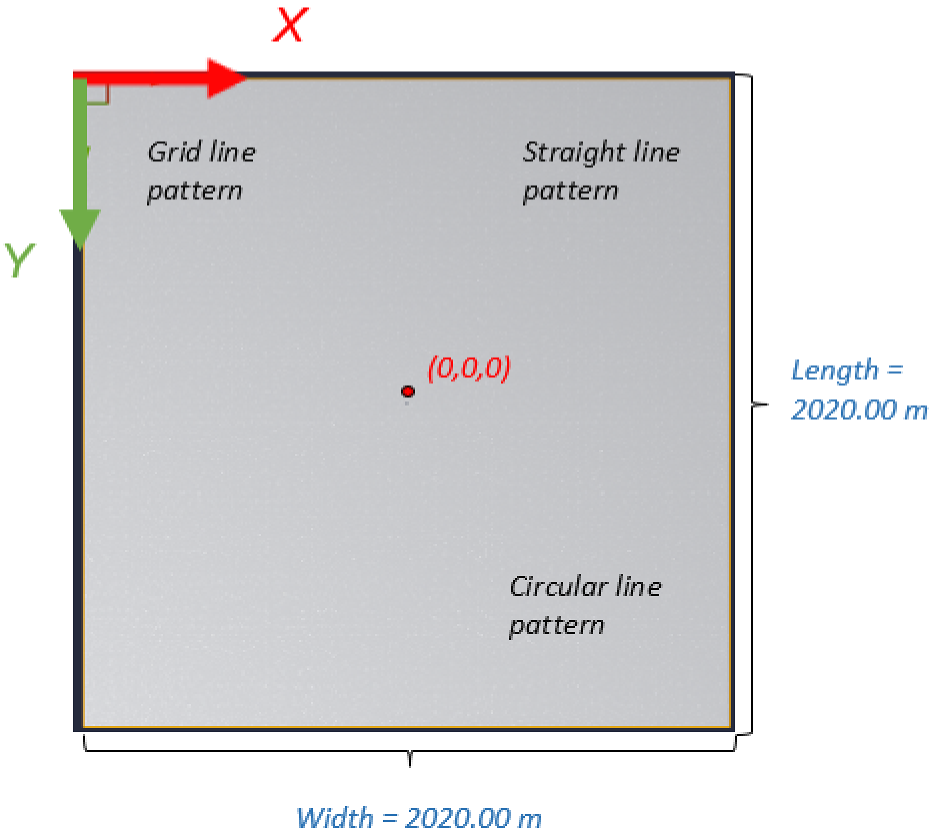
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `Open surface`.

Layout

The scene contains line patterns that you can use for vehicle testing. The scene uses the world coordinate system to locate objects.



Scene Dimensions

This table provides the scene corner locations in the world coordinate system. Dimensions are in m.

Location	X	Y	Z
Scene — Bottom left	`-1010.00`	`1010.00`	`0`
Scene — Top right	`1010.00`	`-1010.00`	`0`

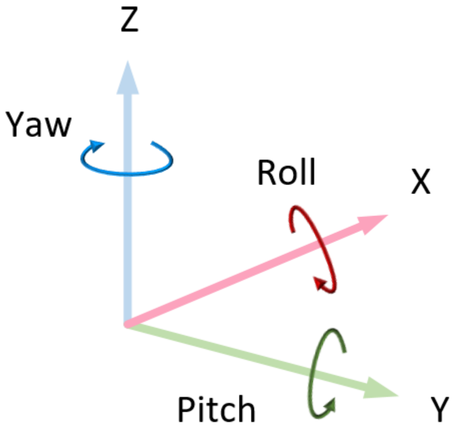
Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X (m)	**Y** (m)	**Z** (m)	**Roll** (deg)	**Pitch** (deg)	**Yaw** (deg)
`0`	`0`	`0`	`0`	`0`	`0`

World Coordinate System

The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `BlackLake`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner

Behavior changed in R2022b

Starting from R2022b, the Open Surface scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022b locations.

See Also

Simulation 3D Scene Configuration | Curved Road | Double Lane Change | Large Parking Lot | Parking Lot | Straight Road | US City Block | US Highway | Virtual Mcity

Topics

“Unreal Engine Simulation Environment Requirements and Limitations”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Customize 3D Scenes for Vehicle Dynamics Simulations”

Double Lane Change

Double lane change 3D environment

Description

The **Double Lane Change** scene is a 3D environment of a straight road containing cones, traffic signs, and barrels. The cones are set up for a vehicle to perform a double lane change maneuver. The scene is rendered using RoadRunner.

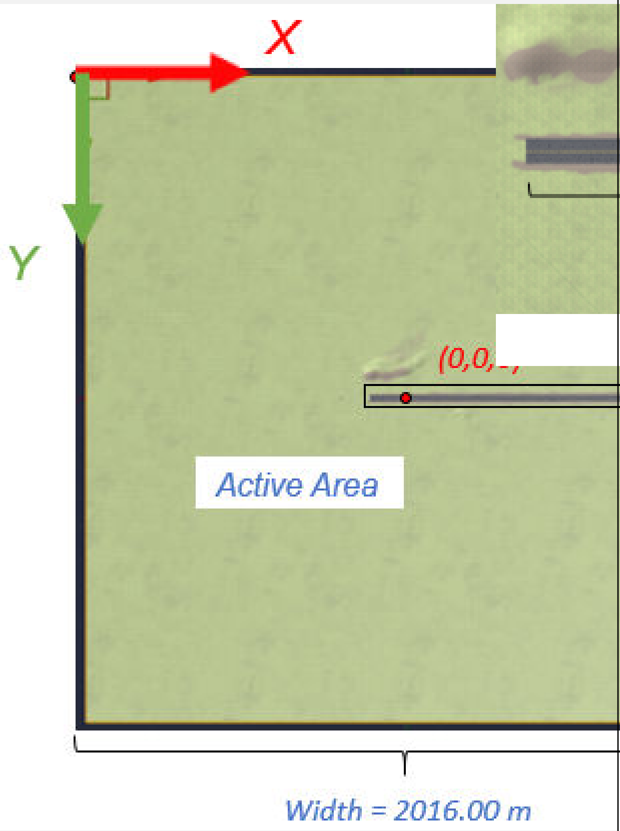
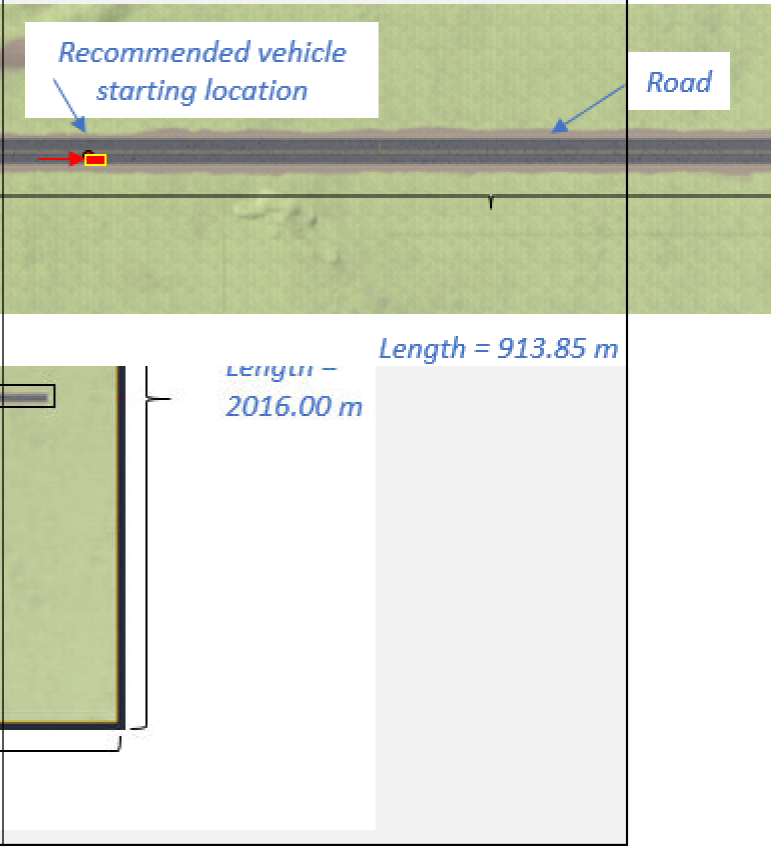
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `Double lane change`.

Layout

The scene uses the world coordinate system to locate objects. The active area of the scene contains the road.

Overall	Active Area
	

Scene Dimensions

This table provides the scene area corner locations in the world coordinate system. Dimensions are in m.

Locations	X	Y	Z
Scene — Top left	-1008	-1008	0
Scene — Bottom right	1008	1008	0
Active area — Bottom left	-800	8.35	0

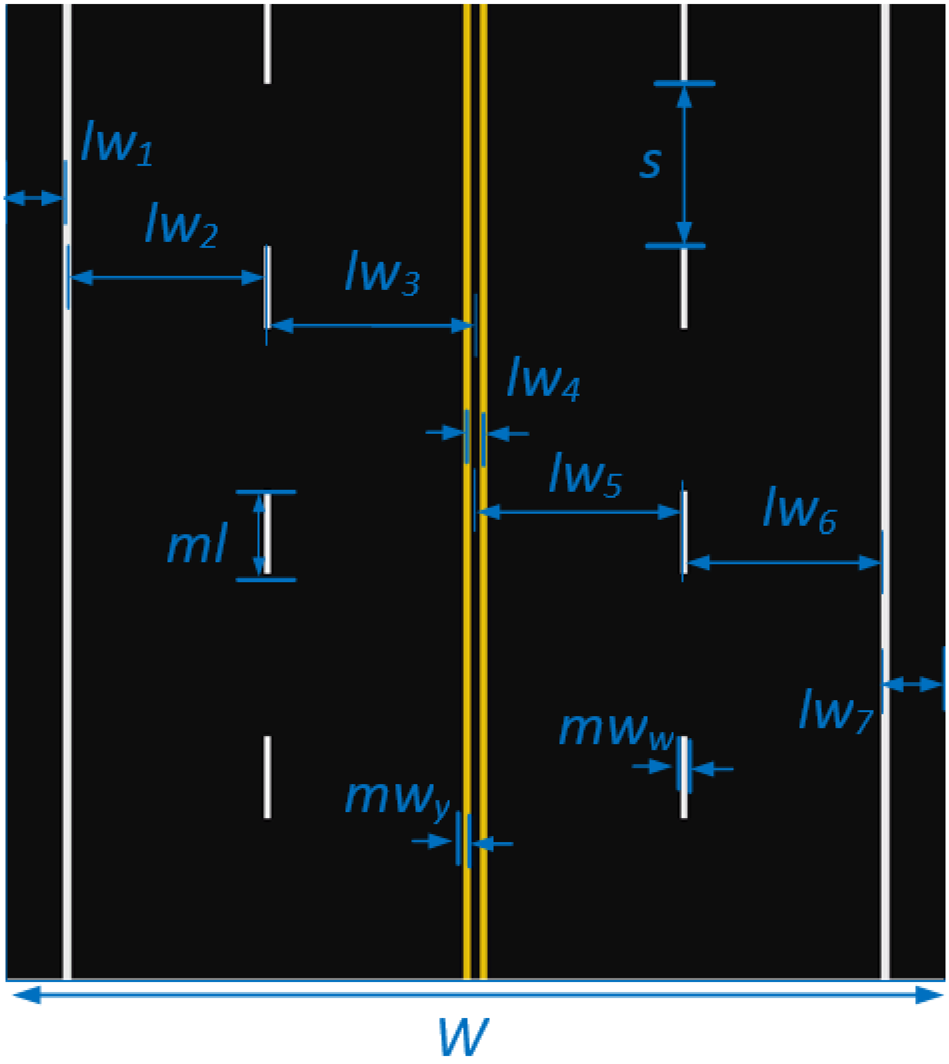
Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
0	5.7	0	0	0	0

Lane Dimensions

This figure and table provides the lane dimensions, in m.

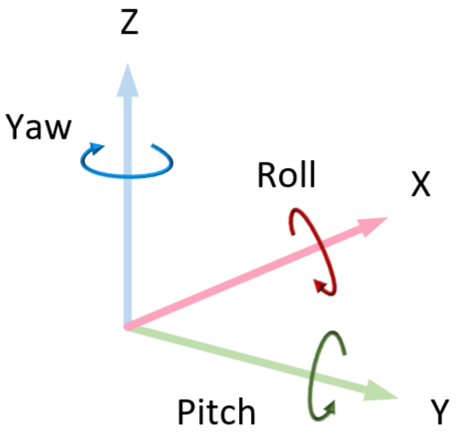


Variable	Dimension (m)
lw_1	0.625
lw_2	3.85
lw_3	3.85
lw_4	0.34
lw_5	3.85
lw_6	3.85
lw_7	0.625
ml	1.5
s	4.5

Variable	Dimension (m)
mw_w	`0.125`
mw_y	`0.125`
W	`16.70`

World Coordinate System

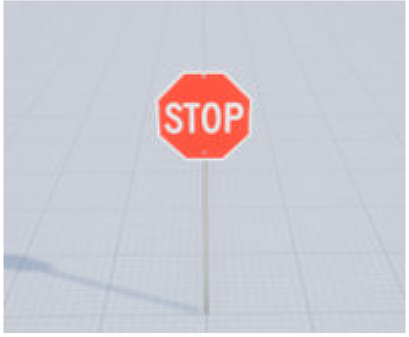
The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about X-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about Y-axis
Z	Extends upwards Yaw — Left-handed rotation about Z-axis

Objects

Traffic Signs



Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m.

Object	Unreal Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Traffic sign	`Sign_R1-1_0Node`	`248.80`	`-10.00`	`0`	`0`	`0`	`0`
	`Sign_R1-1_0Node75`	`248.80`	`10.00`	`0`			

Traffic Signal Light

In the Unreal Editor, the Double Lane Change scene has a `Sim3DGetInteger` actor with signal name `TrafficLight1`. You can use it with the Simulation 3D Message Set block to control the traffic signal light color.

Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m.

Object	Unreal Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Traffic signal light	`SM_TrafficLightsSideOnly`	`5.43`	`9.00`	`0`	`0`	`0`	`180.00°`

Barrels

Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m.

Object	Unreal Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Barrels	`Drum01Node`	`252.70`	`7.50`	`0`	`0`	`0`	`180.00°`
	`Drum01Node67`	`252.70`	`5.35`	`0`	`0`	`0`	`0`
	`Drum01Node68`	`252.70`	`3.20`	`0`	`0`	`0`	`0`
	`Drum01Node69`	`252.70`	`-1.05`	`0`	`0`	`0`	`0`
	`Drum01Node70`	`252.70`	`-1.1`	`0`	`0`	`0`	`0`
	`Drum01Node71`	`252.70`	`-3.25`	`0`	`0`	`0`	`0`
	`Drum01Node72`	`252.70`	`-5.40`	`0`	`0`	`0`	`0`
	`Drum01Node73`	`252.70`	`-7.55`	`0`	`0`	`0`	`0`

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `DblLnChng`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner

Behavior changed in R2022b

Starting from R2022b, the Double Lane Change scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022b locations.

See Also

Simulation 3D Scene Configuration | Curved Road | Open Surface | Large Parking Lot | Parking Lot | Straight Road | US City Block | US Highway | Virtual Mcity

Topics

“Send Double-Lane Change Scene Data”
“Unreal Engine Simulation Environment Requirements and Limitations”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Customize 3D Scenes for Vehicle Dynamics Simulations”

US City Block

US city block 3D environment

Description

The **US City Block** scene is a 3D environment of a US city block that contains 15 intersections and 30 traffic lights. The scene is rendered using RoadRunner.

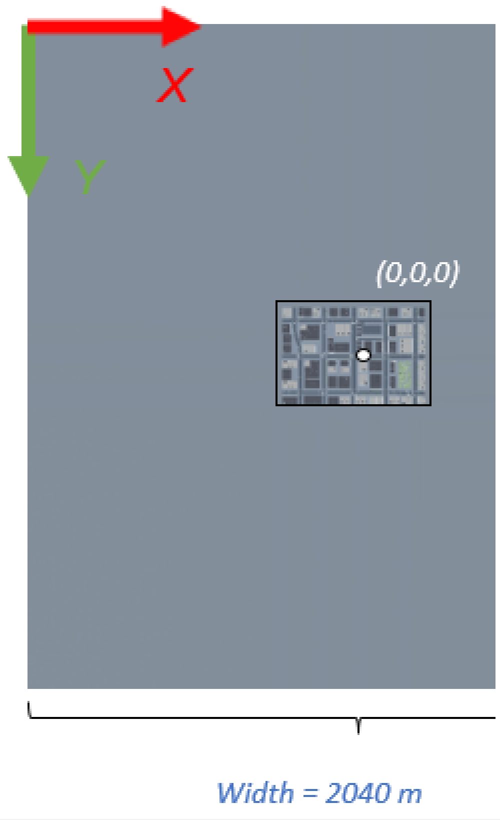
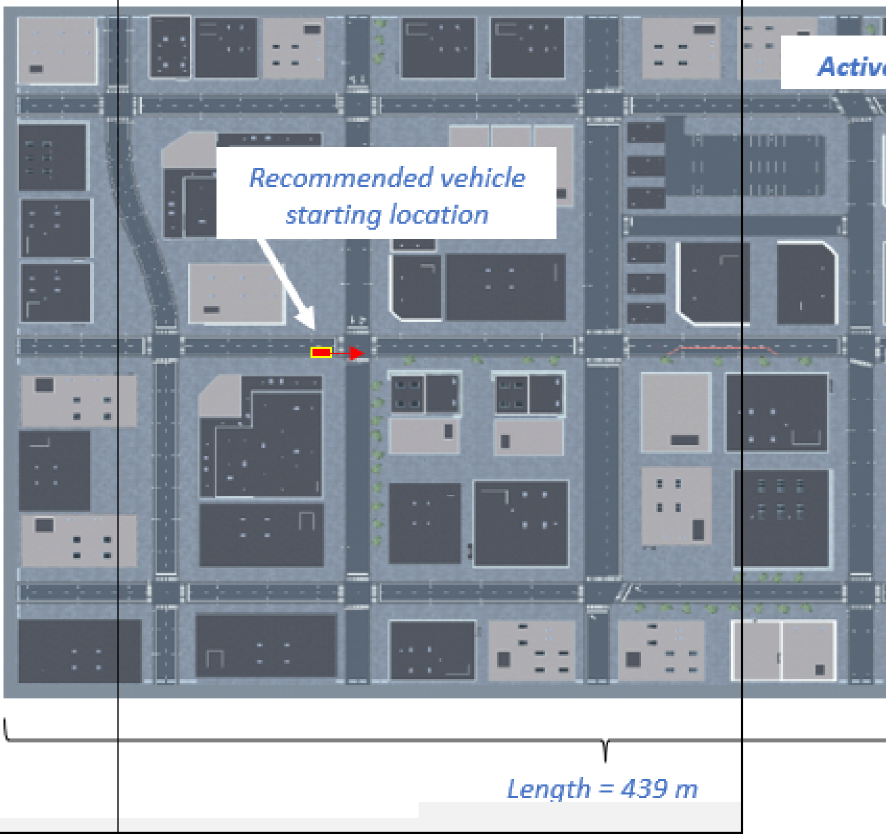
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `US city block`.

Layout

The scene uses the world coordinate system to locate objects.

Overall	Active Area
	

Scene Dimensions

This table provides the scene area corner locations in the world coordinate system. Dimensions are in m.

Locations	X (m)	Y (m)	Z (m)
Scene — Top left	`-1020`	`-1020`	`0`
Scene — Bottom right	`1020`	`1020`	`0`
Active area — Bottom left	`-240.77`	`151.67`	`0`

Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X **(m)**	**Y** **(m)**	**Z** **(m)**	**Roll** **(deg)**	**Pitch** **(deg)**	**Yaw** **(deg)**
`-125.19`	`1.65`	`0.04` *`-0.04` in vehicle Z-down coordinate system*	`0`	`0`	`0`

Intersections

The US city block scene has 15 intersections, as indicated in this diagram.

This table provides the intersection locations in the world coordinate system. Dimensions are in m.

Intersection	Center Location		
	X **(m)**	**Y** **(m)**	**Z** **(m)**
1	`-202.60`	`-108`	`.01`

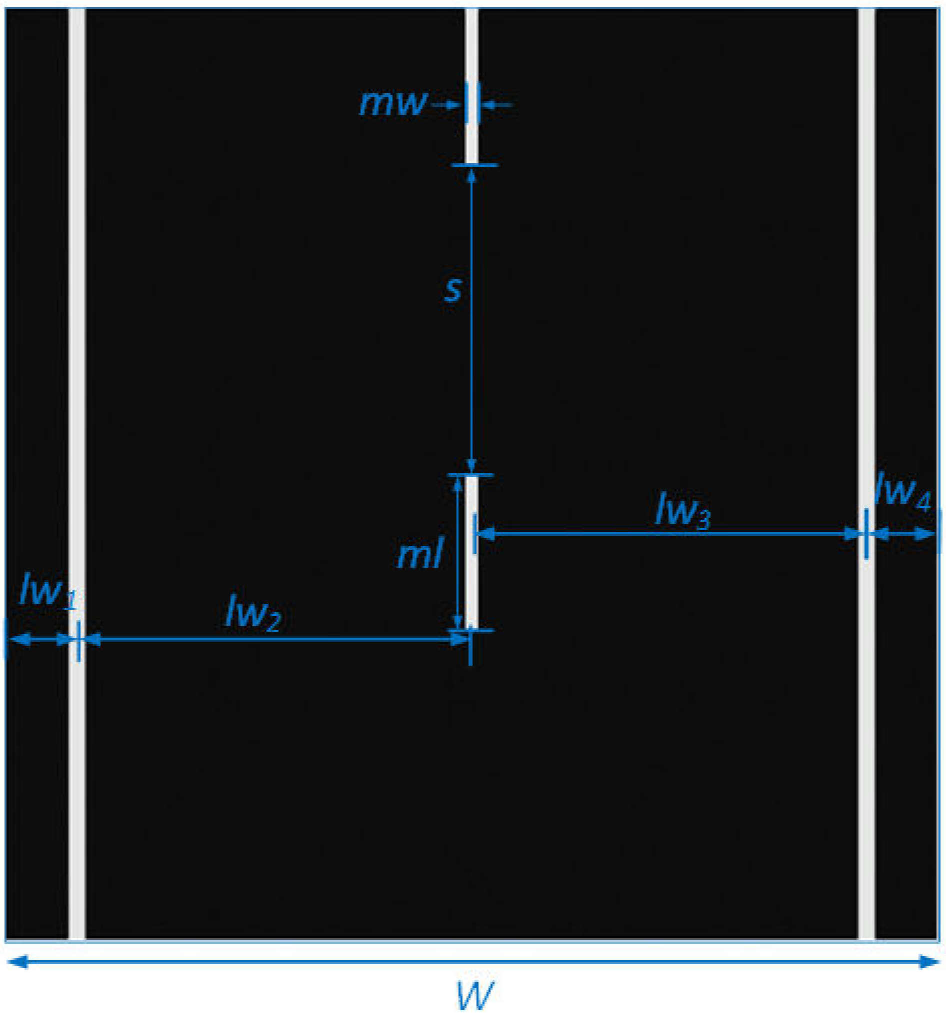
Intersection	Center Location		
	X (m)	Y (m)	Z (m)
2	-112.60	-108	.01
3	-20.38	-108	.01
4	74.58	-108	.01
5	166.40	-108	.01
6	-184.60	0	.01
7	-112.60	0	.01
8	-20.34	0	.01
9	76.40	0	.01
10	166.46	0	.01
11	-184.60	110.50	.01
12	-112.60	110.50	.01
13	-22.60	110.50	.01
14	76.40	110.50	.01
15	166.40	112.50	.01

Lane Dimensions

The scene contains three types of roads.

Road Type 1

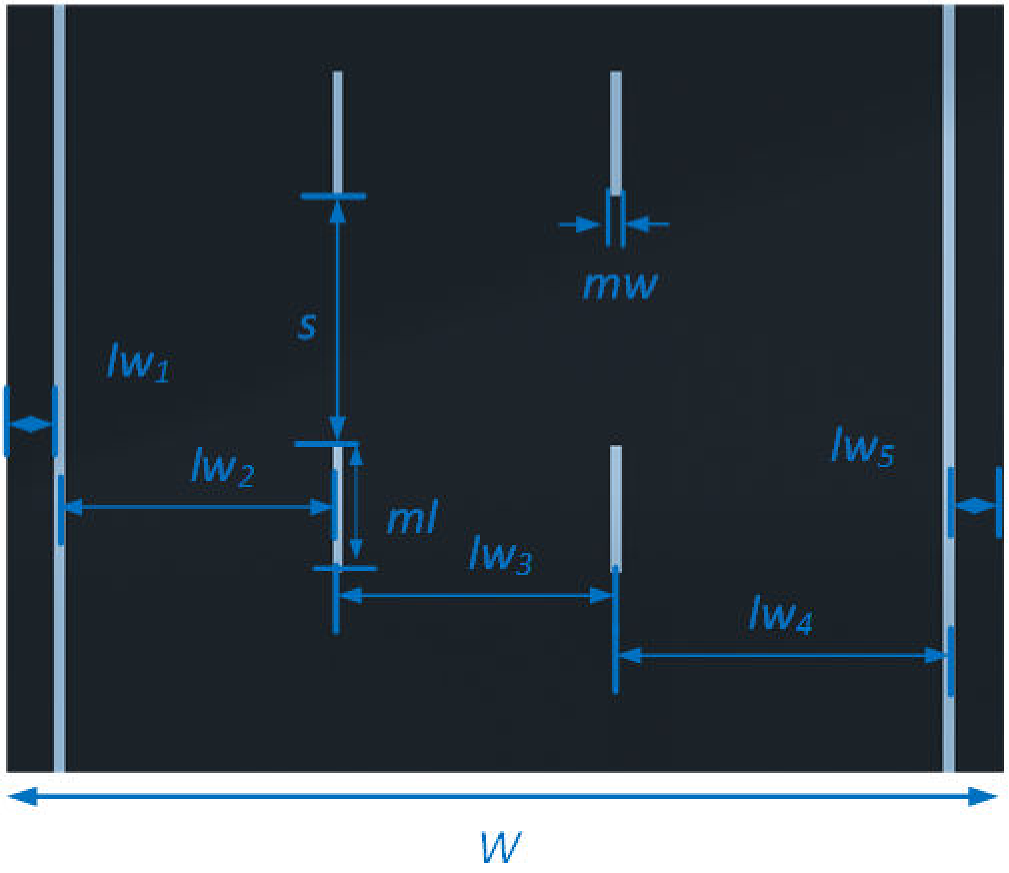
This figure and table provides the road type 1 lane dimensions, in m.



Variable	Dimension (m)
lw_1	`0.65`
lw_2	`3.85`
lw_3	`3.85`
lw_4	`0.65`
ml	`1.5`
s	`4.5`
mw	`0.125`
W	`9`

Road Type 2

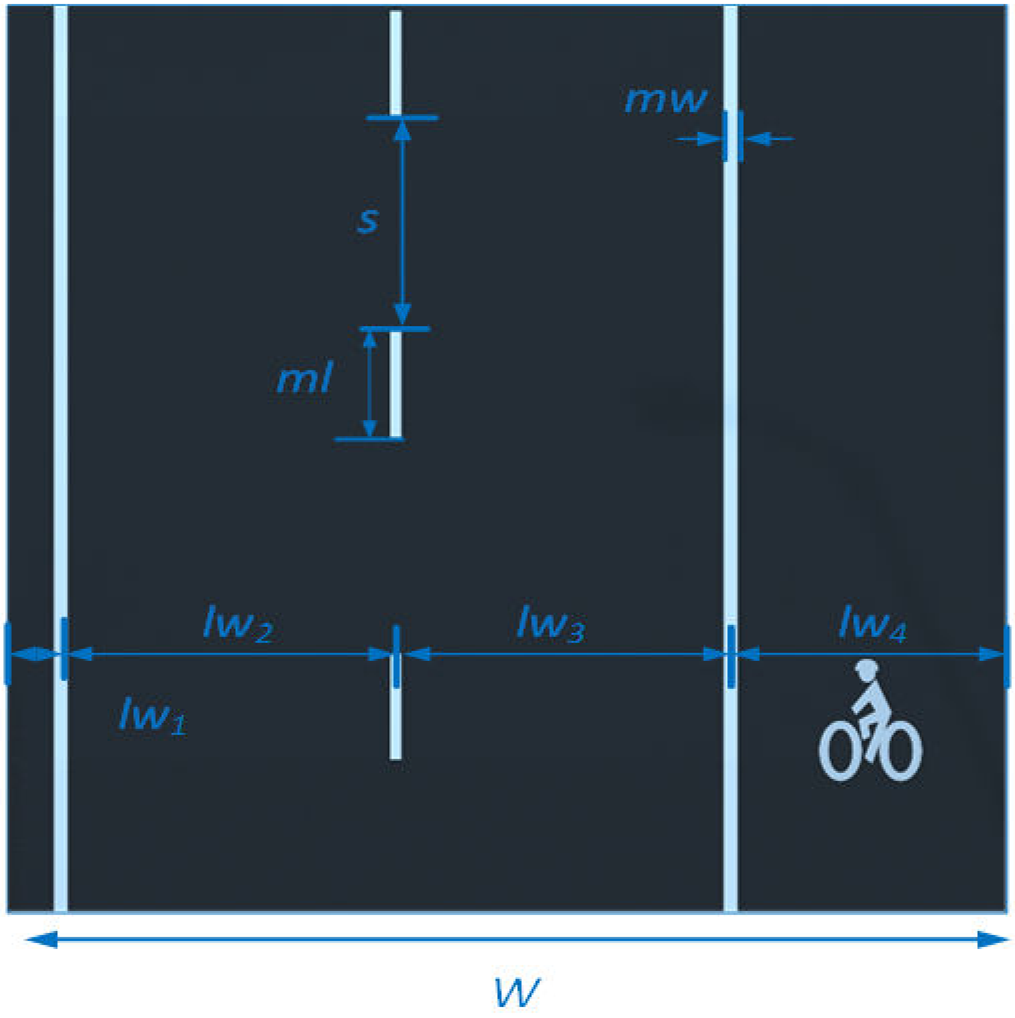
This figure and table provides the road type 2 lane dimensions, in m.



Variable	Dimension (m)
lw_1	0.73
lw_2	3.77
lw_3	3.77
lw_4	4.5
lw_5	0.73
ml	1.5
s	4.5
mw	0.125
W	13.5

Road Type 3

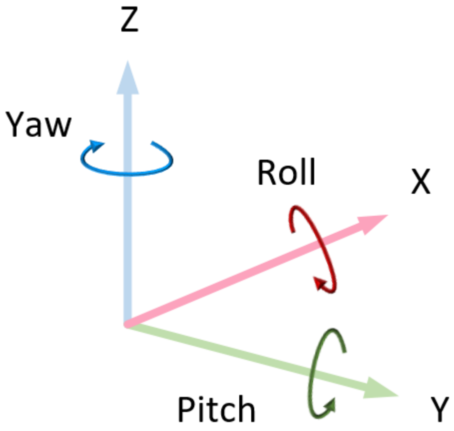
This figure and table provides the road type 3 lane dimensions, in m.



Variable	Dimension (m)
lw_1	0.65
lw_2	3.85
lw_3	3.85
lw_4	3.15
ml	1.5
s	4.5
mw	0.125
W	11.5

World Coordinate System

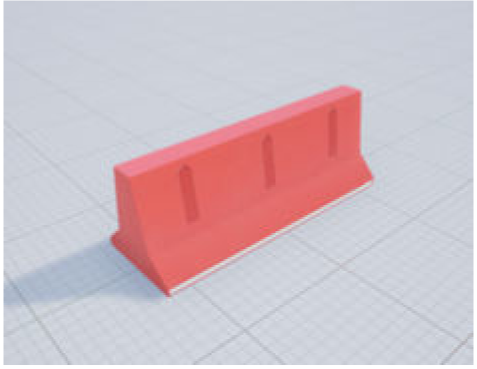
The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	Description
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Objects

Barrier



Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m.

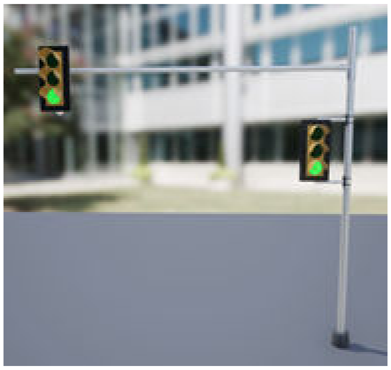
Unreal Engine Editor Name		Location					
		X	Y	Z	Roll	Pitch	Yaw
f_shaped_barrier_mesh_	PropNode2552	69.71	150.15	0.09	0	0	0
	PropNode2554	74.43	150.15	0.01	0	0	0
	PropNode2559	168.36	150.15	0.01	0	0	0
	PropNode2594	-110.71	-147.37	0.01	0	0	0
	PropNode2538	-191.29	150.15	0.08	0	0	0
	PropNode2527	-192.46	-147.40	0.03	0	0	0
	PropNode2592	-102.49	-147.40	0.04	0	0	0
	PropNode2568	197.05	1.98	0.01	0	0	-90°
	PropNode2524	-204.50	-147.40	0.01	0	0	0
	PropNode2537	-240.00	-120.63	0.07	0	0	-90°
	PropNode2571	197.05	-101.32	0.06	0	0	-90°
	PropNode2586	-16.60	-147.40	0.01	0	0	0
	PropNode2540	-182.61	150.15	0.01	0	0	0
	PropNode2525	-200.71	-147.40	0.01	0	0	0
	PropNode2531	-240.00	6.67	0.12	0	0	-90°
	PropNode2530	-240.00	1.93	0.01	0	0	-90°
	PropNode2588	-29.31	-147.40	0.04	0	0	0
	PropNode2595	-114.52	-147.40	0.01	0	0	0
	PropNode2584	-24.42	-147.40	0.01	0	0	0
	PropNode2529	-240.00	-1.82	0.01	0	0	-90°

Unreal Engine Editor Name		Location					
		X	Y	Z	Roll	Pitch	Yaw
	PropNode2556	159.73	150.15	0.11	0	0	0
	PropNode2569	197.05	5.43	0.01	0	0	-90°
	PropNode2574	164.46	-147.40	0.11	0	0	-180°
	PropNode2526	-195.90	-105.25	0	0	0	0
	PropNode2561	197.05	114.37	0.01	0	0	-90°
	PropNode2575	168.39	-147.40	0.01	0	0	0
	PropNode2549	-16.49	150.15	0.11	0	0	0
	PropNode2581	82.13	-147.40	0.03	0	0	0
	PropNode2543	119.29	150.15	0.13	0	0	0
	PropNode2566	197.05	12.11	0.05	0	0	-90°
	PropNode2593	-105.93	-147.40	0.10	0	0	0
	PropNode2523	-208.80	-147.40	0.13	0	0	0
	PropNode2577	156.30	-147.40	0.03	0	0	0
	PropNode2590	-7.98	-147.40	0.03	0	0	0
	PropNode2582	65.37	-147.40	0.12	0	0	0
	PropNode2570	197.05	-114.66	0.13	0	0	-90°
	PropNode2550	-24.53	150.15	0.01	0	0	0
	PropNode2548	-29.31	150.15	0.06	0	0	0
	PropNode2567	197.05	-1.90	0.01	0	0	-90°
	PropNode2557	173.10	150.15	0.12	0	0	0

Unreal Engine Editor Name		Location					
		X	Y	Z	Roll	Pitch	Yaw
	PropNode2553	83.12	150.15	0.03	0	0	0
	PropNode2597	-122.75	-147.37	0.04	0	0	0
	PropNode2555	78.37	150.15	0.01	0	0	0
	PropNode2591	-99.03	-147.40	0.04	0	0	0
	PropNode2560	197.05	119.24	0.12	0	0	-90°
	PropNode2573	197.05	-106.00	0.01	0	0	-90°
	PropNode2547	-110.71	150.15	0.01	0	0	
	PropNode2533	-240.00	103.96	0.04	0	0	-90°
	PropNode2534	-240.00	108.62	0.01	0	0	-90°
	PropNode2579	73.95	-147.40	0.01	0	0	
	PropNode2564	197.05	-6.67	0.07	0	0	-90°
	PropNode2589	-32.70	-147.40	0.04	0	0	
	PropNode2520	-32.70	-109.92	0.01	0	0	-90°
	PropNode2562	197.05	110.62	0.01	0	0	-90°
	PropNode2532	-240.00	100.81	0.04	0	0	-90°
	PropNode2563	197.05	105.79	0.07	0	0	-90°
	PropNode2522	-240.00	101.32	0.03	0	0	-90°
	PropNode2545	-102.57	150.15	0.03	0	0	0
	PropNode2541	-177.93	150.15	0.04	0	0	0
	PropNode2587	-11.39	147. 40	0.12	0	0	0

Unreal Engine Editor Name		Location					
		X	Y	Z	Roll	Pitch	Yaw
	PropNode2558	164.52	150.15	0.12	0	0	0
	PropNode2546	-114.50	150.15	0.01	0	0	0
	PropNode2565	-197.05	8.89	0.11	0	0	-90°
	PropNode2572	197.05	-109.93	0.01	0	0	-90°
	PropNode2521	-240.00	-106.09	0.01	0	0	-90°
	PropNode2536	-240.00	117.19	0.13	0	0	-90°
	PropNode2528	-240.00	-6.67	0.07	0	0	-90°
	PropNode2583	62.05	-147.40	0.04	0	0	0
	PropNode2544	-105.91	150.15	0.10	0	0	0
	PropNode2794	159.70	-147.40	0.11	0	0	0
	PropNode2585	-20.74	-147.40	0.01	0	0	0
	PropNode2576	173.09	-147.40	0.12	0	0	0
	PropNode2535	-240.00	112.41	0.01	0	0	-90°
	PropNode2551	-20.68	150.15	0.01	0	0	0
	PropNode2578	70.13	-147.40	0.01	0	0	0
	PropNode2596	-119.32	-147.41	0.13	0	0	0
	PropNode2580	78.73	-147.40	0.11	0	0	0
	PropNode2542	-174.47	-150.15	0.04	0	0	0

Traffic Lights



The US City Scene contains 30 traffic lights, two at each of the 15 intersections. Each intersection has a traffic light group. If you have the “Customize 3D Scenes for Vehicle Dynamics Simulations” for customizing scenes, you can control the timing of the traffic lights.

Locations

This table provides the traffic light names and locations in the world coordinate system. Dimensions are in m. Only one of the traffic lights in the group can be green at a time. The traffic lights are green for 10 s and yellow for 3 s. At the start of the simulation, the first traffic lights in the group are green (for example, `SM_TrafficLights1_3` and `SM_TrafficLights2_3`). The second lights in the group are red (for example, `SM_TrafficLights1_4` and `SM_TrafficLights2_4`).

Intersection	Unreal Engine Editor Name		Location					
	Traffic Light Group	Traffic Light	X	Y	Z	Roll	Pitch	Yaw
1	`TrafficLightGroup`	`SM_TrafficLights1_3`	`-196.55`	`-100.65`	`0`	`0`	`0`	`90°`
		`SM_TrafficLights1_4`	`-210.20`	`-113.40`	`0`	`0`	`0`	`0`
2	`TrafficLightGroup2`	`SM_TrafficLights2_3`	`-106.35`	`98.35`	`0`	`0`	`0`	`-90°`
		`SM_TrafficLights2_4`	`-120.40`	`-113.50`	`0`	`0`	`0`	`0`
3	`TrafficLightGroup3`	`SM_TrafficLights3_1`	`-13.10`	`-116.20`	`0.2`	`0`	`0`	`90°`

Intersection	Unreal Engine Editor Name		Location					
	Traffic Light Group	Traffic Light	X	Y	Z	Roll	Pitch	Yaw
		SM_TrafficLights3_4	-30.60	-113.80	0	0	0	0
4	TrafficLightGroup4	SM_TrafficLights4_3	71.40	-100.30	0	0	0	-100°
		SM_TrafficLights4_4	64.80	-113.0	0	0	0	0
5	TrafficLightGroup5	SM_TrafficLights5_1	171.50	-115.70	0	0	0	90°
		SM_TrafficLights5_4	157.40	-113.50	0	0	0	0
6	TrafficLightGroup6	SM_TrafficLights6_2	-177.30	5.70	0	0	0	180°
		SM_TrafficLights6_3	-189.60	7.40	0	0	0	-90°
7	TrafficLightGroup7	SM_TrafficLights7_2	-105.20	5.50	0	0	0	180°
		SM_TrafficLights7_3	-117.80	7.70	0.2	0	0	-90°
8	TrafficLightGroup8	SM_TrafficLights8_1	-13.10	-7.60	0.1	0	0	90°

Intersection	**Unreal Engine Editor Name**		**Location**					
	Traffic Light Group	**Traffic Light**	**X**	**Y**	**Z**	**Roll**	**Pitch**	**Yaw**
		SM_TrafficLights8_2	-10.90	5.60	0	0	0	180°
9	TrafficLightGroup9	SM_TrafficLights9_2	85.90	7.60	0.2	0	0	180°
		SM_TrafficLights9_3	70.90	9.20	0	0	0	-90°
10	TrafficLightGroup10	SM_TrafficLights10_1	172.10	-7.70	0	0	0	90°
		SM_TrafficLights10_2	173.70	7.50	0	0	0	180°
11	TrafficLightGroup11	SM_TrafficLights11_3	-189.80	118.45	0	0	0	-90°
		SM_TrafficLights11_4	-191.05	104.55	0	0	0	0
12	TrafficLightGroup12	SM_TrafficLights12_3	-117.60	117.60	0	0	0	-90°
		SM_TrafficLights12_4	-120.50	105.40	0	0	0	0
13	TrafficLightGroup13	SM_TrafficLights13_1	-12.80	102.50	0	0	0	90°

Intersection	Unreal Engine Editor Name		Location					
	Traffic Light Group	Traffic Light	X	Y	Z	Roll	Pitch	Yaw
		`SM_TrafficLights13_4`	`-30.50`	`105.30`	`0`	`0`	`0`	`0`
14	`TrafficLightGroup14`	`SM_TrafficLights14_3`	`70.90`	`118.70`	`0`	`0`	`0`	`-90°`
		`SM_TrafficLights14_4`	`69.30`	`105.30`	`0`	`0`	`0`	`0`
15	`TrafficLightGroup15`	`SM_TrafficLights15_1`	`171.40`	`105.20`	`0`	`0`	`0`	`90°`
		`SM_TrafficLights15_4`	`158.40`	`107.20`	`0`	`0`	`0`	`0`

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `USCityBlock`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner

Behavior changed in R2022b

Starting from R2022b, the US City Block scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022b locations.

See Also

Simulation 3D Scene Configuration | Curved Road | Double Lane Change | Open Surface | Large Parking Lot | Parking Lot | Straight Road | Virtual Mcity | US Highway

Topics

“Unreal Engine Simulation Environment Requirements and Limitations”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Customize 3D Scenes for Vehicle Dynamics Simulations”

US Highway

US highway 3D environment

Description

The **US Highway** scene is a 3D environment of a US highway that contains barriers, cones, and traffic signs. The scene is rendered using RoadRunner.

