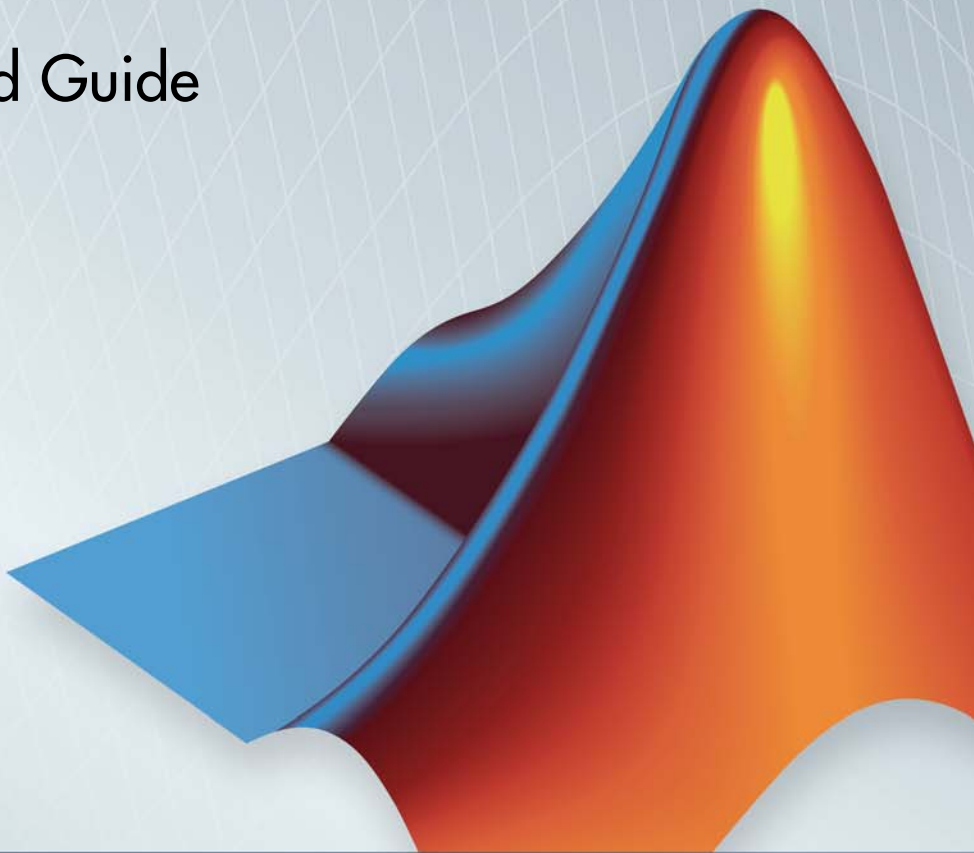


**Simscape™**

# Getting Started Guide

**R2014a**



**MATLAB® & SIMULINK®**



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*Simscape™ Getting Started Guide*

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# Product Fundamentals

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## **Simscape Product Description**

### **Model and simulate multidomain physical systems**

Simscape™ provides an environment for modeling and simulating physical systems spanning mechanical, electrical, hydraulic, and other physical domains. It provides fundamental building blocks from these domains that you can assemble into models of physical components, such as electric motors, inverting op-amps, hydraulic valves, and ratchet mechanisms. Because Simscape components use physical connections, your models match the structure of the system you are developing.

Simscape models can be used to develop control systems and test system-level performance. You can extend the libraries using the MATLAB® based Simscape language, which enables text-based authoring of physical modeling components, domains, and libraries. You can parameterize your models using MATLAB variables and expressions, and design control systems for your physical system in Simulink®. To deploy your models to other simulation environments, including hardware-in-the-loop (HIL) systems, Simscape supports C-code generation.

