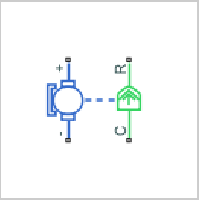
DC Motor

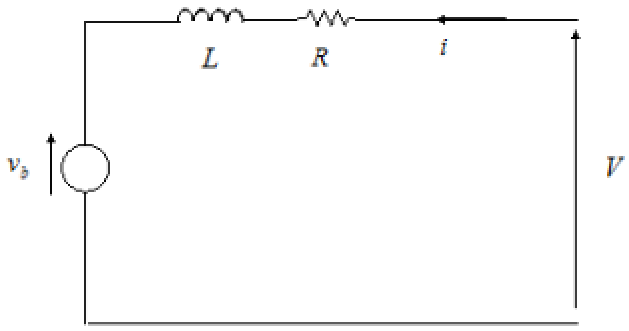
DC motor model with electrical and torque characteristics and fault modeling

Library: Simscape / Electrical / Electromechanical / Brushed Motors



Description

The DC Motor block represents the electrical and torque characteristics of a DC motor using the following equivalent circuit model:



You specify the equivalent circuit parameters for this model when you set the **Model parameterization** parameter to `By equivalent circuit parameters`. The resistor *R* corresponds to the resistance you specify in the **Armature resistance** parameter. The inductor L corresponds to the inductance you specify in the **Armature inductance** parameter.

You can specify how to generate the magnetic field of the DC motor by setting the **Field type** parameter to the desired option. The permanent magnets in the motor induce the following back emf v_b in the armature:

$$v_b = k_v \omega$$

where k_v is the **Back-emf constant** and ω is the angular velocity. The motor produces the following torque, which is proportional to the motor current i:

$$T_E = k_t i$$

where k_t is the **Torque constant**. The DC Motor block assumes that there are no electromagnetic losses. This means that mechanical power is equal to the electrical power dissipated by the back emf in the armature. Equating these two terms gives:

$$T_E \omega = v_b i$$
$$k_t i \omega = k_v \omega i$$
$$k_v = k_t$$

As a result, you specify either k_v or k_t in the block parameters.

If the magnetic field is generated from the current flowing through the windings, the **Back-emf constant** depends on the field current I_f:

$$k_v = L_{af} I_f$$

where L_{af} is the **Field-armature mutual inductance**.

The torque-speed characteristic for the DC Motor block is related to the parameters in the preceding figure. When you set the **Model parameterization** parameter to `By stall torque & no-load speed` or `By rated power, rated speed & no-load speed`, the block solves for the equivalent circuit parameters as follows:

1. For the steady-state torque-speed relationship, L has no effect.
2. Sum the voltages around the loop and rearrange for i:

$$i = \frac{V - v_b}{R} = \frac{V - k_v\omega}{R}$$

3. Substitute this value of i into the equation for torque:

$$T_E = \frac{k_t}{R}(V - k_v\omega)$$

When you set the **Model parameterization** parameter to `By stall torque & no-load speed`, the block uses the preceding equation to determine values for R and k_t (and equivalently k_v).

When you set the **Model parameterization** parameter to `By rated power, rated speed & no-load speed`, the block uses the rated speed and power to calculate the rated torque. The block uses the rated torque and no-load speed values in the preceding equation to determine values for R and k_t.

The block models motor inertia J and damping λ for all values of the **Model parameterization** parameter. The resulting torque across the block is:

$$T = \frac{k_t}{R}(V - k_v\omega) - J\dot{\omega} - \lambda\omega$$

It is not always possible to measure rotor damping, and rotor damping is not always provided on a manufacturer datasheet. An alternative is to use the no-load current to infer a value for rotor damping.

For no-load, the electrically-generated mechanical torque must equal the rotor damping torque:

$$k_t i_{noload} = \lambda\omega_{noload}$$

where i_{noload} is the no-load current. If you select `By no-load current` for the **Rotor damping parameterization** parameter, then this equation is used in addition to the torque-speed equation to determine values for λ and the other equation coefficients.

The value for rotor damping, whether specified directly or in terms of no-load current, is taken into account when determining equivalent circuit parameters for **Model parameterization** options `By stall torque and no-load speed` and `By rated power, rated speed and no-load speed`.

When a positive current flows from the electrical **+** to **-** ports, a positive torque acts from the mechanical **C** to **R** ports.

Faults

The DC Motor block allows you to model two types of faults:

- Armature winding fault — The armature winding fails and goes open circuit.
- Field winding fault — The field winding that creates the magnetic field fails and goes open circuit.