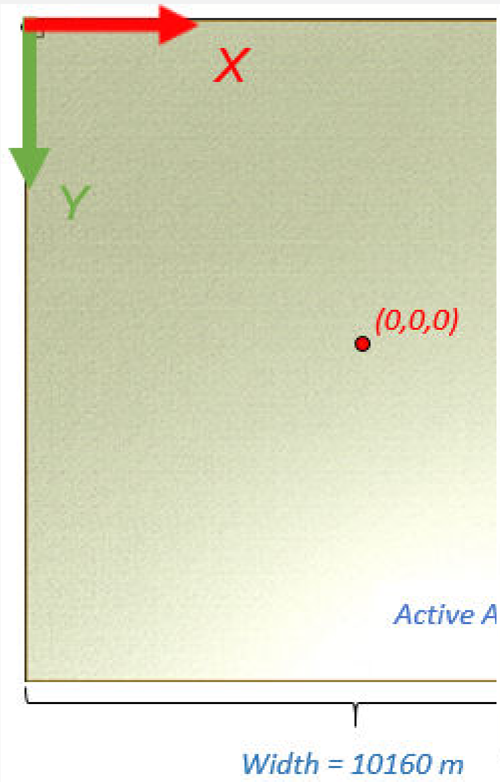
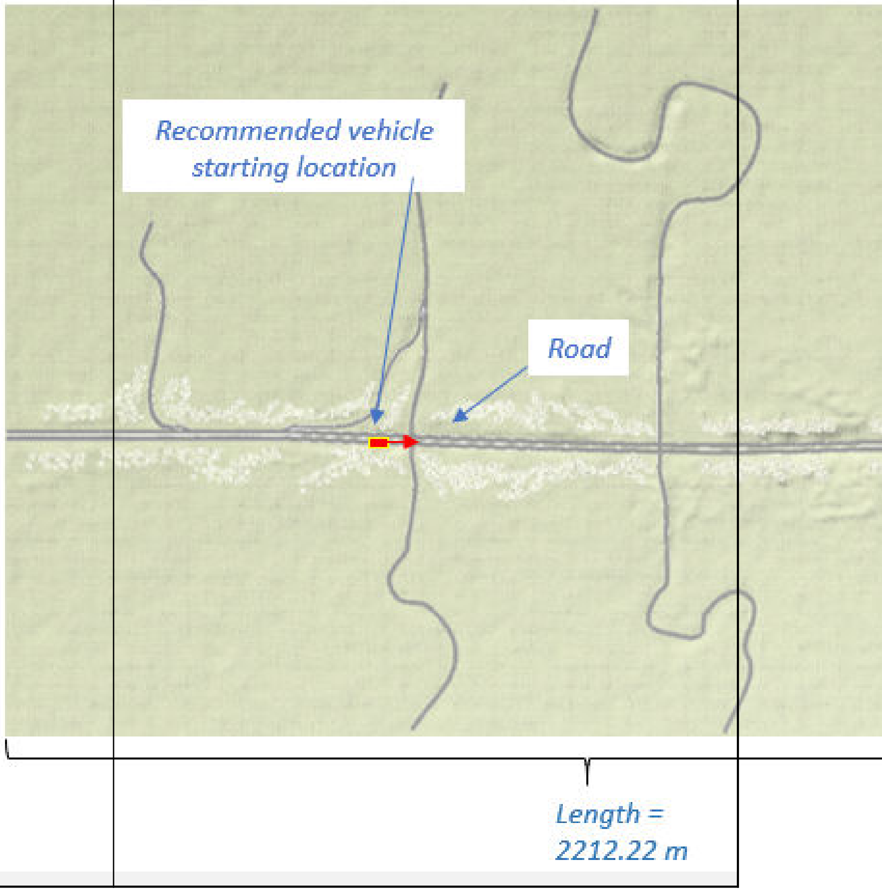
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `US highway`.

Layout

The scene uses the world coordinate system to locate objects. The active area of the scene contains the road.

Overall	Active Area
	

Scene Dimensions

This table provides the scene area corner locations in the world coordinate system. Dimensions are in m.

Locations	X (m)	Y (m)	Z (m)
Scene — Top left	-5080	-5080	1
Scene — Bottom right	5080	5080	1
Active area — Bottom left	2867.41	3169.93	1

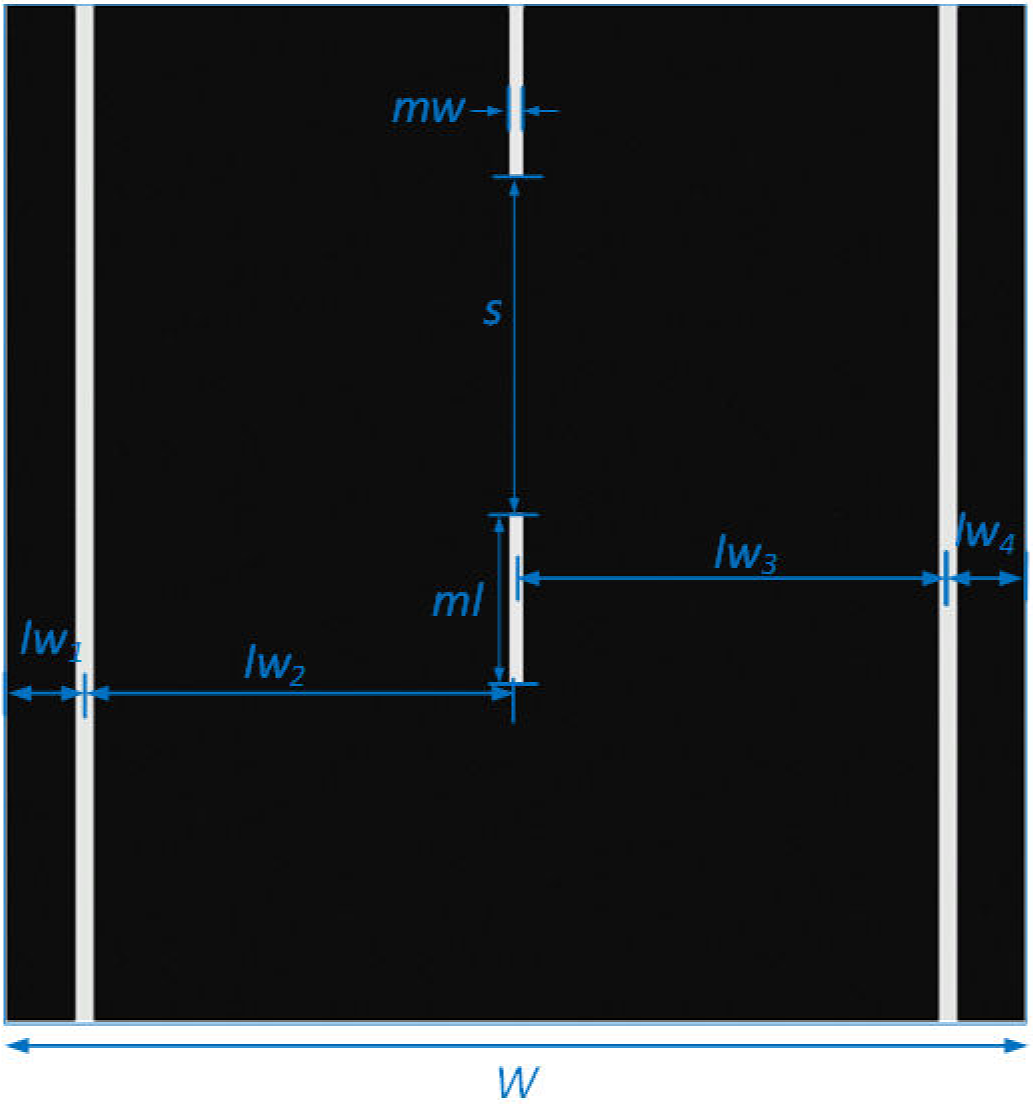
Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X **(m)**	**Y** **(m)**	**Z** **(m)**	**Roll** **(deg)**	**Pitch** **(deg)**	**Yaw** **(deg)**
`3592.00`	`2617.00`	`1.00` *`-1.00` in vehicle Z-down coordinate system*	`0`	`0`	`0`

Lane Dimensions

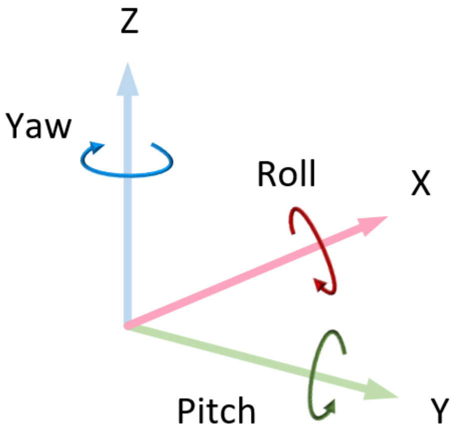
This figure and table provides the lane dimensions, in m.



Variable	**Dimension (m)**
lw_1	`0.625`
lw_2	`3.85`
lw_3	`3.85`
lw_4	`0.625`
ml	`1.5`
s	`4.5`
mw	`0.125`
W	`8.95`

World Coordinate System

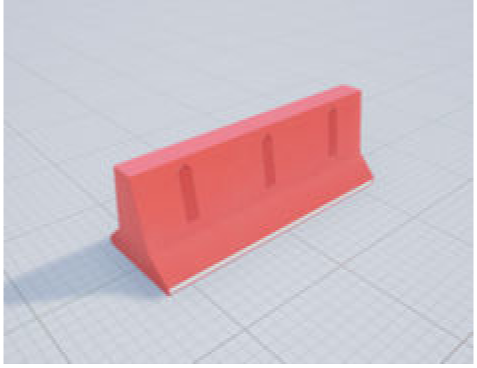
The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	**Description**
X	Forward direction of the vehicle Roll — Right-handed rotation about X-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about Y-axis
Z	Extends upwards Yaw — Left-handed rotation about Z-axis

Objects

Barrier

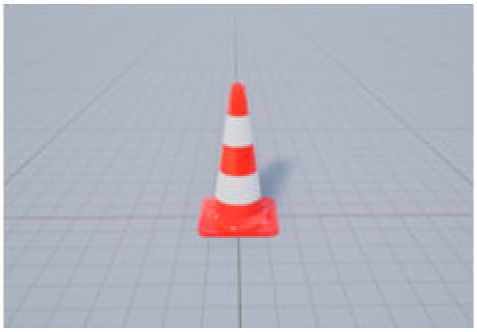


Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m.

Unreal Engine Editor Name		Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
f_shaped_barrier_mesh_	PropNode	2866.45	2609.80	1.01	0	0	-90°
	PropNode9914	2866.45	2593.70	1.01			
	PropNode9912	2866.45	2606.03	1.01			
	PropNode9913	2866.45	2597.61	1.01			

Cones

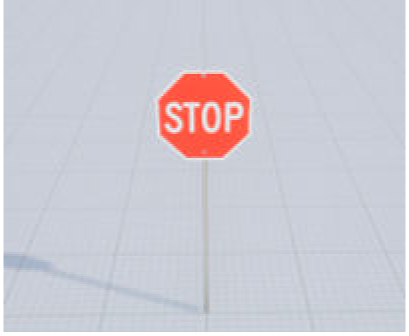


Locations

This table provides the cone tag names and locations in the world coordinate system. Dimensions are in m.

Unreal Engine Editor Name		**Location**					
		X **(m)**	**Y** **(m)**	**Z** **(m)**	**Roll** **(deg)**	**Pitch** **(deg)**	**Yaw** **(deg)**
`TrafficCone01_`	`PropNode4970`	`3022.85`	`2599.90`	`1`	`0`	`0`	`0`
	`PropNode4969`	`3022.85`	`2599.10`	`1`			
	`PropNode4968`	`3022.85`	`2598.25`	`1`			
	`PropNode4967`	`3022.85`	`2597.30`	`1`			
	`PropNode4966`	`3022.85`	`2596.50`	`1`			
	`PropNode4965`	`3022.85`	`2595.65`	`1`			
	`PropNode4964`	`3022.85`	`2594.70`	`1`			
	`PropNode4963`	`3022.85`	`2593.90`	`1`			
	`PropNode4962`	`3022.85`	`2593.05`	`1`			
	`PropNode4961`	`3022.85`	`2592.20`	`1`			
	`PropNode`	`3022.85`	`2591.40`	`1`			

Traffic Signs



Locations

This table provides the traffic sign tag names and locations in the world coordinate system. Dimensions are in m.

Unreal Engine Editor Name		Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
`Sign_`	`HighwayEast_0_ExitSignNode`	`3368.15`	`2588.20`	`1`	`0`	`0`	`-90°`
	`ExitRight8_0_ExitSignNode`	`3232.70`	`2588.40`	`1`	`0`	`0`	`-90°`
	`W1-8_R01_0_RightChevronWarningSignNode`	`3154.80`	`2584.50`	`1`	`0`	`0`	`-85°`
	`W1-8_R01_0_RightChevronWarningSignNode15`	`3149.10`	`2579.45`	`1`	`0`	`0`	`-85°`
	`W1-8_R01_0_RightChevronWarningSignNode17`	`3144.15`	`2571.95`	`1`	`0`	`0`	`-85°`
	`Sign_W1-8_R01_0_RightChevronWarningSignNode19`	`3139.45`	`2562.60`	`1`	`0`	`0`	`-85°`

Tips

- If you have the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, then you can modify this scene. In the Unreal Engine project file that comes with the support package, this scene is named `USHighway`.

  For more details on customizing scenes, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

Scene rendered using RoadRunner

Behavior changed in R2022b

Starting from R2022b, the US Highway scene in the Unreal Engine 3D environment is rendered using RoadRunner. As a result, the locations of scene objects, including cones and parked vehicles, are moved from their pre-R2022b locations.

See Also

Simulation 3D Scene Configuration | Curved Road | Double Lane Change | Open Surface | Large Parking Lot | Parking Lot | Straight Road | US City Block | Virtual Mcity

Topics

“Unreal Engine Simulation Environment Requirements and Limitations”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Customize 3D Scenes for Vehicle Dynamics Simulations”

Virtual Mcity

Virtual Mcity 3D environment

Description

The **Virtual Mcity** scene is a 3D environment containing a virtual representation of Mcity®, which is a testing ground belonging to the University of Michigan. For more details, see Mcity Test Facility.

The scene is rendered using the Unreal Engine from Epic Games.

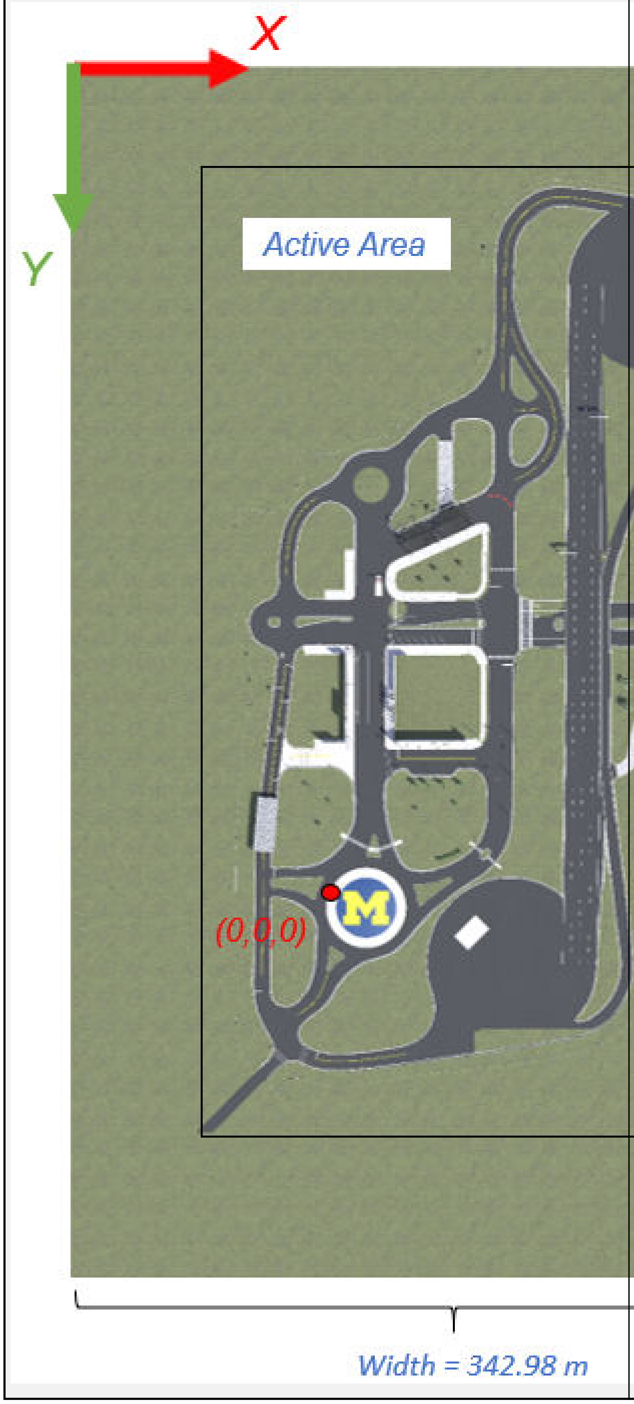
Setup

To simulate a driving maneuver in this scene:

1. Add a Simulation 3D Scene Configuration block to your Simulink model.
2. In this block, set the **Scene source** parameter to `Default Scenes`.
3. Set the enabled **Scene name** parameter to `Virtual Mcity`.

Layout

The scene uses the world coordinate system to locate objects. The active area of the scene contains the road.

Overall	Active Area
	

Scene Dimensions

This table provides the scene area corner locations in the world coordinate system. Dimensions are in m.

Locations	**X** **(m)**	**Y** **(m)**	**Z** **(m)**
Scene — Top left	`-116.85`	`-369.18`	`-.02`
Scene — Bottom right	`226.13`	`172.26`	`-.02`
Active area — Bottom left	`-60.61`	`106.75`	`-.02`

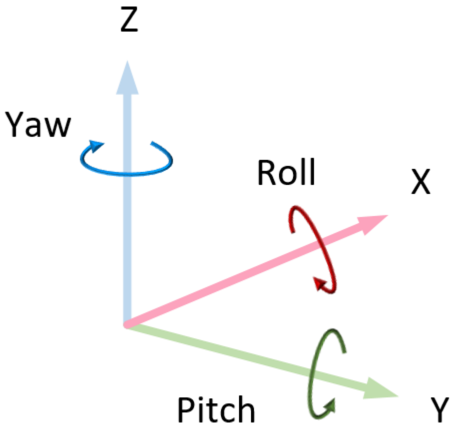
Recommended Starting Location

This table provides the recommended starting location for the vehicle in the world coordinate system. Dimensions are in m and deg.

Recommended Starting Location					
X **(m)**	**Y** **(m)**	**Z** **(m)**	**Roll** **(deg)**	**Pitch** **(deg)**	**Yaw** **(deg)**
`-26.00`	`76.0`	`0`	`0`	`0`	`-40`

World Coordinate System

The 3D visualization environment uses a world coordinate system with axes that are fixed in the inertial reference frame.



Axis	**Description**
X	Forward direction of the vehicle Roll — Right-handed rotation about *X*-axis
Y	Extends to the right of the vehicle, parallel to the ground plane Pitch — Right-handed rotation about *Y*-axis
Z	Extends upwards Yaw — Left-handed rotation about *Z*-axis

Vehicles

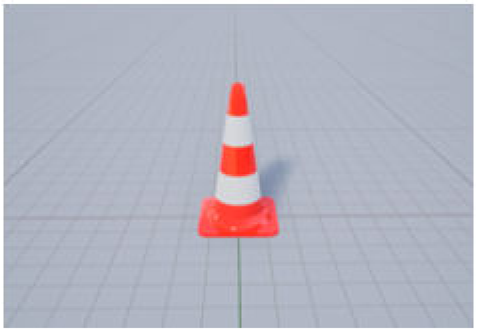
Trucks, Bicycles, and Sedans

This table provides the vehicle tag names and initial locations for other vehicles in the scene, in the world coordinate system. Dimensions are in m and deg.

Object	Unreal Engine Editor Name	Locations					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Vehicle	`SK_BoxTruck`	`20.96`	`-136.90`	`0`	`0`	`0`	`-90`
	`SM_Motorcycle`	`42.50`	`-157.60`	`0`	`0`	`0`	`-20`
	`SK_SedanCar`	`5.83`	`-117.91`	`0`	`0`	`0`	`0`
	`SM_Bicycle`	`10.88`	`-84.42`	`0`	`0`	`0`	`90`

Objects

Cones

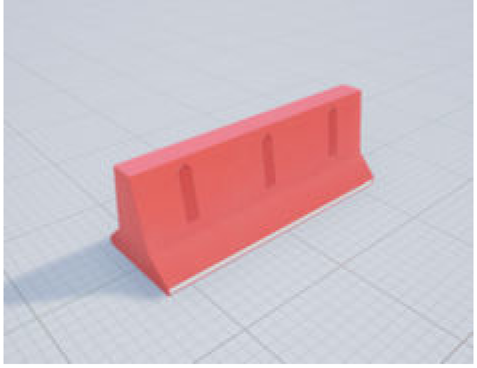


Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m and deg.

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
`Cone`	`SM_Cone`	`22.33`	`-131.51`	`0`	`0`	`0`	`0`
	`SM_Cone2`	`21.23`	`-131.51`	`0`	`0`	`0`	`0`
	`SM_Cone3`	`20.03`	`-131.51`	`0`	`0`	`0`	`0`
	`SM_Cone4`	`18.93`	`-131.51`	`0`	`0`	`0`	`0`

Barrier



Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m and deg.

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Barrier	SM_Barrier13	79.65	-173.39	0	0	0	-35
	SM_Barrier14	77.31	-175.94	0	0	0	-55
	SM_Barrier15	74.42	-177.49	0	0	0	-80
	SM_Barrier16	71.18	-177.64	0	0	0	-95

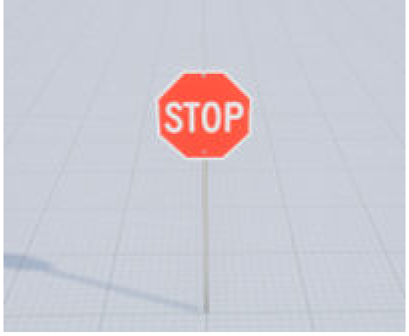
Animals

Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m and deg.

Object	**Unreal Engine Editor Name**	**Location**					
		X (m)	**Y (m)**	**Z (m)**	**Roll (deg)**	**Pitch (deg)**	**Yaw (deg)**
Animals	`Deer`	`36.84`	`-122.15`	`0`	`0`	`0`	`0`

Traffic Signs



Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m and deg.

Object	**Unreal Engine Editor Name**	**Location**					
		X (m)	**Y (m)**	**Z (m)**	**Roll (deg)**	**Pitch (deg)**	**Yaw (deg)**
Traffic signs	`SM_StopSign`	`-35.21`	`44.19`	`0`	`0`	`0`	`95`
	`SM_YellowRoadSign`	`-38.75`	`18.14`	`-.02`	`0`	`0`	`-170`
	`LargeDoubleArrowSign4`	`-35.19`	`-4.39`	`0`	`0`	`0`	`-90`
	`LargeDoubleArrowSign`	`-31.01`	`-60.55`	`0`	`0`	`0`	`-80`
	`RailroadSign2`	`-27.06`	`-88.67`	`0`	`0`	`0`	`5`
	`RailroadSign`	`-17.79`	`-89.77`	`0`	`0`	`0`	`-170`
	`SM_YieldSign`	`26.80`	`-165.14`	`0`	`0`	`0`	`0`
	`SM_StopSign7`	`54.84`	`-200.43`	`0`	`0`	`0`	`-90`

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
	LargeDoubleArrowSign3	47.54	-218.00	0	0	0	-15
	SM_StopSign9	70.32	-195.66	0	0	0	0
	SM_YellowRoadSign3	82.66	-285.75	-.02	0	0	15
	SM_SpeedLimitSign2	80.89	-226.85	-.06	0	0	0
	LargeDoubleArrowSign5	104.10	-212.80	0	0	0	80
	ChevronAlignmentSign	98.45	-191.22	0	0	0	101
	ChevronAlignmentSign2	102.05	-197.62	0	0	0	76.5
	ChevronAlignmentSign3	103.98	-206.06	0	0	0	85
	SM_Large_Exit_Sign	122.45	-212.50	0	0	0	0
	SM_Large_Exit_Sign2	101.79	-151.66	0	0	0	180
	SM_StopSign3	32.01	-163.68	0	0	0	160
	SM_StopSign2	54.98	-177.12	0	0	0	90
	SM_StopSign5	126.63	-58.50	0	0	0	155
	SM_StopSign6	125.28	-130.73	0	0	0	-180
	SM_StopSign8	82.01	-192.74	0	0	0	-180
	SM_StopSign4	59.90	-161.03	0	0	0	-25
	LargeSingleArrowSign	121.01	-148.56	0	0	0	0

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
	SM_YieldSign2	162.22	-109.64	0	0	0	25
	SM_WindingRoadSign	127.11	-50.21	.01	0	0	50
	SchoolBusOnlySign	44.03	-51.11	0	0	0	90
	SM_YellowRoadSign5	68.05	-47.03	.01	0	0	-175
	SM_CrossSignal8	74.37	-14.11	0	0	0	-165
	SM_CrossSignal7	64.69	-22.69	0	0	0	-150
	SM_CrossSignal6	62.51	-20.34	0	0	0	40
	SM_CrossSignal5	72.42	-12.06	0	0	0	40
	SM_YellowRoadSign2	60.01	-2.69	-.01	0	0	50
	SM_CrossSignal2	28.53	-20.58	0	0	0	-20
	SM_CrossSignal	21.19	-17.95	0	0	0	-20
	SM_CrossSignal3	17.55	-21.53	0	0	0	-170
	SM_CrossSignal4	6.59	-27.66	0	0	0	-145
	SM_YieldSign4	4.89	-23.42	0	0	0	-140
	SM_YellowRoadSign4	9.23	-45.63	0	0	0	-175
	SM_BikeLaneSign	24.13	-92.03	.15	0	0	0

Traffic Lights

Locations

This table provides the object names and locations in the world coordinate system. Dimensions are in m and deg.

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
Traffic lights	SM_TrafficLights	27.40	-138.55	.16	0	0	90
	SM_TrafficLights2	9.38	-106.90	.16	0	0	-90
	SM_TrafficLightsSideOnly3	8.44	-47.95	-.03	0	0	-92.2
	SM_TrafficLightsSideOnly4	1.64	-55.10	.16	0	0	-5
	SM_TrafficLightsSideOnly5	9.24	-67.70	.16	0	0	85
	SM_TrafficLightsSideOnly6	24.50	-67.82	.16	0	0	85
	SM_TrafficLights3	27.89	-109.86	.16	0	0	180
	SM_HangingTrafficLightSingle	74.43	-69.25	7.37	0	0	0

Object	Unreal Engine Editor Name	Location					
		X (m)	Y (m)	Z (m)	Roll (deg)	Pitch (deg)	Yaw (deg)
	`SM_HangingTrafficLightSingle2`	`76.13`	`-69.10`	`7.34`	`0`	`0`	`0`
	`SM_HangingTrafficLightSingle3`	`82.58`	`-60.10`	`7.57`	`0`	`0`	`-90`
	`SM_HangingTrafficLightSingle4`	`82.65`	`-61.48`	`7.54`	`0`	`0`	`-90`
	`SM_HangingTrafficLightSingle6`	`73.67`	`-51.25`	`7.97`	`0`	`0`	`-180`
	`SM_HangingTrafficLightSingle7`	`75.07`	`-51.25`	`7.95`	`0`	`0`	`-180`
	`SM_HangingTrafficLight`	`-24.78`	`-61.49`	`6.71`	`0`	`0`	`100`
	`SM_RailroadCrossing4`	`-18.21`	`-86.63`	`.01`	`0`	`0`	`8`
	`SM_RailroadCrossing5`	`-26.73`	`-90.78`	`.01`	`0`	`0`	`-172`

Limitations

- In the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package, this scene is not available for customization.

  For details on which scenes you can customize, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Version History

Introduced in R2018b

See Also

Simulation 3D Scene Configuration | Curved Road | Double Lane Change | Open Surface | Large Parking Lot | Parking Lot | Straight Road | US City Block | US Highway

Topics

“Unreal Engine Simulation Environment Requirements and Limitations”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Customize 3D Scenes for Vehicle Dynamics Simulations”

External Websites

Mcity Test Facility

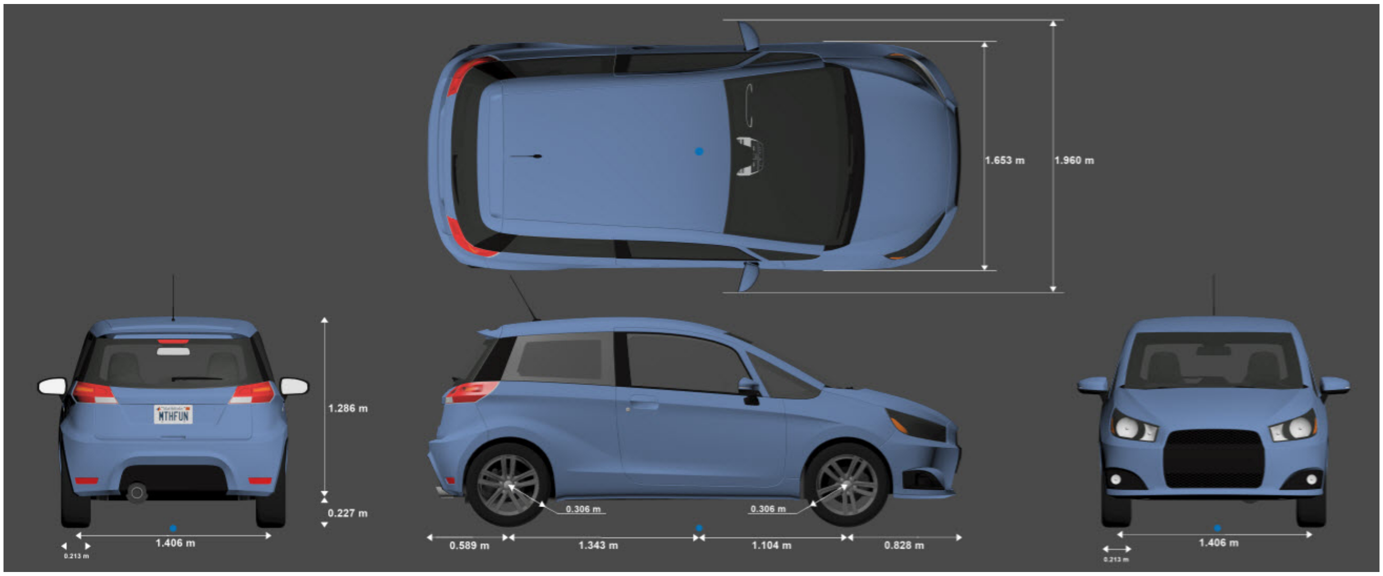
Vehicle Dimensions

Hatchback

Hatchback vehicle dimensions

Description

Hatchback is one of the vehicles that you can use within the 3D simulation environment. This environment is rendered using the Unreal Engine from Epic Games. The diagram provides the dimensions of this vehicle. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the vehicle in the vehicle coordinate system. The origin is on the ground, at the geometric center of the vehicle. For more detailed views of these diagrams, see the **Dimensions** section.



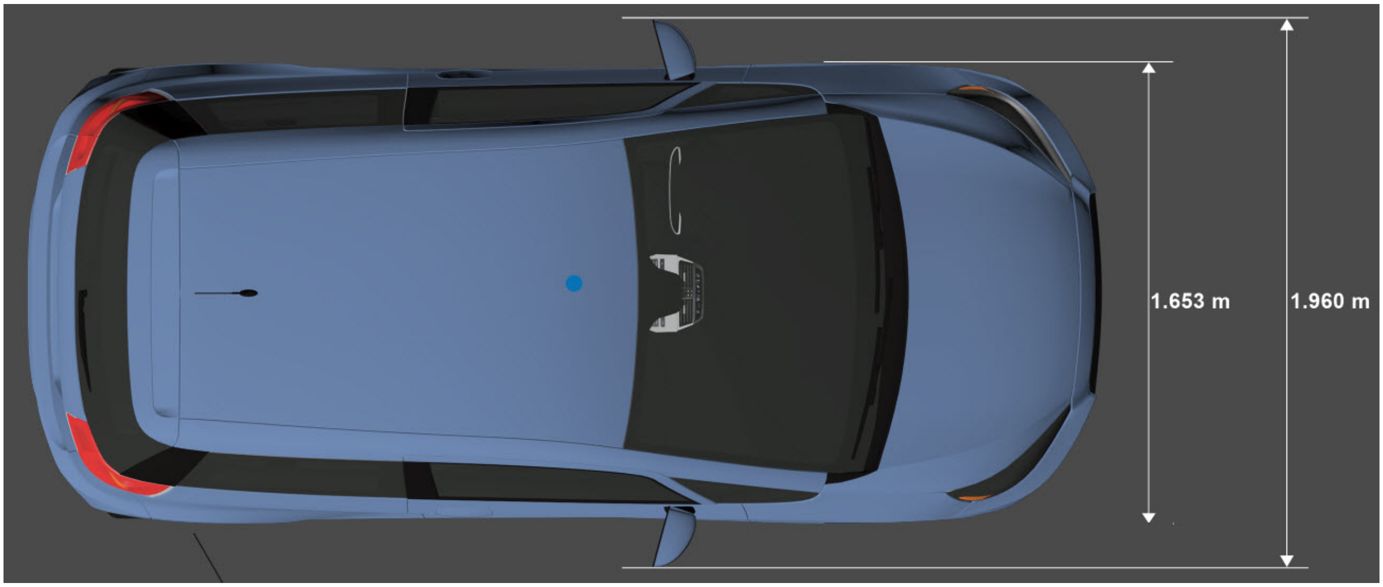
To add this type of vehicle to the 3D simulation environment:

1. Add a Simulation 3D Vehicle or Simulation 3D Vehicle with Ground Following block to your Simulink model.
2. In the block, set the **Type** parameter to `Hatchback`.

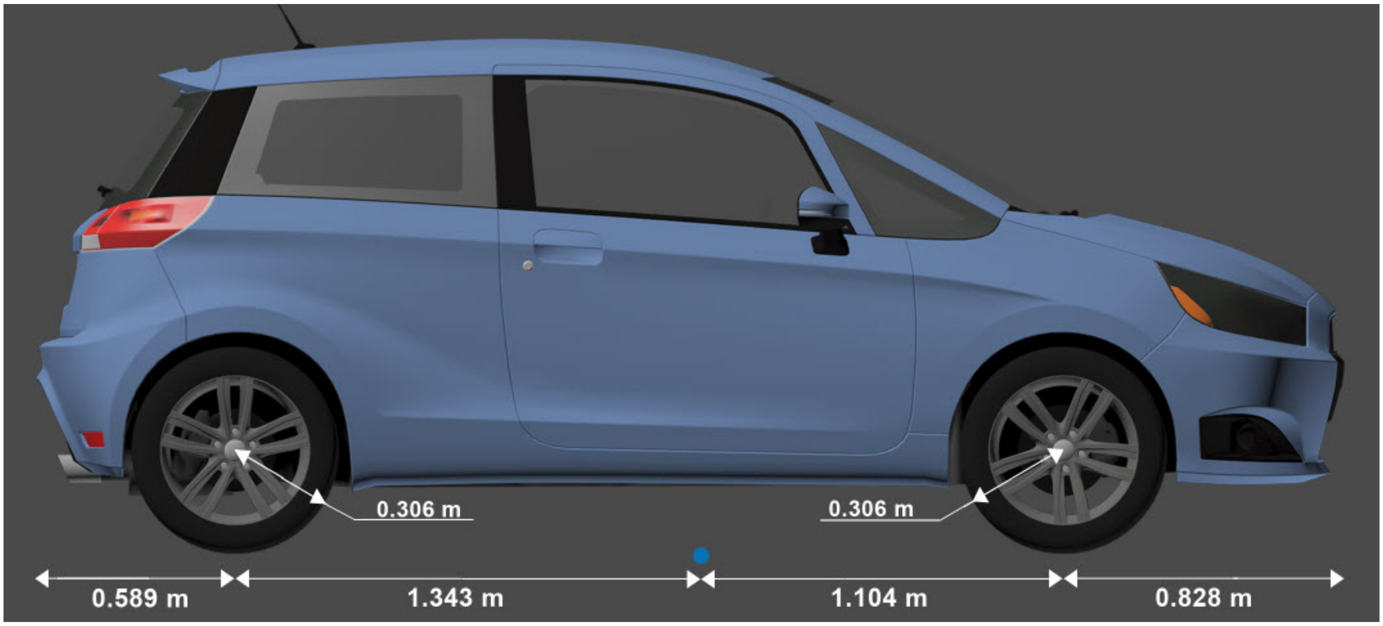
Dimensions

`Top-down view` — Vehicle width dimensions

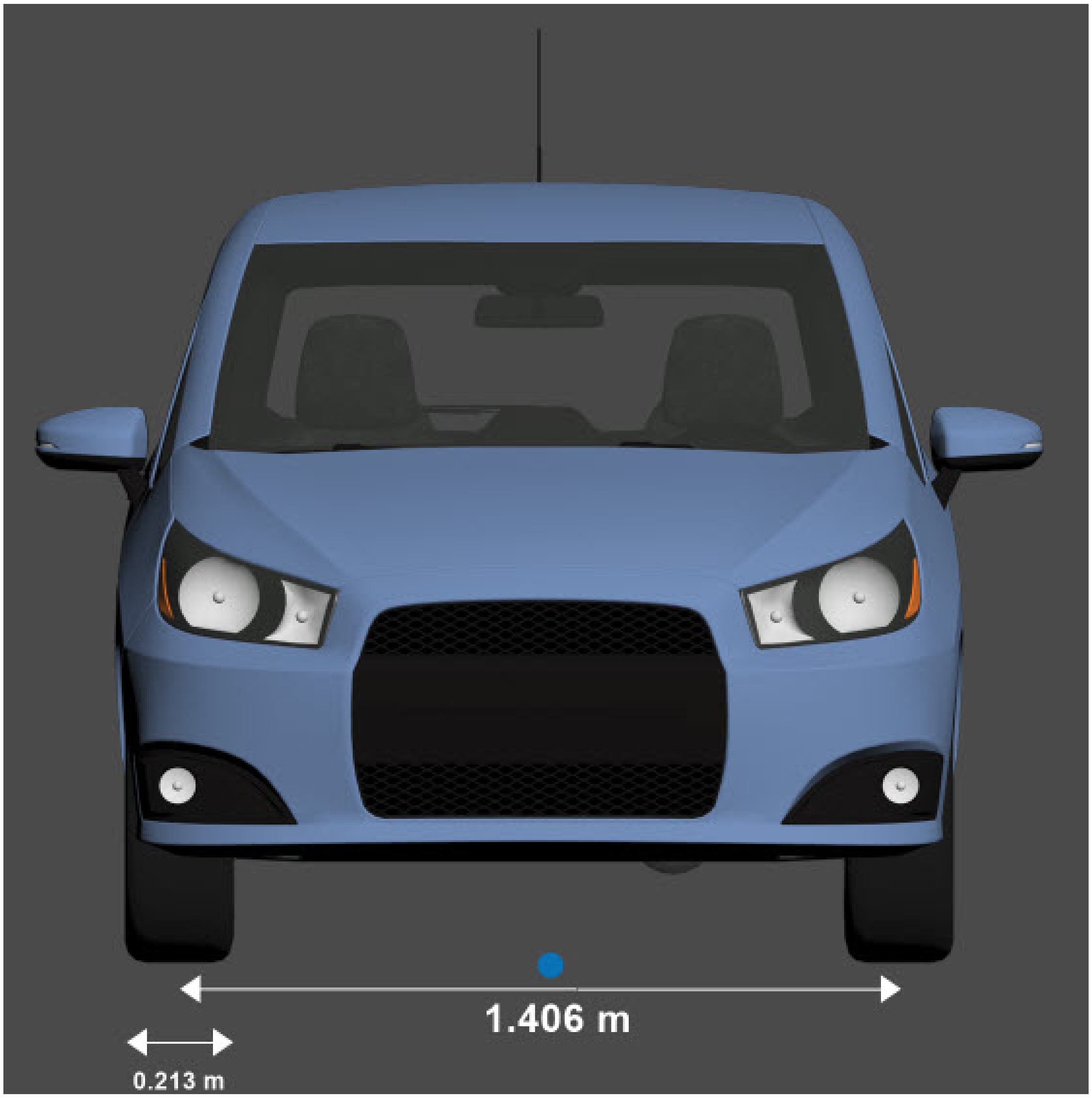
diagram



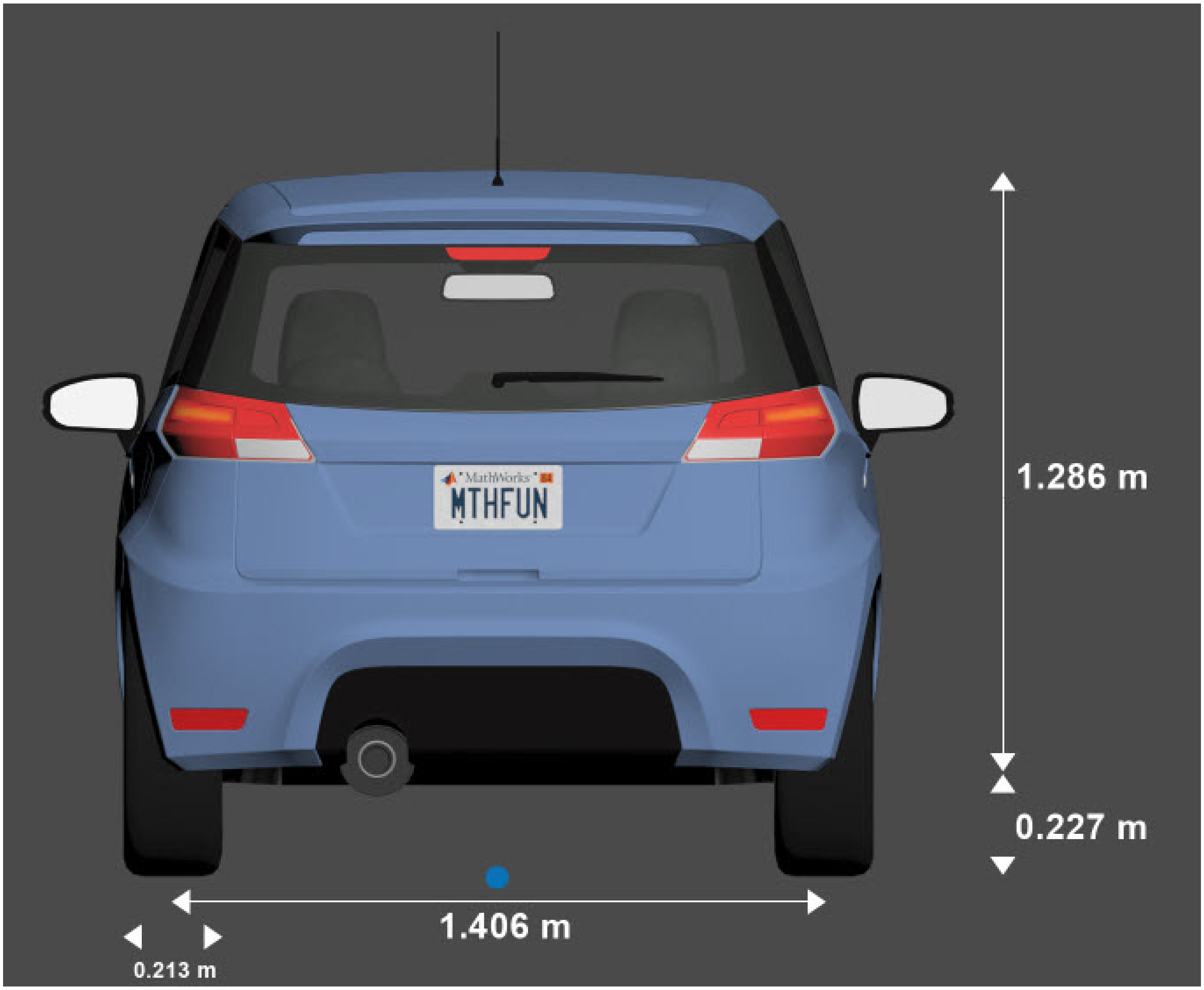
`Side view` — Vehicle length, front overhang, and rear overhang dimensions
diagram



`Front view` — Tire width and front axle dimensions
diagram



`Rear view` — Vehicle height and rear axle dimensions
diagram



Sensor Mounting Locations

In the 3D simulation sensor blocks, use the **Mounting location** parameter to mount sensors at predefined locations on the vehicle. The table shows the *X*, *Y*, and *Z* positions of the mounting locations relative to the vehicle origin. These locations are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up from the ground.