### **Key Features**

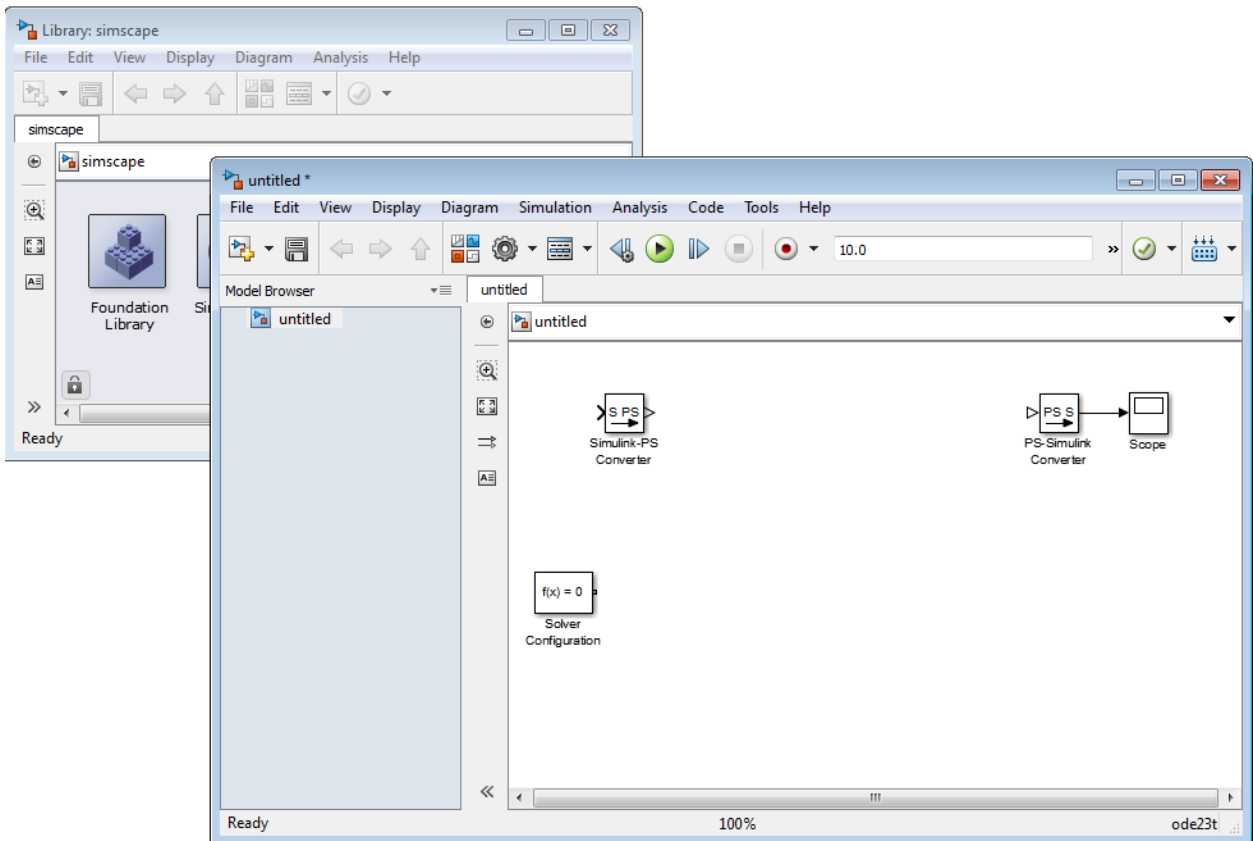
- Single environment for modeling and simulating mechanical, electrical, hydraulic, thermal, and other multidomain physical systems
- Libraries of physical modeling blocks and mathematical elements for developing custom components
- MATLAB based Simscape language, enabling text-based authoring of physical modeling components, domains, and libraries
- Physical units for parameters and variables, with all unit conversions handled automatically
- Ability to simulate models that include blocks from related physical modeling products without purchasing those products
- Support for C-code generation



## Creating a New Simscape Model

Simscape models require certain blocks to be present in the model configuration, such as a Solver block, or domain-specific reference blocks. Other blocks, although not required, are highly likely to be needed, such as Simulink-PS Converter and PS-Simulink Converter blocks. An easy way to start a new Simscape model is by using the `ssc_new` command.

When you type `ssc_new` at the MATLAB Command prompt, the software opens the main Simscape library and creates a new model prepopulated with certain blocks, as shown in the following illustration.