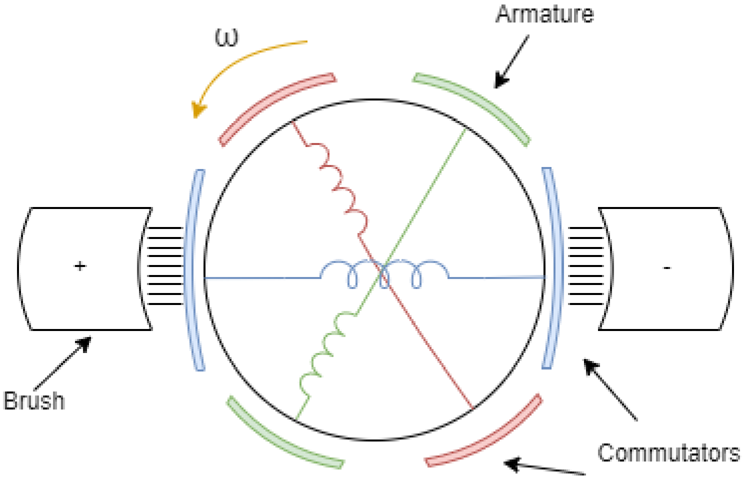
The block can trigger fault events:

- At a specific time (temporal fault).
- When a current limit is exceeded for longer than a specific time interval (behavioral fault).

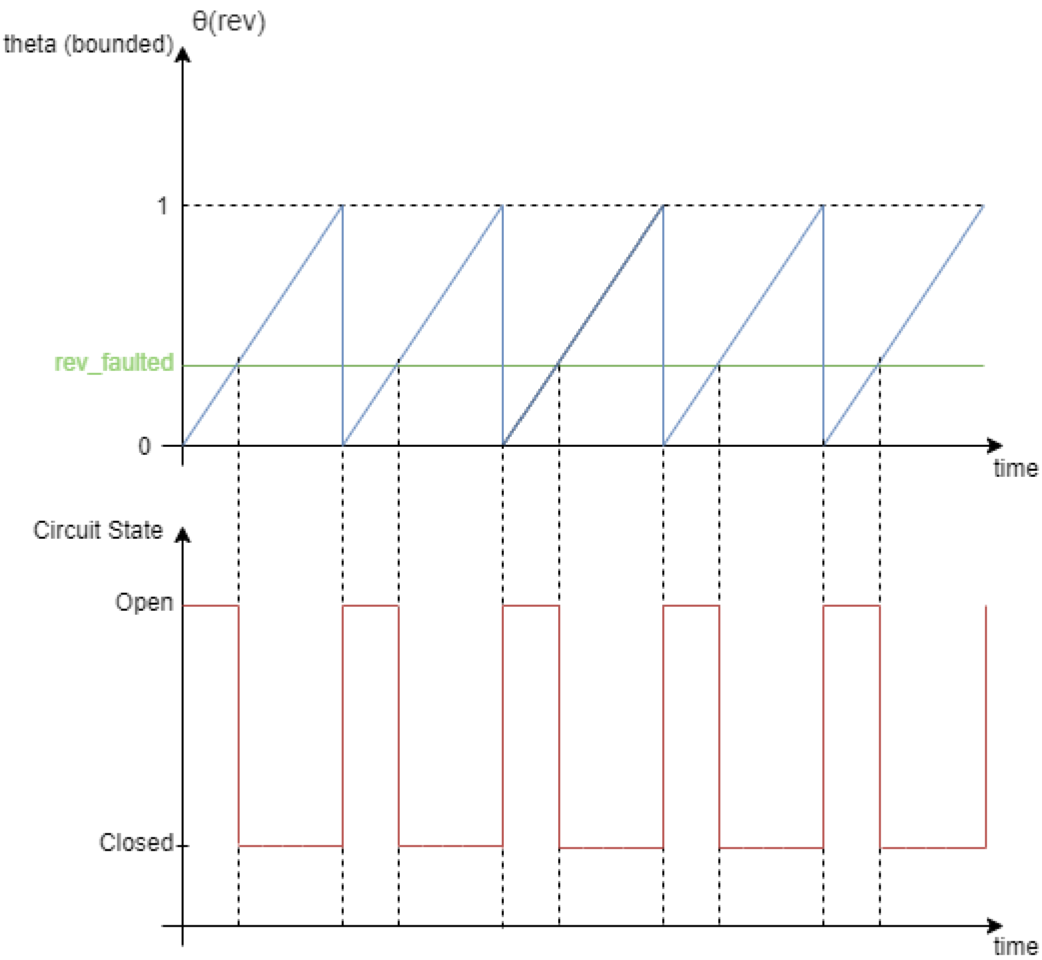
You can enable or disable these trigger mechanisms separately.