Hatchback — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	1.93	0	0.51
`Rear bumper`	–1.93	0	0.51
`Right mirror`	0.43	–0.84	1.01
`Left mirror`	0.43	0.84	1.01
`Rearview mirror`	0.32	0	1.27
`Hood center`	1.44	0	1.01
`Roof center`	0	0	1.57

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

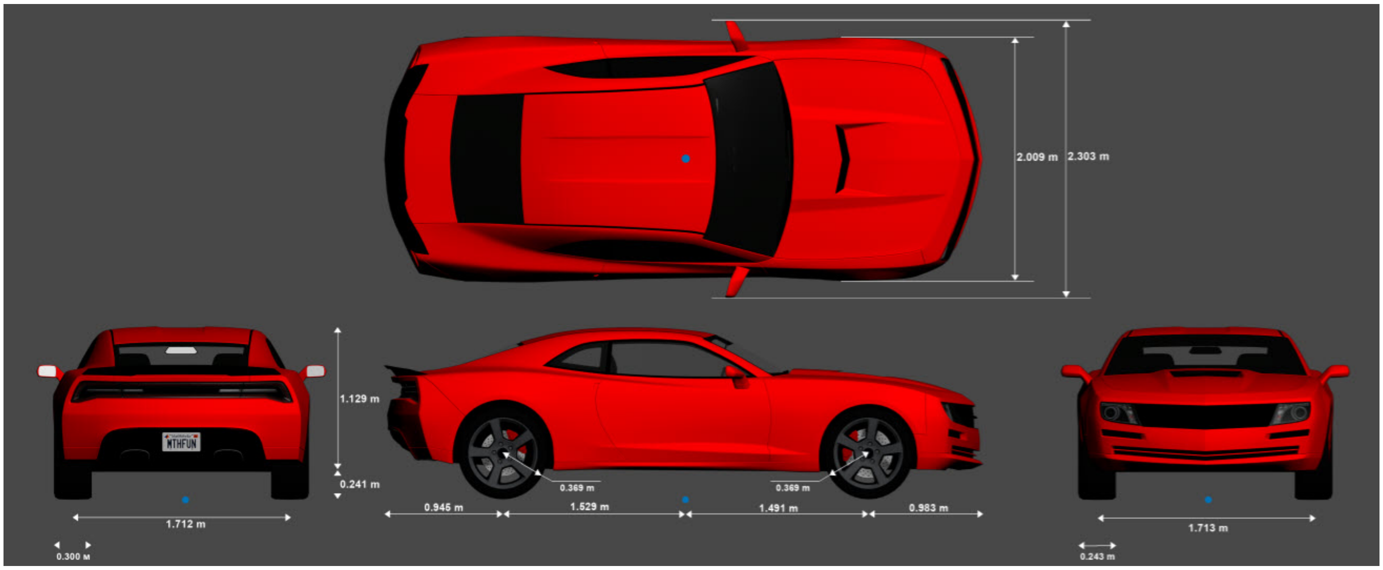
"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Muscle Car

Muscle car vehicle dimensions

Description

Muscle Car is one of the vehicles that you can use within the 3D simulation environment. This environment is rendered using the Unreal Engine from Epic Games. The following diagram provides the dimensions of this vehicle. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the vehicle in the vehicle coordinate system. The origin is on the ground, at the geometric center of the vehicle. For more detailed views of these diagrams, see the **Dimensions** section.



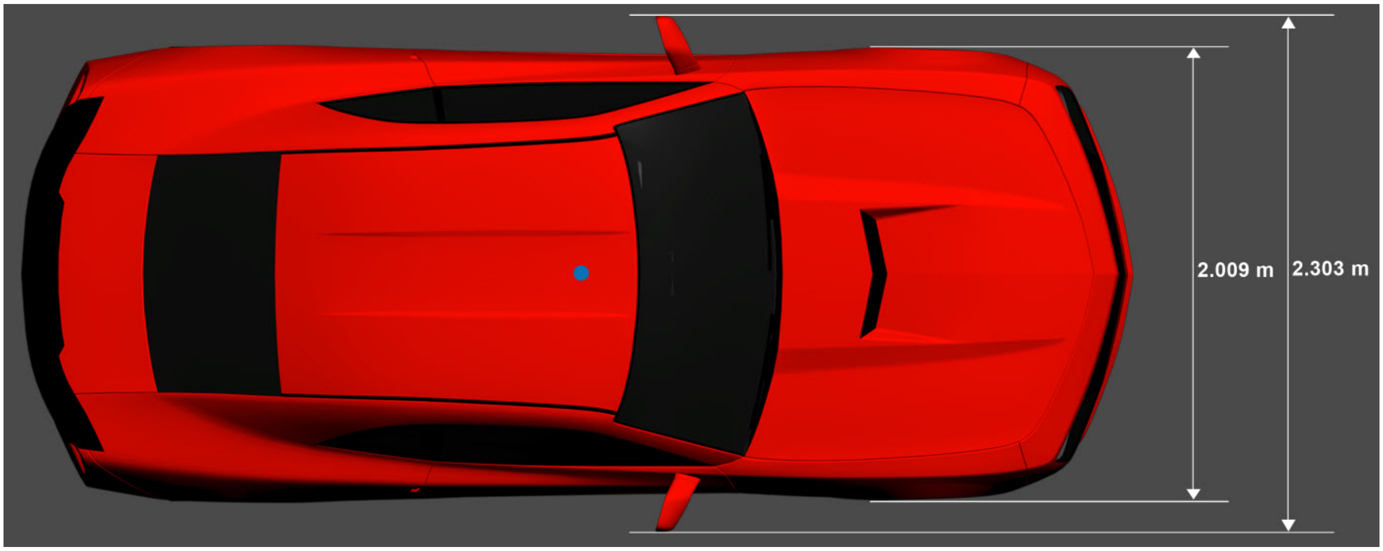
To add this type of vehicle to the 3D simulation environment:

1. Add a Simulation 3D Vehicle or Simulation 3D Vehicle with Ground Following block to your Simulink model.
2. In the block, set the **Type** parameter to `Muscle car`.

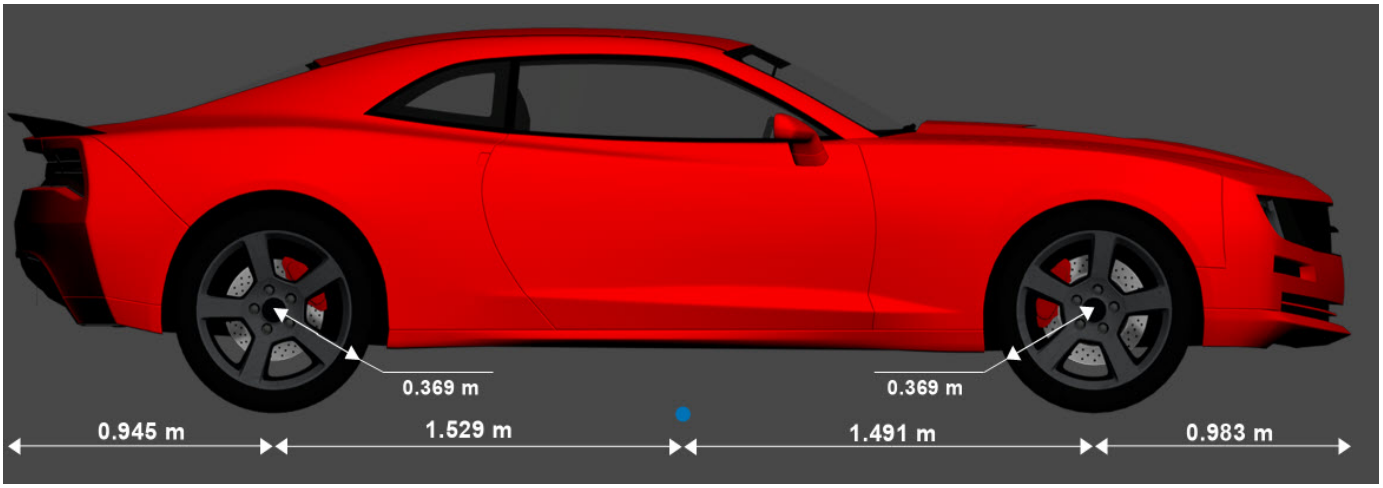
Dimensions

`Top-down view` — Vehicle width dimensions

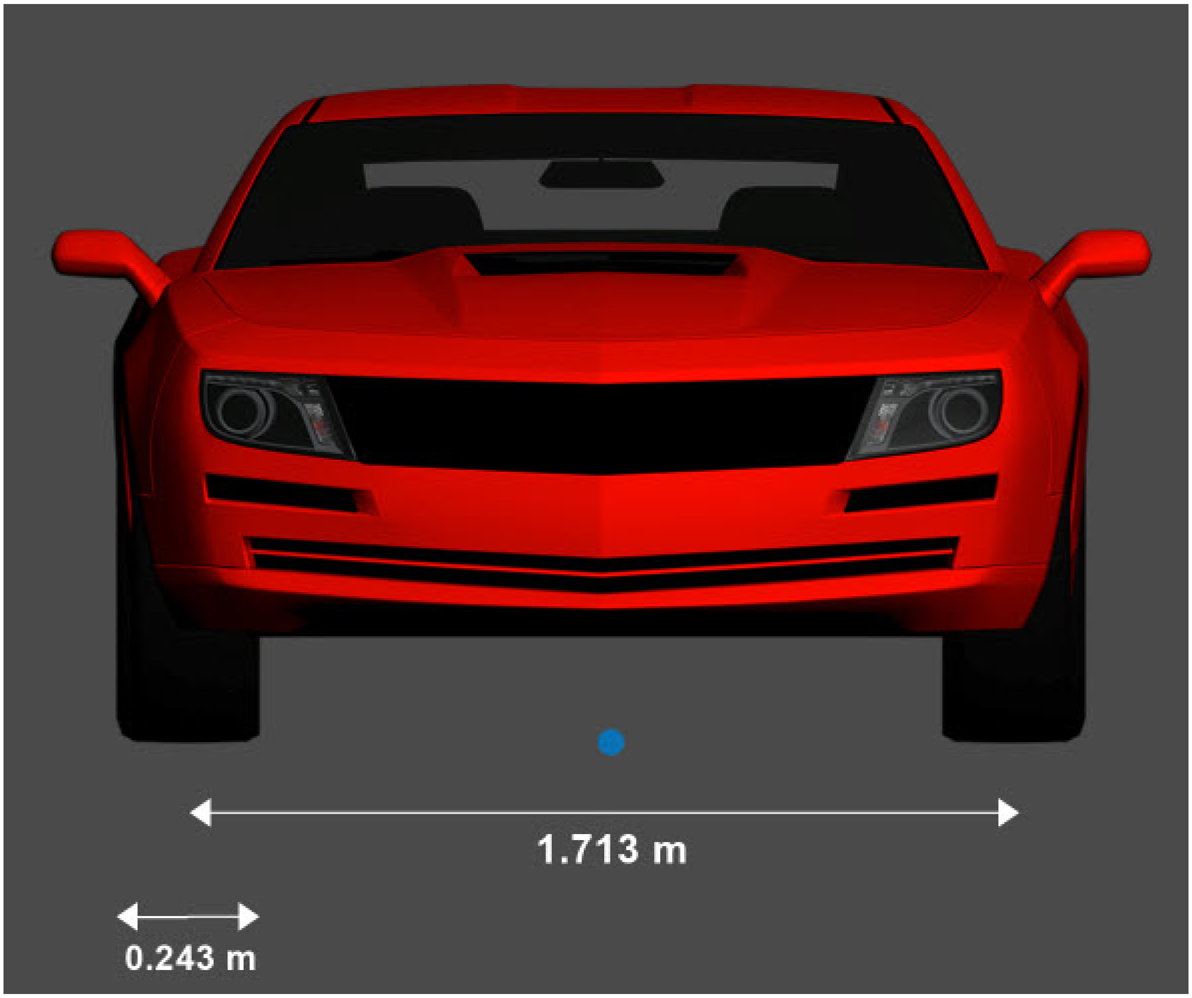
diagram



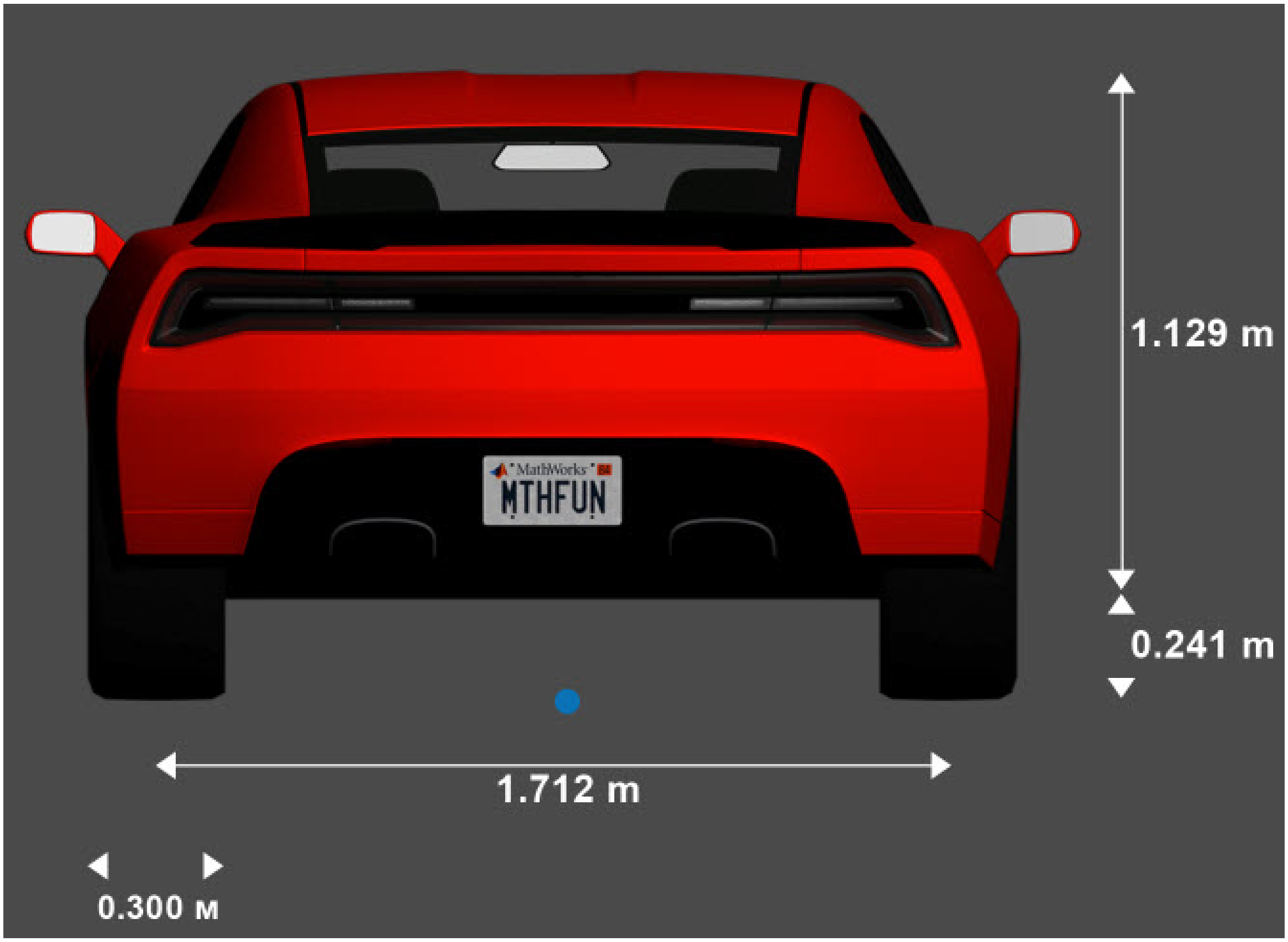
`Side view` — Vehicle length, front overhang, and rear overhang dimensions
diagram



`Front view` — Tire width and front axle dimensions
diagram



`Rear view` — Vehicle height and rear axle dimensions
diagram



Sensor Mounting Locations

In the 3D simulation sensor blocks, use the **Mounting location** parameter to mount sensors at predefined locations on the vehicle. The table shows the *X*, *Y*, and *Z* positions of the mounting locations relative to the vehicle origin. These locations are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up from the ground.

Muscle Car — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	2.47	0	0.45
`Rear bumper`	–2.47	0	0.45
`Right mirror`	0.43	–1.08	1.01
`Left mirror`	0.43	1.08	1.01
`Rearview mirror`	0.32	0	1.20
`Hood center`	1.28	0	1.14
`Roof center`	–0.25	0	1.58

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

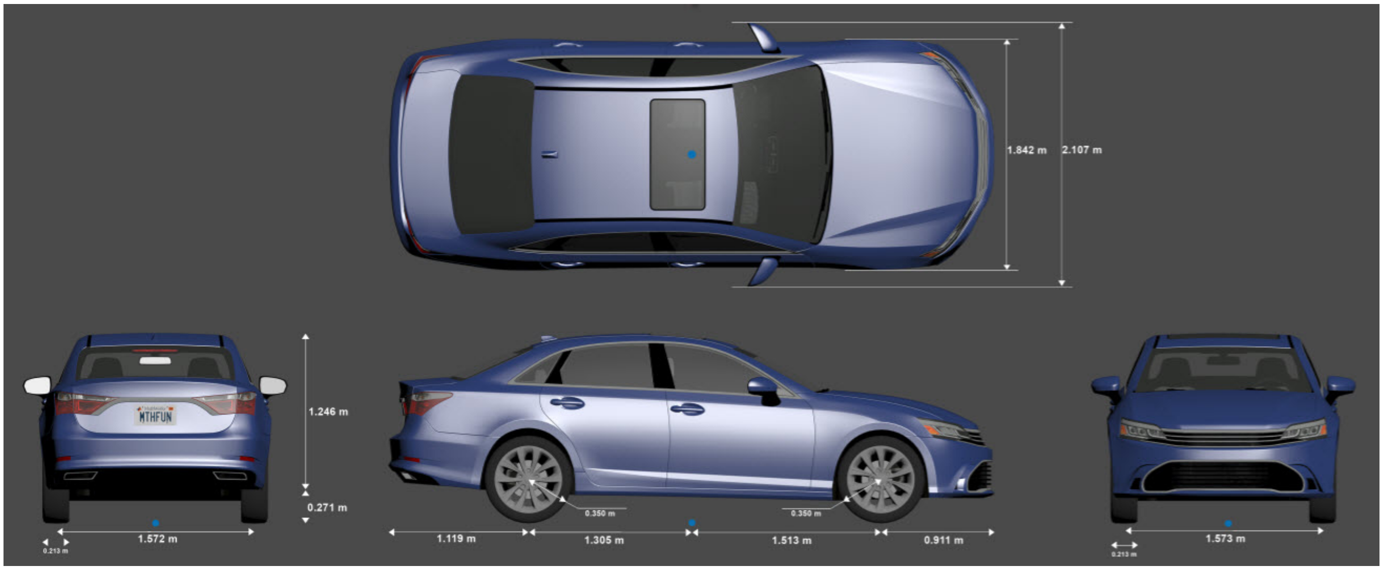
“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”

Sedan

Sedan vehicle dimensions

Description

Sedan is one of the vehicles that you can use within the 3D simulation environment. This environment is rendered using the Unreal Engine from Epic Games. The diagram provides the dimensions of this vehicle. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the vehicle in the vehicle coordinate system. The origin is on the ground, at the geometric center of the vehicle. For more detailed views of these diagrams, see the **Dimensions** section.

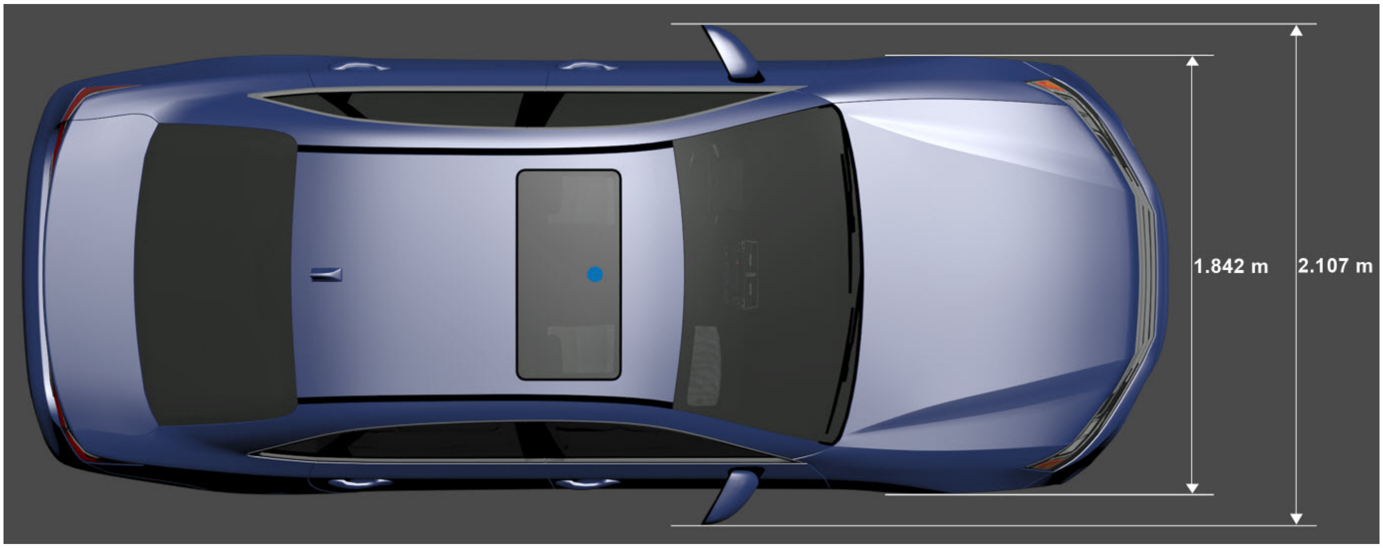


To add this type of vehicle to the 3D simulation environment:

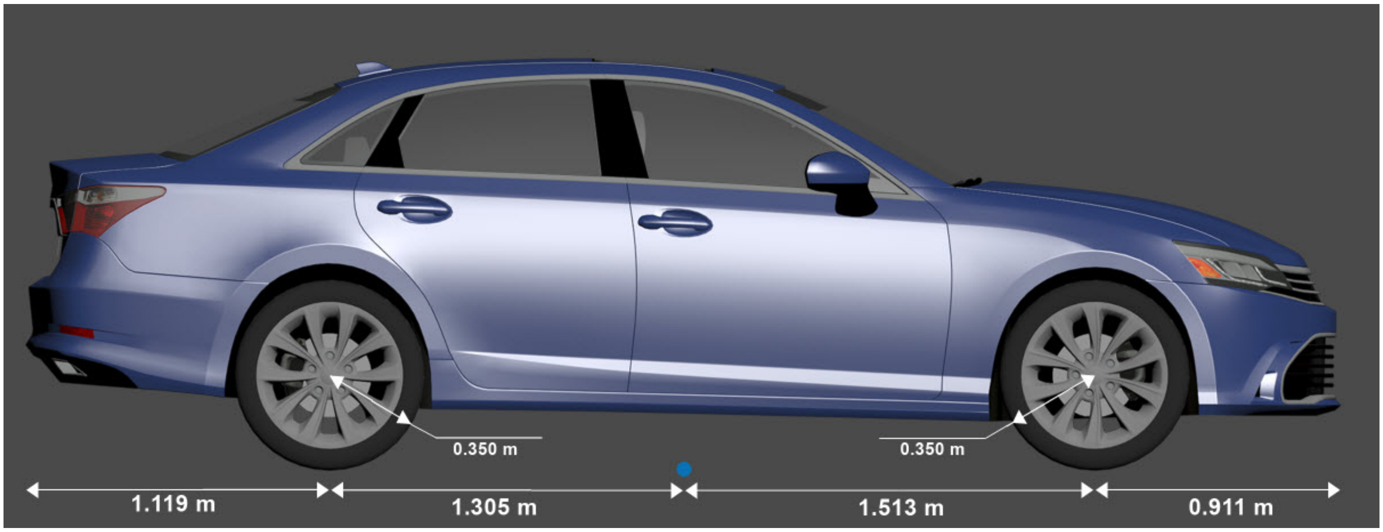
1. Add a Simulation 3D Vehicle or Simulation 3D Vehicle with Ground Following block to your Simulink model.
2. In the block, set the **Type** parameter to `Sedan`.

Dimensions

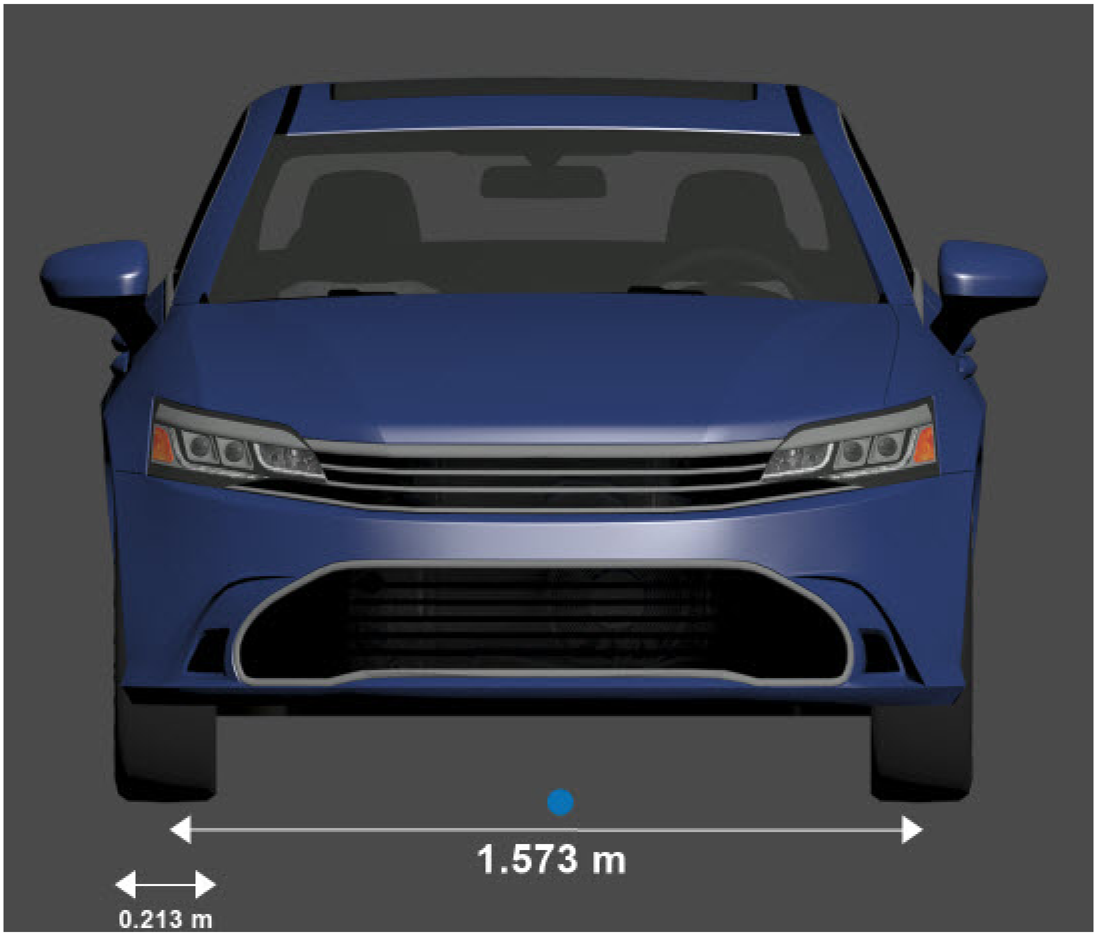
`Top-down view` — Vehicle width dimensions
diagram



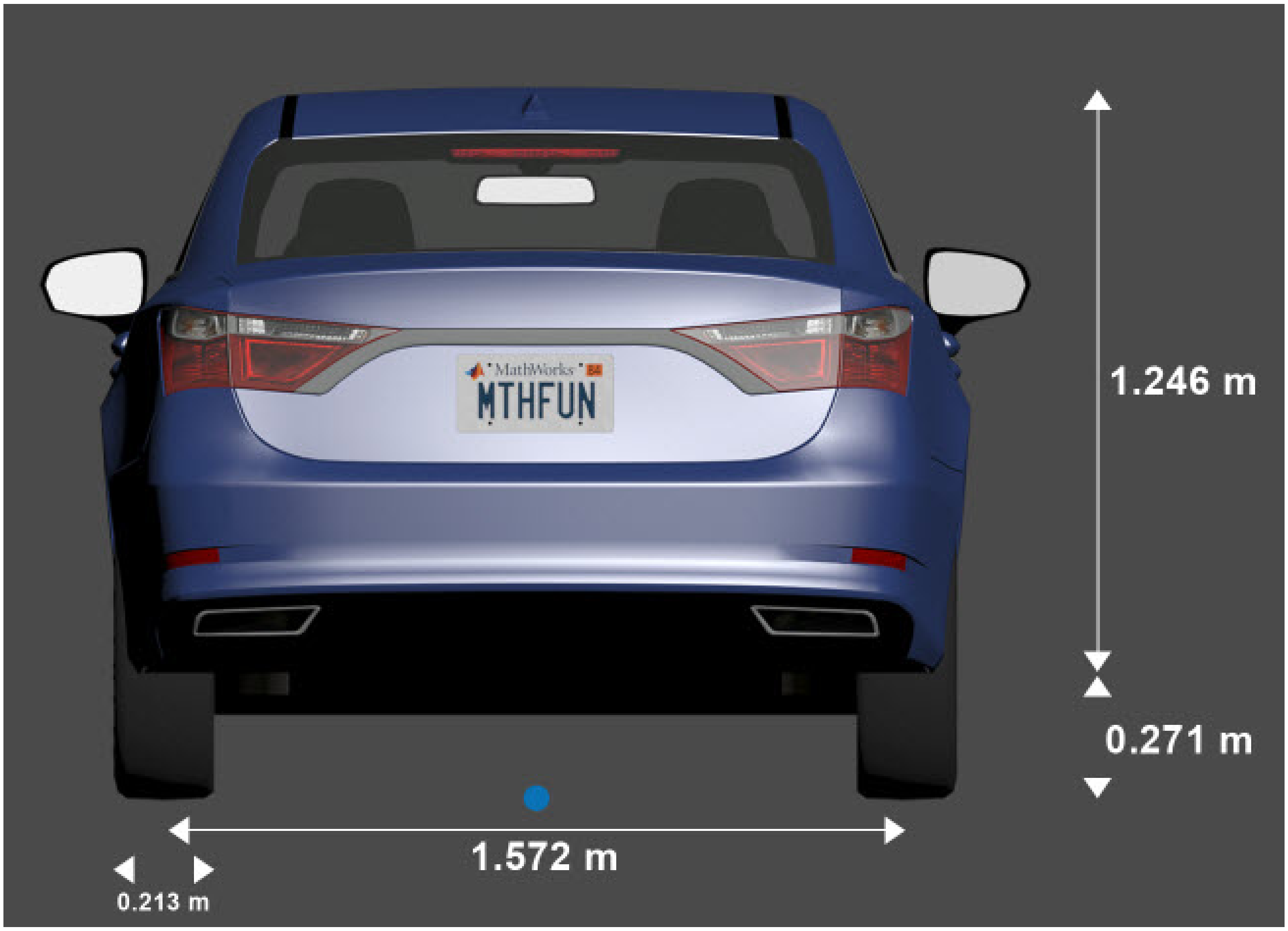
Side view — Vehicle length, front overhang, and rear overhang dimensions
diagram



Front view — Tire width and front axle dimensions
diagram



`Rear view` — Vehicle height and rear axle dimensions
diagram



Sensor Mounting Locations

In the 3D simulation sensor blocks, use the **Mounting location** parameter to mount sensors at predefined locations on the vehicle. The table shows the *X*, *Y*, and *Z* positions of the mounting locations relative to the vehicle origin. These locations are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up from the ground.

Sedan — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	2.42	0	0.51
`Rear bumper`	–2.42	0	0.51
`Right mirror`	0.59	–0.94	1.09
`Left mirror`	0.59	0.94	1.09
`Rearview mirror`	0.43	0	1.31
`Hood center`	1.46	0	1.11
`Roof center`	–0.45	0	1.69

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Sport Utility Vehicle

Sport utility vehicle dimensions

Description

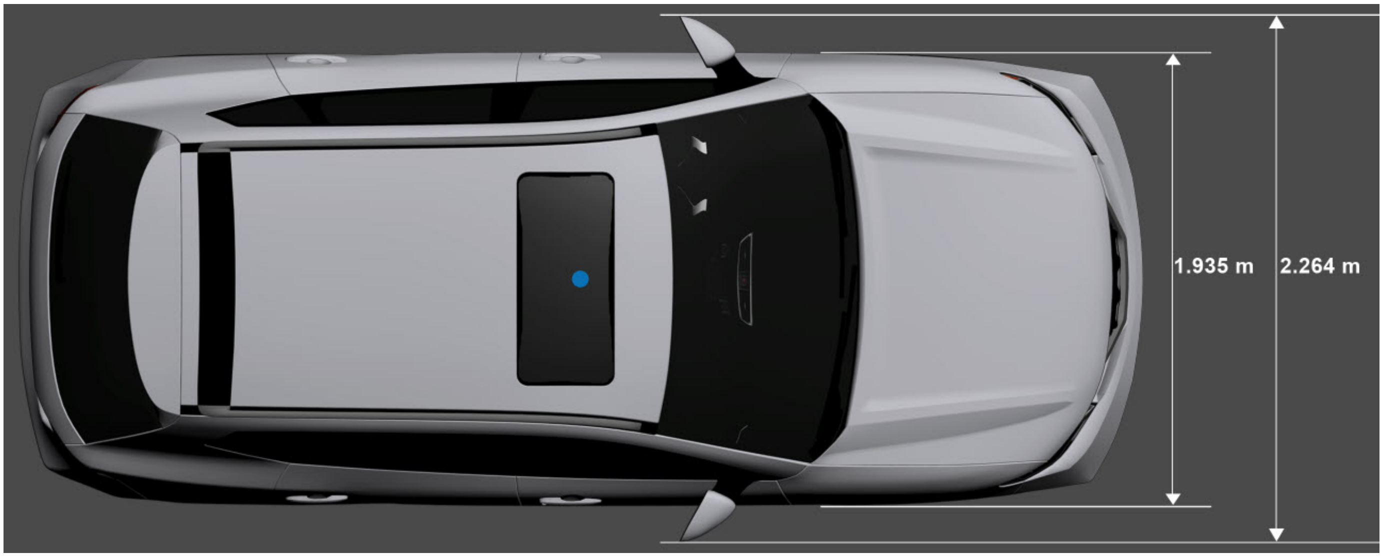
Sport Utility Vehicle is one of the vehicles that you can use within the 3D simulation environment. This environment is rendered using the Unreal Engine from Epic Games. The following diagram provides the dimensions of this vehicle. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the vehicle in the vehicle coordinate system. The origin is on the ground, at the geometric center of the vehicle. For more detailed views of these diagrams, see the **Dimensions** section.

To add this type of vehicle to the 3D simulation environment:

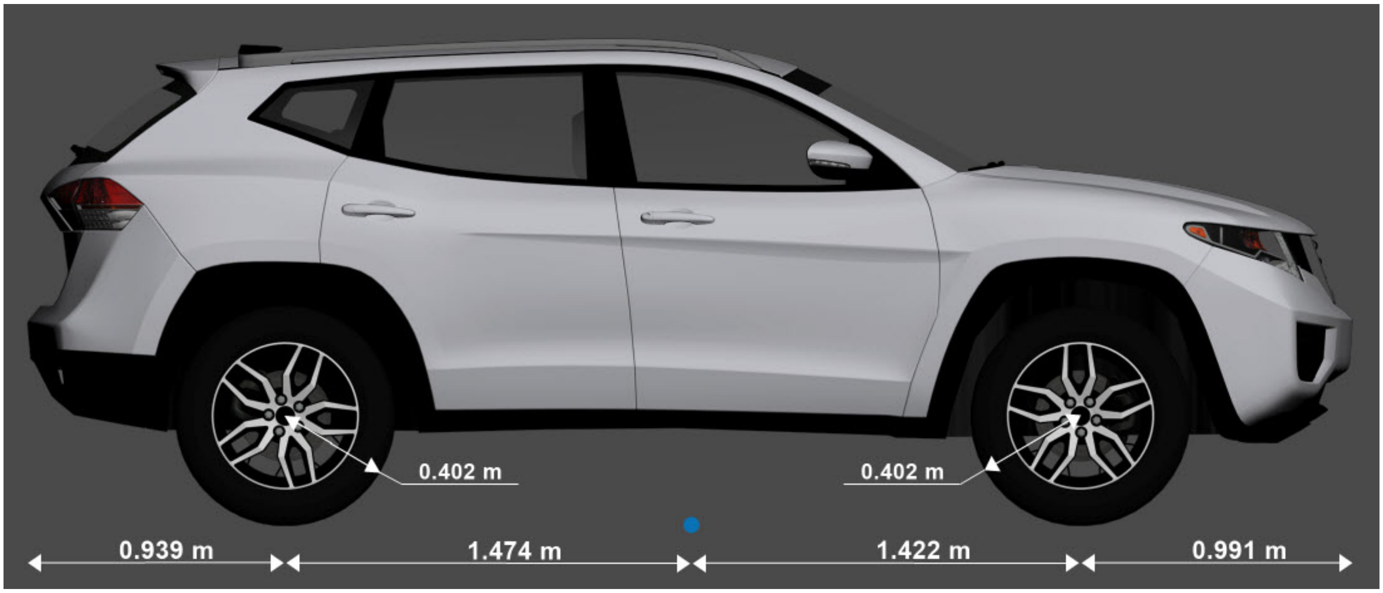
1. Add a Simulation 3D Vehicle or Simulation 3D Vehicle with Ground Following block to your Simulink model.
2. In the block, set the **Type** parameter to `Sport utility vehicle`.

Dimensions

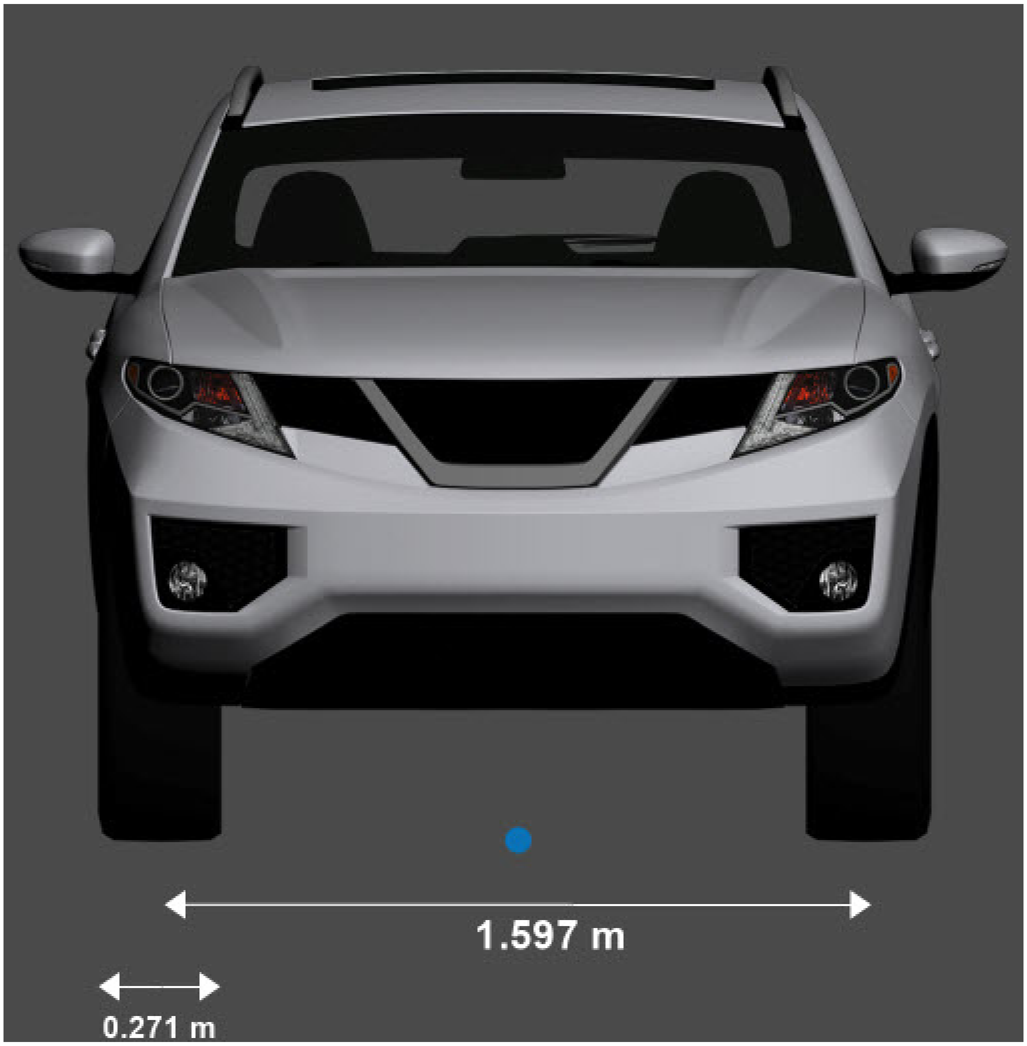
`Top-down view` — Vehicle width dimensions
diagram



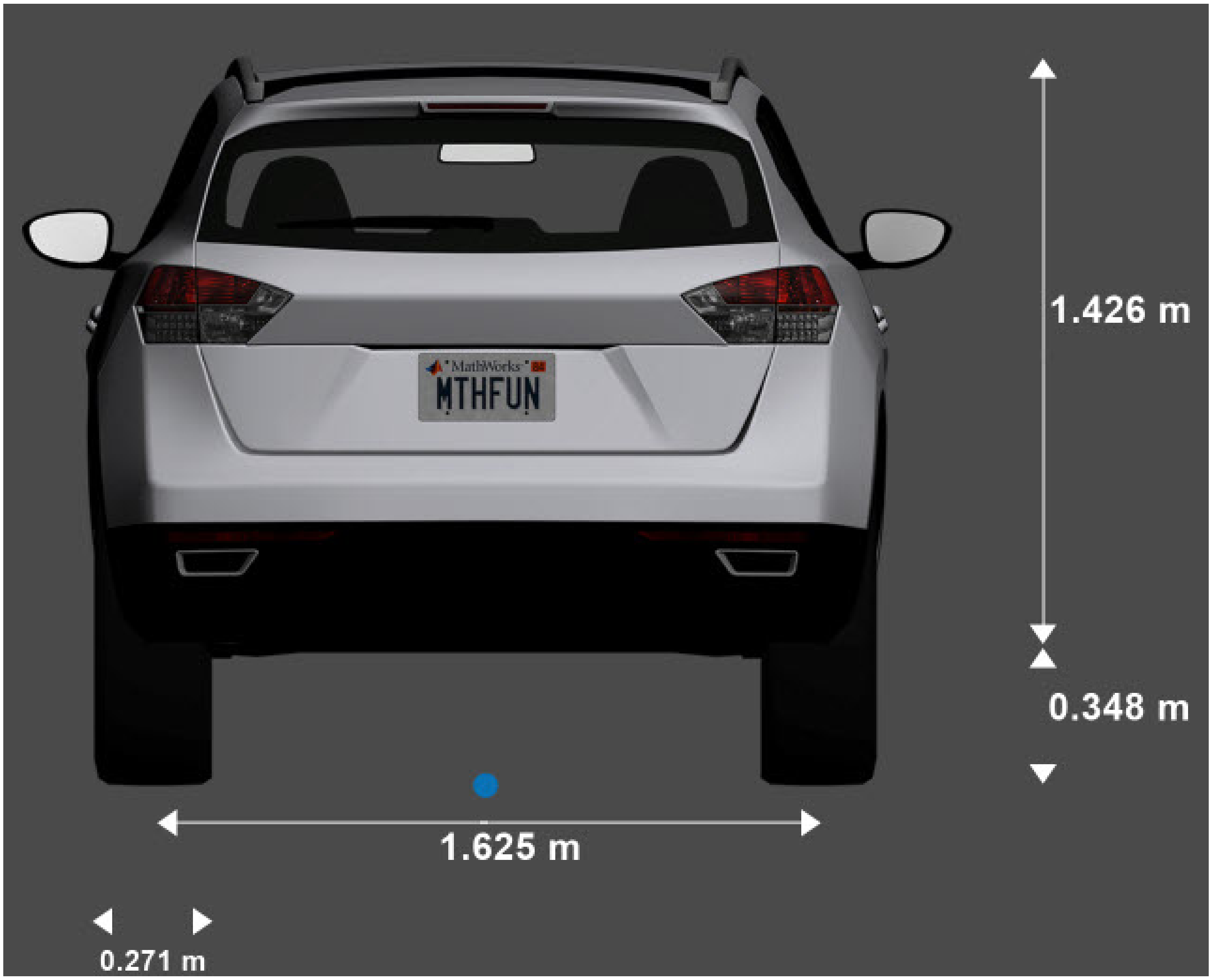
`Side view` — Vehicle length, front overhang, and rear overhang dimensions
diagram



`Front view` — Tire width and front axle dimensions
diagram



`Rear view` — Vehicle height and rear axle dimensions
diagram



Sensor Mounting Locations

In the 3D simulation sensor blocks, use the **Mounting location** parameter to mount sensors at predefined locations on the vehicle. The table shows the *X*, *Y*, and *Z* positions of the mounting locations relative to the vehicle origin. These locations are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up from the ground.