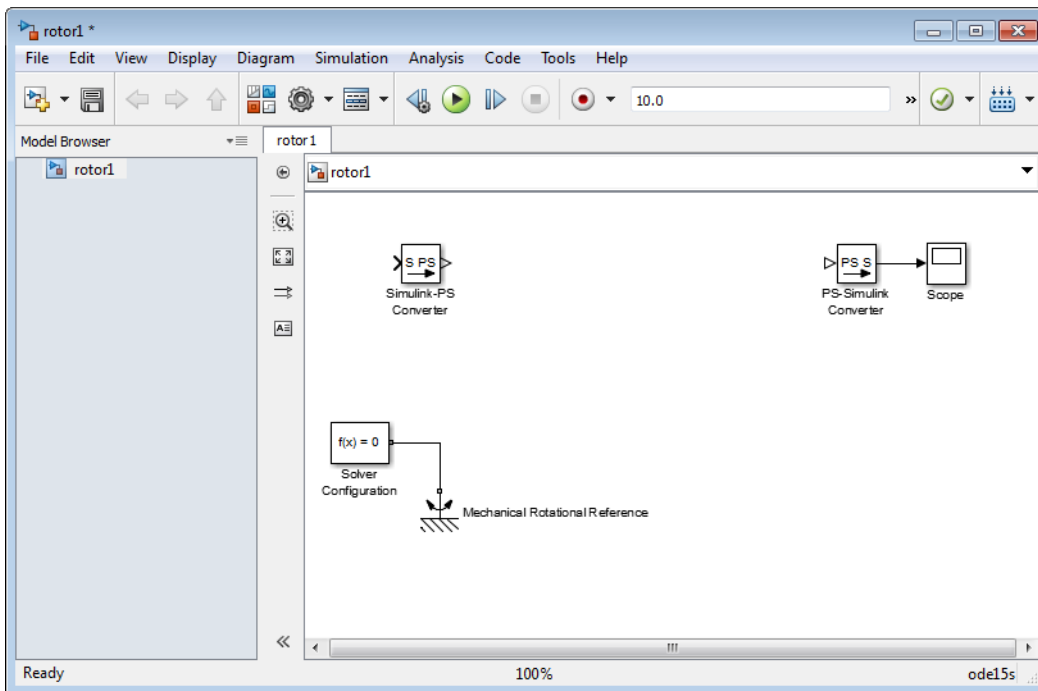


By default, the model name is not specified, the model contains a Solver Configuration block with the default solver set to `ode23t`, a Simulink-PS Converter block, and a PS-Simulink Converter block connected to a Scope block.

You can use the `ssc_new` command arguments to specify the model name, add a domain-specific reference block, and change the default solver. See the `ssc_new` command reference page for details. For example, typing

```
ssc_new('rotor1','rotational','ode15s')
```

creates the following model.



After using `ssc_new`, continue developing your model by copying the blocks, as needed, and adding other blocks from the Simscape libraries.

For electrical models, you can also use the Creating A New Circuit example as a template for a new model. This example also opens an Electrical Starter

Palette, which contains links to the most often used electrical components. Open the example by typing `ssc_new_elec` in the MATLAB Command Window and use **File > Save As** to save it under the desired model name. Then delete the unwanted components and add new ones from the Electrical Starter Palette and from Simscape libraries.