You can choose whether to issue an assertion when a fault occurs, by using the **Reporting when a fault occurs** parameter. The assertion can take the form of a warning or an error. By default, the block does not issue an assertion.

This figure shows a generic representation of a DC motor, with brushes, armatures, commutators, and their windings:



If you set the **Enable armature winding open-circuit fault** parameter to `Yes`, the armature fails at the time specified by the **Time at which armature winding fault is triggered** parameter for a temporal fault, or when the winding currents exceeds the value of the **Maximum permissible armature winding current** parameter for a behavioral fault. When the armature fails, the voltage source connected to this block observes an open circuit for a fraction of the total motor revolution, specified by the **Fraction of revolution during which armature is open-circuit** parameter, `rev_faulted`. This figure illustrates the circuit state behaviour for a certain `rev_faulted` during the entire revolution period:



Thermal Port

The block has an optional thermal port, hidden by default. To expose the thermal port, right-click the block in your model, and then from the context menu select **Simscape** > **Block choices** > **Show thermal port**. This action displays the thermal port **H** on the block icon, and exposes the **Temperature Dependence** and **Thermal Port** parameters.

Use the thermal port to simulate the effects of copper resistance losses that convert electrical power to heat. For more information on using thermal ports and on the **Temperature Dependence** and **Thermal Port** parameters, see Simulating Thermal Effects in Rotational and Translational Actuators.

Ports

Conserving

expand all

`+` — Positive terminal
electrical

`-` — Negative terminal
electrical

`C` — Motor case
mechanical

`R` — Motor rotor
mechanical

`F+` — Positive field
electrical

`F-` — Negative field
electrical

`H` — Thermal port
thermal

Parameters

expand all

Electrical Torque

`Field type` — Type of field
`Permanent Magnet` (default) | `Wound`

`Model parameterization` — Block parameterization
`By equivalent circuit parameters` (default) | `By stall torque & no-load speed` | `By rated power, rated speed & no-load speed`

`Field resistance` — Field resistance
`100 Ohm` (default)

`Field inductance` — Field inductance
`1 H` (default)

`Field-armature mutual inductance` — Field-armature mutual inductance
`0.15 H` (default)

`Initial field current` — **Initial field current**
`0` `A` (default)

`Armature resistance` — **Armature resistance**
`3.9` `Ohm` (default)

`Armature inductance` — **Armature inductance**
`12e-6` `H` (default)

`Define back-emf or torque constant` — **Constants specification**
`Specify back-emf constant` (default) | `Specify torque constant`

`Back-emf constant` — **Back-emf constant**
`0.072e-3` (default) | `V/rpm`

`Torque constant` — **Torque constant**
`6.876e-4` `N*m/A` (default)

`Stall torque` — **Stall torque**
`0.24e-3` `N*m`. (default)

`No-load speed` — **No-load speed**
`19100` `rpm` (default)

`Rated speed (at rated load)` — **Rated speed**
`15000` `rpm` (default)

`Rated load (mechanical power)` — **Rated load**
`0.08` `W` (default)

`Rated DC supply voltage` — **Rated DC supply voltage**
`1.5` `V` (default)

`Rotor damping parameterization` — **Rotor damping parameterization**
`By damping value` (default) | `By no-load current`

`No-load current` — **No-load current**
`0` `A` (default)

`DC supply voltage when measuring no-load current` — **DC supply voltage when measuring no-load current**
`1.5` `V` (default)

Mechanical

`Rotor inertia` — **Rotor inertia**
`0.01` `g*cm^2` (default)

`Rotor damping` — **Rotor dissipated energy**
`0` `N*m/(rad/s)` (default)

`Initial rotor speed` — **Initial rotor speed**
`0` `rpm` (default)

Temperature Dependence

This tab appears only for blocks with exposed thermal port. For more information, see Thermal Port.

`Resistance temperature coefficient` — **Resistance temperature coefficient**
`3.93e-3` `1/K` (default)

`Measurement temperature` — **Measurement temperature**
`25` `degC` (default)

Thermal Port

This tab appears only for blocks with exposed thermal port. For more information, see Thermal Port.