Sport Utility Vehicle — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	2.42	0	0.51
`Rear bumper`	–2.42	0	0.51
`Right mirror`	0.60	–1	1.35
`Left mirror`	0.60	1	1.35
`Rearview mirror`	0.39	0	1.55
`Hood center`	1.58	0	1.39
`Roof center`	–0.56	0	2

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

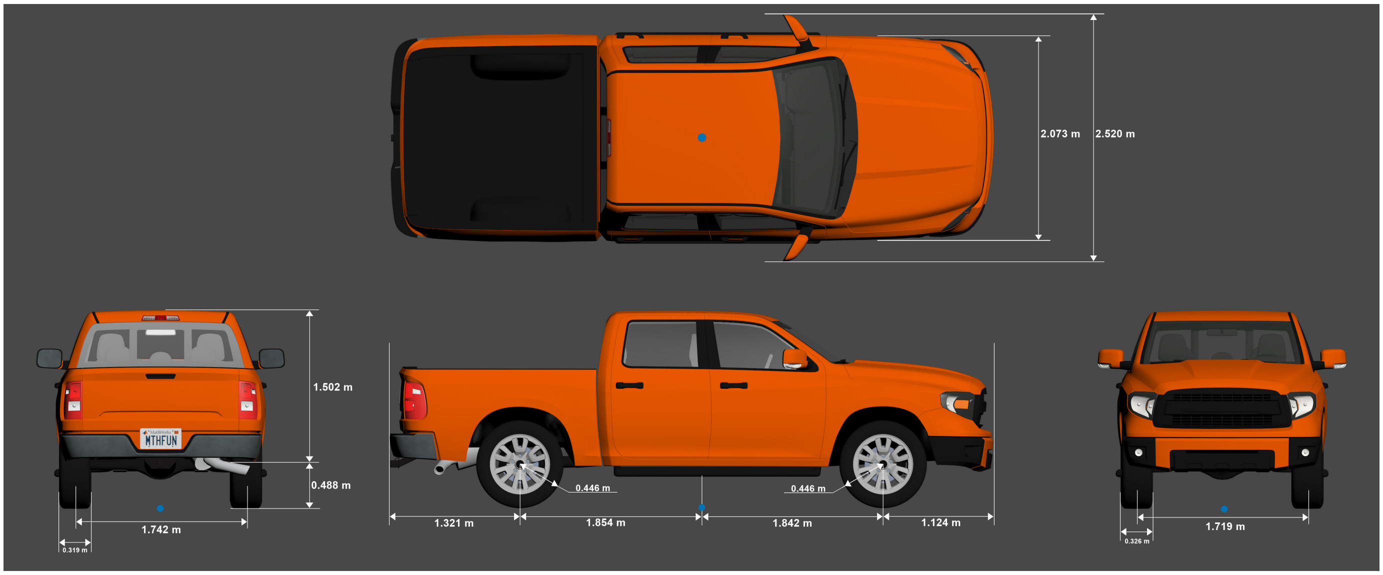
“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”

Small Pickup Truck

Small pickup truck vehicle dimensions

Description

Small Pickup Truck is one of the vehicles that you can use within the 3D simulation environment. This environment is rendered using the Unreal Engine from Epic Games. The following diagram provides the dimensions of this vehicle. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the vehicle in the vehicle coordinate system. The origin is on the ground, at the geometric center of the vehicle. For more detailed views of these diagrams, see the **Dimensions** section.



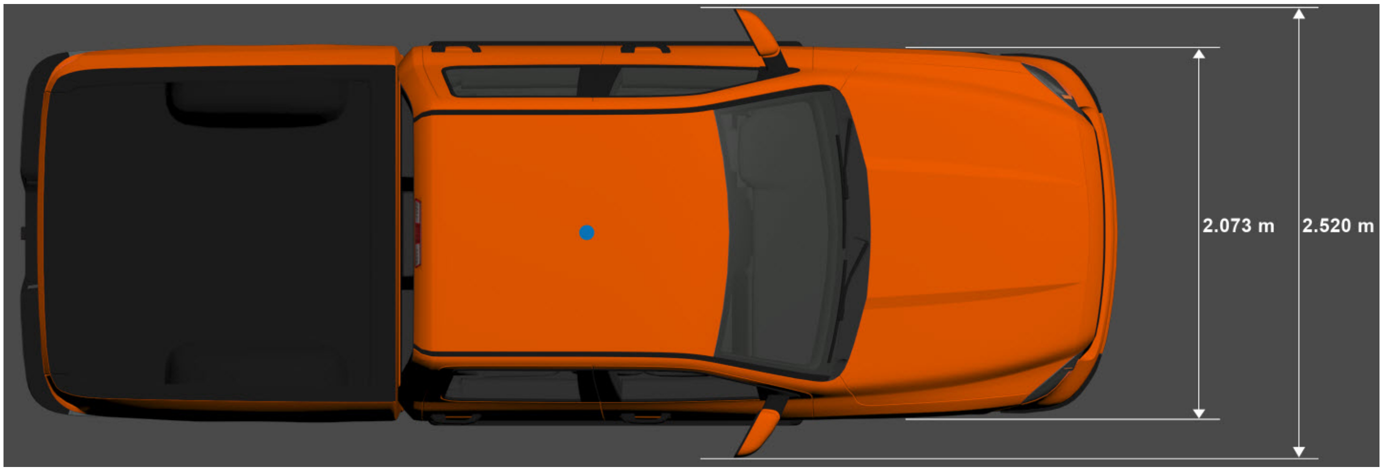
To add this type of vehicle to the 3D simulation environment:

1. Add a Simulation 3D Vehicle or Simulation 3D Vehicle with Ground Following block to your Simulink model.
2. In the block, set the **Type** parameter to `Small pickup truck`.

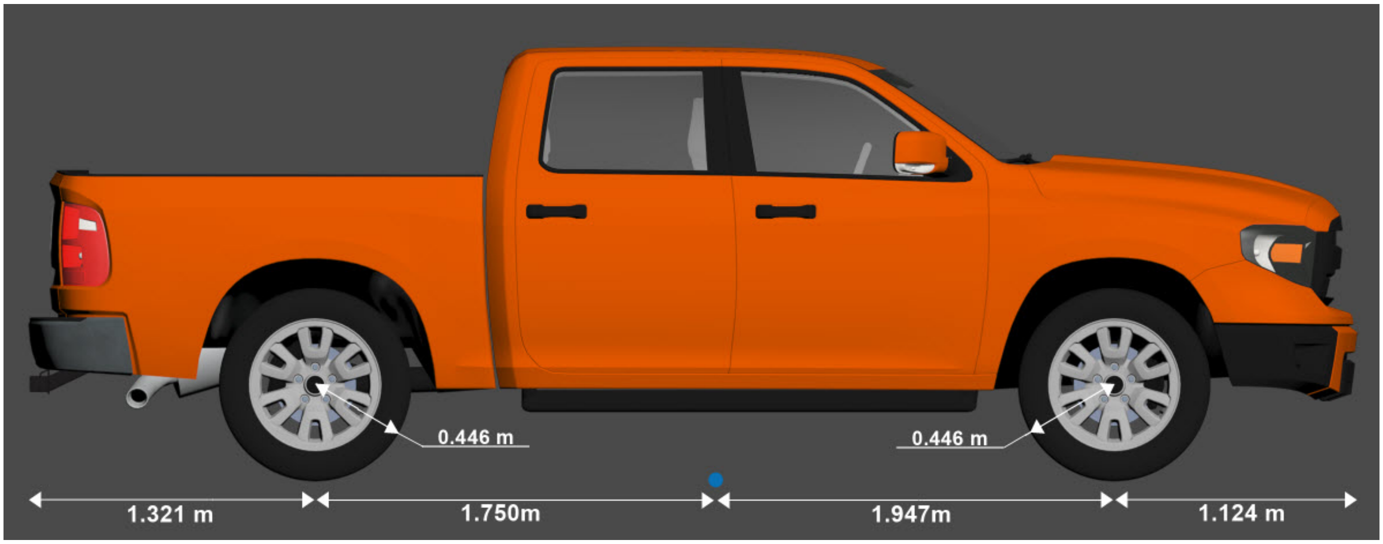
Dimensions

`Top-down view` — Vehicle width dimensions

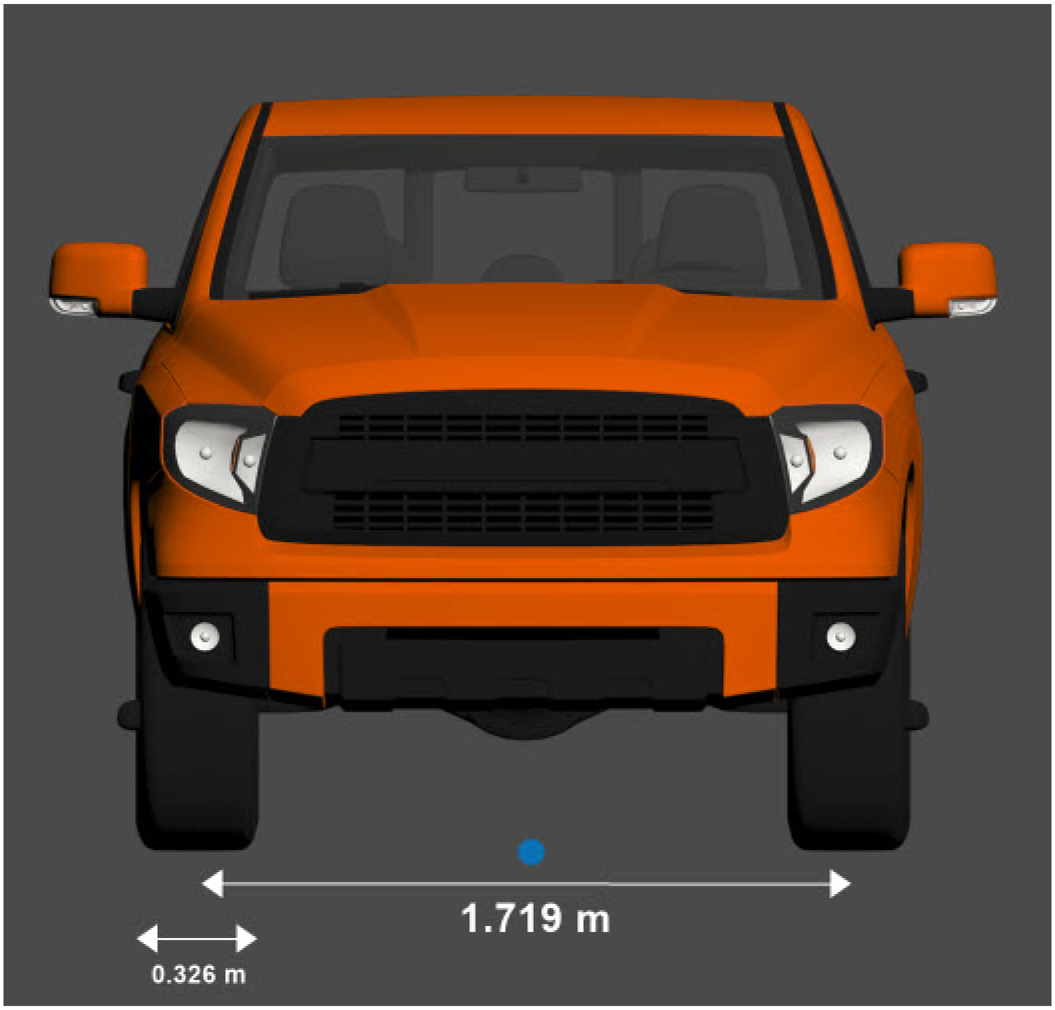
diagram



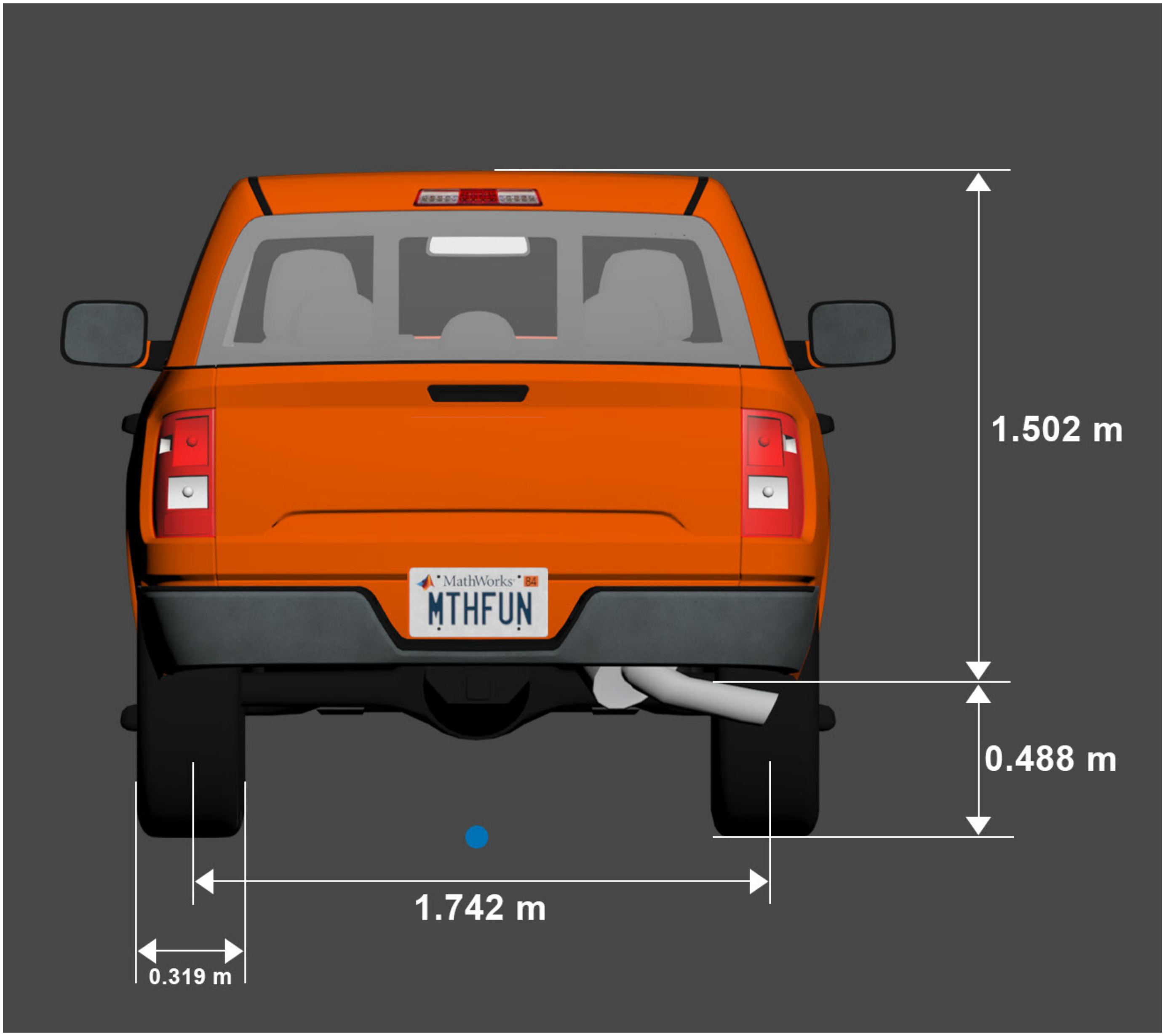
`Side view` — Vehicle length, front overhang, and rear overhang dimensions
diagram



`Front view` — Tire width and front axle dimensions
diagram



`Rear view` — Vehicle height and rear axle dimensions
diagram



Sensor Mounting Locations

In the 3D simulation sensor blocks, use the **Mounting location** parameter to mount sensors at predefined locations on the vehicle. The table shows the *X*, *Y*, and *Z* positions of the mounting locations relative to the vehicle origin. These locations are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up from the ground.

Small Pickup Truck — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	3.07	0	0.51
`Rear bumper`	–3.07	0	0.51
`Right mirror`	1.10	–1.13	1.52
`Left mirror`	1.10	1.13	1.52
`Rearview mirror`	0.85	0	1.77
`Hood center`	2.22	0	1.59
`Roof center`	0	0	2.27

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”

Box Truck

Box truck vehicle dimensions

Description

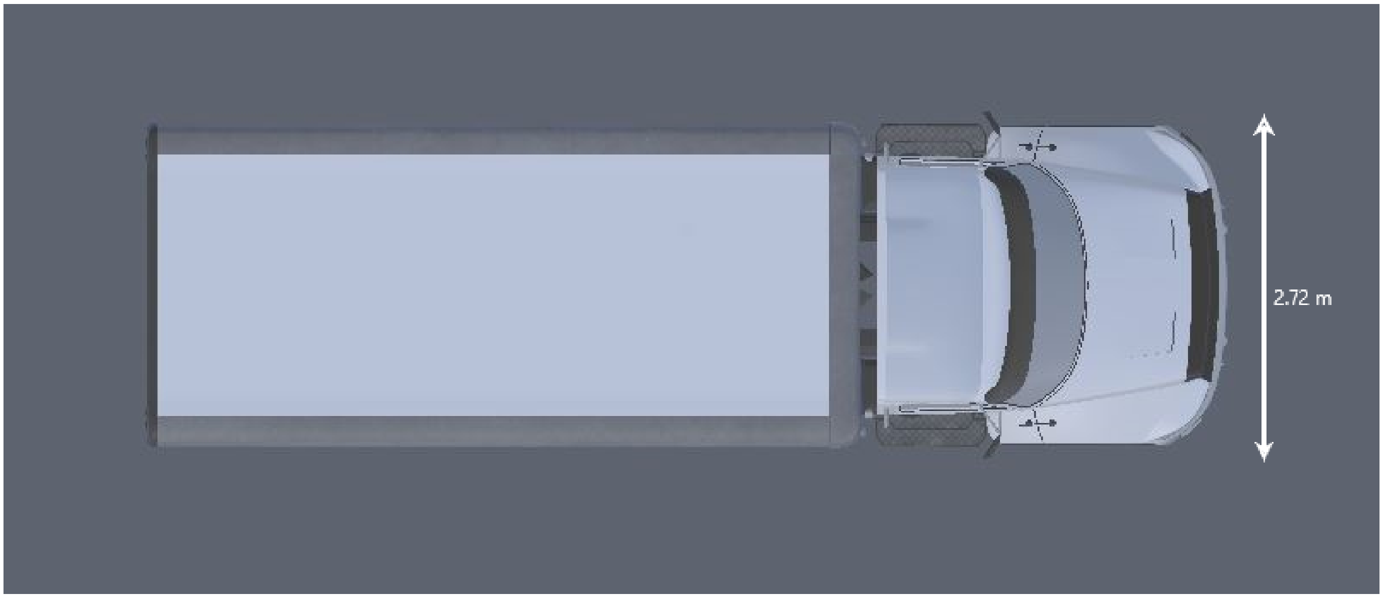
Box truck is one of the vehicles that you can use within the 3D simulation environment. This environment is rendered using the Unreal Engine from Epic Games. The following diagram provides the dimensions of this vehicle. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the vehicle in the vehicle coordinate system. The origin is on the ground, at the geometric center of the vehicle. For more detailed views of these diagrams, see the **Dimensions** section.

To add this type of vehicle to the 3D simulation environment:

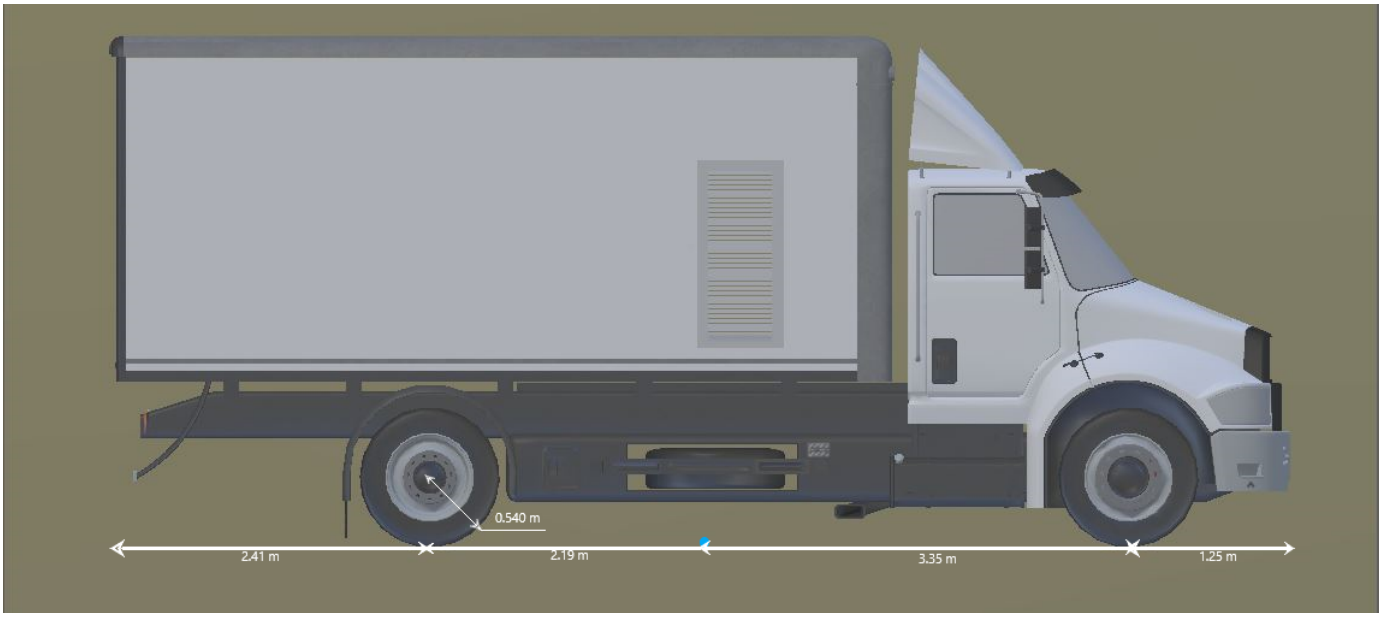
1. Add a Simulation 3D Vehicle or Simulation 3D Vehicle with Ground Following block to your Simulink model.
2. In the block, set the **Type** parameter to `Box truck`.

Dimensions

`Top-down view` — Vehicle width dimensions
diagram



`Side view` — Vehicle length, front overhang, and rear overhang dimensions
diagram



`Front view` — Tire width and front axle dimensions

diagram

`Rear view` — Vehicle height and rear axle dimensions
diagram

Sensor Mounting Locations

In the 3D simulation sensor blocks, use the **Mounting location** parameter to mount sensors at predefined locations on the vehicle. The table shows the *X*, *Y*, and *Z* positions of the mounting locations relative to the vehicle origin. These locations are in the vehicle coordinate system, where:

- The *X*-axis points forward from the vehicle.
- The *Y*-axis points to the left of the vehicle, as viewed when facing forward.
- The *Z*-axis points up from the ground.

Box Truck — Sensor Locations Relative to Vehicle Origin

Mounting Location	X (m)	Y (m)	Z (m)
`Front bumper`	5.10	0	0.60
`Rear bumper`	–5	0	0.60
`Right mirror`	2.90	1.60	2.10
`Left mirror`	2.90	–1.60	2.10
`Rearview mirror`	2.60	0.20	2.60
`Hood center`	3.80	0	2.10
`Roof center`	1.30	0	4.20

See Also

Simulation 3D Scene Configuration | Simulation 3D Vehicle | Simulation 3D Vehicle with Ground Following

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Cab-Over Tractor

Cab-over tractor dimensions

Description

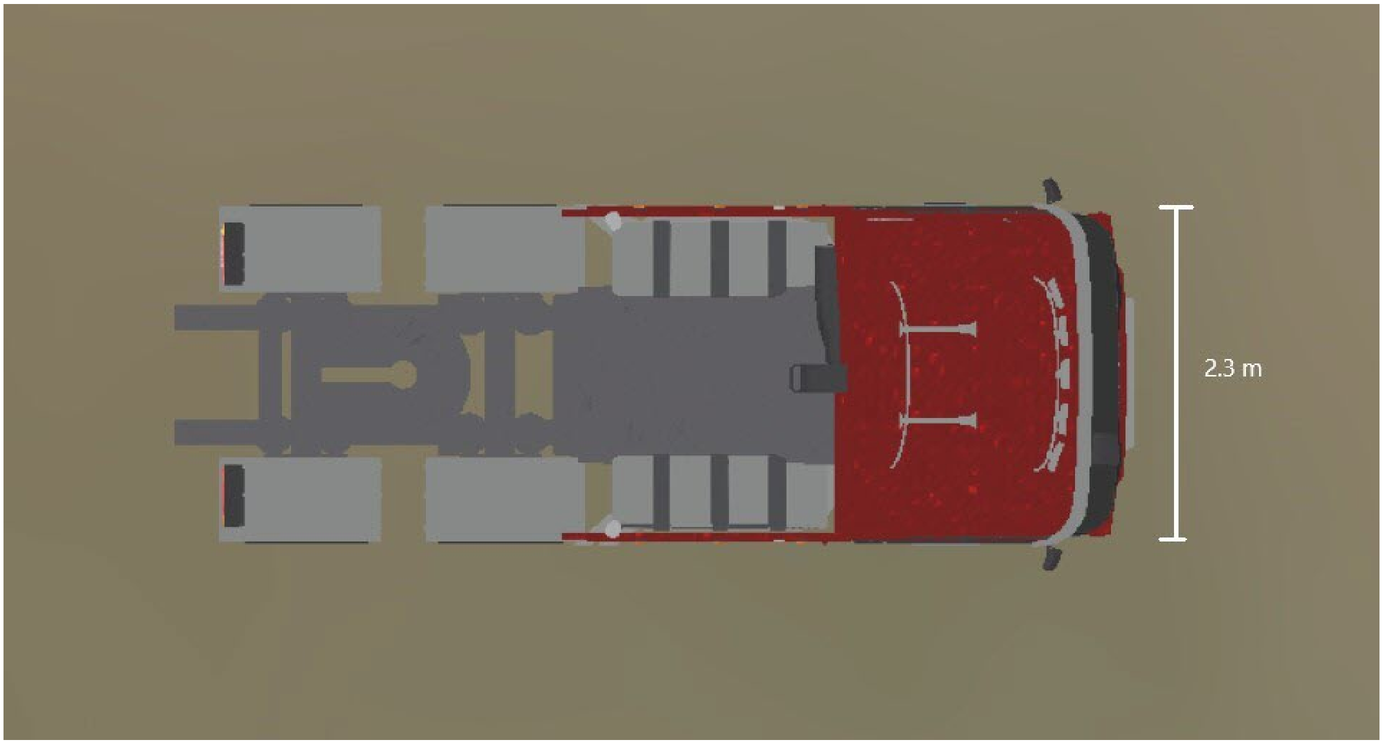
Cab-Over Tractor is one of the tractors that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this tractor. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the tractor in the vehicle coordinate system. The origin is on the ground, at the geometric center of the tractor.

To add this type of tractor to the 3D simulation environment:

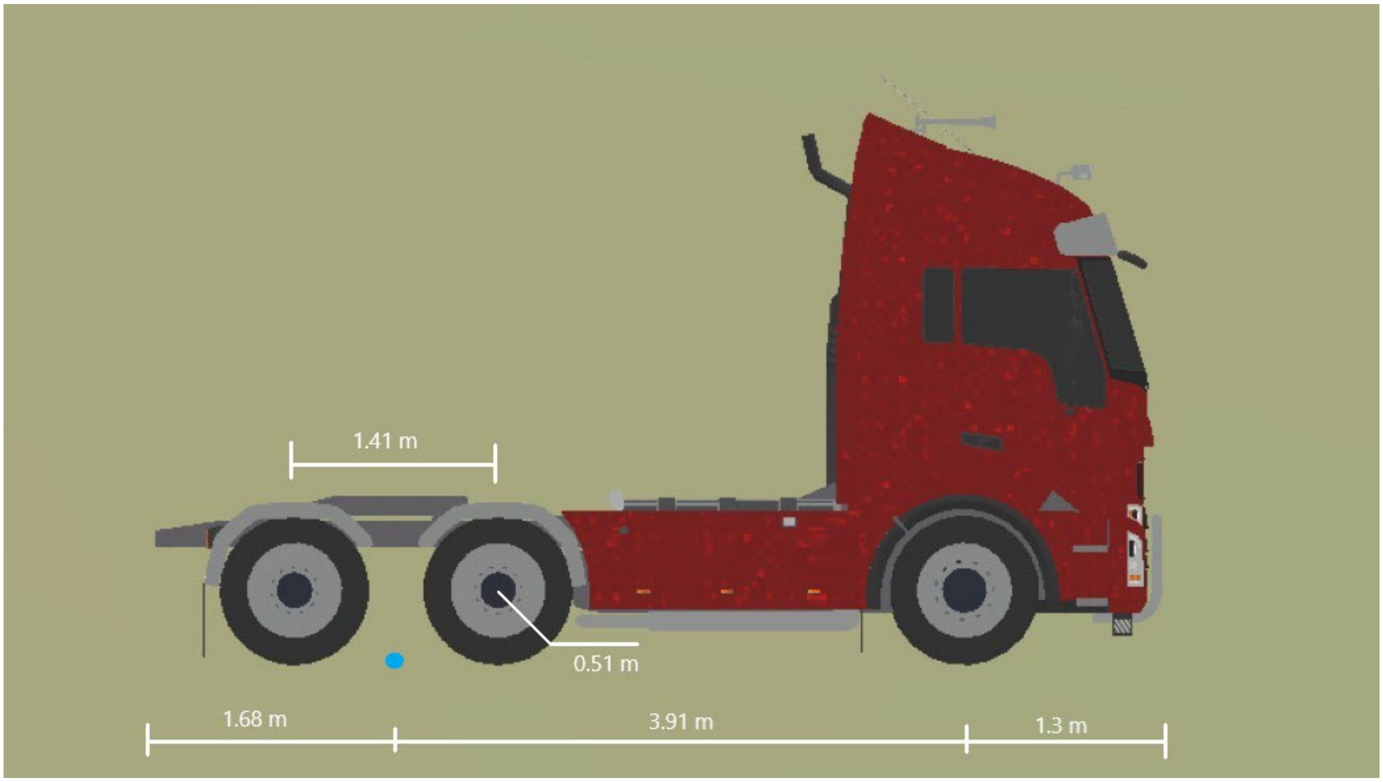
1. Add a Simulation 3D Tractor block to your Simulink model.
2. In the block, set the **Type** parameter to `Cab-over tractor`.

Dimensions

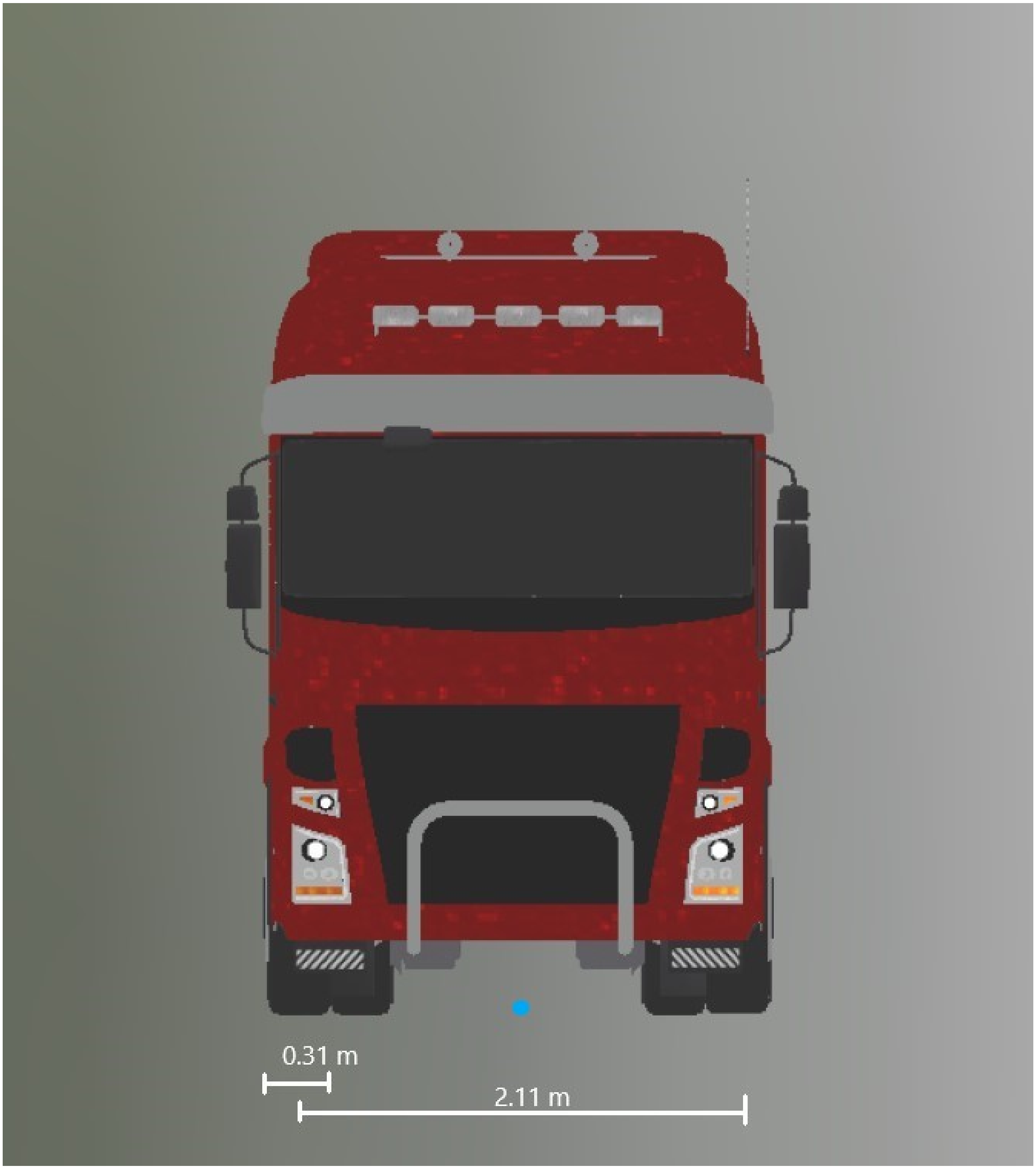
`Top-down view` — Tractor width dimensions
diagram



`Side view` — Tractor length, front overhang, and rear overhang dimensions
diagram



`Front view` — Tire width and front axle dimensions
diagram



See Also

Simulation 3D Tractor | Simulation 3D Scene Configuration

Topics
"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Conventional Tractor

Conventional tractor dimensions

Description

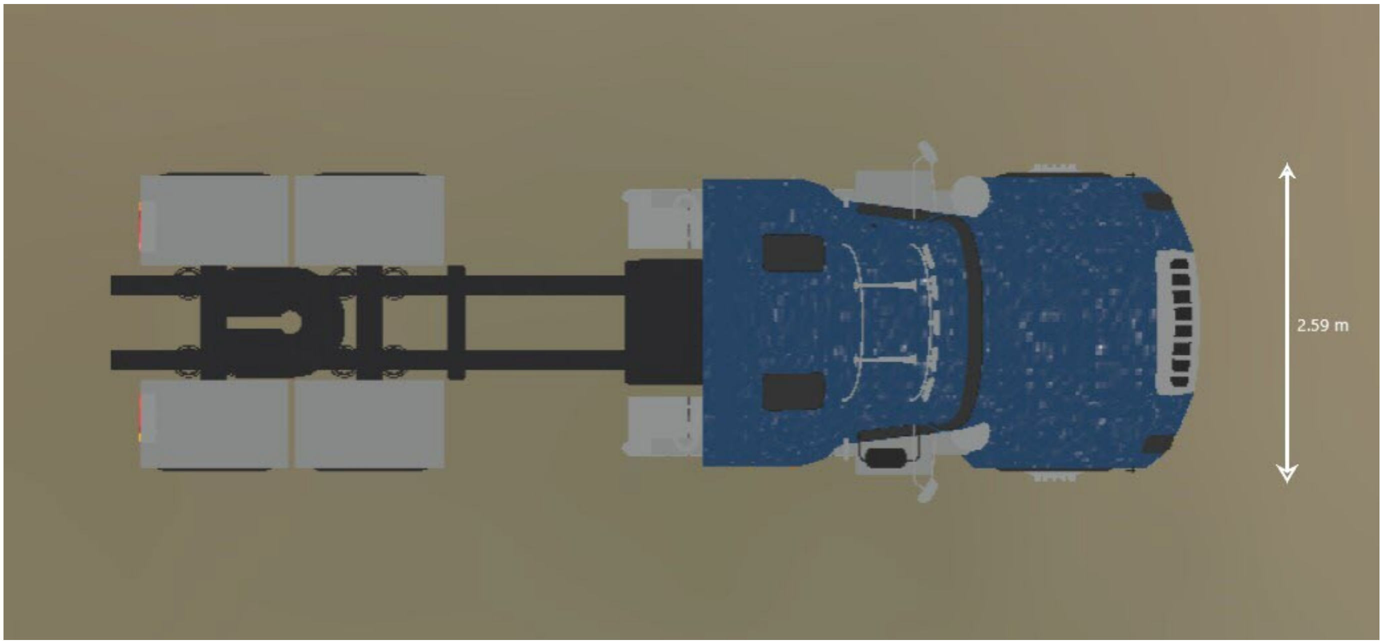
Conventional Tractor is one of the tractors that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this tractor. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the tractor in the vehicle coordinate system. The origin is on the ground, at the geometric center of the tractor.

To add this type of tractor to the 3D simulation environment:

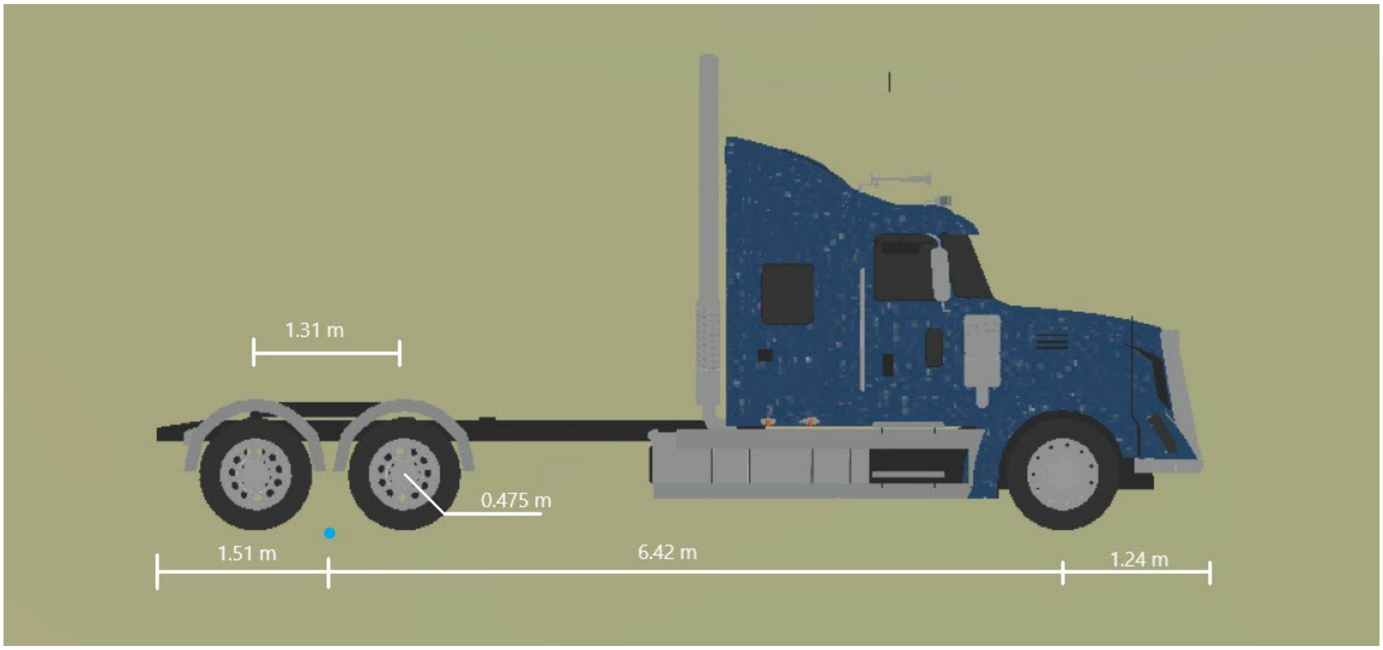
1. Add a Simulation 3D Tractor block to your Simulink model.
2. In the block, set the **Type** parameter to `Conventional tractor`.

Dimensions

`Top-down view` — Tractor width dimensions
diagram



`Side view` — Tractor length, front overhang, and rear overhang dimensions
diagram



`Front view` — Tire width and front axle dimensions
diagram


0.30 m
2.20 m

See Also

Simulation 3D Tractor | Simulation 3D Scene Configuration

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Two-Axle Trailer

Two-axle trailer dimensions

Description

Two-Axle Trailer is one of the trailers that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this trailer. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the trailer in the vehicle coordinate system. The origin is on the ground, at the geometric center of the trailer.

To add this type of trailer to the 3D simulation environment:

1. Add a Simulation 3D Trailer block to your Simulink model.
2. In the block, set the **Type** parameter to `Two-axle trailer`.