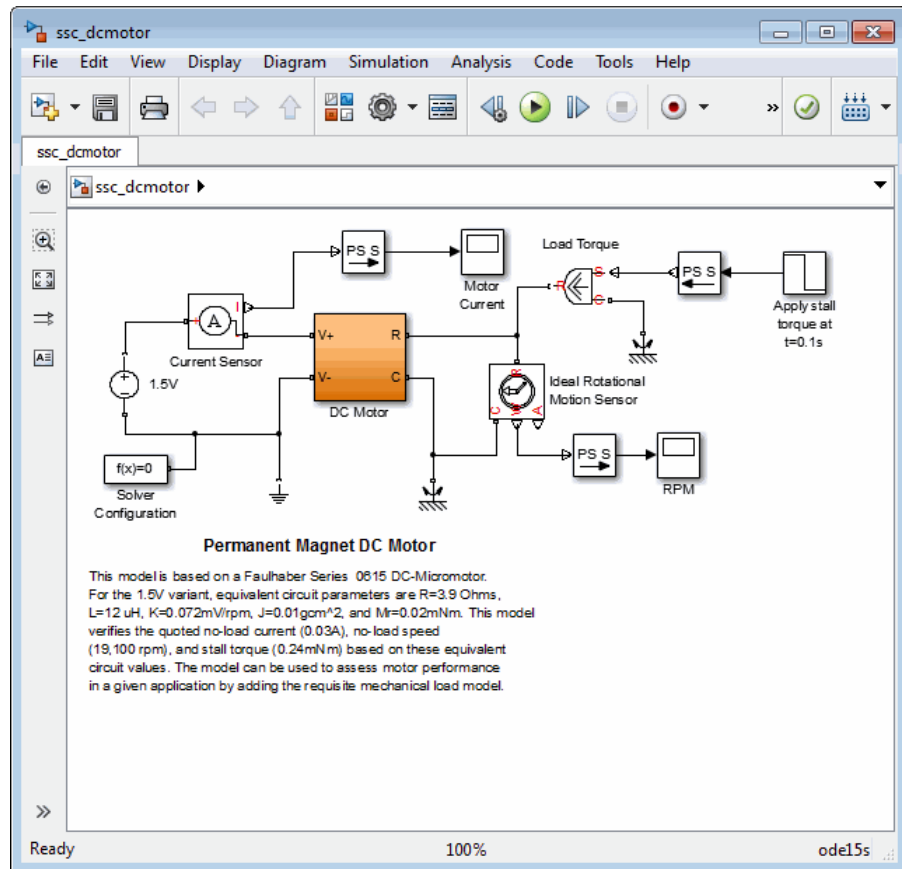
## Evaluating Performance of a DC Motor

This example shows how to simulate systems that span electrical and mechanical domains. You learn how to model physical components with Simscape blocks, connect them into a realistic model, use Simulink blocks as well, and then simulate and modify a motor model.

The model is based on a Faulhaber Series 0615 DC-Micromotor. The model uses equivalent circuit parameters for the 1.5V motor to verify manufacturer-quoted no-load speed, no-load current, and stall torque. You can use the model to assess motor performance in a given application by adding the requisite mechanical load model.

### Explore the Model

- 1** To open the Permanent Magnet DC Motor example model, type `ssc_dcmotor` in the MATLAB Command Window.



### Main Model Window

The main model window contains a DC Motor subsystem with two electrical and two mechanical rotational ports.

The electrical ports connect to the electrical circuit, which consists of an Electrical Reference block, representing an electrical ground, a 1.5 V DC voltage source, and a current sensor. The current sensor connects, through a PS-Simulink Converter block, to a Simulink scope labeled Motor Current.

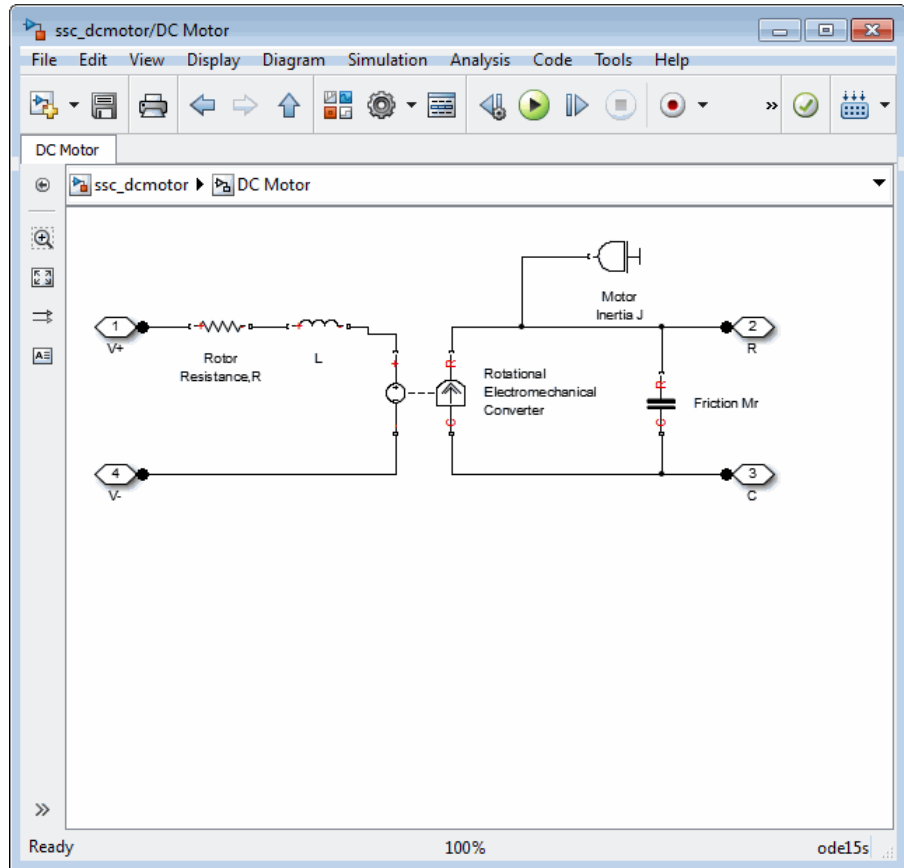
On the mechanical side, a Mechanical Rotational Reference block represents a reference point for the other elements. An ideal rotational

motion sensor connects, through a PS-Simulink Converter block, to a Simulink scope labeled RPM.