`Thermal mass` — **Thermal mass**
`100` `J/K` (default)

`Initial temperature` — **Initial temperature**
`25` `degC` (default)

Faults

`Enable armature winding open-circuit fault` — **Whether to enable armature winding faults**
`No` (default) | `Yes`

`Fraction of revolution during which armature is open-circuit` — **Fraction of revolution during which armature is open-circuit**
`1/3` (default)

`Faulted armature winding open-circuit conductance` — **Open-circuit conductance of faulted armature winding**
`1e-5` `S` (default)

`Armature winding fault trigger` — **Fault trigger for armature winding**
`Temporal` (default) | `Behavioral`

`Time at which armature winding fault is triggered` — **Time at which armature winding fault is triggered**
`1 s` (default)

`Maximum permissible armature winding current` — **Maximum permissible armature winding current**
`inf A` (default)

`Time to fail when exceeding armature winding current` — **Time to fail when exceeding armature winding current**
`1 s` (default)

`Enable field winding open-circuit fault` — **Whether to enable field winding faults**
`No` (default) | `Yes`

`Faulted field winding open-circuit conductance` — **Open-circuit conductance of faulted field winding**
`1e-5 S` (default)

`Field winding fault trigger` — **Fault trigger for field winding**
`Temporal` (default) | `Behavioral`

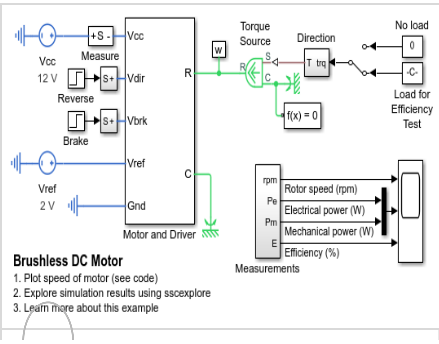
`Time at which field winding fault is triggered` — **Time at which field winding fault is triggered**
`1 s` (default)

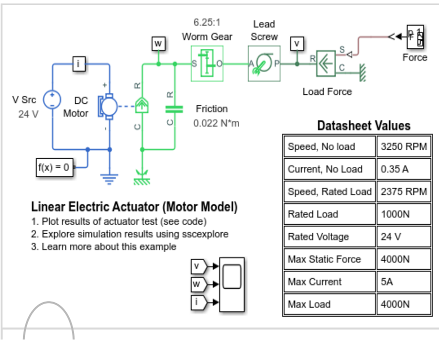
`Maximum permissible field winding current` — **Maximum permissible field winding current**
`inf A` (default)

`Time to fail when exceeding field winding current` — **Time to fail when exceeding field winding current**
`1 s` (default)

`Reporting when a fault occurs` — **Reporting when a fault occurs**
`None` (default) | `Warn` | `Error`

Model Examples



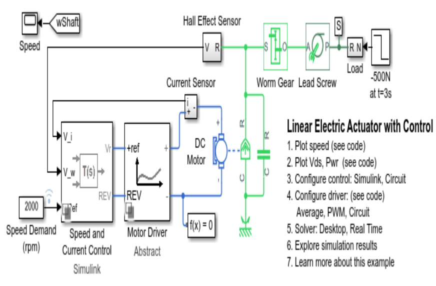


Brushless DC Motor

How a system-level model of a brushless DC motor (i.e. a servomotor) can be constructed and parameterized based on datasheet

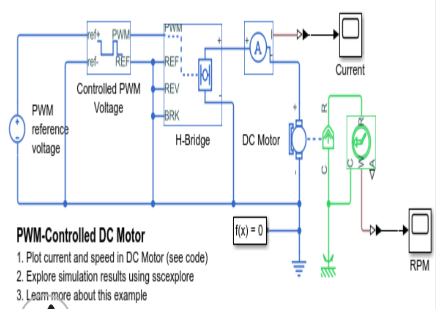
Linear Electric Actuator (Motor Model)

How to develop a model of an uncontrolled linear actuator using datasheet parameter values. The actuator consists of a DC motor



Linear Electric Actuator with Control

A detailed implementation model of a controlled linear actuator. The actuator consists of a DC motor driving a worm gear which in turn



PWM-Controlled DC Motor

How to use the Controlled PWM Voltage and H-Bridge blocks to control a motor. The DC Motor block uses manufacturer datasheet

References

[1] Bolton, W. *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*, 3rd edition Pearson Education, 2004..

Extended Capabilities

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

See Also

Induction Machine (Single-Phase) | Shunt Motor | Simplified PMSM Drive | Universal Motor

Introduced in R2008a