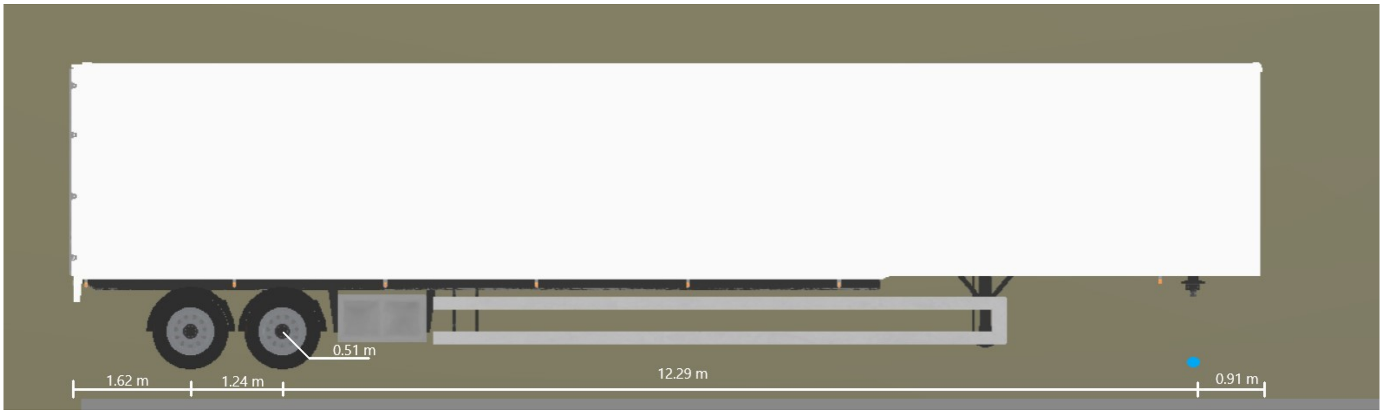
Dimensions

`Top-down view` — Trailer width dimensions

diagram

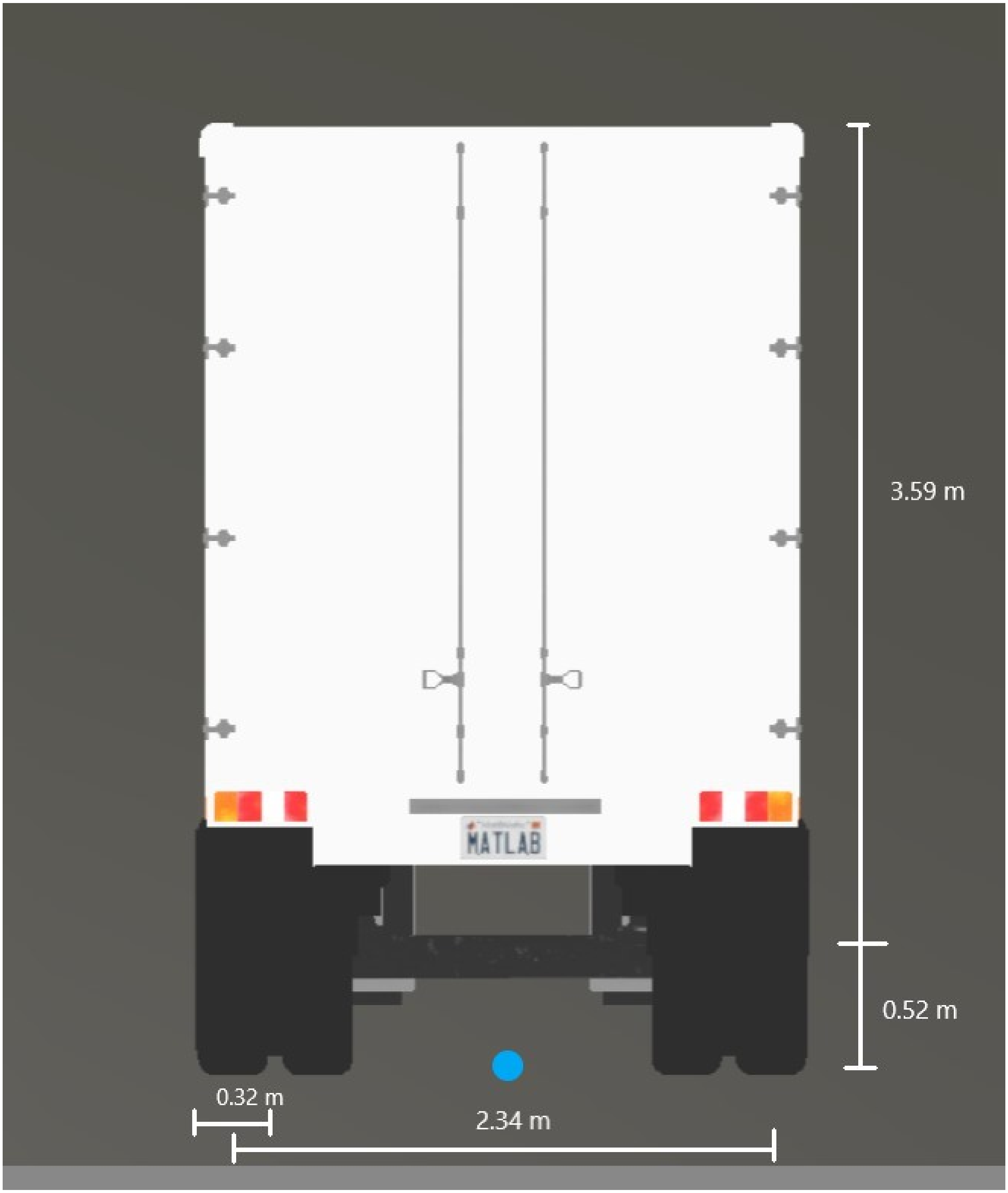
`Side view` — Trailer length, front overhang, and rear overhang dimensions

diagram



`Back view` — Tire width and front axle dimensions

diagram



See Also

Simulation 3D Trailer | Simulation 3D Scene Configuration

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Three-Axle Trailer

Three-axle trailer dimensions

Description

Three-Axle Trailer is one of the trailers that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this trailer. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the trailer in the vehicle coordinate system. The origin is on the ground, at the geometric center of the trailer.

To add this type of trailer to the 3D simulation environment:

1. Add a Simulation 3D Trailer block to your Simulink model.
2. In the block, set the **Type** parameter to `Three-axle trailer`.

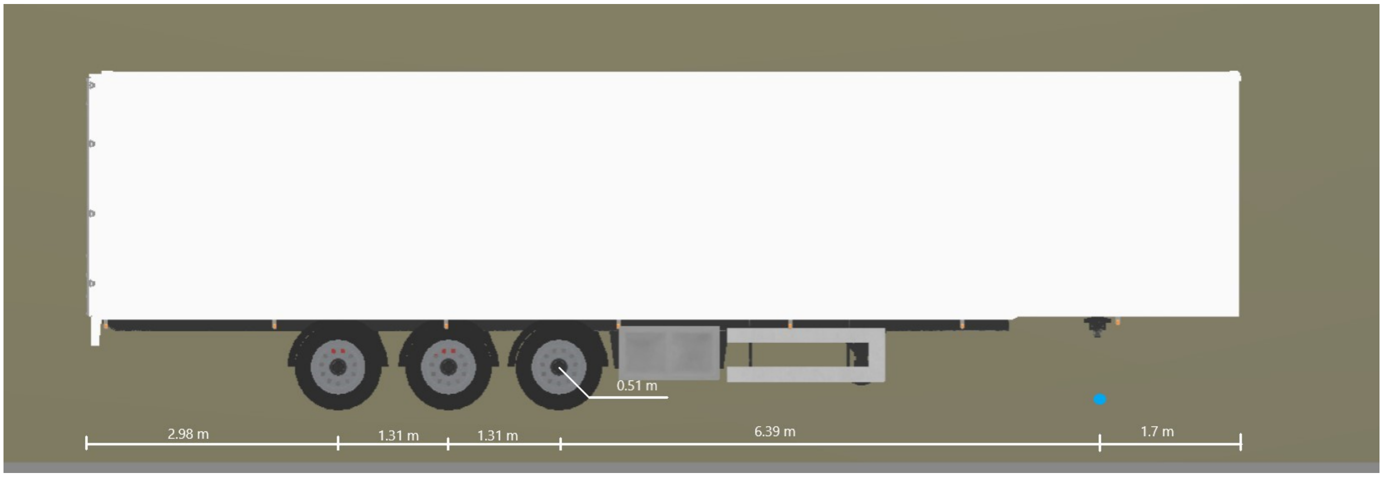
Dimensions

`Top-down view` — Trailer width dimensions

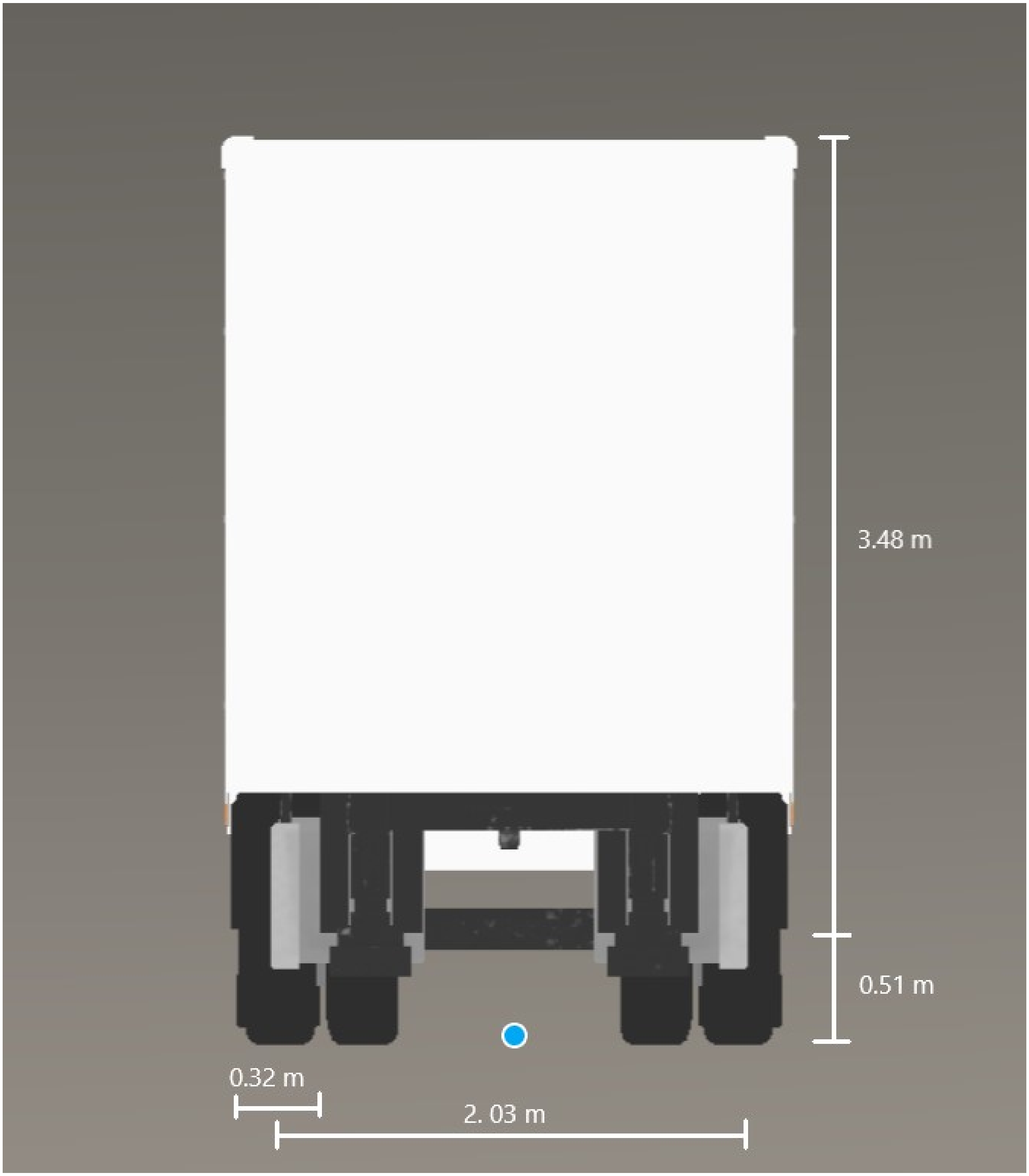
diagram

`Side view` — Trailer length, front overhang, and rear overhang dimensions

diagram



`Front view` — Tire width and front axle dimensions
diagram



See Also

Simulation 3D Trailer | Simulation 3D Scene Configuration

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

“How 3D Simulation for Vehicle Dynamics Blockset Works”

One-Axle Dolly

One-axle dolly dimensions

Description

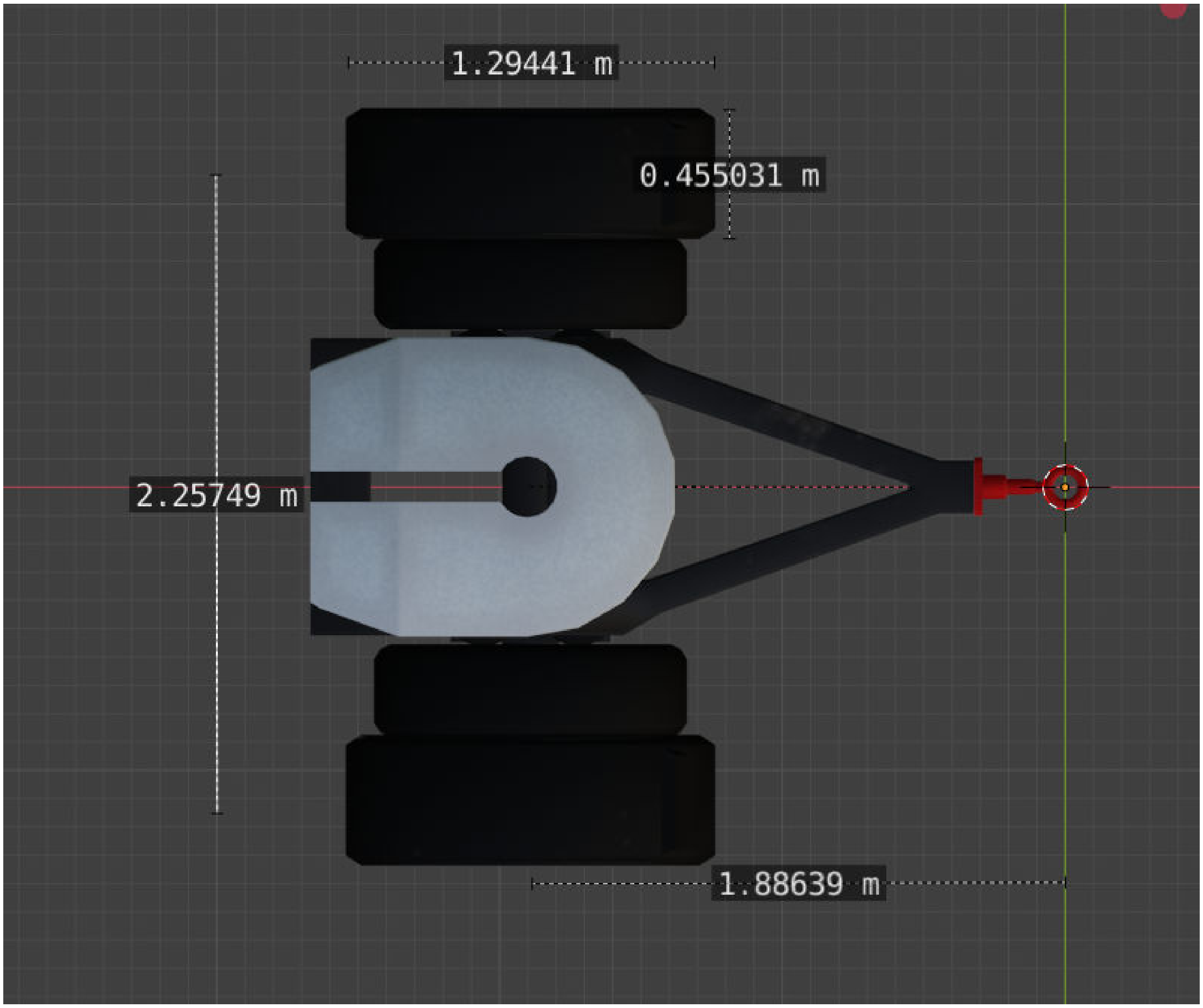
The **One-Axle Dolly** is one of the dollies that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this dolly. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the dolly in the vehicle coordinate system. The origin is on the ground plane, at the projection of the hitch socket.

To add this type of dolly to the 3D simulation environment:

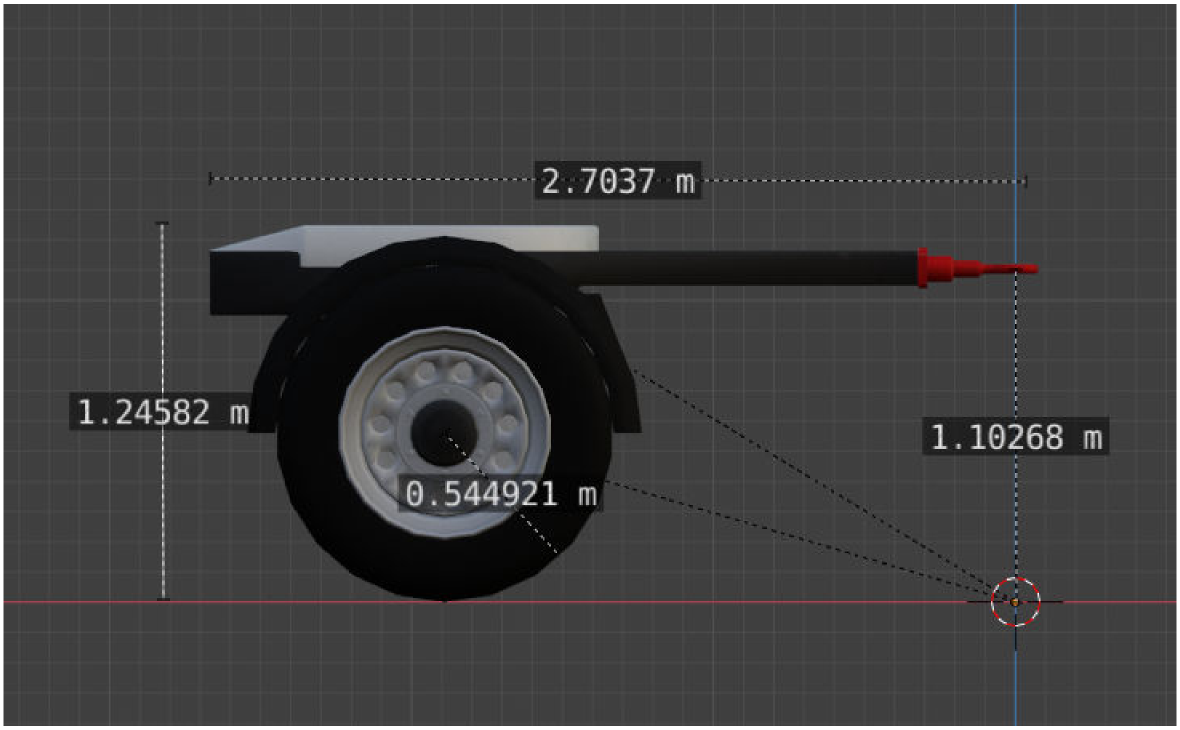
1. Add a Simulation 3D Dolly block to your Simulink model.
2. In the block, set the **Type** parameter to `One-axle dolly`.

Dimensions

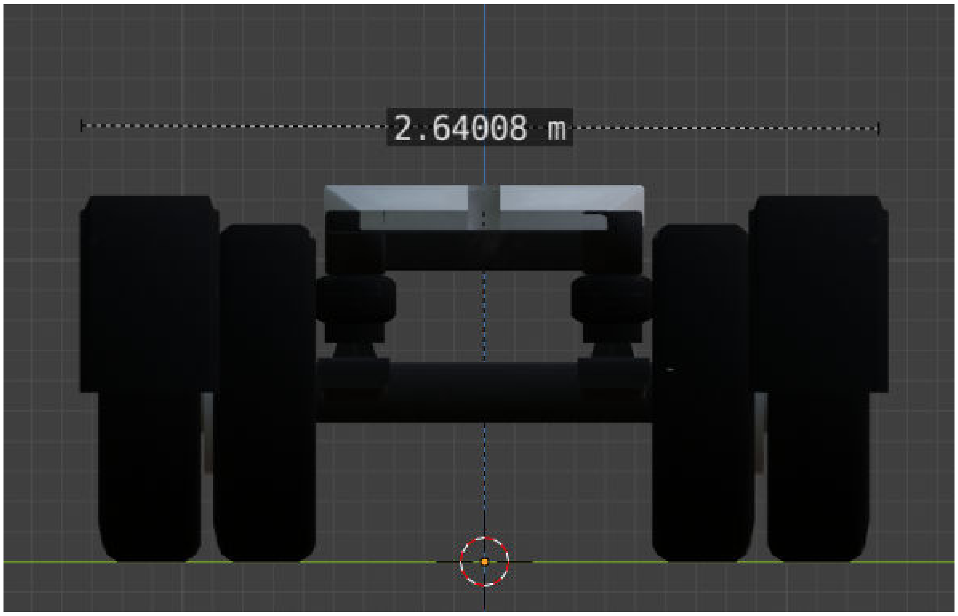
`Top-down view` — Dolly width
diagram



Side view — Dolly length and height
diagram



`Front view` — Dolly width
diagram



See Also

Simulation 3D Dolly | Simulation 3D Scene Configuration

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”

"How 3D Simulation for Vehicle Dynamics Blockset Works"

Two-Axle Dolly

Two-axle dolly dimensions

Description

The **Two-Axle Dolly** is one of the dollies that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this dolly. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the dolly in the vehicle coordinate system. The origin is on the ground plane, at the projection of the hitch socket.

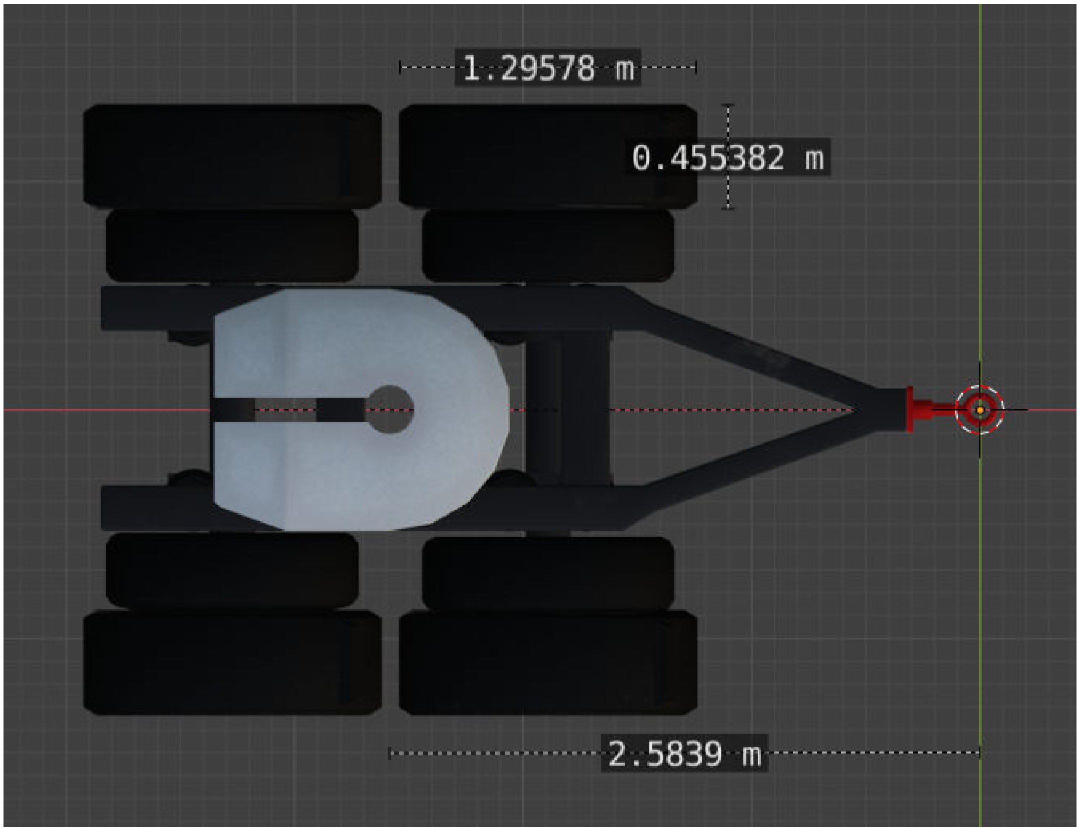
To add this type of dolly to the 3D simulation environment:

1. Add a Simulation 3D Dolly block to your Simulink model.
2. In the block, set the **Type** parameter to `Two-axle dolly`.

Dimensions

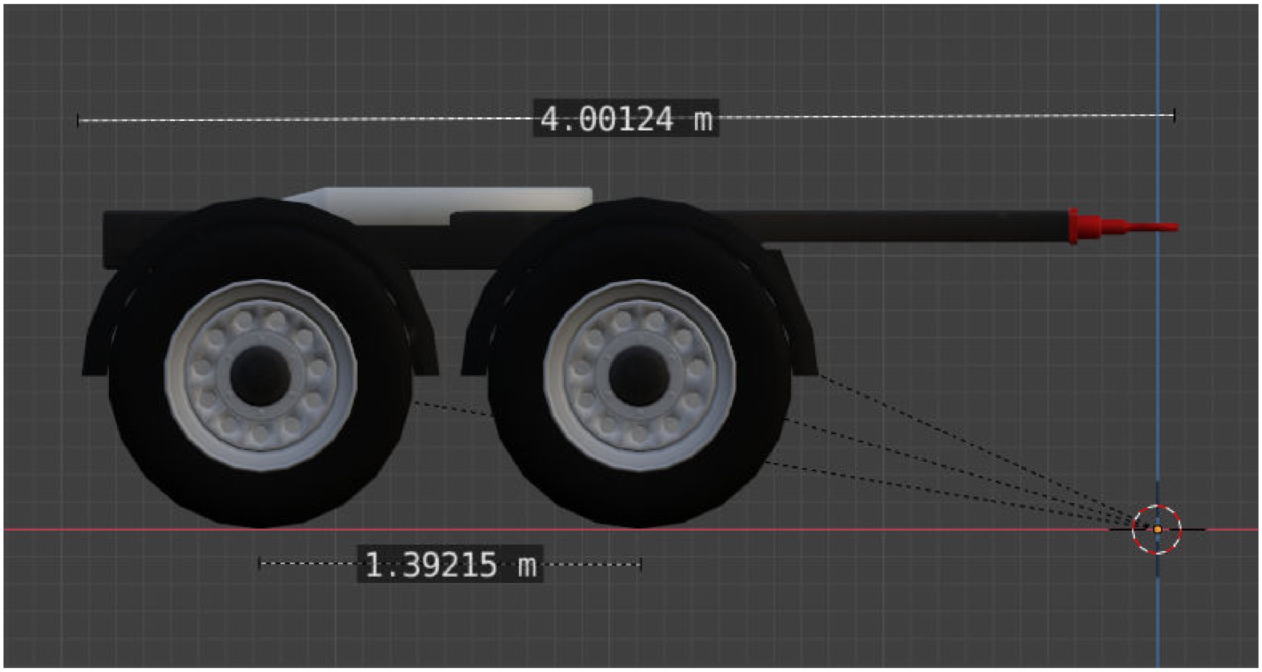
`Top-down view` — Dolly and tire width

diagram



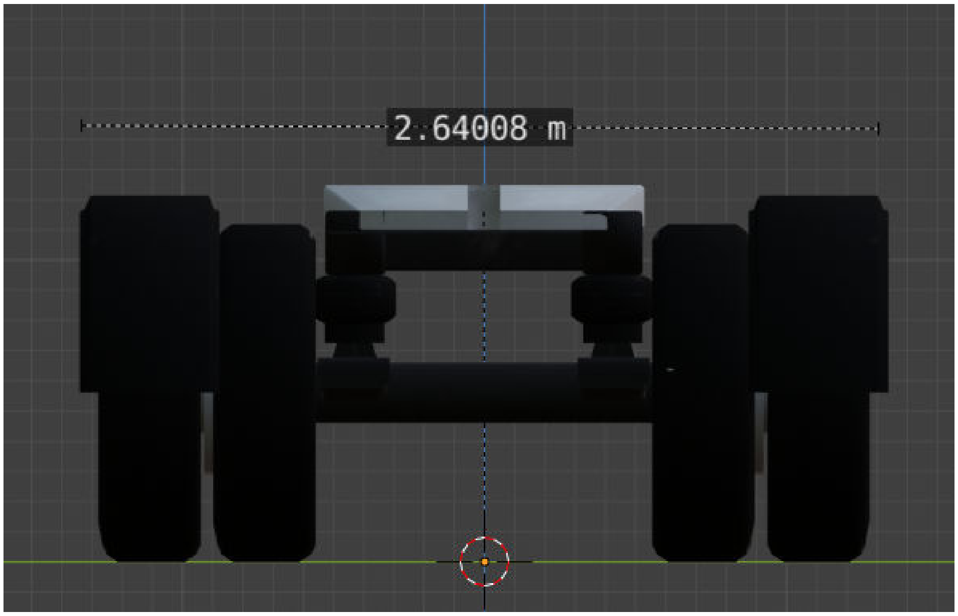
`Side view` — Dolly length and height

diagram



`Front view` — Dolly width

diagram



See Also

Simulation 3D Dolly | Simulation 3D Scene Configuration

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Three-Axle Dolly

Three-axle dolly dimensions

Description

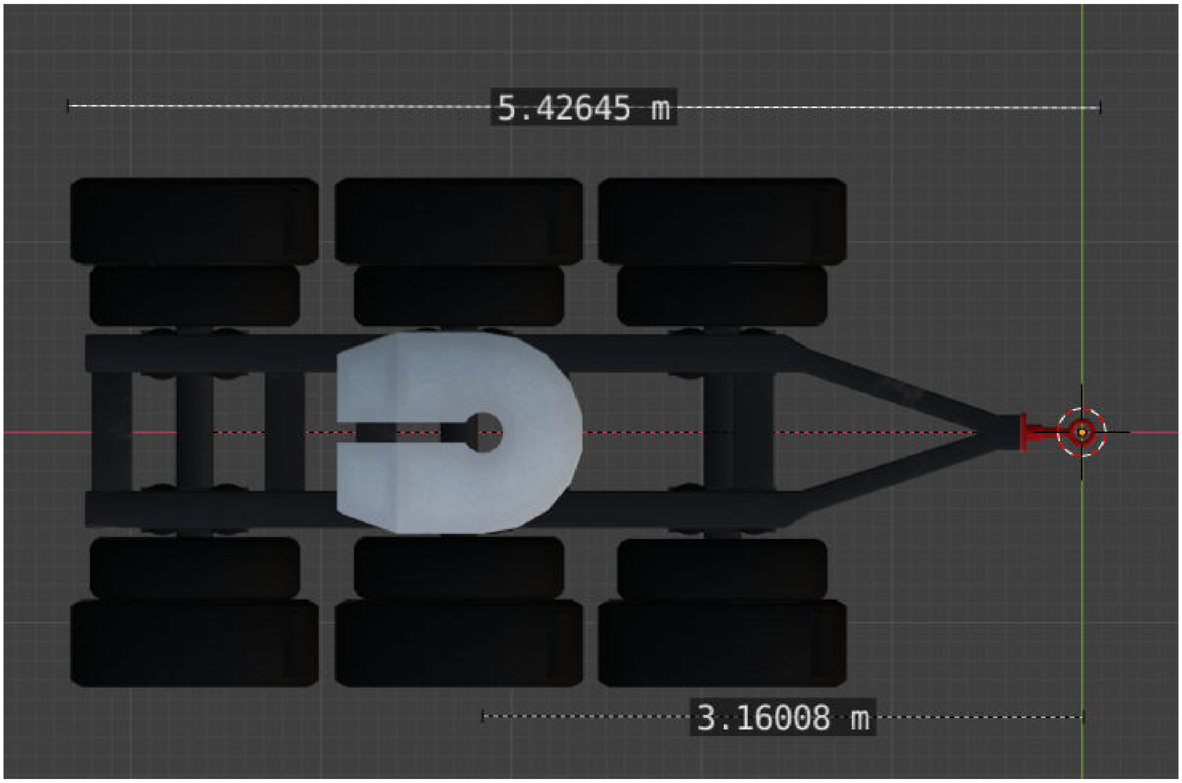
The **Three-Axle Dolly** is one of the dollies that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this dolly. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the dolly in the vehicle coordinate system. The origin is on the ground plane, at the projection of the hitch socket.

To add this type of dolly to the 3D simulation environment:

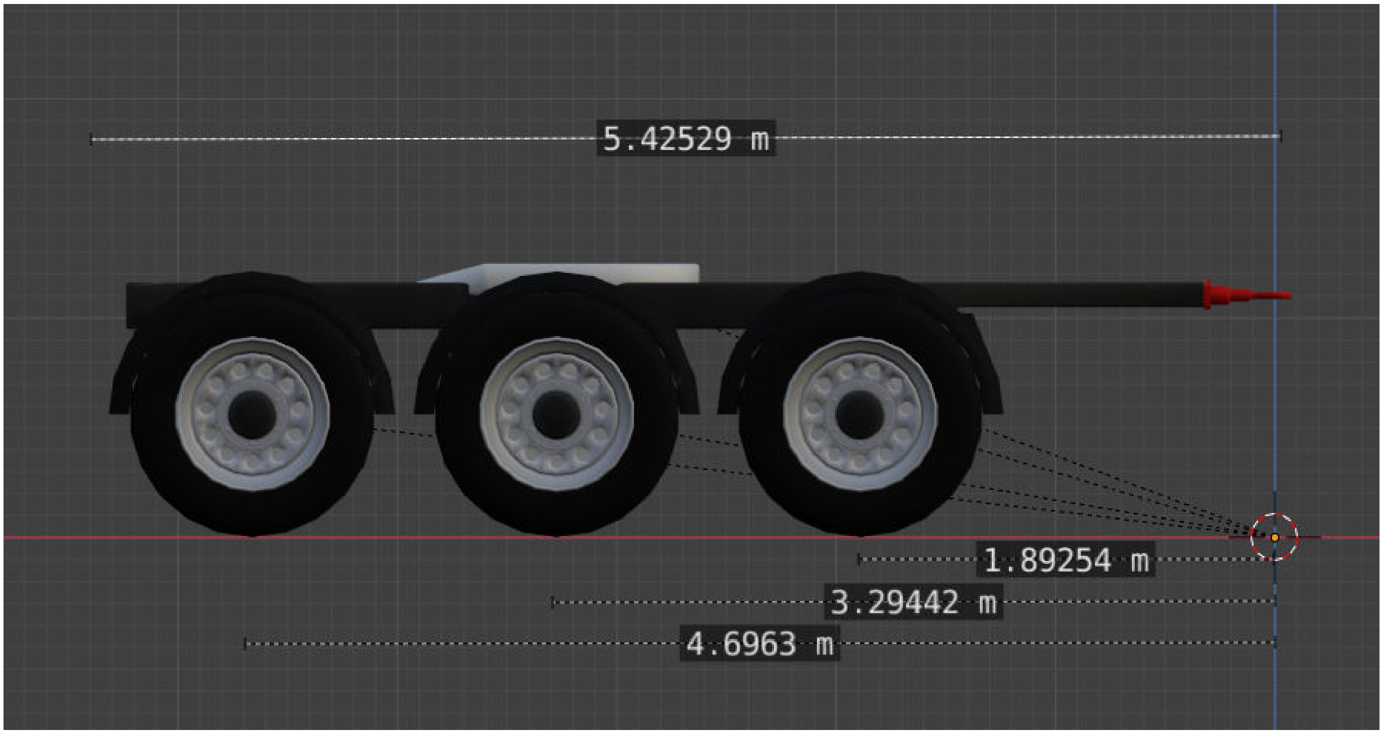
1. Add a Simulation 3D Dolly block to your Simulink model.
2. In the block, set the **Type** parameter to `Three-axle dolly`.

Dimensions

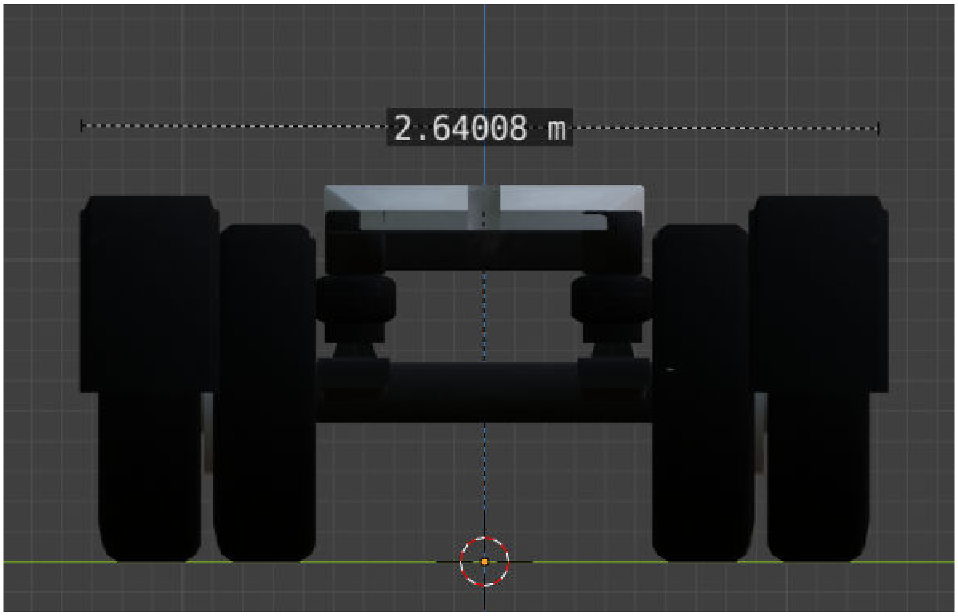
`Top-down view` — Dolly and tire width
diagram



`Side view` — Dolly length and height
diagram



`Front view` — Dolly width
diagram



See Also

Simulation 3D Dolly | Simulation 3D Scene Configuration

Topics
"Coordinate Systems in Vehicle Dynamics Blockset"

“How 3D Simulation for Vehicle Dynamics Blockset Works”

Scooter

Scooter dimensions

Description

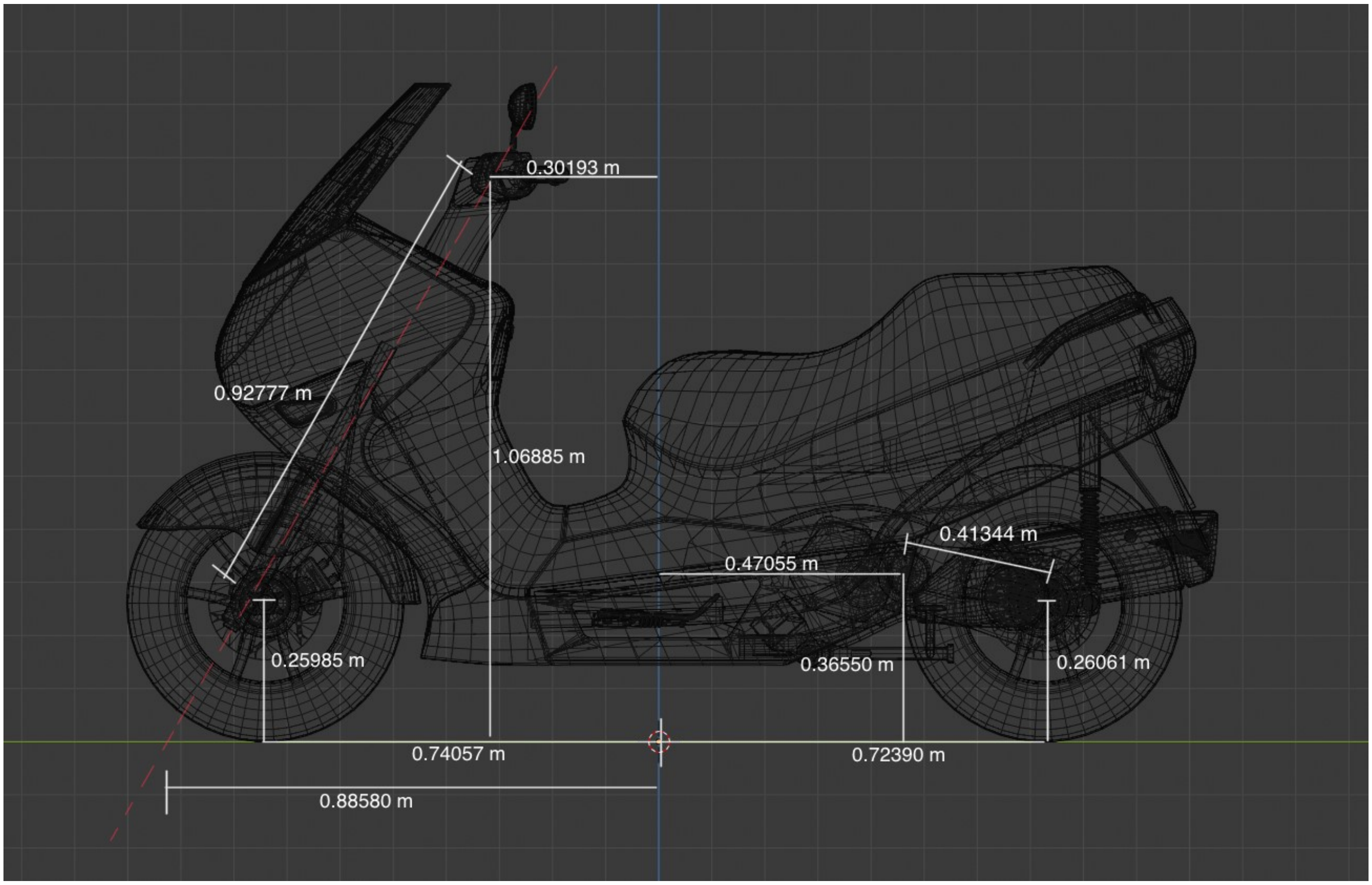
The **Scooter** is one of the motorcycles that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this scooter. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the scooter in the vehicle coordinate system. The origin is on the ground plane, at the projection of the hitch socket.

To add this type of scooter to the 3D simulation environment:

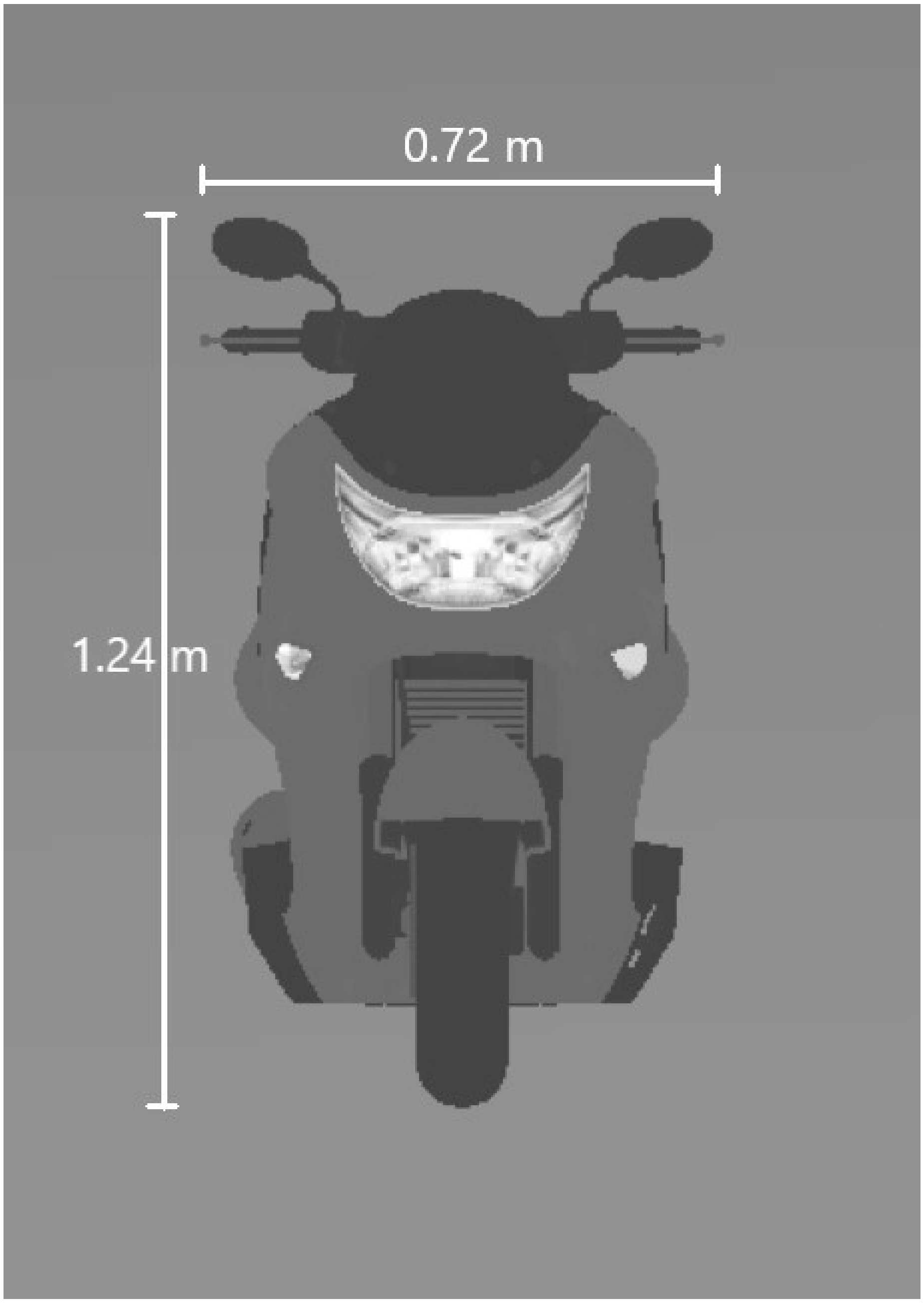
1. Add a Simulation 3D Motorcycle block to your Simulink model.
2. In the block, set the **Type** parameter to `Scooter`.