The motor load is represented by an Ideal Torque Source block, which on one side connects to a Mechanical Rotational Reference block, and on the other side to the motor shaft. A regular Simulink Step source provides the control signal. A Simulink-PS Converter block converts the control signal into a physical signal and applies it to the control port of the Ideal Torque Source block.

The diagram also contains a Solver Configuration block, which is required in any Simscape model. It contains parameters relevant to numerical algorithms for Simscape simulations.


- 2** Double-click the DC Motor subsystem to open it.

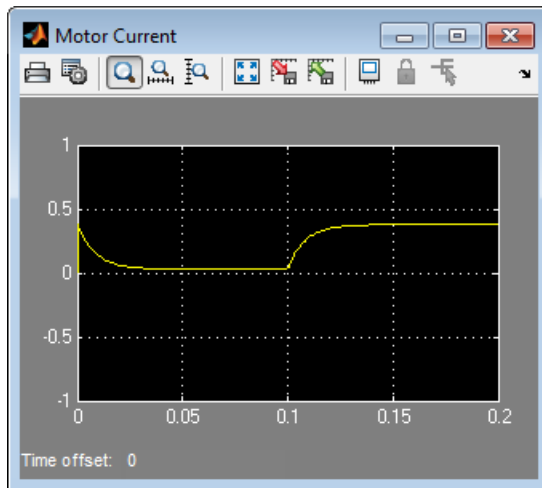


### DC Motor Subsystem

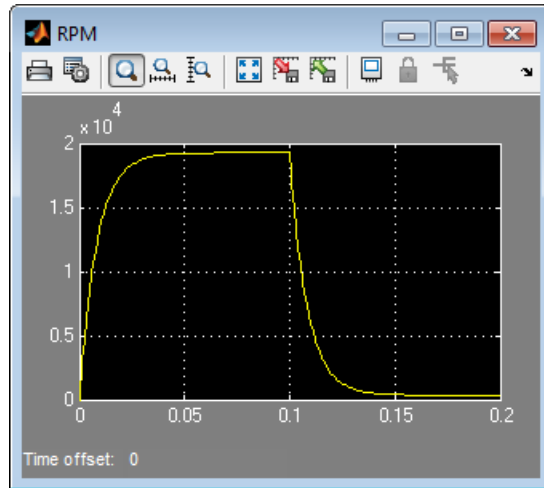
The motor consists of an electrical circuit and a mechanical circuit, connected by the Rotational Electromechanical Converter block. The electrical circuit consists of a Rotor Resistance block and an Inductance block  $L$ . It contains two electrical ports, corresponding to the  $V+$  and  $V-$  electric terminals of the motor. The mechanical circuit contains a Rotational Friction block, Motor Inertia  $J$ , and two mechanical rotational ports,  $C$  and  $R$ , corresponding to the motor case and rotor, respectively. Notice how the  $C$  and  $R$  ports of the Friction block and the Rotational Electromechanical Converter block are connected to the  $C$  and  $R$  ports of the motor, to preserve the correct direction of variables in the Physical Network.

### Run the Model

- 1 Double-click the Motor Current and RPM scopes to open them. During simulation, these windows display the motor current and shaft speed, respectively, as functions of time.
- 2 In the toolbar of the model window, click  to start the simulation. The Simscape solver evaluates the model, calculates the initial conditions, and runs the simulation. This process might take a few seconds. The message in the bottom-left corner of the model window provides the status.
- 3 Examine the simulation results in the Motor Current and RPM scope windows.