Dimensions

`Side view` — Scooter length and detailed dimensions
diagram



`Front view` — Scooter width and height
diagram



See Also

Simulation 3D Motorcycle | Simulation 3D Scene Configuration

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

Motor Bike

Motor bike dimensions

Description

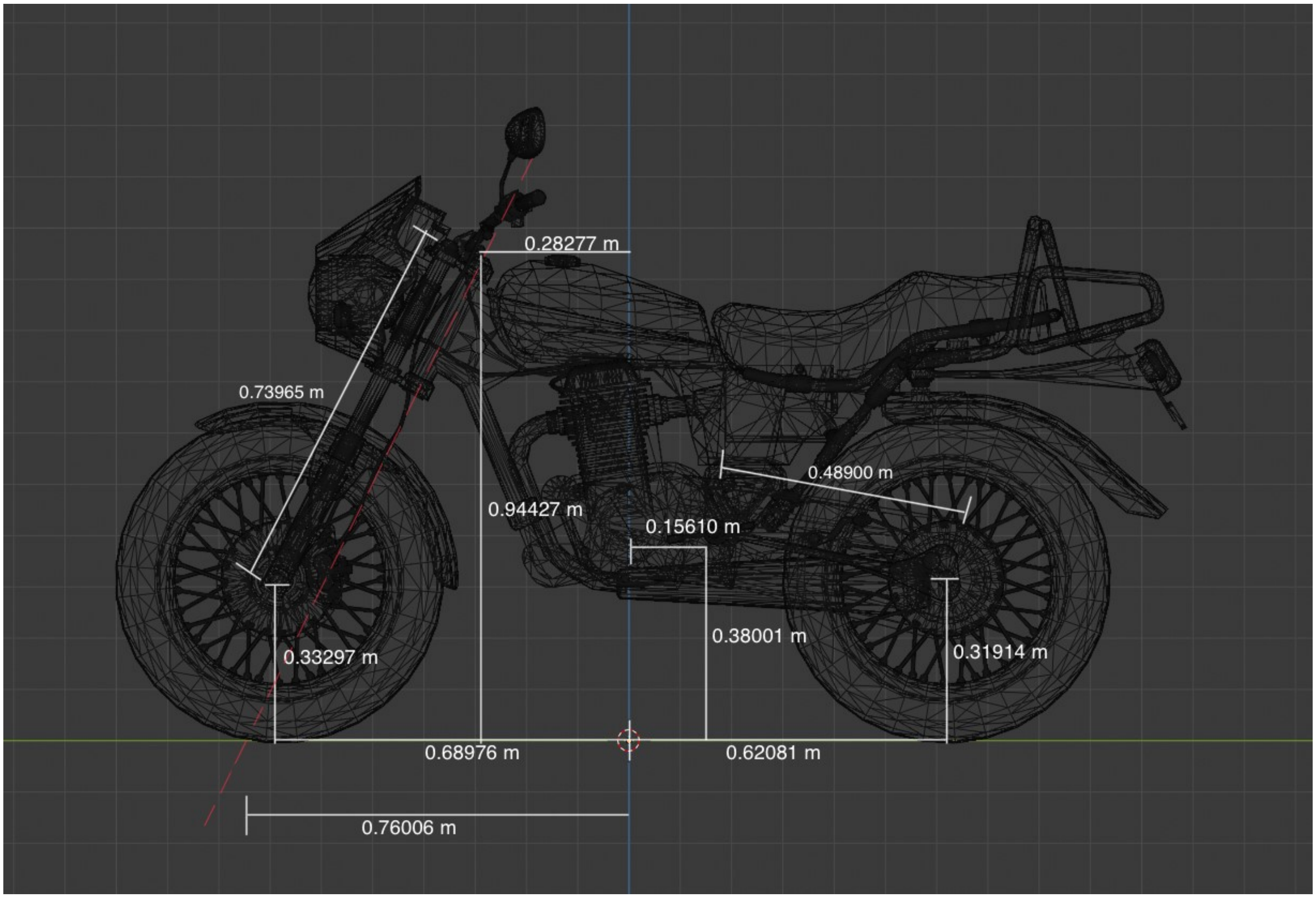
The **Motor bike** is one of the motorcycles that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this dolly. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the dolly in the vehicle coordinate system. The origin is on the ground plane, at the projection of the hitch socket.

To add this type of dolly to the 3D simulation environment:

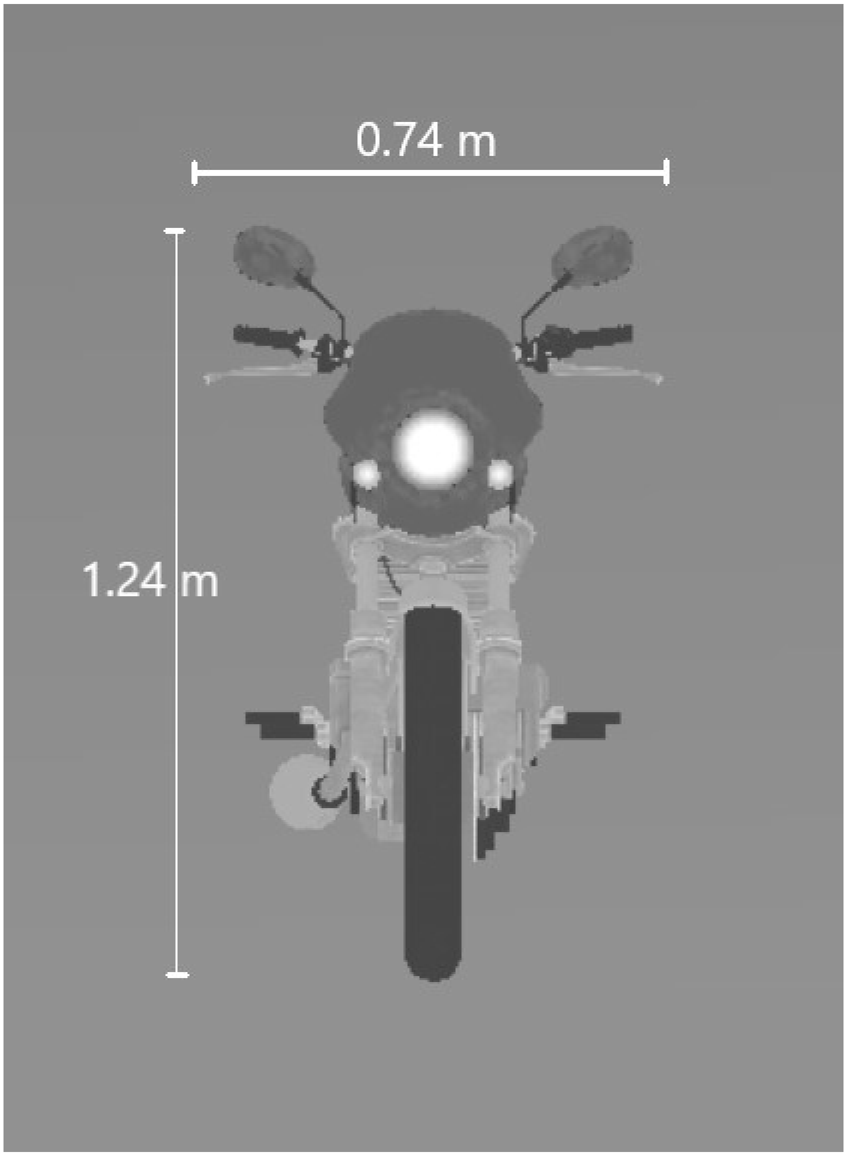
1. Add a Simulation 3D Motorcycle block to your Simulink model.
2. In the block, set the **Type** parameter to `Motor bike`.

Dimensions

`Side view` — Motor bike length and detailed dimensions
diagram



`Front view` — Motor bike width and height
diagram



See Also

Simulation 3D Motorcycle | Simulation 3D Scene Configuration

Topics

“Coordinate Systems in Vehicle Dynamics Blockset”
“How 3D Simulation for Vehicle Dynamics Blockset Works”

Sports Bike

Sports bike dimensions

Description

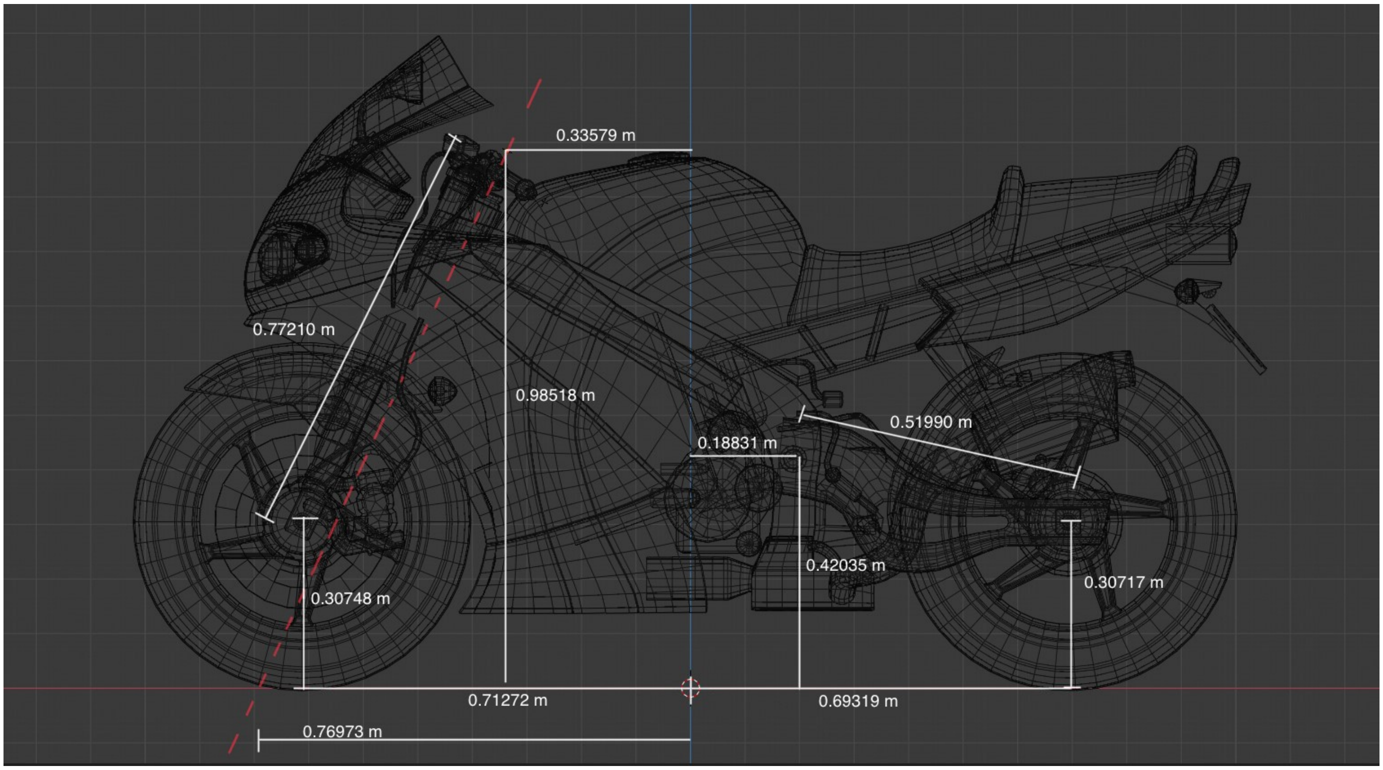
The **Sports bike** is one of the motorcycles that you can use in the 3D simulation environment. The environment is rendered using the Unreal Engine from Epic Games. The **Dimensions** section provides the dimensions of this dolly. The height dimensions are with respect to the vertical ground plane. The length and width dimensions are with respect to the origin of the dolly in the vehicle coordinate system. The origin is on the ground plane, at the projection of the hitch socket.

To add this type of dolly to the 3D simulation environment:

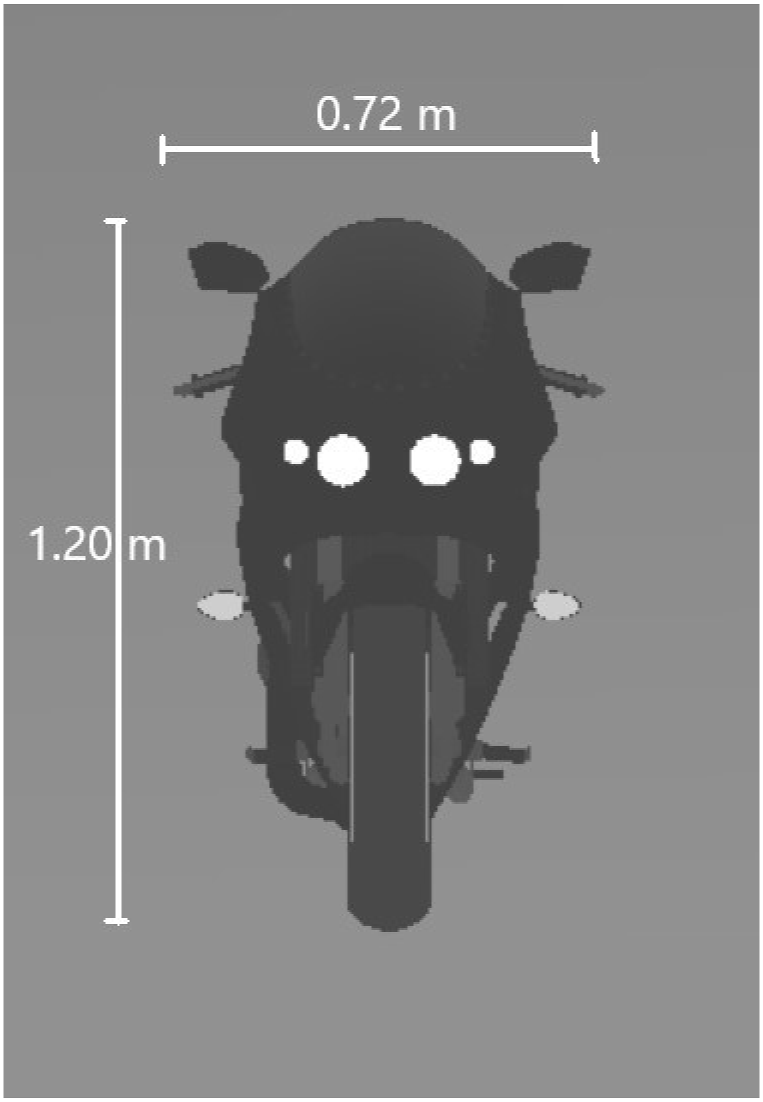
1. Add a Simulation 3D Motorcycle block to your Simulink model.
2. In the block, set the **Type** parameter to `Sports bike`.

Dimensions

`Side view` — Sports bike length and detailed dimensions
diagram



`Front view` — Sports bike width and height
diagram



See Also

Simulation 3D Motorcycle | Simulation 3D Scene Configuration

Topics

"Coordinate Systems in Vehicle Dynamics Blockset"
"How 3D Simulation for Vehicle Dynamics Blockset Works"

10

Blocks in Reference Applications

3D Engine

Configure scenes in reference applications

Description

The 3D Engine block implements the 3D simulation environment. Vehicle Dynamics Blockset integrates the 3D simulation environment with Simulink so that you can query the world around the vehicle for virtually testing perception, control, and planning algorithms.

To position the vehicle in the scene:

1. Select the position initialization method:
   - **Recommended for scene** — Set the initial vehicle position to values recommended for the scene
   - **User-specified** — Set your own initial vehicle position
2. Click **Update the model workspaces with the initial values** to overwrite the initial vehicle position in the model workspaces with the applied values.

Ports

Input

`VehFdbk` — Vehicle feedback

`Bus`

Bus containing vehicle feedback signals, including velocity, acceleration, and steering wheel torque.

Parameters

3D Engine

`3D Engine` — Enable 3D visualization

`off` (default) | `on`

Enable 3D visualization.

Scene — 3D scene

`Straight road` | `Curved road` | `Parking lot` | `Double lane change` | `Open surface` | `US city block` | `US highway` | `Virtual Mcity` | `Large parking lot`

Specify the name of the 3D scene.

`Engine frame rate, dt3D` — Graphics

`.03` (default)

Graphics frame rate, in s. The graphics frame rate is the inverse of the sample time.

`Recommended for scene` — Initial vehicle position

`on` (default) | `off`

Use vehicle positions that are recommended for the scene.

`User-specified` — Initial vehicle position
`off` (default) | `on`

Specify to set your own initial vehicle position values.

`Initial longitudinal position, X_o` — Initial longitudinal position
`off` (default) | `on`

Initial vehicle CG position along the earth-fixed *X*-axis, in m.

`Initial lateral position, Y_o` — Initial lateral position
`off` (default) | `on`

Initial vehicle CG position along the earth-fixed *Y*-axis, in m.

`Initial vertical position, Z_o` — Initial vertical position
`off` (default) | `on`

Initial vehicle CG position along the earth-fixed *Z*-axis, in m.

`Initial roll angle, phi_o` — Roll
`off` (default) | `on`

Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll), in rad.

`Initial pitch angle, theta_o` — Pitch
`off` (default) | `on`

Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch), in rad.

`Initial yaw angle, psi_o` — Yaw
`off` (default) | `on`

Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw), in rad.

Version History

Introduced in R2019a

See Also

Curved Road | Double Lane Change | Open Surface | Large Parking Lot | Parking Lot | Straight Road | US City Block | US Highway | Virtual Mcity

Topics

“Double-Lane Change Maneuver”
“Slowly Increasing Steering Maneuver”
“Swept-Sine Steering Maneuver”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Unreal Engine Simulation Environment Requirements and Limitations”

External Websites

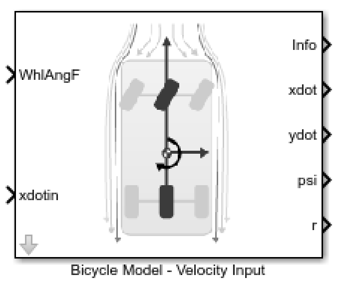
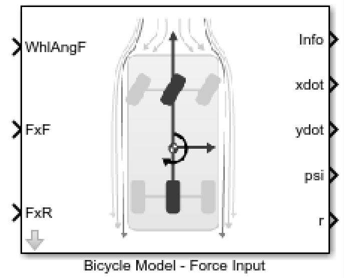
Unreal Engine

Bicycle Model

Implement a single track 3DOF rigid vehicle body to calculate longitudinal, lateral, and yaw motion

Description

The Bicycle Model block implements a rigid two-axle single track vehicle body model to calculate longitudinal, lateral, and yaw motion. The block accounts for body mass, aerodynamic drag, and weight distribution between the axles due to acceleration and steering. There are two types of Bicycle Model blocks.

Block	Implementation
Bicycle Model - Velocity Input 	• Block assumes that the external longitudinal velocity is quasi-steady state so the longitudinal acceleration is approximately zero. • Since the motion is quasi-steady, the block calculates only lateral forces using the tire slip angles and linear cornering stiffness.
Bicycle Model - Force Input 	• Block uses the external longitudinal force to accelerate or brake the vehicle. • Block calculates lateral forces using the tire slip angles and linear cornering stiffness.

To calculate the normal forces on the front and rear axles, the block uses rigid-body vehicle motion, suspension system forces, and wind and drag forces. The block resolves the force and moment components on the rigid vehicle body frame.

Ports

Input

`WhlAngF` — Wheel angle
`scalar`

Front wheel angle, in rad.

FxF — Force Input: Total longitudinal force on the front axle
`scalar`

Longitudinal force on the front axle, Fx_F, along vehicle-fixed x-axis, in N.

Bicycle Model - Force Input block input port.

`FxR` — Force Input: Total longitudinal force on the rear axle
`scalar`

Longitudinal force on the rear axle, Fx_R, along vehicle-fixed `x`-axis, in N.

Bicycle Model - Force Input block input port.

`xdotin` — Velocity Input: Longitudinal velocity
`scalar`

Vehicle CG velocity along vehicle-fixed *x*-axis, in m/s.

Bicycle Model - Velocity Input block input port.

Output

`Info` — Bus signal
bus

Bus signal containing these block values.

Signal				Description	Value	Units
`InertFrm`	`Cg`	`Disp`	`X`	Vehicle CG displacement along the earth-fixed *X*-axis	Computed	m
			`Y`	Vehicle CG displacement along the earth-fixed *Y*-axis	Computed	m
			`Z`	Vehicle CG displacement along the earth-fixed *Z*-axis	`0`	m
		`Vel`	`Xdot`	Vehicle CG velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Vehicle CG velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Vehicle CG velocity along the earth-fixed *Z*-axis	`0`	m/s
		`Ang`	`phi`	Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll)	`0`	rad
			`theta`	Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch)	`0`	rad
			`psi`	Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw)	Computed	rad

Signal				Description	Value	Units
	FrntAxl	Disp	X	Front wheel displacement along the earth-fixed *X*-axis	Computed	m
			Y	Front wheel displacement along the earth-fixed *Y*-axis	Computed	m
			Z	Front wheel displacement along the earth-fixed *Z*-axis	0	m
		Vel	Xdot	Front wheel velocity along the earth-fixed *X*-axis	Computed	m/s
			Ydot	Front wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
			Zdot	Front wheel velocity along the earth-fixed *Z*-axis	0	m/s
	RearAxl	Disp	X	Rear wheel displacement along the earth-fixed *X*-axis	Computed	m
			Y	Rear wheel displacement along the earth-fixed *Y*-axis	Computed	m
			Z	Rear wheel displacement along the earth-fixed *Z*-axis	0	m
		Vel	Xdot	Rear wheel velocity along the earth-fixed *X*-axis	Computed	m/s
			Ydot	Rear wheel velocity along the earth-fixed *Y*-axis	Computed	m/s
			Zdot	Rear wheel velocity along the earth-fixed *Z*-axis	0	m/s
	Hitch	Disp	X	Hitch offset from axle plane along the earth-fixed *X*-axis	Computed	m
			Y	Hitch offset from center plane along the earth-fixed *Y*-axis	Computed	m
			Z	Hitch offset from axle plane along the earth-fixed *Z*-axis	Computed	m
		Vel	Xdot	Hitch offset velocity from axle plane along the earth-fixed *X*-axis	Computed	m

Signal				Description	Value	Units
			`Ydot`	Hitch offset velocity from center plane along the earth-fixed *Y*-axis	Computed	m
			`Zdot`	Hitch offset velocity from axle plane along the earth-fixed *Z*-axis	Computed	m
	`Geom`	`Disp`	`X`	Vehicle chassis offset from axle plane along the earth-fixed *X*-axis	Computed	m
			`Y`	Vehicle chassis offset from center plane along the earth-fixed *Y*-axis	Computed	m
			`Z`	Vehicle chassis offset from axle plane along the earth-fixed *Z*-axis	Computed	m
		`Vel`	`Xdot`	Vehicle chassis offset velocity along the earth-fixed *X*-axis	Computed	m/s
			`Ydot`	Vehicle chassis offset velocity along the earth-fixed *Y*-axis	Computed	m/s
			`Zdot`	Vehicle chassis offset velocity along the earth-fixed *Z*-axis	Computed	m/s
`BdyFrm`	`Cg`	`Vel`	`xdot`	Vehicle CG velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Vehicle CG velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Vehicle CG velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Ang`	`Beta`	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad
		`AngVel`	`p`	Vehicle angular velocity about the vehicle-fixed *x*-axis (roll rate)	`0`	rad/s
			`q`	Vehicle angular velocity about the vehicle-fixed *y*-axis (pitch rate)	`0`	rad/s
			`r`	Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate)	Computed	rad/s

Signal				Description	Value	Units
		`Acc`	`ax`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	gn
			`ay`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	gn
			`az`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	gn
			`xddot`	Vehicle CG acceleration along the vehicle-fixed *x*-axis	Computed	m/s^2
			`yddot`	Vehicle CG acceleration along the vehicle-fixed *y*-axis	Computed	m/s^2
			`zddot`	Vehicle CG acceleration along the vehicle-fixed *z*-axis	`0`	m/s^2
		`AngAcc`	`pdot`	Vehicle angular acceleration about the vehicle-fixed *x*-axis	`0`	rad/s
			`qdot`	Vehicle angular acceleration about the vehicle-fixed *y*-axis	`0`	rad/s
			`rdot`	Vehicle angular acceleration about the vehicle-fixed *z*-axis	Computed	rad/s
		`DCM`	Direction cosine matrix		Computed	rad
	`Forces`	`Body`	`Fx`	Net force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`	Net force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`	Net force on vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`Ext`	`Fx`	External force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`	External force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N

Signal					Description	Value	Units
			`Fz`		External force on vehicle CG along the vehicle-fixed *z*-axis	`0`	N
		`Hitch`	`Fx`		Hitch force applied to body at the hitch location along the vehicle-fixed *x*-axis	Input	N
			`Fy`		Hitch force applied to body at the hitch location along the vehicle-fixed *y*-axis	Input	N
			`Fz`		Hitch force applied to body at the hitch location along the vehicle-fixed *z*-axis	Input	N
		`FrntAxl`	`Fx`		Longitudinal force on front wheel, along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Lateral force on front wheel along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Normal force on front wheel, along the vehicle-fixed *z*-axis	Computed	N
		`RearAxl`	`Fx`		Longitudinal force on rear wheel, along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Lateral force on rear wheel along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Normal force on rear wheel, along the vehicle-fixed *z*-axis	Computed	N
		`Tires`	`FrntTire`	`Fx`	Front tire force, along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Front tire force, along the vehicle-fixed *y*-axis	Computed	N
				`Fz`	Front tire force, along the vehicle-fixed *z*-axis	Computed	N
			`RearTire`	`FxFx`	Rear tire force, along the vehicle-fixed *x*-axis	Computed	N
				`Fy`	Rear tire force, along the vehicle-fixed *y*-axis	Computed	N

Signal					Description	Value	Units
				`Fz`	Rear tire force, along the vehicle-fixed *z*-axis	Computed	N
		`Drag`	`Fx`		Drag force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Drag force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Drag force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
		`Grvty`	`Fx`		Gravity force on vehicle CG along the vehicle-fixed *x*-axis	Computed	N
			`Fy`		Gravity force on vehicle CG along the vehicle-fixed *y*-axis	Computed	N
			`Fz`		Gravity force on vehicle CG along the vehicle-fixed *z*-axis	Computed	N
	`Moments`	`Body`	`Mx`		Body moment on vehicle CG about the vehicle-fixed *x*-axis	`0`	N·m
			`My`		Body moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		Body moment on vehicle CG about the vehicle-fixed *z*-axis	`0`	N·m
		`Drag`	`Mx`		Drag moment on vehicle CG about the vehicle-fixed *x*-axis	`0`	N·m
			`My`		Drag moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m
			`Mz`		Drag moment on vehicle CG about the vehicle-fixed *z*-axis	`0`	N·m
		`Ext`	`Mx`		External moment on vehicle CG about the vehicle-fixed *x*-axis	`0`	N·m
			`My`		External moment on vehicle CG about the vehicle-fixed *y*-axis	Computed	N·m

Signal				Description	Value	Units
			`Mz`	External moment on vehicle CG about the vehicle-fixed *z*-axis	`0`	N·m
		`Hitch`	`Mx`	Hitch moment at the hitch location about vehicle-fixed *x*-axis	`0`	N·m
			`My`	Hitch moment at the hitch location about vehicle-fixed *y*-axis	Computed	N·m
			`Mz`	Hitch moment at the hitch location about vehicle-fixed *z*-axis	`0`	N·m
	`FrntAxl`	`Disp`	`x`	Front wheel displacement along the vehicle-fixed *x*-axis	Computed	m
			`y`	Front wheel displacement along the vehicle-fixed *y*-axis	Computed	m
			`z`	Front wheel displacement along the vehicle-fixed *z*-axis	Computed	m
		`Vel`	`xdot`	Front wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Front wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s
			`zdot`	Front wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngFL`	Front left wheel steering angle	Computed	rad
			`WhlAngFR`	Front right wheel steering angle	Computed	rad
	`RearAxl`	`Disp`	`x`	Rear wheel displacement along the vehicle-fixed *x*-axis	Computed	m
			`y`	Rear wheel displacement along the vehicle-fixed *y*-axis	Computed	m
			`z`	Rear wheel displacement along the vehicle-fixed *z*-axis	Computed	m
		`Vel`	`xdot`	Rear wheel velocity along the vehicle-fixed *x*-axis	Computed	m/s
			`ydot`	Rear wheel velocity along the vehicle-fixed *y*-axis	Computed	m/s

Signal					Description	Value	Units
			`zdot`		Rear wheel velocity along the vehicle-fixed *z*-axis	`0`	m/s
		`Steer`	`WhlAngRL`		Rear left wheel steering angle	Computed	rad
			`WhlAngRR`		Rear right wheel steering angle	Computed	rad
	`Hitch`	`Disp`		`x`	Hitch offset from axle plane along the vehicle-fixed *x*-axis	Input	m
				`y`	Hitch offset from center plane along the vehicle-fixed *y*-axis	Input	m
				`z`	Hitch offset from axle plane along the earth-fixed *z*-axis	Input	m
		`Vel`		`xdot`	Hitch offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Hitch offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Hitch offset velocity along the vehicle-fixed *z*-axis	Computed	m/s
	`Pwr`	`Ext`			Applied external power	Computed	W
		`Hitch`			Power loss due to hitch	Computed	W
		`Drag`			Power loss due to drag	Computed	W
	`Geom`	`Disp`		`x`	Vehicle chassis offset from axle plane along the vehicle-fixed *x*-axis	Input	m
				`y`	Vehicle chassis offset from center plane along the vehicle-fixed *y*-axis	Input	m
				`z`	Vehicle chassis offset from axle plane along the earth-fixed *z*-axis	Input	m
		`Vel`		`xdot`	Vehicle chassis offset velocity along the vehicle-fixed *x*-axis	Computed	m/s
				`ydot`	Vehicle chassis offset velocity along the vehicle-fixed *y*-axis	Computed	m/s
				`zdot`	Vehicle chassis offset velocity along the vehicle-fixed *z*-axis	`0`	m/s

Signal				Description	Value	Units
		Ang	Beta	Body slip angle, β $\beta = \frac{V_y}{V_x}$	Computed	rad

Signal			Description	Value	Units
PwrInfo	PwrTrnsfrd	PwrFxExt	Externally applied longitudinal force power	Computed	W
		PwrFyExt	Externally applied lateral force power	Computed	W
		PwrMzExt	Externally applied roll moment power	Computed	W
		PwrFwFx	Longitudinal force applied at the front axle power	Computed	W
		PwrFwFy	Lateral force applied at the front axle power	Computed	W
		PwrFwRx	Longitudinal force applied at the rear axle power	Computed	W
		PwrFwRy	Lateral force applied at the rear axle power	Computed	W
	PwrNotTrnsfrd	PwrFxDrag	Longitudinal drag force power	Computed	W
		PwrFyDrag	Lateral drag force power	Computed	W
		PwrMzDrag	Drag pitch moment power	Computed	W
	PwrStored	PwrStoredGrvty	Rate change in gravitational potential energy	Computed	W
		PwrStoredxdot	Rate of change of longitudinal kinetic energy	Computed	W
		PwrStoredydot	Rate of change of lateral kinetic energy	Computed	W
		PwrStoredr	Rate of change of rotational yaw kinetic energy	Computed	W

xdot — Vehicle body longitudinal velocity

`scalar`

Vehicle CG velocity along vehicle-fixed `x`-axis, in m/s.

ydot — Vehicle body lateral velocity

`scalar`

Vehicle CG velocity along vehicle-fixed `y`-axis, in m/s.

`psi` — Yaw
`scalar`

Rotation of the vehicle-fixed frame about earth-fixed Z-axis (yaw), in rad..

`r` — Yaw rate
`scalar`

Vehicle angular velocity, `r`, about the vehicle-fixed `z`-axis (yaw rate), in rad/s.

Parameters

Longitudinal

`Number of wheels on front axle, NF` — Front wheel count
`2` (default) | `scalar`

Number of wheels on front axle, N_F. The value is dimensionless.

`Number of wheels on rear axle, NR` — Rear wheel count
`2` (default) | `scalar`

Number of wheels on rear axle, N_R. The value is dimensionless.

`Vehicle mass, m` — Vehicle mass
`2000` (default) | `scalar`

Vehicle mass, *m*, in kg.

`Longitudinal distance from center of mass to front axle, a` — Front axle distance
`1.4` (default) | `scalar`

Horizontal distance *a* from the vehicle CG to the front wheel axle, in m.

`Longitudinal distance from center of mass to rear axle, b` — Rear axle distance
`1.6` (default) | `scalar`

Horizontal distance *b* from the vehicle CG to the rear wheel axle, in m.

`Vertical distance from center of mass to axle plane, h` — Height
`0.35` (default) | `scalar`

Height of vehicle CG above the axles, *h*, in m.

`Longitudinal distance from center of mass to hitch, dh` — Distance from CM to hitch
`1` (default) | `scalar`

Longitudinal distance from center of mass to hitch, *dh*, in m.

Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Vertical distance from hitch to axle plane, hh` — Distance from hitch to axle plane
`0.2` (default) | `scalar`

Vertical distance from hitch to axle plane, *hh*, in m.

Dependencies

To enable this parameter, on the **Input signals** pane, select **Hitch forces** or **Hitch moments**.

`Initial inertial frame longitudinal position, X_o` — Position

`0` (default) | `scalar`

Initial vehicle CG displacement along earth-fixed *X*-axis, in m.

`Initial longitudinal velocity, xdot_o` — Velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along vehicle-fixed *x*-axis, in m/s.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal forces`
- `External forces`

Lateral

`Front tire corner stiffness, Cy_f` — Stiffness

`12e3` (default) | `scalar`

Front tire corner stiffness, Cy_f, in N/rad.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **Mapped corner stiffness**.

`Rear tire corner stiffness, Cy_r` — Stiffness

`11e3` (default) | `scalar`

Rear tire corner stiffness, Cy_r, in N/rad.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`

2 Clear **Mapped corner stiffness**.

`Initial inertial frame lateral displacement, Y_o` — Position

`0` (default) | `scalar`

Initial vehicle CG displacement along earth-fixed *Y*-axis, in m.

`Initial lateral velocity, ydot_o` — Velocity

`0` (default) | `scalar`

Initial vehicle CG velocity along vehicle-fixed *y*-axis, in m/s.

Yaw

`Yaw polar inertia, Izz` — Inertia

`4000` (default) | `scalar`

Yaw polar inertia, in kg*m^2.

`Initial yaw angle, psi_o` — Psi rotation

`0` (default) | `scalar`

Rotation of the vehicle-fixed frame about earth-fixed *Z*-axis (yaw), in rad.

`Initial yaw rate, r_o` — Yaw rate

`0` (default) | `scalar`

Vehicle angular velocity about the vehicle-fixed *z*-axis (yaw rate), in rad/s.

Aerodynamic

`Longitudinal drag area, Af` — Effective vehicle cross-sectional area

`2` (default) | `scalar`

Effective vehicle cross-sectional area, A_f, to calculate the aerodynamic drag force on the vehicle, in m^2.

`Longitudinal drag coefficient, Cd` — Air drag coefficient

`.3` (default) | `scalar`

Air drag coefficient, C_d. The value is dimensionless.

`Longitudinal lift coefficient, Cl` — Air lift coefficient

`.1` (default) | `scalar`

Air lift coefficient, C_l. The value is dimensionless.

`Longitudinal drag pitch moment, Cpm` — Pitch drag

`.1` (default) | `scalar`

Longitudinal drag pitch moment coefficient, C_{pm}. The value is dimensionless.

`Relative wind angle vector, beta_w` — Wind angle

`[0:0.01:0.3]` (default) | `vector`

Relative wind angle vector, β_w, in rad.

`Side force coefficient vector, Cs` — Side force coefficient
`[0:0.03:0.9]` (default) | `vector`

Side force coefficient vector coefficient, C_s. The value is dimensionless.

`Yaw moment coefficient vector, Cym` — Yaw moment drag
`[0:0.01:0.3]` (default) | `vector`

Yaw moment coefficient vector coefficient, C_{ym}. The value is dimensionless.

Environment

`Absolute air pressure, Pabs` — Pressure
`101325` (default) | `scalar` | `scalar`

Environmental absolute pressure, P_{abs}, in Pa.

`Air temperature, Tair` — Temperature
`273` (default) | `scalar`

Environmental absolute temperature, T, in K.

Dependencies

To enable this parameter, clear **Air temperature**.

`Gravitational acceleration, g` — Gravity
`9.81` (default) | `scalar`

Gravitational acceleration, g, in m/s^2.

`Nominal friction scaling factor, mu` — Friction scale factor
`1` (default) | `scalar`

Nominal friction scale factor, μ. The value is dimensionless.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter:

1. Set **Axle forces** to one of these options:
   - `External longitudinal velocity`
   - `External longitudinal forces`
2. Clear **External Friction**.

Simulation

`Longitudinal velocity tolerance, xdot_tol` — Tolerance
`.01` (default) | `scalar`

Longitudinal velocity tolerance, in m/s.

`Nominal normal force, Fznom` — Normal force
`5000` (default) | `scalar`

Nominal normal force, in N.

Dependencies

For the Vehicle Body 3DOF Single Track or Vehicle Body 3DOF Dual Track blocks, to enable this parameter, set **Axle forces** to one of these options:

- `External longitudinal velocity`
- `External longitudinal forces`

`Geometric longitudinal offset from axle plane, longOff` — Longitudinal offset
`0` (default) | `scalar`

Vehicle chassis offset from axle plane along body-fixed *x*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Geometric lateral offset from center plane, latOff` — Lateral offset
`0` (default) | `scalar`

Vehicle chassis offset from center plane along body-fixed *y*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Geometric vertical offset from axle plane, vertOff` — Vertical offset
`0` (default) | `scalar`

Vehicle chassis offset from axle plane along body-fixed *z*-axis, in m. When you use the 3D visualization engine, consider using the offset to locate the chassis independent of the vehicle CG.

`Wrap Euler angles, wrapAng` — Selection
`off` (default) | `on`

Wrap the Euler angles to the interval `[-pi, pi]`. For vehicle maneuvers that might undergo vehicle yaw rotations that are outside of the interval, consider deselecting the parameter if you want to:

- Track the total vehicle yaw rotation.
- Avoid discontinuities in the vehicle state estimators.

Version History

Introduced in R2018a

References

[1] Gillespie, Thomas. *Fundamentals of Vehicle Dynamics*. Warrendale, PA: Society of Automotive Engineers (SAE), 1992.

Driver Commands

Configure driver

Description

The Driver Commands block implements the driver model that the reference application uses to generate acceleration, braking, gear, and steering commands. By default, if you select the Reference Generator block parameter **Use maneuver-specific driver, initial position, and scene**, the reference application selects the driver for the maneuver that you specified.

Vehicle Command Mode Setting	Implementation
`Longitudinal Driver`	Longitudinal Driver block — Longitudinal speed-tracking controller. Based on reference and feedback velocities, the block generates normalized acceleration and braking commands that can vary from 0 through 1. Use the block to model the dynamic response of a driver or to generate the commands necessary to track a longitudinal drive cycle.
`Predictive Driver` (default)	Predictive Driver block — Controller that generates normalized steering, acceleration, and braking commands to track longitudinal velocity and a lateral reference displacement. The normalized commands can vary between -1 to 1. The controller uses a single-track (bicycle) model for optimal single-point preview control.
`Open Loop`	Implements an open-loop system so that you can configure the reference application for constant or signal-based steering, acceleration, braking, and gear command input.

Ports

Input

`VehRef` — Vehicle reference signals
Bus

Bus containing the vehicle reference signals, including longitudinal and lateral displacement, and steering.

`VehFdbk` — Vehicle feedback signals
Bus

Bus containing vehicle displacement feedback signals.

Output

`Driver` — Command signals
Bus

Bus containing the commands, including steering, acceleration, braking, and gear commands.

Parameters

`Vehicle command mode` — Enable 3D visualization
`Predictive Driver` (default) | `Longitudinal Driver` | `Open Loop`

Specify driver model.

Version History

Introduced in R2019a

See Also

Longitudinal Driver | Predictive Driver

Reference Generator

Generate maneuver reference signals

Description

The Reference Generator block sets the parameters that configure the maneuver and 3D simulation environment. By default, the block is set for the constant radius maneuver with the 3D simulation engine environment disabled.

Model

Use the **Maneuver** parameter to specify the type of maneuver. After you select the maneuver, use the parameters to specify the maneuver settings. By default:

- **Use maneuver-specific driver, initial position, and scene** — Set to `on`
- **Maneuver start time** — Set to 3s
- **Longitudinal velocity reference** — Set to 30s
- **Longitudinal entrance velocity setpoint units** — Set to mph

Maneuver Setting	Implementation
`Double Lane Change`	"Double-Lane Change Maneuver" • **Vehicle width** — Lane signals for the Visualization subsystem; used for the left and right lane boundaries • **Lateral reference data** — Lateral reference trajectory as a function of the longitudinal distance • **Distance after target speed to begin reference** — Start the maneuver at specified distance after the vehicle reaches the target speed
`Increasing Steer`	"Slowly Increasing Steering Maneuver" • **Handwheel rate** — Linear rate to increase steering wheel angle • **Maximum handwheel angle** — Maximum steering wheel angle
`Swept Sine`	"Swept-Sine Steering Maneuver" • **Steering amplitude** — Sinusoidal wave amplitude • **Final frequency** — Cut off frequency to stop the maneuver

Maneuver Setting	Implementation
`Sine with Dwell`	In the test, the vehicle: • Accelerates until it hits a target velocity. • Maintains the target velocity. • Responds to a sinusoidal with dwell steering command. • **Steer frequency** — Sinusoidal wave frequency • **Steer amplitude** — Sinusoidal wave amplitude • **Dwell time** — Dwell time
`Constant Radius`	“Constant Radius Maneuver” • **Radius value** — Turn radius
`Fishhook`	In the test, the vehicle: • Accelerates until it hits a target velocity. • Maintains the target velocity. • Responds to initial rapid steering input. • Responds to steering overcorrection. • **Steer and countersteer speed** — Steering rate • **Initial dwell time** — Initial steer time • **Countersteer dwell time** — Countersteer time

3D Engine

The 3D engine implements the 3D simulation environment. Vehicle Dynamics Blockset integrates the 3D simulation environment with Simulink so that you can query the world around the vehicle for virtually testing perception, control, and planning algorithms. For 3D engine requirements, see “Unreal Engine Simulation Environment Requirements and Limitations”. To enable the 3D engine, on the **3D Engine** tab, select **Enabled**.

To position the vehicle in the scene:

1. Select the position initialization method:

   - **Recommended for scene** — Set the initial vehicle position to values recommended for the scene
   - **User-specified** — Set your own initial vehicle position
2. Click **Update the model workspaces with the initial values** to overwrite the initial vehicle position in the model workspaces with the applied values.

Ports

Input

VehFdbk — Vehicle feedback

Bus

Bus containing vehicle feedback signals, including velocity, acceleration, and steering wheel torque.

Output

`Vis` — Visualization reference signals
`Bus`

Bus containing the visualization reference signals, including longitudinal and lateral displacement, and steering.

`Ref` — Vehicle reference signals
`Bus`

Bus containing the vehicle reference signals, including longitudinal and lateral displacement, and steering.

`Fdbk` — Vehicle location feedback signals
`Bus`

Bus containing vehicle location feedback signals, including position.

Parameters

Configuration

`Maneuver` — Select maneuver
`Constant Radius` (default) | `Double Lane Change` | `Increasing Steer` | `Swept Sine` | `Sine with Dwell`

Specify the scene type.

`Maneuver start time` — Start time
`scalar`

Maneuver start time, in s.

`Longitudinal velocity reference` — Target velocity
`scalar`

Target velocity.

`Longitudinal entrance velocity setpoint units` — Units
`mph` (default)

Units for target velocity.

`Simulation time` — Simulation time
`scalar`

Time, in s.

Constant Radius

`Radius value` — Radius
`scalar`

Radius value, in m.

`Turn direction` — Turn direction
`Right` (default) | `Left`

Turn direction.

`Lateral acceleration threshold` — Lateral acceleration
`scalar`

Lateral acceleration threshold, in g.

`Stop simulation at lateral acceleration threshold` — Selection
`off` (default) | `on`

Stop simulation if vehicle exceeds lateral acceleration threshold.

Double Lane Change

`Inertial longitudinal position of gate entrance` — Position
`scalar`

Inertial longitudinal position of gate entrance, in m.

`Distance after target speed to begin reference` — Start distance
`scalar`

Distance after target speed to begin reference, in m.

`Vehicle width` — Vehicle width
`scalar`

Vehicle width, in m.

The left and right lane boundaries are a function of the **Vehicle width** parameter.

`Lateral offset` — Lateral offset
`scalar`

Lateral offset, in m.

`Lateral reference position breakpoints` — Breakpoints
`scalar`

Lateral reference position breakpoints, in m.

Use the **Lateral reference position breakpoints** and **Lateral reference data** parameters to specify the lateral reference trajectory as a function of the longitudinal distance.

`Lateral reference data` — Lateral data
`scalar`

Use the **Lateral reference position breakpoints** and **Lateral reference data** parameters to specify the lateral reference trajectory as a function of the longitudinal distance.

Increasing Steer

`Handwheel rate` — Handwheel rate
`scalar`

Handwheel rate, in deg/s.

`Maximum handwheel angle` — Maximum handwheel
`scalar`

Maximum handwheel angle, in deg.

`Steering hold time after max angle reached` — Steering hold
`scalar`

Steering hold, in s.

`Lateral acceleration threshold` — Lateral acceleration
`scalar`

Lateral acceleration threshold, in g.

`Stop simulation at lateral acceleration threshold` — Selection
`off` (default) | `on`

Stop simulation if vehicle exceeds lateral acceleration threshold.

Swept Sign

`Swept time` — Sweep time
`scalar`

Sweep time, in s.

`Steering amplitude` — Steering amplitude
`scalar`

Sinusoidal steering amplitude, in deg.

`Final frequency` — Final frequency
`scalar`

Cut off frequency to stop the maneuver, in Hz.

Fishhook

`Steer and countersteer speed, steerRate` — Steer and countersteer speed
`scalar`

Steer and countersteer speed, in deg/s.

`Steer amplitude, steerAFH` — Steer amplitude
`scalar`

Steer amplitude, in deg.

`Initial dwell time, tDwell1` — Initial dwell time
`scalar`

Initial dwell time, in s.

`Countersteer dwell time, tDwell2` — Countersteer dwell time
`scalar`

Countersteer dwell time, in s.

`Return to center time, tSteer3` — Return to center time
`scalar`

Return to center time, in s.

`Roll rate countersteer initiation zero crossing threshold, pZero` — Crossing threshold
`scalar`

Roll rate countersteer initiation zero crossing threshold, in deg.

3D Engine

`3D Engine` — Enable 3D visualization
`off` (default) | `on`

Enable 3D visualization.

`Scene` — 3D scene
`Straight road` | `Curved road` | `Parking lot` | `Double lane change` | `Open surface` | `US city block` | `US highway` | `Virtual Mcity` | `Large parking lot`

Specify the name of the 3D scene.

`Engine frame rate, dt3D` — Graphics
`.03` (default)

Graphics frame rate, in s. The graphics frame rate is the inverse of the sample time.

`Recommended for scene` — Initial vehicle position
`on` (default) | `off`

Use vehicle positions that are recommended for the scene.

`User-specified` — Initial vehicle position
`off` (default) | `on`

Specify to set your own initial vehicle position values.

`Initial longitudinal position, X_o` — Initial longitudinal position
`off` (default) | `on`

Initial vehicle CG position along the earth-fixed *X*-axis, in m.

`Initial lateral position, Y_o` — Initial lateral position
`off` (default) | `on`

Initial vehicle CG position along the earth-fixed *Y*-axis, in m.

`Initial vertical position, Z_o` — Initial vertical position
`off` (default) | `on`

Initial vehicle CG position along the earth-fixed *Z*-axis, in m.

`Initial roll angle, phi_o` — Roll
`off` (default) | `on`

Rotation of the vehicle-fixed frame about the earth-fixed *X*-axis (roll), in rad.

`Initial pitch angle, theta_o` — Pitch
`off` (default) | `on`

Rotation of the vehicle-fixed frame about the earth-fixed *Y*-axis (pitch), in rad.

`Initial yaw angle, psi_o` — Yaw
`off` (default) | `on`

Rotation of the vehicle-fixed frame about the earth-fixed *Z*-axis (yaw), in rad.

Version History

Introduced in R2019a

See Also

3D Engine | Driver Commands

Topics

“Braking Test”
“Constant Radius Maneuver”
“Double-Lane Change Maneuver”
“Slowly Increasing Steering Maneuver”
“Swept-Sine Steering Maneuver”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Unreal Engine Simulation Environment Requirements and Limitations”

External Websites

Unreal Engine

Straight Maneuver Reference Generator

Generate straight maneuver reference signals

Description

The Straight Maneuver Reference Generator block generates accelerator and brake commands to conduct a straight line maneuver for the “Braking Test”. The acceleration begins at the specified rate until the vehicle achieves the longitudinal velocity setpoint. The vehicle controller maintains the longitudinal velocity setpoint for the specified time or distance. The controller then decelerates the vehicle.

Use the **Maneuver Parameters** to specify the maneuver start time, velocity setpoint, acceleration, and deceleration.

Optionally, on the **Tracking Parameters** tab, select **Enable fault tracking before braking**. Use the parameters to specify fault conditions before braking during a split-mu test. If the vehicle speed, steering angle, or yaw rate is not within the allowable range before braking, the block sets a fault condition. The default values represent compliance with ISO 14512[1].

Ports

Input

`VehFdbk` — Vehicle feedback
`Bus`

Bus containing vehicle feedback signals, including velocity, acceleration, and steering wheel torque.

Output

`Ref` — Vehicle reference signals
`Bus`

Bus containing the vehicle reference signals, including longitudinal and lateral displacement, and steering.

Parameters

Maneuver Parameters

`Maneuver start time, t_start` — Start time
2 (default) | `scalar`

Maneuver start time, in s.

`Longitudinal acceleration at t_start, ax` — Longitudinal acceleration
`0.5` (default) | `scalar`

Longitudinal acceleration at maneuver start, in g.

`Longitudinal velocity reference, xdot_r` — Longitudinal velocity reference, xdot_r
`20` (default) | `scalar`

Longitudinal velocity reference, xdot_r, in units specified by **Units of velocity, xdotUnit**.

`Units of velocity, xdotUnit` — Units
`m/s` (default) | `km/h` | `char`

Units of velocity.

`Brake pedal actuation` — Deceleration trigger
`Longitudinal displacement` (default) | `Time`

Method to start deceleration.

Select `Longitudinal displacement` to specify a displacement to start decelerating the vehicle.

Select `Time` to specify a time to start decelerating the vehicle.

`Longitudinal displacement of vehicle CG, x_brake` — Displacement
`200` (default) | `scalar`

Longitudinal displacement of vehicle CG to start deceleration, in m.

Dependency

To enable this parameter, set **Brake pedal actuation** to `Longitudinal displacement`.

`Brake actuation time, t_brake` — Time
`15` (default) | `scalar`

Time to start deceleration, in s.

Dependency

To enable this parameter, set **Brake pedal actuation** to `Time`.

`Longitudinal deceleration at t_brake, ax_dec` — Deceleration
`1` (default) | `scalar`

Longitudinal deceleration at braking time, in g.

`Transport delay buffer size, BufferSize` — Buffer
`4096` (default) | `scalar`

Transport delay buffer size.

`Select handwheel angle to 0 deg after braking` — Selection
`on` (default) | `off`

Set the handwheel angle to 0 after braking.

Tracking Parameters

`Enable fault tracking before braking` — Enable fault tracking
`on` (default) | `off`

Select this parameter to enable fault tracking before braking. Use the parameters to specify fault conditions before braking during a split-mu test. If the vehicle speed, steering angle, or yaw rate is not within the allowable range before braking, the block sets a fault condition. The default values represent compliance with ISO 14512[1].

`Longitudinal velocity and mean longitudinal velocity, xdot_rmax` — Maximum velocity tolerance

`1` (default) | `scalar`

The longitudinal velocity and mean longitudinal velocity tolerance. If the longitudinal velocity or mean longitudinal velocity exceeds the allowable range, the block sets a fault condition.

Dependencies

To enable this parameter, on the **Tracking Parameters** tab, select **Enable fault tracking before braking**.

`Mean longitudinal velocity and longitudinal velocity reference, xdot_rmean` — Mean velocity tolerance

`2` (default) | `scalar`

The mean longitudinal velocity and longitudinal velocity reference tolerance. If the mean longitudinal velocity or longitudinal velocity exceeds the allowable range, the block sets a fault condition.

Dependencies

To enable this parameter, on the **Tracking Parameters** tab, select **Enable fault tracking before braking**.

`Yaw velocity and mean yaw velocity, r_max` — Yaw velocity tolerance

`1` (default) | `scalar`

The yaw velocity and mean yaw velocity tolerance, in deg/s. If the yaw velocity or mean yaw velocity exceeds the allowable range, the block sets a fault condition.

Dependencies

To enable this parameter, on the **Tracking Parameters** tab, select **Enable fault tracking before braking**.

`Handwheel angle and mean handwheel angle, hw_max` — Handwheel angle tolerance

`3` (default) | `scalar`

Handwheel angle and mean handwheel angle, in deg. If the handwheel angle or mean handwheel angle exceeds the allowable range, the block sets a fault condition.

Dependencies

To enable this parameter, on the **Tracking Parameters** tab, select **Enable fault tracking before braking**.

`Stop simulation when fault occurs` — Select to stop simulation

`off` (default) | `on`

Select this parameter to stop the simulation if a fault occurs.

Dependencies

To enable this parameter, on the **Tracking Parameters** tab, select **Enable fault tracking before braking**.

Version History

Introduced in R2021a

See Also

Road Track Friction

Topics

"Braking Test"

Road Track Friction

Configure road for braking test

Description

The Road Track Friction block implements the road, including friction, for the “Braking Test”. Use the **Type of surface** parameter to specify the friction coefficient scaling factor:

- `Constant friction coefficient scaling factor` — Constant surface friction during the maneuver
- `Split friction coefficient scaling factor` — Two friction coefficients

  Select this option to specify the friction scaling coefficients for a split-mu braking test. Use the enabled parameters to set the ground friction and rectangular surface friction coefficient scaling factors.

Ports

Input

`XWhl` — Wheel displacement along X-axis
4-by-1 array

Wheel displacement along the earth-fixed X-axis, specified as a 4-by-1 array.

`YWhl` — Wheel displacement along Y-axis
4-by-1 array

Wheel displacement along the earth-fixed Y-axis, specified as a 4-by-1 array.

`Cg` — Vehicle CG
3-by-1 array

Vehicle cg, along earth-fixed axis, specified as a 3-by-1 array.

Output

`FricCoeffLambda` — Friction coefficient applied to wheels
4-by-1 array

Wheel friction coefficient, specified as a 4-by-1 array.

Parameters

`Type of surface` — Friction
`Split friction coefficient scaling factor` (default) | `Constant friction coefficient scaling factor`

- `Constant friction coefficient scaling factor` — Constant surface friction during the maneuver

- `Split friction coefficient scaling factor` — Two friction coefficients

  Select this option to specify the friction scaling coefficients for a split-mu braking test. Use the enabled parameters to set the ground friction and rectangular surface friction coefficient scaling factors.

`Scaling factor for the friction coefficient of ground, lambda_g` — Scaling factor

`.6` (default) | `scalar`

Scaling factor for the ground friction coefficient.

`Scaling factor for the friction coefficient of rectangular surface, lambda_r` — Scaling factor

`.8` (default) | `scalar`

Scaling factor for the friction coefficient of the rectangular surface.

Dependencies

To enable this parameter, set **Type of surface/track** to `Split friction coefficient scaling factor`.

`X coordinate of lower left corner of rectangular surface, r_x0` — X coordinate

`175` (default) | `scalar`

X coordinate of lower left corner of rectangular surface, in earth-fixed coordinate system, in m.

Dependencies

To enable this parameter, set **Type of surface/track** to `Split friction coefficient scaling factor`.

`Y coordinate of lower left corner of rectangular surface, r_y0` — X coordinate

`-100` (default) | `scalar`

Y coordinate of lower left corner of rectangular surface, in earth-fixed coordinate system.

Dependencies

To enable this parameter, set **Type of surface/track** to `Split friction coefficient scaling factor`.

`Rectangular surface width in X direction, r_xw` — Rectangular surface

`1000` (default) | `scalar`

Rectangular surface width in X direction, in m.

Dependencies

To enable this parameter, set **Type of surface/track** to `Split friction coefficient scaling factor`.

`Rectangular surface width in Y direction, r_yw` — Rectangular surface

`500` (default) | `scalar`

Rectangular surface width in Y direction, in m.

Dependencies

To enable this parameter, set **Type of surface/track** to `Split friction coefficient scaling factor`.

Version History

Introduced in R2021a

See Also

Straight Maneuver Reference Generator

Topics

"Braking Test"

Lane Change Reference Generator

Generate double-lane change maneuver reference signals

Description

The Lane Change Reference Generator block sets the parameters that configure the double-lane change maneuver.

After the vehicle reaches the reference velocity, the block commands a zero acceleration signal and generates a lateral reference trajectory as a function of the longitudinal displacement. The block also generates signals indicating the left and right lane boundaries as a function of the axle width.

Use the **Steady-state initial conditions** parameter to specify the initial conditions for the maneuver. By default, the parameter is set to `Initialize from model`, and the simulation starts with the vehicle at rest at the specified initial position. If you want to start the simulation at the non-zero steady-state velocity:

1. Set **Steady-state initial conditions** to `Solve using block parameters`.
2. On the **Steady-State Solver** tab, specify the initial conditions, workspace variable, and solver settings. Click **Generate steady state solution**.
3. After the simulation completes, set **Steady-state initial conditions** to `Resume from a workspace variable`.
4. Set **Steady-state solution to start from, ssVar** to the workspace variable you specified in step 2.
5. Run the simulation.

For an example, see “Start Double-Lane Change Maneuver at Target Velocity”.

Ports

Input

`VehFdbk` — Vehicle feedback

Bus

Bus containing vehicle feedback signals, including velocity, acceleration, and steering wheel torque.

Output

Lane — Lane boundaries

Bus

Bus containing left, right, and lateral reference lane boundaries.

`Ref` — Vehicle reference signals

Bus

Bus containing the vehicle reference signals, including longitudinal and lateral displacement, and steering.

Parameters

Maneuver

`Steady-state initial conditions` — Start maneuver from steady-state
`Initialize from model` (default) | `Solve using block parameters` | `Resume from a workspace variable`

Use the **Steady-state initial conditions** parameter to specify the steady-state initial conditions for the maneuver. By default, the simulation will not find or start the simulation at the steady-state operating points.

Setting	Description
`Initialize from model`	Simulation starts maneuver at the simulation start time specified by **Maneuver start time, t_start** at longitudinal velocity of 0.
`Solve using block parameters`	Simulation *finds* the steady-state operating points using the parameters on the **Steady-State Solver** tab.
`Resume from a workspace variable`	Simulation *starts* at the steady-state operating points workspace variable specified by **Steady-state solution to start from, ssVar**.

`Steady-state solution to start from, ssVar` — Workspace variable with steady-state operating points
`char`

Workspace variable containing the steady-state operating points.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Resume from a workspace variable`.

`Maneuver start time, t_start` — Start time
`scalar`

Maneuver start time, in s.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Initialize from model`.

`Inertial longitudinal position of gate entrance, XGate` — Position
175 (default) | `scalar`

Inertial longitudinal position of gate entrance, in m.

`Longitudinal entrance velocity setpoint, xdot_r` — Target velocity
35 (default) | `scalar`

Target velocity.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Initialize from model` or `Solve using block parameters`.

`Longitudinal entrance velocity setpoint units, xdotUnit` — Units

`mph` (default)

Units for target velocity.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Initialize from model` or `Solve using block parameters`.

`Vehicle width, vehW` — Vehicle width

2 (default) | `scalar`

Vehicle width, in m.

The left and right lane boundaries are a function of the **Vehicle width** parameter.

`Lateral offset, latoff` — Lateral offset

`scalar`

Lateral offset, in m.

`Lateral reference position breakpoints, latRefbp` — Breakpoints

`scalar`

Lateral reference position breakpoints, in m.

Use the **Lateral reference position breakpoints** and **Lateral reference data** parameters to specify the lateral reference trajectory as a function of the longitudinal distance.

`Lateral reference data, latRef` — Lateral data

`scalar`

Use the **Lateral reference position breakpoints** and **Lateral reference data** parameters to specify the lateral reference trajectory as a function of the longitudinal distance.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Initialize from model` or `Solve using block parameters`.

Steady-State Solver

`Initial longitudinal position, X_o` — Initial longitudinal position

175 (default) | `scalar`

Initial vehicle CG position along the earth-fixed *X*-axis, in m.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Initial lateral position, Y_o` — Initial lateral position

`scalar`

Initial vehicle CG position along the earth-fixed *Y*-axis, in m.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Initial heading (yaw) angle, psi_o` — Initial yaw angle

`scalar`

Initial vehicle yaw angle about the earth-fixed *Z*-axis, in rad.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Steady-state solver tolerance, ssTol` — Solver velocity tolerance

`scalar`

Steady-state solver velocity tolerance.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Maximum simulated time to reach steady-state, ssMaxTime` — Max time

`scalar`

Maximum simulated time to reach steady-state, in s.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Workspace variable name to generate, ssWSName` — Steady-state operating points

`scalar`

Name of workspace variable containing steady-state operating points.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

Version History

Introduced in R2019a

See Also

Driver Commands

Topics

“Double-Lane Change Maneuver”

“Start Double-Lane Change Maneuver at Target Velocity”

Slowly Increasing Steer Reference Generator

Generate slowly increasing steer maneuver reference signals

Description

The Slowly Increasing Steer Reference Generator block sets the parameters that configure the slowly increasing steer maneuver.

The block generates steering, accelerator, and brake commands to conduct a linearly increasing steering maneuver. The steering command begins at the specified rate once the vehicle reaches the longitudinal velocity setpoint. After the vehicle achieves the maximum steering angle, the vehicle maintains the steering angle for a desired duration. The block then reduces the steering angle to zero at the same rate. A longitudinal controller regulates the vehicle at the prescribed speed throughout the maneuver.

Use the **Steady-state solver mode** parameter to specify the initial conditions for the maneuver. By default, the parameter is set to `Initialize from model`, and the simulation starts with the vehicle at rest at the specified initial position. If you want to start the simulation at the non-zero steady-state velocity:

1. Set **Steady-state solver mode** to `Solve using block parameters`.
2. On the **Steady-State Solver** tab, specify the initial conditions, workspace variable, and solver settings. Click **Generate steady state solution**.
3. After the simulation completes, set **Steady-state solver mode** to `Resume from a workspace variable`.
4. Set **Steady-state solution to start from, ssVar** to the workspace variable you specified in step 2.
5. Run the simulation.

Ports

Input

VehFdbk — Vehicle feedback
Bus

Bus containing vehicle feedback signals, including velocity, acceleration, and steering wheel torque.

Output

`Ref` — Vehicle reference signals
Bus

Bus containing the vehicle reference signals, including longitudinal and lateral displacement, and steering.

Parameters

Maneuver

`Steady-state solver mode` — Start maneuver from steady-state
`Initialize from model` (default) | `Solve using block parameters` | `Resume from a workspace variable`

Use the **Steady-state solver mode** parameter to specify the steady-state initial conditions for the maneuver. By default, the simulation will not find or start the simulation at the steady-state operating points.

Setting	Description
`Initialize from model`	Simulation starts maneuver at the simulation start time specified by **Maneuver start time, t_start** at longitudinal velocity of 0.
`Solve using block parameters`	Simulation *finds* the steady-state operating points using the parameters on the **Steady-State Solver** tab.
`Resume from a workspace variable`	Simulation *starts* at the steady-state operating points workspace variable specified by **Steady-state solution to start from, ssVar**.

`Steady-state solution to start from, ssVar` — Workspace variable with steady-state operating points
`char`

Workspace variable containing the steady-state operating points.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Resume from a workspace variable`.

`Maneuver start time, t_start` — Start time
`scalar`

Maneuver start time, in s.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Initialize from model`.

`Longitudinal speed setpoint, xdot_r` — Target velocity
`50` (default) | `scalar`

Target velocity.

`Longitudinal speed setpoint units, xdotUnit` — Units
`mph` (default)

Units for target velocity.

`Handwheel rate, omega_hw` — Handwheel rate
`scalar`

Handwheel rate, in deg/s.

`Maximum absolute handwheel angle, theta_max` — Maximum handwheel
`scalar`

Maximum handwheel angle, in deg.

`Steering hold time after max angle reached, t_stop` — Steering hold
`scalar`

Steering hold, in s.

`Lateral acceleration absolute threshold, ay_max` — Lateral acceleration
`scalar`

Lateral acceleration threshold, in g.

Steady-State Solver

`Initial longitudinal position, X_o` — Initial longitudinal position
175 (default) | `scalar`

Initial vehicle CG position along the earth-fixed *X*-axis, in m.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Initial lateral position, Y_o` — Initial lateral position
`scalar`

Initial vehicle CG position along the earth-fixed *Y*-axis, in m.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Initial heading (yaw) angle, psi_o` — Initial yaw angle
`scalar`

Initial vehicle yaw angle about the earth-fixed *Z*-axis, in rad.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Steady-state solver tolerance, ssTol` — Solver velocity tolerance
`scalar`

Steady-state solver velocity tolerance.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Maximum simulated time to reach steady-state, ssMaxTime` — Max time
`scalar`

Maximum simulated time to reach steady-state, in s.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Workspace variable name to generate, ssWSName` — Steady-state operating points
`scalar`

Name of workspace variable containing steady-state operating points.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

Version History

Introduced in R2019a

See Also

Driver Commands

Topics

"Slowly Increasing Steering Maneuver"

Swept Sine Reference Generator

Generate swept-sine maneuver reference signals

Description

The Swept Sine Reference Generator block sets the parameters that configure the swept-sine maneuver. Once the vehicle reaches the target longitudinal velocity, the block generates a sinusoidal steering command with linearly increasing frequency, up to the maximum specified in the allotted time.

Use the **Steady-state solver mode** parameter to specify the initial conditions for the maneuver. By default, the parameter is set to `Initialize from model`, and the simulation starts with the vehicle at rest at the specified initial position. If you want to start the simulation at the non-zero steady-state velocity:

1. Set **Steady-state solver mode** to `Solve using block parameters`.
2. On the **Steady-State Solver** tab, specify the initial conditions, workspace variable, and solver settings. Click **Generate steady state solution**.
3. After the simulation completes, set **Steady-state solver mode** to `Resume from a workspace variable`.
4. Set **Steady-state solution to start from, ssVar** to the workspace variable you specified in step 2.
5. Run the simulation.

Ports

Input

VehFdbk — Vehicle feedback
`Bus`

Bus containing vehicle feedback signals, including velocity, acceleration, and steering wheel torque.

Output

Ref — Vehicle reference signals
`Bus`

Bus containing the vehicle reference signals, including longitudinal and lateral displacement, and steering.

Parameters

Maneuver

`Steady-state solver mode` — Start maneuver from steady-state
`Initialize from model` (default) | `Solve using block parameters` | `Resume from a workspace variable`

Use the **Steady-state solver mode** parameter to specify the steady-state initial conditions for the maneuver. By default, the simulation will not find or start the simulation at the steady-state operating points.

Setting	Description
`Initialize from model`	Simulation starts maneuver at the simulation start time specified by **Maneuver start time, t_start** at longitudinal velocity of 0.
`Solve using block parameters`	Simulation *finds* the steady-state operating points using the parameters on the **Steady-State Solver** tab.
`Resume from a workspace variable`	Simulation *starts* at the steady-state operating points workspace variable specified by **Steady-state solution to start from, ssVar**.

`Steady-state solution to start from, ssVar` — Workspace variable with steady-state operating points

`char`

Workspace variable containing the steady-state operating points.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Resume from a workspace variable`.

`Maneuver start time, t_start` — Start time

`scalar`

Maneuver start time, in s.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Initialize from model`.

`Longitudinal velocity setpoint, xdot_ref` — Target velocity

`50` (default) | `scalar`

Target velocity.

`Longitudinal speed setpoint units, xdotUnit` — Units

`mph` (default)

Units for target velocity.

`Steering amplitude, theta_hw` — Steering amplitude

`scalar`

Sinusoidal steering amplitude, in deg.

`Final frequency, theta_hw_final` — Final frequency

`scalar`

Cut off frequency to stop the maneuver, in Hz.

`Swept time, t_sweep` — Sweep time

`scalar`

Sweep time, in s.

Steady-State Solver

`Initial longitudinal position, X_o` — Initial longitudinal position

175 (default) | `scalar`

Initial vehicle CG position along the earth-fixed *X*-axis, in m.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Initial lateral position, Y_o` — Initial lateral position

`scalar`

Initial vehicle CG position along the earth-fixed *Y*-axis, in m.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Initial heading (yaw) angle, psi_o` — Initial yaw angle

`scalar`

Initial vehicle yaw angle about the earth-fixed *Z*-axis, in rad.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Steady-state solver tolerance, ssTol` — Solver velocity tolerance

`scalar`

Steady-state solver velocity tolerance.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Maximum simulated time to reach steady-state, ssMaxTime` — Max time

`scalar`

Maximum simulated time to reach steady-state, in s.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

`Workspace variable name to generate, ssWSName` — Steady-state operating points

`scalar`

Name of workspace variable containing steady-state operating points.

Dependencies

To enable this parameter, set **Steady-state initial conditions** to `Solve using block parameters`.

Version History

Introduced in R2019a

See Also

Driver Commands

Topics

“Swept-Sine Steering Maneuver”

11

Classes

sim3d.Editor

Interface to the Unreal Engine project

Description

Use the `sim3d.Editor` class to interface with the Unreal Editor.

To develop scenes with the Unreal Editor and co-simulate with Simulink, you need the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package. The support package contains an Unreal Engine project that allows you to customize the Vehicle Dynamics Blockset scenes. For information about the support package, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Creation

Syntax

`sim3d.Editor(project)`

Description

MATLAB creates an `sim3d.Editor` object for the Unreal Editor project specified in `sim3d.Editor( project)`.

Input Arguments

`project` — Project path and name
string array

Project path and name.

Example: `"C:\Local\AutoVrtlEnv\AutoVrtlEnv.uproject"`

Data Types: `string`

Properties

`Uproject` — Project path and name
string array

This property is read-only.

Project path and name with Unreal Engine project file extension.

Example: `"C:\Local\AutoVrtlEnv\AutoVrtlEnv.uproject"`

Data Types: `string`

Object Functions

open	Open the Unreal Editor

Examples

Open Project in Unreal Editor

Open an Unreal Engine project in the Unreal Editor.

Create an instance of the `sim3d.Editor` class for the Unreal Engine project located in `C:\Local\AutoVrtlEnv\AutoVrtlEnv.uproject`.

```
editor = sim3d.Editor(fullfile("C:\Local\AutoVrtlEnv\AutoVrtlEnv.uproject"))
```

Open the project in the Unreal Editor.

```
editor.open();
```

Version History

Introduced in R2019b

See Also

Topics

“Customize 3D Scenes for Vehicle Dynamics Simulations”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Unreal Engine Simulation Environment Requirements and Limitations”

open

Open the Unreal Editor

Syntax

`[status,result] = open(sim3dEditorObj)`

Description

`[status,result] = open(sim3dEditorObj)` opens the Unreal Engine project in the Unreal Editor.

To develop scenes with the Unreal Editor and co-simulate with Simulink, you need the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package. The support package contains an Unreal Engine project that allows you to customize the Vehicle Dynamics Blockset scenes. For information about the support package, see “Customize 3D Scenes for Vehicle Dynamics Simulations”.

Input Arguments

`sim3dEditorObj` — sim3d.Editor object
`sim3d.Editor` object

`sim3d.Editor` object for the Unreal Engine project.

Output Arguments

`status` — Command exit status
0 | nonzero integer

Command exit status, returned as either `0` or a nonzero integer. When the command is successful, `status` is `0`. Otherwise, `status` is a nonzero integer.

- If `command` includes the ampersand character (&), then `status` is the exit status when `command` starts
- If `command` does not include the ampersand character (&), then `status` is the exit status upon `command` completion.

`result` — Output of operating system command
character vector

Output of the operating system command, returned as a character vector. The system shell might not properly represent non-Unicode® characters.

Version History

Introduced in R2019b

See Also

`sim3d.Editor`

Topics

"Customize 3D Scenes for Vehicle Dynamics Simulations"
"How 3D Simulation for Vehicle Dynamics Blockset Works"
"Unreal Engine Simulation Environment Requirements and Limitations"

ASim3dActor

Abstract class to use as a base class for user-defined Unreal Engine C++ or blueprint actors

Description

`ASim3dActor` is an abstract class that you can use as a base class for user-defined Unreal Engine C++ or blueprint actors.

The base classes are inherently synchronized during co-simulation with a Simulink model. Additionally, the Simulation 3D Actor Transform Set block can control the base class. To extend behavior of `ASim3dActor`, you can use the message interface functions to override the class methods so they send and receive messages to and from a model.

`ASim3dActor` is included in the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects. For information about the support package, see "Customize 3D Scenes for Vehicle Dynamics Simulations".

Properties

`Translation` — Actor translation
1-by-3 (default) | number of parts per actor-by-3

This property is protected. It is used in the derived C++ class. Value is set by the Simulation 3D Actor Transform Set block.

Actor translation along world *X*-, *Y*, and *Z*- axes, respectively, in m. Array dimensions are number of parts per actor-by-3.

Data Types: `float`

`Rotation` — Actor rotation
1-by-3 (default) | number of parts per actor-by-3

This property is protected. It is used in the derived C++ class. Value is set by the Simulation 3D Actor Transform Set block.

Actor rotation across a [-pi/2, pi/2] range about world *X*-, *Y*, and *Z*- axes, respectively, in rad. Array dimensions are number of parts per actor-by-3.

Data Types: `float`

`Scale` — Actor scale
1-by-3 (default) | number of parts per actor-by-3

This property is protected. It is used in the derived C++ class. Value is set by the Simulation 3D Actor Transform Set block.

Actor scale. Array dimensions are number of parts per actor-by-3.

Data Types: `float`

Object Functions

Sim3dSetup	C++ method that sets up actor in Unreal Engine 3D simulation
Sim3dStep	C++ method that steps actor in Unreal Engine 3D simulation
Sim3dRelease	C++ method that releases actor in Unreal Engine 3D simulation

Version History

Introduced in R2020b

See Also

`StartSimulation3DMessageReader` | `ReadSimulation3DMessage` | `StopSimulation3DMessageReader` | `StartSimulation3DMessageWriter` | `WriteSimulation3DMessage` | `StopSimulation3DMessageWriter`

External Websites

Unreal Engine 4 Documentation

Sim3dSetup

C++ method that sets up actor in Unreal Engine 3D simulation

Syntax

`void ASetGetActorLocation::Sim3dSetup()`

Description

The C++ method `void ASetGetActorLocation::Sim3dSetup()` sets up an actor in the Unreal Engine 3D simulation environment. The Unreal Engine `AActor::BeginPlay` class calls the `Sim3dSetup` method every frame.

Examples

Set Up Actor

```
void ASetGetActorLocation::Sim3dSetup()
{
       Super::Sim3dSetup();
              if (Tags.Num() != 0) {
                  FString tagName = Tags.Top().ToString();

                  FString MessageReaderTag = tagName;
                  MessageReaderTag.Append(TEXT("SimulinkMessage_OUT")); // a message from Simulink model
                  MessageReader = StartSimulation3DMessageReader (TCHAR_TO_ANSI(*MessageReaderTag), MAX_MESSAGE_SIZE);

                  FString MessageWriterTag = tagName;
                  MessageWriterTag.Append(TEXT("SimulinkMessage_IN")); // a message to Simulink model
                  MessageWriter = StartSimulation3DMessageWriter (TCHAR_TO_ANSI(*MessageWriterTag) ), MAX_MESSAGE_SIZE);
              }
}
```

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

"Customize 3D Scenes for Vehicle Dynamics Simulations"

External Websites

Unreal Engine 4 Documentation

Sim3dStep

C++ method that steps actor in Unreal Engine 3D simulation

Syntax

`void ASetGetActorLocation::Sim3dStep(float DeltaSeconds)`

Description

The C++ method `void ASetGetActorLocation::Sim3dStep(float DeltaSeconds)` steps an actor in the Unreal Engine 3D simulation environment. The Unreal Engine `AActor::Tick` class calls the `Sim3dStep` method.

Examples

Step Actor

```
void ASetGetActorLocation::Sim3dStep(float DeltaSeconds)
{
	Super::Sim3dStep(DeltaSeconds);
	uint32 messageSize = MAX_MESSAGE_SIZE;
	int statusR = ReadSimulation3DMessage (MessageReader, &messageSize, message);
	...
	int statusW = WriteSimulation3DMessage (MessageWriter, messageSize, message);
}
```

Input Arguments

`DeltaSeconds` — Elapsed time

`.01`

Time elapsed since Unreal Engine modified the frame.

Data Types: `float`

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

“Customize 3D Scenes for Vehicle Dynamics Simulations”

External Websites

Unreal Engine 4 Documentation

Sim3dRelease

C++ method that releases actor in Unreal Engine 3D simulation

Syntax

`void ASetGetActorLocation::Sim3dRelease()`

Description

The C++ method `void ASetGetActorLocation::Sim3dRelease()` releases an actor in the Unreal Engine 3D simulation environment. The Unreal Engine `AActor::EndPlay` class calls the `Sim3dRelease` method when the 3D simulation ends.

Examples

Release Actor

```
void ASetGetActorLocation::Sim3dRelease()
{
   Super::Sim3dRelease();
   if (MessageReader) {
         StopSimulation3DMessageReader (SignalReader);
   }
   MessageReader = nullptr;

   if (MessageWriter) {
         StopSimulation3DMessageWriter (SignalWriter);
   }
   MessageWriter = nullptr;
}
```

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

"Customize 3D Scenes for Vehicle Dynamics Simulations"

External Websites

Unreal Engine 4 Documentation

StartSimulation3DMessageReader

Constructs a message reader object in the Unreal Editor

Syntax

`MessageReader = StartSimulation3DMessageReader(topicName, maxDataSize)`

Description

`MessageReader = StartSimulation3DMessageReader(topicName, maxDataSize)` constructs a message reader object in the Unreal Editor.

The C++ syntax is

```
void *StartSimulation3DMessageReader(const char* topicName,uint32 maxDataSize);
```

Input Arguments

`topicName` — Simulink signal topic name

`mySignal`

Name of the Simulink signal with the message topic.

Data Types: `char *`

`maxDataSize` — Maximum size of data

`number of bytes` | `scalar`

Maximum size of the data, in bytes.

Data Types: `uint32`

Output Arguments

`MessageReader` — Pointer to message reader object

object pointer

Pointer to message reader object, `ReadSimulation3DMessage`.

Data Types: `void *`

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

“Customize 3D Scenes for Vehicle Dynamics Simulations”

External Websites
Unreal Engine 4 Documentation

ReadSimulation3DMessage

Receives message from Simulink model using a message reader object

Syntax

`status=ReadSimulation3DMessage(MessageReader, dataSize, data)`

Description

`status=ReadSimulation3DMessage(MessageReader, dataSize, data)` receives a message from a Simulink model using a message reader object.

The C++ syntax is

```
int ReadSimulation3DMessage(void *MessageReader, uint32 dataSize, void *data);
```

Input Arguments

`MessageReader` — Pointer to message reader object

object pointer

Pointer to message reader object, `ReadSimulation3DMessage`.

Data Types: `void *`

`dataSize` — Size of data

`number of bytes` | `scalar`

Size of data, that is, `data (sizeof(datatype) *num_of_elements)`. For example, if you want to read a vector of 3 floats, the data size is `sizeof(float)*3`.

Data Types: `uint32`

`data` — Pointer to data object

object pointer

Pointer to data object.

Data Types: `void *`

Output Arguments

`status` — Operation exit status

0 | nonzero integer

Status, returned as either `0` or a nonzero integer. When the operation is successful, `status` is `0`. Otherwise, `status` is a nonzero integer.

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

"Customize 3D Scenes for Vehicle Dynamics Simulations"

External Websites

Unreal Engine 4 Documentation

StopSimulation3DMessageReader

Deletes message reader object in the Unreal Editor

Syntax

`status=StopSimulation3DMessageReader(MessageReader)`

Description

`status=StopSimulation3DMessageReader(MessageReader)` deletes the Unreal Editor 3D message reader object.

The C++ syntax is

```
int StopSimulation3DMessageReader(void * MessageReader);
```

Input Arguments

`MessageReader` — Pointer to message reader object
object pointer

Pointer to message reader object, `ReadSimulation3DMessage`.

Data Types: `void *`

Output Arguments

`status` — Operation exit status
0 | nonzero integer

Status, returned as either `0` or a nonzero integer. When the operation is successful, `status` is `0`. Otherwise, `status` is a nonzero integer.

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

"Customize 3D Scenes for Vehicle Dynamics Simulations"

External Websites

Unreal Engine 4 Documentation

StartSimulation3DMessageWriter

Constructs a message writer object in the Unreal Editor

Syntax

`MessageWriter = StartSimulation3DMessageWriter(topicName, maxDataSize)`

Description

`MessageWriter = StartSimulation3DMessageWriter(topicName, maxDataSize)` constructs a message writer object in the Unreal Editor.

The C++ syntax is

```
void *StartSimulation3DMessageWriter(const char* topicName, uint32 maxDataSize);
```

Input Arguments

`topicName` — Simulink signal topic name
`mySignal`

Name of the Simulink signal with the message topic.

Data Types: `char *`

`maxDataSize` — Maximum size of data
`number of bytes` | `scalar`

Maximum size of the data, in bytes.

Data Types: `uint32`

Output Arguments

`MessageWriter` — Pointer to message writer object
object pointer

Pointer to message writer object, `WriteSimulation3DMessage`.

Data Types: `void *`

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

“Customize 3D Scenes for Vehicle Dynamics Simulations”

External Websites

Unreal Engine 4 Documentation

WriteSimulation3DMessage

Sends message to Simulink model using a message writer object

Syntax

`status=WriteSimulation3DMessage(MessageWriter, dataSize, data)`

Description

`status=WriteSimulation3DMessage(MessageWriter, dataSize, data)` sends a message to a Simulink model using a message writer object.

The C++ syntax is

```
int WriteSimulation3DMessage(void * MessageWriter, uint32 dataSize, void *data);
```

Input Arguments

`MessageWriter` — Pointer to message writer object
object pointer

Pointer to message writer object, `WriteSimulation3DMessage`.

Data Types: `void *`

`dataSize` — Size of data
`number of bytes` | `scalar`

Size of data, that is, `data (sizeof(datatype) *num_of_elements)`. For example, if you want to read a vector of 3 floats, the data size is `sizeof(float)*3`.

Data Types: `uint32`

`data` — Pointer to data object
object pointer

Pointer to data object.

Data Types: `void *`

Output Arguments

`status` — Operation exit status
0 | nonzero integer

Status, returned as either `0` or a nonzero integer. When the operation is successful, `status` is `0`. Otherwise, `status` is a nonzero integer.

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

"Customize 3D Scenes for Vehicle Dynamics Simulations"

External Websites

Unreal Engine 4 Documentation

StopSimulation3DMessageWriter

Deletes message writer object in the Unreal Editor

Syntax

`status=StopSimulation3DMessageWriter(MessageWriter)`

Description

`status=StopSimulation3DMessageWriter(MessageWriter)` deletes the Unreal Editor 3D message writer object.

The C++ syntax is

```
int StopSimulation3DMessageWriter(void *MessageWriter);
```

Input Arguments

`MessageWriter` — Pointer to message writer object
object pointer

Pointer to message writer object, `WriteSimulation3DMessage`.

Data Types: `void *`

Output Arguments

`status` — Operation exit status
0 | nonzero integer

Status, returned as either `0` or a nonzero integer. When the operation is successful, `status` is `0`. Otherwise, `status` is a nonzero integer.

Version History

Introduced in R2020b

See Also

`ASim3dActor`

Topics

"Customize 3D Scenes for Vehicle Dynamics Simulations"

External Websites

Unreal Engine 4 Documentation

copyExampleSim3dProject

Copy support package files and plugins to specified folder

Syntax

```
sim3d.utils.copyExampleSim3dProject(DestFldr)
sim3d.utils.copyExampleSim3dProject(DestFldr,Name=Value)
```

Description

`sim3d.utils.copyExampleSim3dProject(DestFldr)` copies the Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package files to the destination folder, `DestFldr`.

`sim3d.utils.copyExampleSim3dProject(DestFldr,Name=Value)` copies support package files to the destination with additional options specified by name-value arguments.

Running the `sim3d.utils.copyExampleSim3dProject` function configures your environment so that you can customize scenes. The destination folder contains these Vehicle Dynamics Blockset Interface for Unreal Engine 4 Projects support package components.

- An Unreal project, defined in `AutoVrtlEnv.uproject`, and its associated files. The project includes editable versions of the prebuilt 3D scenes that you can select from the **Scene description** parameter of the Simulation 3D Scene Configuration block.
- Three plugins, `MathWorkSimulation`: `RoadRunnerMaterials`, and `MathWorksAutomotiveContent`. These plugins establish the connection between MATLAB and the Unreal Editor and are required for co-simulation.

Input Arguments

`DestFldr` — Destination folder
character vector

Destination folder name, specified as a character vector.

Note You must have write permission for the destination folder.

Data Types: `char` | `string`

Name-Value Pair Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

`Source` — Support package source folder
character vector

Support package source folder, specified as a character vector. The folder contains the downloaded support packages files.

By default, if you do not specify the source folder, `copyExampleSim3dProject` copies the file from the support package installation folder, `matlabshared.supportpkg.getSupportPackageRoot()`.

Example: `Source="shared\sim3dprojects\spkg\"`

Data Types: `char` | `string`

`VerboseOutput` — Option to enable verbose logging
`0` or `false` (default) | `1` or `true`

Option to enable verbose logging, specified as a logical `0` (false) or `1` (true). Verbose logging displays intermediate iteration information on the MATLAB command line.

Example: `VerboseOutput=true`

Data Types: `logical`

Examples

Copy Support Package Files to Destination Folder

Copy the support package files to `C:\project`.

```
sim3d.utils.copyExampleSim3dProject("C:\project");
```

Copy the support package files to `C:\project` with `VerboseOutput` set to `true`.

```
sim3d.utils.copyExampleSim3dProject("C:\project", VerboseOutput=true)
```

```
Copying ...\spkg\project\AutoVrtlEnv to C:\project\AutoVrtlEnv
Creating C:\project\AutoVrtlEnv\Plugins
Copying ...\spkg\plugins\mw_aerospace\MathWorksAerospace to C:\project\AutoVrtlEnv\Plugins\MathW
Copying ...\spkg\plugins\mw_automotive\MathWorksAutomotiveContent to C:\project\AutoVrtlEnv\Plugi
Copying ...\spkg\plugins\mw_simulation\MathWorksSimulation to C:\project\AutoVrtlEnv\Plugins\Math
Copying ...\spkg\plugins\mw_uav\MathWorksUAVContent to C:\project\AutoVrtlEnv\Plugins\MathWorksU
Copying ...\spkg\plugins\rr_materials\RoadRunnerMaterials to C:\project\AutoVrtlEnv\Plugins\Road
Ensuring C:\project\AutoVrtlEnv\AutoVrtlEnv.uproject is writable
Enabling plugin MathWorksSimulation in C:\project\AutoVrtlEnv\AutoVrtlEnv.uproject
Enabling plugin MathWorksUAVContent in C:\project\AutoVrtlEnv\AutoVrtlEnv.uproject
Enabling plugin MathWorksAutomotiveContent in C:\project\AutoVrtlEnv\AutoVrtlEnv.uproject
Enabling plugin RoadRunnerMaterials in C:\project\AutoVrtlEnv\AutoVrtlEnv.uproject
```

Version History

Introduced in R2022b

See Also

Topics
“Install Support Package and Configure Environment”
“How 3D Simulation for Vehicle Dynamics Blockset Works”
“Unreal Engine Simulation Environment Requirements and Limitations”

External Websites
Unreal Engine
Using Unreal Engine with Simulink

sim3d.maps

Access additional scenes from the server

Description

Use the `sim3d.maps` to download and access additional scenes from the server so that they can be automatically available in the Simulation 3D Scene Configuration block.