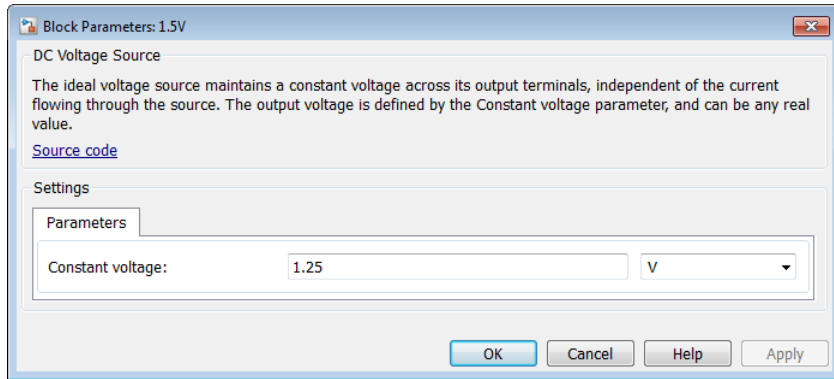


For the first 0.1 seconds, the motor has no external load, and the speed builds up to the no-load value. Then at 0.1 seconds, the stall torque is applied as a load to the motor shaft. Zooming in on the RPM and Motor Current scopes shows that the model matches the manufacturer parameters for no-load speed, no-load current, and stall torque.

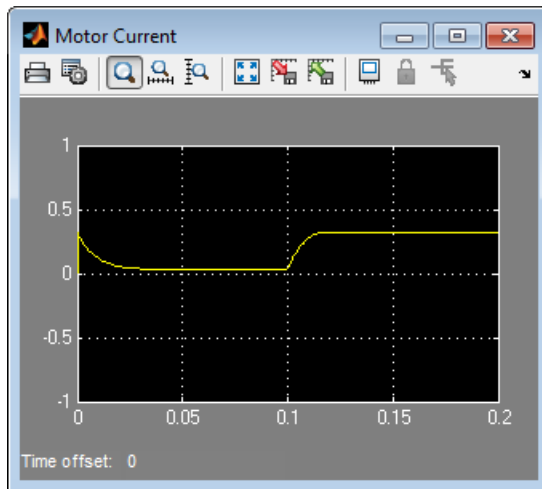
### Change the Supply Voltage

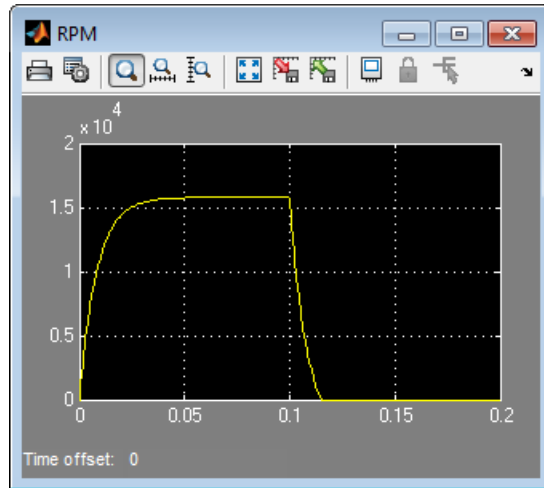
Reduce the supply voltage to 1.25 volts (to simulate the battery running down) and vary the load torque to find the maximum torque at this reduced voltage.

- 1 Double-click the 1.5V DC Voltage Source block. Set **Constant voltage** to 1.25 V.



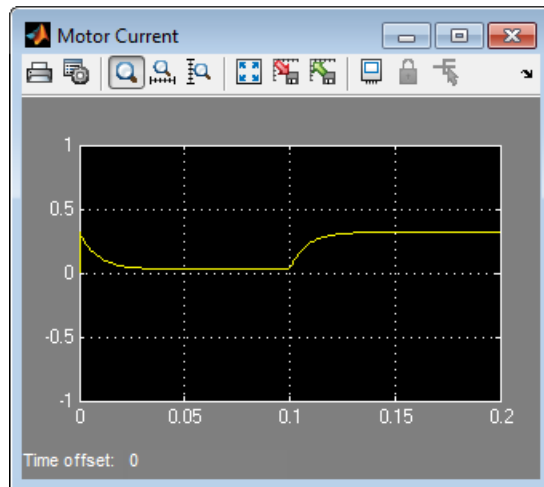
2 Run the simulation. Note the effect of reduced voltage on the no-load speed.