Object Functions

sim3d.maps.Map.download	Download maps from the server
sim3d.maps.Map.server	List of maps available for download from the server
sim3d.maps.Map.delete	Delete local maps downloaded from the server
sim3d.maps.Map.local	List of locally available maps

Troubleshooting

- If you cannot reach the server, the download will fail due to a timeout.
- If the download fails while updating an existing map, the existing outdated file will remain functional.
- If you delete the CSV file, you will lose automatic tracking of updates for the existing maps.

Version History

Introduced in R2022b

See Also

Simulation 3D Scene Configuration

sim3d.maps.Map.download

Download maps from the server

Syntax

`sim3d.maps.Map.download(Scene)`

Description

`sim3d.maps.Map.download(Scene)` downloads the map `Scene` from the server.

Examples

Download Suburban Scene Map

This example shows how to download and access the Suburban scene map from the Simulation 3D Scene Configuration block.

To begin, check the maps available in the server.

```
sim3d.maps.Map.server
```

```
        MapName                        Description                    Version    MinimumRelease
    ________________    __________________________________________    _______    ______________

    "Suburban scene"    "a suburban area beyond the city's border"      "1"         "R2022b"
```

Download the Suburban scene from the server.

```
sim3d.maps.Map.download('Suburban scene')
```

```
Map is susccesfully downloaded and is up-to-date
```

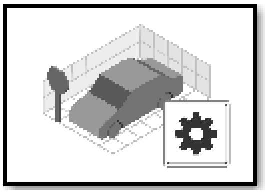
Check if the downloaded maps are available in your local machine.

```
sim3d.maps.Map.local
```

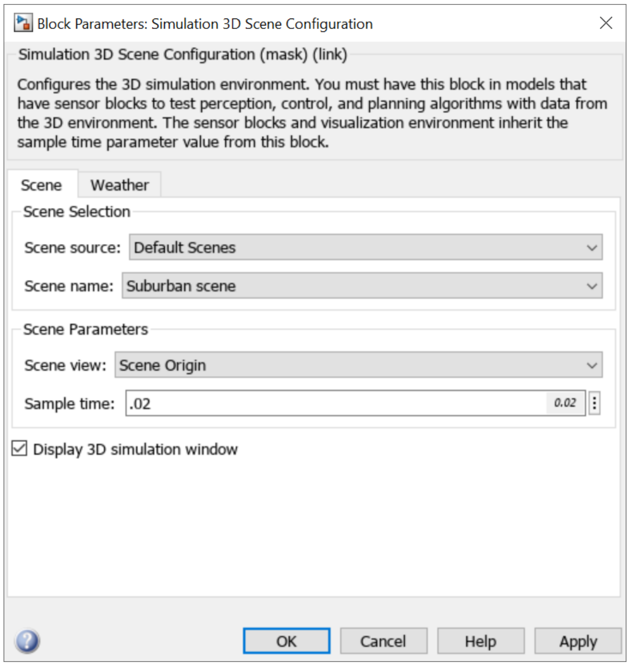
```
        MapName                        Description                    Version    MinimumRelease
    ________________    __________________________________________    _______    ______________

    "Suburban scene"    "a suburban area beyond the city's border"      "1"         "R2022b"
```

Add the Simulation 3D Scene Configuration block to your model.



Open the block mask and select the suburban scene from **Scene name**.



Block Parameters: Simulation 3D Scene Configuration

Simulation 3D Scene Configuration (mask) (link)

Configures the 3D simulation environment. You must have this block in models that have sensor blocks to test perception, control, and planning algorithms with data from the 3D environment. The sensor blocks and visualization environment inherit the sample time parameter value from this block.

Scene Selection

Scene source: Default Scenes

Scene name: Suburban scene

Scene Parameters

Scene view: Scene Origin

Sample time: .02

☑ Display 3D simulation window

Run the model.

Input Arguments

Scene — Name of scene

string | character array

Name of the map being downloaded from the server, specified as a string or character array. Maps are downloaded in the default folder that is added to MATLAB search path at startup.

Maps are stored by user profile. For multiuser setup with a single MATLAB installation, the maps will be downloaded multiple times.

If a new version of the map is available on the server, you will see a warning message asking you to download the map again to get the recent version.

Version History

Introduced in R2022b

See Also

`sim3d.maps` | `sim3d.maps.Map.server` | `sim3d.maps.Map.delete` | `sim3d.maps.Map.local`

sim3d.maps.Map.server

List of maps available for download from the server

Syntax

```
sim3d.maps.Map.server
```

Description

`sim3d.maps.Map.server` lists the available maps in the server.

Examples

Download Suburban Scene Map

This example shows how to download and access the Suburban scene map from the Simulation 3D Scene Configuration block.

To begin, check the maps available in the server.

```
sim3d.maps.Map.server
```

```
        MapName                      Description                  Version    MinimumRelease
    ________________    __________________________________________    _______    ______________

    "Suburban scene"    "a suburban area beyond the city's border"      "1"         "R2022b"
```

Download the Suburban scene from the server.

```
sim3d.maps.Map.download('Suburban scene')
```

```
Map is susccesfully downloaded and is up-to-date
```

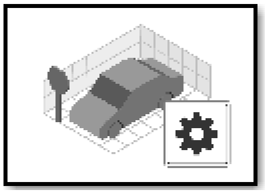
Check if the downloaded maps are available in your local machine.

```
sim3d.maps.Map.local
```

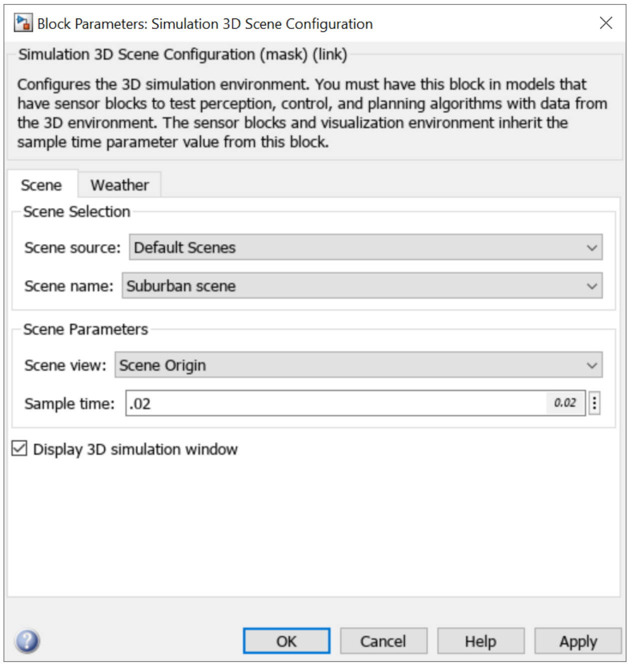
```
        MapName                      Description                  Version    MinimumRelease
    ________________    __________________________________________    _______    ______________

    "Suburban scene"    "a suburban area beyond the city's border"      "1"         "R2022b"
```

Add the Simulation 3D Scene Configuration block to your model.



Open the block mask and select the suburban scene from **Scene name**.



Block Parameters: Simulation 3D Scene Configuration

Simulation 3D Scene Configuration (mask) (link)

Configures the 3D simulation environment. You must have this block in models that have sensor blocks to test perception, control, and planning algorithms with data from the 3D environment. The sensor blocks and visualization environment inherit the sample time parameter value from this block.

Scene source: Default Scenes

Scene name: Suburban scene

Scene view: Scene Origin

Sample time: .02

☑ Display 3D simulation window

Run the model.

Version History

Introduced in R2022b

See Also

`sim3d.maps` | `sim3d.maps.Map.download` | `sim3d.maps.Map.delete` | `sim3d.maps.Map.local`

sim3d.maps.Map.delete

Delete local maps downloaded from the server

Syntax

`sim3d.maps.Map.delete(Scene)`

Description

`sim3d.maps.Map.delete(Scene)` deletes the map `Scene` from your local system.

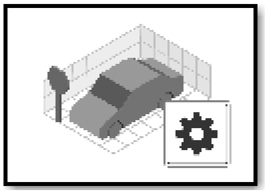
Examples

Download Suburban Scene Map

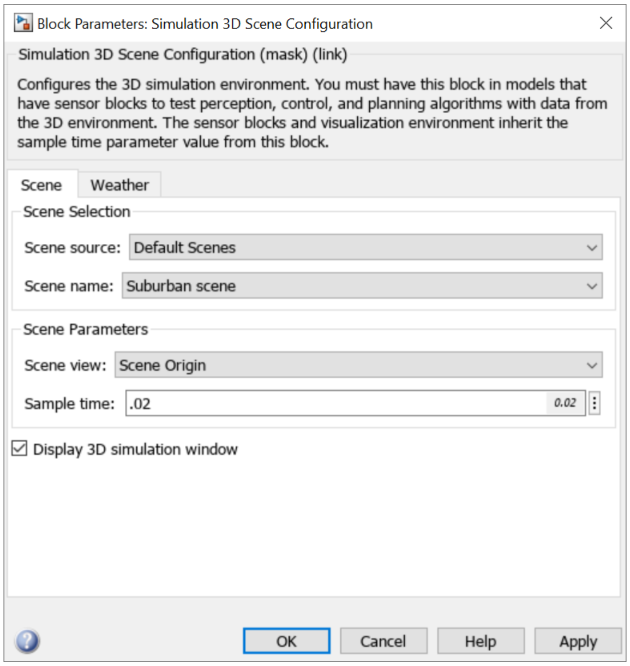
This example shows how to download and access the Suburban scene map from the Simulation 3D Scene Configuration block.

To begin, check the maps available in the server.

Add the Simulation 3D Scene Configuration block to your model.



Open the block mask and select the suburban scene from **Scene name**.



Block Parameters: Simulation 3D Scene Configuration

Simulation 3D Scene Configuration (mask) (link)

Configures the 3D simulation environment. You must have this block in models that have sensor blocks to test perception, control, and planning algorithms with data from the 3D environment. The sensor blocks and visualization environment inherit the sample time parameter value from this block.

Scene Selection

Scene source: Default Scenes

Scene name: Suburban scene

Scene Parameters

Scene view: Scene Origin

Sample time: .02

☑ Display 3D simulation window

Run the model.

Delete the model and check if the map is till available locally.

```
sim3d.maps.Map.delete('Suburban scene')
```

```
Suburban scene was successfully deleted
```

Input Arguments

Scene — Name of scene

string | character array

Name of the map being deleted, specified as a string or character array. Once the map is deleted, it automatically disappears from the Simulation 3D Scene Configuration block mask menu.

Version History

Introduced in R2022b

See Also

`sim3d.maps` | `sim3d.maps.Map.download` | `sim3d.maps.Map.server` | `sim3d.maps.Map.local`

sim3d.maps.Map.local

List of locally available maps

Syntax

`sim3d.maps.Map.local`

Description

`sim3d.maps.Map.local` lists the locally available maps.

Examples

Download Suburban Scene Map

This example shows how to download and access the Suburban scene map from the Simulation 3D Scene Configuration block.

To begin, check the maps available in the server.

```
sim3d.maps.Map.server
```

```
        MapName                        Description                     Version    MinimumRelease
    ________________    __________________________________________    _______    ______________

    "Suburban scene"    "a suburban area beyond the city's border"      "1"         "R2022b"
```

Download the Suburban scene from the server.

```
sim3d.maps.Map.download('Suburban scene')
```

```
Map is susccesfully downloaded and is up-to-date
```

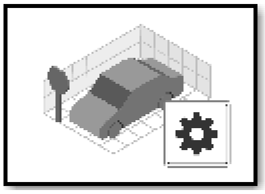
Check if the downloaded maps are available in your local machine.

```
sim3d.maps.Map.local
```

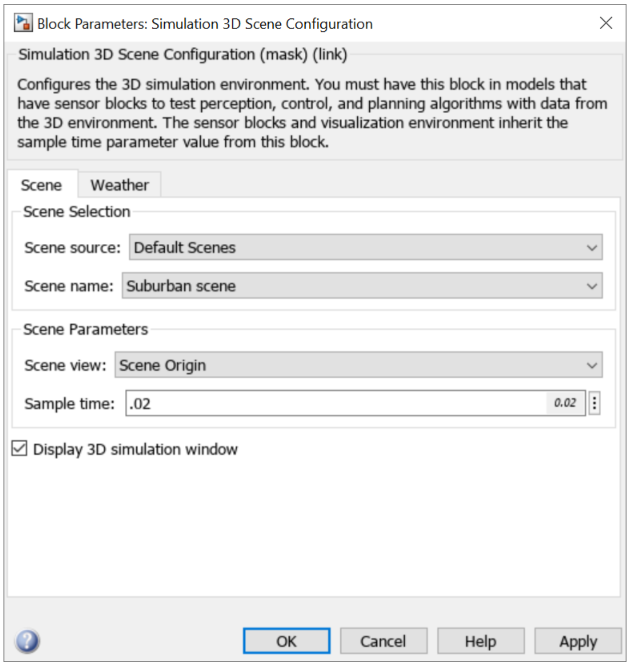
```
        MapName                        Description                     Version    MinimumRelease
    ________________    __________________________________________    _______    ______________

    "Suburban scene"    "a suburban area beyond the city's border"      "1"         "R2022b"
```

Add the Simulation 3D Scene Configuration block to your model.



Open the block mask and select the suburban scene from **Scene name**.



Block Parameters: Simulation 3D Scene Configuration

Simulation 3D Scene Configuration (mask) (link)

Configures the 3D simulation environment. You must have this block in models that have sensor blocks to test perception, control, and planning algorithms with data from the 3D environment. The sensor blocks and visualization environment inherit the sample time parameter value from this block.

Scene Selection

Scene source: Default Scenes

Scene name: Suburban scene

Scene Parameters

Scene view: Scene Origin

Sample time: .02

☑ Display 3D simulation window

Run the model.

Version History

Introduced in R2022b

See Also

`sim3d.maps` | `sim3d.maps.Map.download` | `sim3d.maps.Map.server` | `sim3d.maps.Map.delete`

12

Apps

Virtual Vehicle Composer

Configure, build, and analyze a virtual automotive vehicle

Description

The **Virtual Vehicle Composer** app enables you to configure and build a virtual vehicle that you can use for system-level performance analysis, including component sizing, fuel economy, drive cycle tracking, software integration testing, and hardware-in-the-loop (HIL) testing. Use the app to quickly enter your vehicle parameter data, build a virtual vehicle model, run test scenarios, and analyze the results.

The virtual vehicle model contains the blocks and reference application subsystems available with Powertrain Blockset™, Vehicle Dynamics Blockset, Simscape™ Driveline™, and Simscape Electrical™. You can use the app to quickly configure the architecture and enter parameter data.

If you have Powertrain Blockset, use the app to:

- Analyze design tradeoffs and size components.
- Configure hybrid-electric vehicle (HEV) architectures.

If you have Vehicle Dynamics Blockset, use the app to:

- Analyze ride-and-handling effects of standard test maneuvers.
- Visualize your virtual vehicle in the Unreal Engine simulation environment.

If you have Simscape Driveline and Simscape Electrical, use the app to configure the vehicle plant and powertrain architecture with Simscape subsystems.

To build, operate, and analyze your virtual vehicle, use the **Composer** tab. The options and settings depend on the available products.

Step	Section	Button		Description
1	**Configure**	🛠	**Setup**	Select **New**, then specify: • Project, folder, and model name **Note** The combined folder and project name must be less than 80 characters. • Powertrain architecture • Model template • Vehicle dynamics
2		🛢	**Data and Calibration**	Specify the chassis, tire, brake type, powertrain, environment, and driver. For each selection, enter the vehicle parameter data.

Step	Section	Button		Description
3			**Scenario and Test**	Select the virtual vehicle driving maneuvers and add them to the test plan. Options include drive cycle scenarios for longitudinal studies and standard test maneuvers for vehicle dynamics studies.
4			**Logging**	Select the model signal data to log when operating your virtual vehicle. Options include vehicle position, velocity, and acceleration.
5	**Build**		**Virtual Vehicle**	Build your virtual vehicle. When you build, the **Virtual Vehicle Composer** creates a Simulink model that contains the vehicle architecture and the data that you specify in the configuration.
6	**Operate**		**Run Test Plan**	Use the Simulation Manager to operate your model using the test plans that you specify in step 3.
7	**Analyze**		**Simulation Data Inspector**	Use the Simulation Data Inspector to view and inspect the simulation signals that you select in step 4.

Required Products

The **Virtual Vehicle Composer** requires either of these products:

- “Powertrain Blockset”
- “Vehicle Dynamics Blockset”

  If you want to run your virtual vehicle in the Unreal Engine 3D simulation environment, see the requirements in “Unreal Engine Simulation Environment Requirements and Limitations”.

If you have these Simscape products, you can use the app to configure the vehicle plant with Simscape subsystems:

- “Simscape Driveline”
- “Simscape Electrical”

Setup

Use the app to quickly enter your virtual vehicle class, powertrain architecture, model template, and vehicle dynamics.

Parameter	Description
Powertrain architecture	Specify the powertrain architecture. By default, the parameter is set to `Conventional Vehicle`. The conventional vehicle architecture has a spark-ignition (SI) or compression-ignition (CI) internal combustion engine, transmission, chassis, and associated powertrain control algorithms. You can also select `Electric Vehicle 1EM` to specify an electric vehicle (EV) powertrain architecture. If you have Powertrain Blockset, you can specify model architectures for hybrid electric vehicles (HEVs). The HEV and EV model architectures include an internal combustion engine, chassis, transmission, battery, motor, generator, and associated powertrain control algorithms.
Model template	Specify a `Simulink` or `Simscape` vehicle plant and powertrain architecture. By default, the virtual vehicle uses a `Simulink` model template. If you have Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simscape subsystems that model a conventional vehicle. If you have Simscape Driveline and Simscape Electrical, you can configure the vehicle plant and powertrain architecture with Simscape subsystems that model EVs and HEVs.
Vehicle Dynamics	Configure the virtual vehicle dynamics. •  `Longitudinal vehicle dynamics` — Suitable for fuel economy and energy management analysis. •  `Combined longitudinal and lateral vehicle dynamics` — If you have Vehicle Dynamics Blockset, you can specify dynamics suitable for vehicle handling, stability, and ride comfort analysis. The virtual vehicle uses the *Z*-up coordinate system as defined in SAE J670 and ISO 8855. For more information, see “Coordinate Systems in Vehicle Dynamics Blockset”.

Data and Calibration

Use the app to quickly enter your virtual vehicle parameter data for the vehicle architecture, vehicle dynamics model, chassis, powertrain, and driver. For each selection, enter the parameter data.

Parameter	Description
Chassis	Select the chassis type.

Parameter	Description
Tire	Select the tire model and tire data. The available parameters depend on the available products, vehicle architecture, and vehicle model.
Brake Type	Select the brake type, including `Disc`, `Drum`, and `Mapped`. Use the **Brake Control Unit** parameter to specify the brake control.
Powertrain	Select the engine, transmission, drivetrain, differential system, and electrical system parameters for your virtual vehicle. The available parameters depend on the products, vehicle architecture, and vehicle model.
Driver	Select the driver. The parameter setting `Longitudinal Driver` implements a longitudinal speed-tracking controller. If you have Vehicle Dynamics Blockset, you can set **Driver** to `Predictive Driver` to track longitudinal velocity and a lateral reference displacement.
Environment	The parameter setting `Standard Ambient` implements an ambient environment model.
Steering System	If you have Vehicle Dynamics Blockset and set **Vehicle dynamics** to `Combined longitudinal and lateral vehicle dynamics`, you can specify the steering system, including `Kinematic Steering`, `Dynamic Steering`, and `Mapped Steering`.
Suspension	If you have Vehicle Dynamics Blockset and set **Vehicle dynamics** to `Combined longitudinal and lateral vehicle dynamics`, you can specify the suspension system, including `Kinematics and Compliance Independent Suspension` and `MacPherson Front Suspension Solid Axle Rear Suspension`.

Scenario and Test

Select the scenario to use to test your virtual vehicle.

If you set **Scenario** to `Drive Cycle`, you can use:

- Drive cycles from predefined sources. By default, the block includes the `FTP–75` drive cycle. To install additional drive cycles from a support package, see “Support Package for Maneuver and Drive Cycle Data”. The support package has drive cycles that include the gear shift schedules, for example, `JC08` and `CUEDC`.
- Workspace variables that define your own drive cycles.
- `.mat`, `.xls`, `.xlsx`, or `.txt` files.
- Wide open throttle (WOT) parameters, including initial and nominal reference speed, deceleration start time, and final reference speed.

If you have Vehicle Dynamics Blockset and set **Vehicle dynamics** to `Combined longitudinal and lateral vehicle dynamics`, you can select maneuvers for vehicle handling, stability, and ride analysis. Maneuvers include:

- `Double Lane Change`
- `Increasing Steer`
- `Constant Radius`

If you want to run your virtual vehicle in the Unreal Engine 3D simulation environment, set **3D Simulation** to `Enable`. For hardware requirements, see “Unreal Engine Simulation Environment Requirements and Limitations”.

Logging

Select the model signal data to log when operating your virtual vehicle. Options include vehicle position, velocity, and acceleration. By default, the app lists frequently used signals.

Virtual Vehicle

Build your virtual vehicle. When you build, the **Virtual Vehicle Composer** creates a Simulink model that contains the specified vehicle architecture and data.

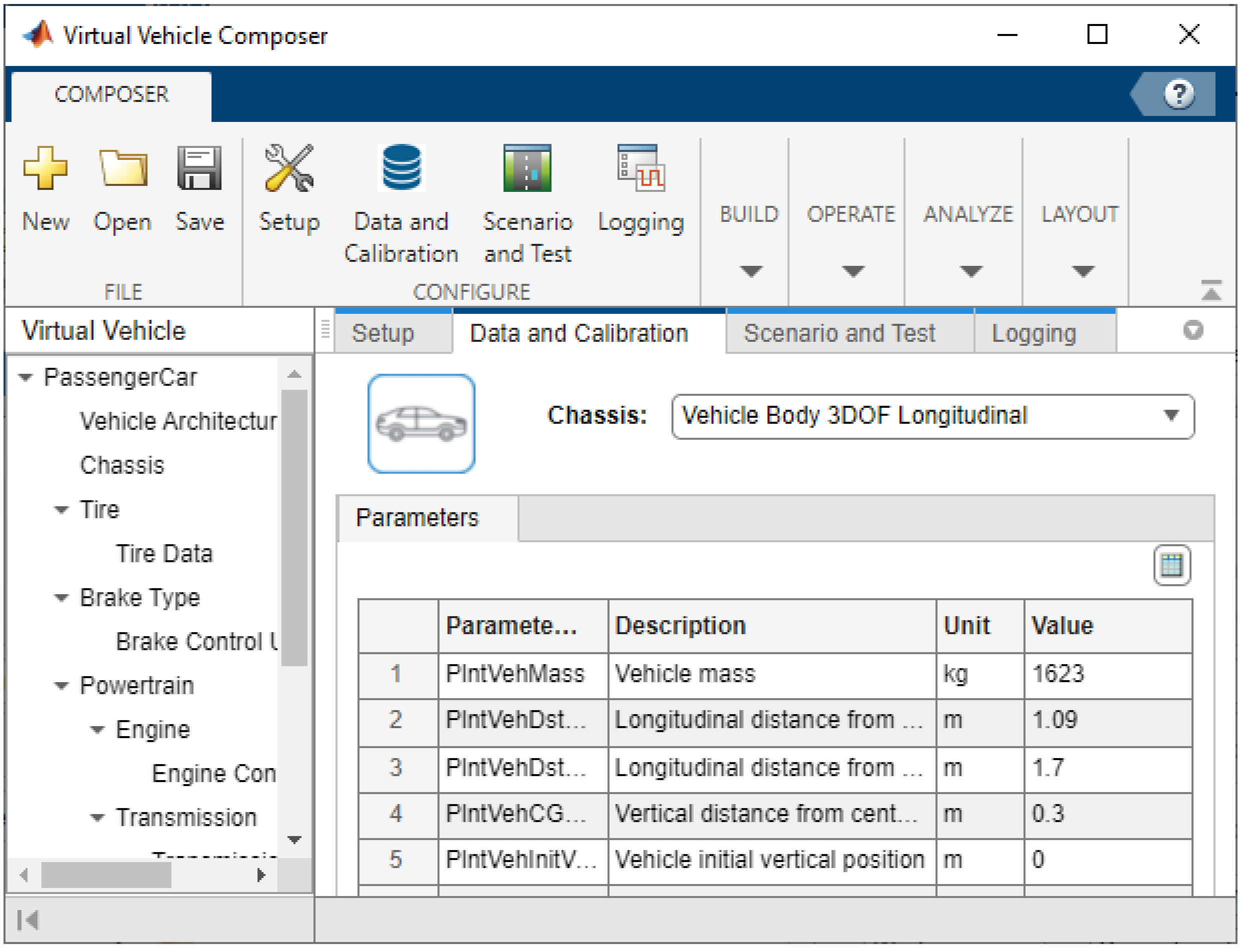
Test Plan

Simulate your model in the scenario that you specified in **Vehicle Scenario and Test**.

Simulation Data Inspector

Use the Simulation Data Inspector to view and inspect the simulation signals.

If you run your virtual vehicle through more than one test scenario, the Simulation Data Inspector displays the results from the last simulation. To see results from previous simulations, load the archived results.



Chassis: Vehicle Body 3DOF Longitudinal

	Paramete...	Description	Unit	Value
1	PlntVehMass	Vehicle mass	kg	1623
2	PlntVehDst...	Longitudinal distance from ...	m	1.09
3	PlntVehDst...	Longitudinal distance from ...	m	1.7
4	PlntVehCG...	Vertical distance from cent...	m	0.3
5	PlntVehInitV...	Vehicle initial vertical position	m	0

Open the Virtual Vehicle Composer App

- MATLAB Toolstrip: On the **Apps** tab, under **Automotive**, click the app icon.
- MATLAB Command Window: Enter `virtualVehicleComposer`.

Examples

- "Get Started with the Virtual Vehicle Composer"

Parameters

Setup

`Project name` — Project name

`VVProj` (default)

Name of virtual vehicle project, specified as a character vector.

Note The combined folder and project name must be less than 80 characters.

Data Types: `char`

`Project folder` — Project folder

`C:\Users\`*`UserName`*`\MATLAB\Projects\examples` (default)

Project folder path, specified as a character vector.

Note The combined folder and project name must be less than 80 characters.

Data Types: `char`

`Model name` — Virtual vehicle model name

`ConfiguredVirtualVehicleModel` (default)

Name of virtual vehicle model, specified as a character vector.

Data Types: `char`

`Powertrain architecture` — Hybrid electric, conventional, or electric vehicle

`Conventional Vehicle` | `Electric Vehicle 1EM` | `Hybrid Electric IPS` | `Hybrid Electric MM` | `Hybrid Electric P0` | `Hybrid Electric P1` | `Hybrid Electric P2` | `Hybrid Electric P3` | `Hybrid Electric P4`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Conventional Vehicle`	✔	✔	Model architecture for a vehicle with a SI or CI internal combustion engine, transmission, and associated powertrain control algorithms. If you have Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.
`Electric Vehicle 1EM`	✔	✔	Model architecture for an electric vehicle (EV) with a motor-generator, battery, direct-drive transmission, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.
`Hybrid Electric IPS`	✔		Model architecture for a input power split (IPS) hybrid electric vehicle (HEV) with an internal combustion engine, transmission, battery, motor, generator, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.
`Hybrid Electric MM`	✔		Model architecture for a multimode HEV with an internal combustion engine, transmission, battery, motor, generator, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.
`Hybrid Electric P0`	✔		Model architecture for a HEV P0 with an internal combustion engine, transmission, battery, motor, generator, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Hybrid Electric P1`	✔		Model architecture for a HEV P1 with an internal combustion engine, transmission, battery, motor, generator, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.
`Hybrid Electric P2`	✔		Model architecture for a HEV P2 with an internal combustion engine, transmission, battery, motor, generator, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.
`Hybrid Electric P3`	✔		Model architecture for a HEV P3 with an internal combustion engine, transmission, battery, motor, generator, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.
`Hybrid Electric P4`	✔		Model architecture for a HEV P4 with an internal combustion engine, transmission, battery, motor, generator, and associated powertrain control algorithms. If you have Simscape Electrical and Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simulink or Simscape model templates.

`Model template` — Vehicle plant and powertrain architecture template
`Simulink` (default) | `Simscape`

Use the parameter to specify a `Simulink` or `Simscape` vehicle plant and powertrain architecture. By default, the virtual vehicle uses a `Simulink` model template. If you have Simscape Driveline, you can configure the vehicle plant and powertrain architecture with Simscape subsystems that model a conventional vehicle.

If you have Simscape Driveline and Simscape Electrical, you can configure the vehicle plant and powertrain architecture with Simscape subsystems that model EVs and HEVs.

`Vehicle dynamics` — Virtual vehicle longitudinal or lateral vehicle dynamics

`Longitudinal vehicle dynamics` (default) | `Combined longitudinal and lateral vehicle dynamics`

Use the parameter to configure the virtual vehicle dynamics.

-  `Longitudinal vehicle dynamics` — Suitable for fuel economy and energy management analysis.
-  `Combined longitudinal and lateral vehicle dynamics` — If you have Vehicle Dynamics Blockset, you can specify dynamics suitable for vehicle handling, stability, and ride comfort analysis.

The virtual vehicle uses the *Z*-up coordinate system as defined in SAE J670 and ISO 8855. For more information, see “Coordinate Systems in Vehicle Dynamics Blockset”.

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Longitudinal vehicle dynamics`	✔	✔	Model suitable for fuel economy and energy management analysis.
`Combined longitudinal and lateral vehicle dynamics`		✔	Model suitable for vehicle handling, stability, and ride comfort analysis.

Data and Calibration

`Chassis` — Chassis type

`Vehicle Body 1DOF Longitudinal` | `Vehicle Body 3DOF Longitudinal` | `Vehicle Body 6DOF Longitudinal and Lateral`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Vehicle Body 1DOF Longitudinal`	✔	✔	Chassis model for 1DOF longitudinal vehicle dynamics. Available when you set **Vehicle dynamics** to `Longitudinal vehicle dynamics`.
`Vehicle Body 3DOF Longitudinal`	✔	✔	Chassis model for 3DOF longitudinal vehicle dynamics. Available when you set **Vehicle dynamics** to `Longitudinal vehicle dynamics`.
`Vehicle Body 6DOF Longitudinal and Lateral`		✔	Chassis model for 3DOF longitudinal vehicle dynamics. Available when you set **Vehicle dynamics** to `Combined longitudinal and lateral vehicle dynamics`.

`Tire` — Virtual vehicle tires
`MF Tires Longitudinal` | `Fiala Tires Longitudinal and Lateral` | `MF Tires Longitudinal and Lateral` | `Longitudinal Combined Slip Tire`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`MF Tires Longitudinal`	✔	✔	Tire model suitable for longitudinal vehicle dynamics studies, including fuel economy and energy management analysis.
`Fiala Tires Longitudinal and Lateral`		✔	Tire models suitable for lateral vehicle dynamics studies, including vehicle handling, stability, and ride comfort analysis. Implements a simplified tire with lateral and longitudinal slip capability. Uses a translational friction model to calculate the forces and moments during combined longitudinal and lateral slip. If you do not have the tire coefficients needed by the Magic Formula, consider using this setting for studies that do not involve extensive nonlinear combined lateral slip or lateral dynamics.
`MF Tires Longitudinal and Lateral`		✔	Tire models suitable for lateral vehicle dynamics studies, including vehicle handling, stability, and ride comfort analysis. Tire model implements the longitudinal and lateral behavior of a wheel characterized by the Magic Formula. You can use **Tire Data**

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Longitudinal Combined Slip Tire`		✔	parameter to specify fitted tire data sets provided by the Global Center for Automotive Performance Simulation (GCAPS) for tires, including: • `Light passenger car 205/60R15` • `Mid-size passenger car 235/45R18` • `Performance car 225/40R19` • `SUV 265/50R20` • `Light truck 275/65R18` • `Commercial truck 295/75R22.5`

`Brake Type` — Virtual vehicle brakes
`Disc` | `Drum` | `Mapped`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Disc`	✔	✔	Brake model converts the brake cylinder pressure into a braking force.
`Drum`	✔	✔	Brake model converts the applied force and brake geometry into a net braking torque.
`Mapped`	✔	✔	Brake model is a function of the wheel speed and applied brake pressure.

`Brake Control Unit` — Brake control
`Bang Bang ABS` | `Open Loop` | `Five-State ABS and TCS`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Bang Bang ABS`	✔	✔	Anti-lock braking system (ABS) feedback controller that switches between two states to regulate wheel slip. The bang-bang control minimizes the error between the actual slip and the desired slip. For the desired slip, the controller uses the slip value at which the mu-slip curve reaches a peak value. This desired slip value is optimal for minimum braking distance.
`Open Loop`	✔	✔	Open loop brake control. The controller sets the brake pressure command to a reference brake pressure based on the brake command.
`Five-State ABS and TCS`	✔	✔	Five-state ABS and traction control system (TCS) that uses logic-switching based on wheel deceleration and vehicle acceleration to control the braking pressure at each wheel. Consider using five-state ABS and TCS control to prevent wheel lock-up, decrease braking distance, or maintain yaw stability during the maneuver. The default ABS parameters are set to work on roads that have a constant friction coefficient scaling factor of 0.6.

Engine — Virtual vehicle engine
`Simple Engine (SI)` | `Simple Engine (CI)` | `CI Engine` | `CI Mapped Engine` | `SI Engine` | `SI Mapped Engine` | `SI DL Engine`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Simple Engine (SI)`	✔	✔	Simplified SI engine model using a maximum torque verses engine speed table, two scalar fuel mass properties, and one scalar engine efficiency parameter to estimate engine torque and fuel flow. Selecting `Simple Engine SI` sets the **Engine Control Unit** parameter to `Simple ECU`.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Simple Engine (CI)`	✔	✔	Simplified CI engine model using a maximum torque verses engine speed table, two scalar fuel mass properties, and one scalar engine efficiency parameter to estimate engine torque and fuel flow. Selecting `Simple Engine CI` sets the **Engine Control Unit** parameter to `Simple ECU`.
`CI Engine`	✔		Compression-ignition (CI) engine from intake to the exhaust port. Selecting `CI Engine` sets the **Engine Control Unit** parameter to `CI Engine Controller`.
`CI Mapped Engine`	✔	✔	Mapped CI engine model using power, air mass flow, fuel flow, exhaust temperature, efficiency, and emission performance lookup tables. Selecting `CI Mapped Engine` sets the **Engine Control Unit** parameter to `CI Engine Controller`.
`SI Engine`	✔		Spark-ignition (SI) engine from intake to exhaust port. Selecting `SI Engine` sets the **Engine Control Unit** parameter to `SI Engine Controller`.
`SI Mapped Engine`	✔	✔	Mapped SI engine model using power, air mass flow, fuel flow, exhaust temperature, efficiency, and emission performance lookup tables. Selecting `SI Mapped Engine` sets the **Engine Control Unit** parameter to `SI Engine Controller`.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`SI DL Engine`	✔		Deep learning SI engine. Available if you have the Deep Learning Toolbox™ and Statistics and Machine Learning Toolbox™ licenses. Use this setting to generate a dynamic deep learning SI engine model to use for powertrain control, diagnostic, and estimator algorithm design. Selecting `SI DL Engine` sets the **Engine Control Unit** parameter to `SI Engine Controller`.

Transmission — Virtual vehicle transmission
`Ideal Fixed Gear Transmission` | `Automatic Transmission with Torque Converter` | `Automated Manual Transmission` | `No Transmission`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Ideal Fixed Gear Transmission`	✔	✔	Idealized fixed-gear transmission without a clutch or synchronization. Use this setting to model the overall gear ratio and power loss when you do not need a detailed transmission model.
`Automatic Transmission with Torque Converter`	✔		Automatic transmission with a torque converter.
`Automated Manual Transmission`	✔		Ideal automated transmission (AMT). An AMT is a manual transmission with additional actuators and an electronic control unit (ECU) to regulate clutch and gear selection based on commands from a controller. Specify the number of gears as an integer vector with corresponding gear ratios, inertias, viscous damping, and efficiency factors. The clutch and synchronization engagement rates are linear and adjustable.
`No Transmission`	✔		No transmission.

Dependencies

To enable this parameter, set **Powertrain architecture** to any of these options:

- `Conventional Vehicle`
- `Hybrid Electric Vehicle P0`
- `Hybrid Electric Vehicle P1`
- `Hybrid Electric Vehicle P2`
- `Hybrid Electric Vehicle P3`
- `Hybrid Electric Vehicle P4`

`Transmission Control Unit` — Virtual vehicle transmission control

`PRNDL Controller`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`PRNDL Controller`	✔	✔	Controller that optimizes forward, reverse, neutral, park, and N-speed gear shift scheduling for fuel economy.

Dependencies

To enable this parameter, set **Powertrain architecture** to any of these options:

- `Conventional Vehicle`
- `Hybrid Electric Vehicle P0`
- `Hybrid Electric Vehicle P1`
- `Hybrid Electric Vehicle P2`
- `Hybrid Electric Vehicle P3`
- `Hybrid Electric Vehicle P4`

`Drivetrain` — Virtual vehicle drivetrain

`Front Wheel Drive`|`Front Wheel Drive`|`All Wheel Drive`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Front Wheel Drive`	✔	✔	Configure vehicle with front wheel drive.
`Rear Wheel Drive`	✔	✔	Configure vehicle with rear wheel drive.
`All Wheel Drive`	✔	✔	Configure vehicle with all wheel drive.

`Differential System` — Virtual vehicle differential system

`Open Differential`|`Active Differential`|`Limited Slip Differential`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Open Differential`	✔	✔	Differential as a planetary bevel gear train. The block matches the driveshaft bevel gear to the crown (ring) bevel gear. You can specify: • Carrier-to-driveshaft ratio • Crown wheel location • Viscous and damping coefficients for the axles and carrier
`Active Differential`	✔	✔	Active differential that accounts for the power transfer from the transmission to the axles. The model implements the active differential as an open differential coupled to either a spur or a planetary differential gear set.
`Limited Slip Differential`	✔	✔	Differential as a planetary bevel gear train. The block matches the driveshaft bevel gear to the crown (ring) bevel gear. You can specify: • Carrier-to-driveshaft ratio • Crown wheel location • Viscous and damping coefficients for the axles and carrier • Type of slip coupling

`Electrical System` — Virtual vehicle electric machine and energy storage
`Electrical System 1EM Battery` | `Electrical System 2EM` | `Electrical System 1EM`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Electrical System Settings	Powertrain Blockset	Vehicle Dynamics Blockset	Powertrain Architecture	Description
`Electrical System 1EM Battery`	✔		`Electrical System 1EM`	• Mapped motor and drive electronics operating in torque-control mode. • Lithium ion battery model based on discharge characteristics taken at different temperatures.

Electrical System Settings	Powertrain Blockset	Vehicle Dynamics Blockset	Powertrain Architecture	Description
`Electrical System 1EM Battery` with **Energy Storage** set to `Ideal Voltage Source`	✔	✔	`Electrical System 1EM`	• Mapped motor and drive electronics operating in torque-control mode. • Ideal voltage source battery model.
`Electrical System 2EM`	✔		• `Hybrid Electric Vehicle IPS` • `Hybrid Electric Vehicle MM`	• Two mapped motors and drive electronics operating in torque-control mode. • Lithium ion battery model based off of discharge characteristics taken at different temperatures.
`Electrical System 1EM`	✔		• `Hybrid Electric Vehicle P0` • `Hybrid Electric Vehicle P1` • `Hybrid Electric Vehicle P2` • `Hybrid Electric Vehicle P3` • `Hybrid Electric Vehicle P4`	• Two mapped motors and drive electronics operating in torque-control mode. • Lithium ion battery model with DC-DC conversion.

Use the **Electrical Machine** parameters to specify a mapped motor and drive electronics operating in torque-control mode.

Use the **Energy Storage** parameters to specify a datasheet battery model for a lithium-ion battery.

`Vehicle Control Unit` — HEV and EV virtual vehicle control

`EV 1EM` | `HEVIPS RuleBased` | `HEVMM RuleBased` | `HEVP0 Optimal` | `HEVP1 Optimal` | `HEVP2 Optimal` | `HEVP3 Optimal` | `HEVP4 Optimal`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Powertrain Architecture	Description
`EV 1EM`	✔	✔	`Electric Vehicle`	Controls the motor with torque arbitration and power management. Implements regenerative braking.
`HEVIPS RuleBased`	✔		`Hybrid Electric Vehicle IPS`	Controls the motor, generator, and engine through a set of rules and decision logic implemented in Stateflow.
`HEVMM RuleBased`	✔		`Hybrid Electric Vehicle MM`	
`HEVP0 Optimal`	✔		`Hybrid Electric Vehicle P4`	Implements an equivalent consumption minimization strategy (ECMS) to control the energy management of hybrid electric vehicles (HEVs). The strategy optimizes the torque split between the engine and motor to minimize energy consumption while maintaining the battery state of charge (SOC).
`HEVP1 Optimal`	✔		`Hybrid Electric Vehicle P4`	
`HEVP2 Optimal`	✔		`Hybrid Electric Vehicle P4`	
`HEVP3 Optimal`	✔		`Hybrid Electric Vehicle P4`	
`HEVP4 Optimal`	✔		`Hybrid Electric Vehicle P4`	

`Driver` — Virtual vehicle driver
`Longitudinal Driver` | `Predictive Driver`

If you have Vehicle Dynamics Blockset, you can set **Driver** to `Predictive Driver` to track longitudinal velocity and a lateral reference displacement.

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Longitudinal Driver`	✔	✔	Implements a longitudinal speed-tracking controller.
`Predictive Driver`		✔	Track longitudinal velocity and a lateral reference displacement. Available when you set **Vehicle dynamics** to `Combined longitudinal and lateral vehicle dynamics`.

`Environment` — Virtual vehicle environment
`Standard Ambient`

The parameter setting `Standard Ambient` implements an ambient environment model.

`Steering System` — Steering
`Mapped` | `Kinematic` | `Dynamic`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Mapped`		✔	Mapped rack-and-pinion steering model.
`Kinematic`		✔	Kinematic model for ideal rack-and-pinion steering. Gears convert the steering rotation into linear motion.
`Dynamic`		✔	Dynamic model for ideal rack-and-pinion steering. Gears convert the steering rotation into linear motion.

`Suspension` — Suspension
`Kinematics and Compliance Independent Suspension` | `MacPherson Front Suspension`
`Solid Axle Rear Suspension`

These parameters depend on the available products. This table summarizes the parameters available with Powertrain Blockset or Vehicle Dynamics Blockset.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`Kinematics and Compliance Independent Suspension`		✔	Kinematics and compliance (K & C) test suspension characteristics measured from simulated or actual laboratory suspension tests.

Setting	Powertrain Blockset	Vehicle Dynamics Blockset	Description
`MacPherson Front Suspension Solid Axle Rear Suspension`		✔	Independent MacPherson suspension for multiple axles with multiple tracks per axle.

Programmatic Use

Entering the command `virtualVehicleComposer` opens a new session of the app, enabling you to configure, build, and analyze your virtual vehicle.

Version History

Introduced in R2022a

Configure vehicles with Simscape subsystems

If you have these Simscape products, you can use the **Virtual Vehicle Composer** app to configure the vehicle plant with Simscape subsystems.

- Simscape Driveline
- Simscape Electrical

When you build your virtual vehicle, on the **Setup** tab, set **Model template** to `Simscape`.

The app provides the Simscape subsystem templates for longitudinal vehicle analysis.

See Also

Topics

"Get Started with the Virtual Vehicle Composer"
"Simulation Data Inspector"
"How 3D Simulation for Vehicle Dynamics Blockset Works"