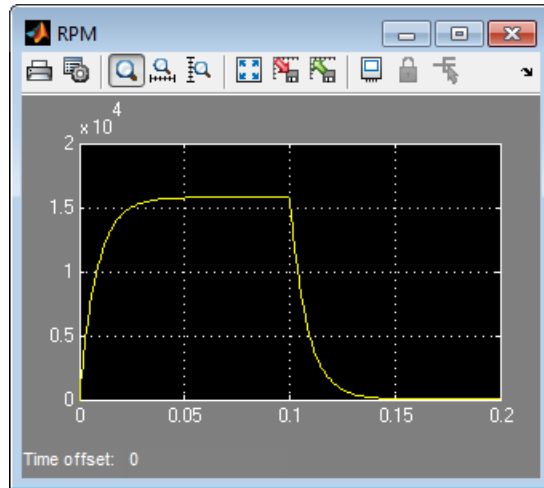




- 3 Try varying the load torque to find the maximum torque at this reduced voltage. Double-click the Step source block, enter different final values for the input signal, and rerun the simulation.

The next illustration shows the simulation results for **Final value** set to  $-0.2e-3$ , which corresponds to  $(1.25/1.5) * 0.24\text{mNm}$ , as the magnitude of the torque-speed curve is proportional to voltage for a DC motor.

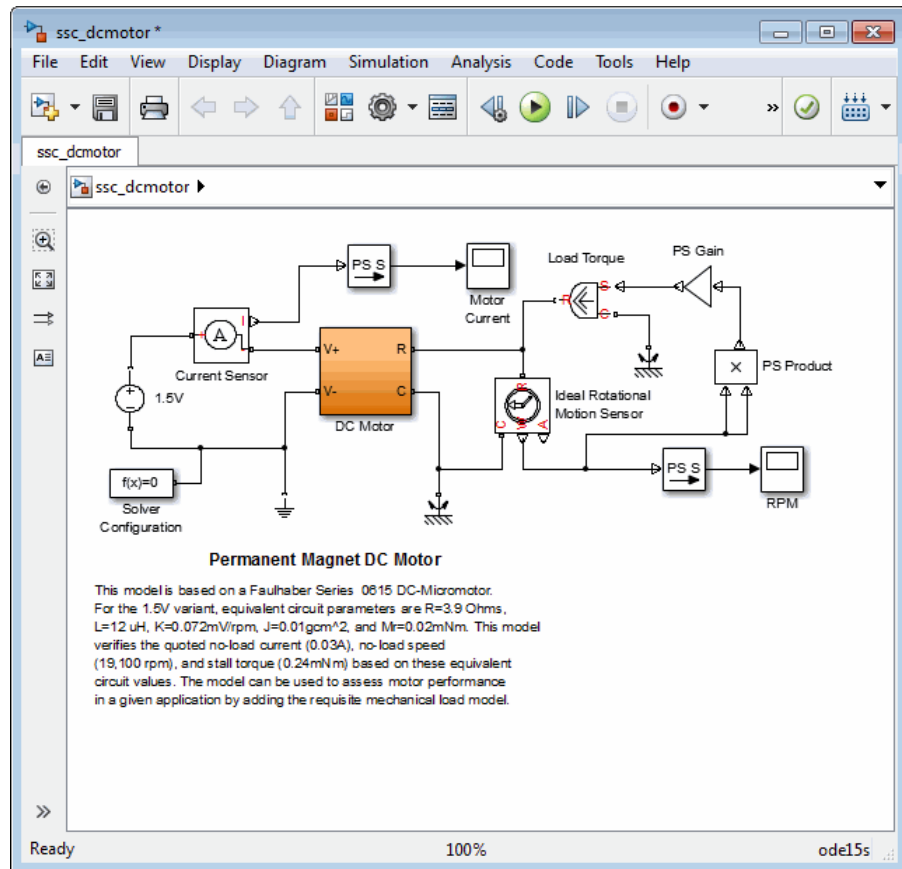




## Change the Motor Load

Replace the torque source with a simple mechanical load, for example, a fan, for which the torque is defined by  $\alpha \cdot \text{speed}^2$ , where  $\alpha$  is  $-1e-10$  Nm/(rad/s)<sup>2</sup>.

- 1 Delete the Step source and the Simulink-PS Converter block from the model.
- 2 In the **Simscape** block library, open **Foundation Library > Physical Signals > Functions**.
- 3 Drag the PS Product block and the PS Gain block to the model window.
- 4 Connect the blocks as shown in the following illustration. To rotate a block, select it and press **Ctrl+R**.



- 5 Double-click the Gain block to open its dialog box. Enter **Gain** value of  $-1e-10$  and click **OK**.
- 6 Run the simulation and assess motor performance with the new load.

