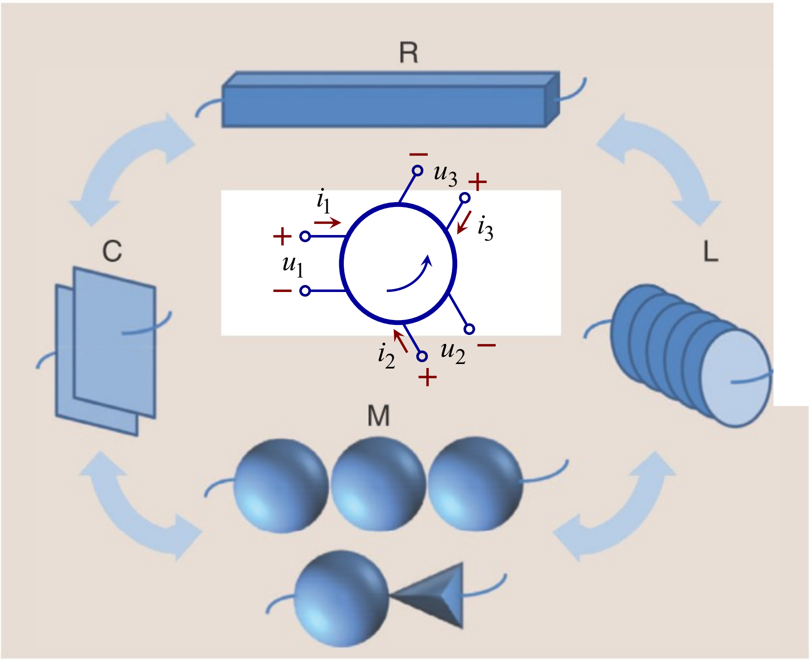
Рачунарска анализа електричних кола



Милка Потребић

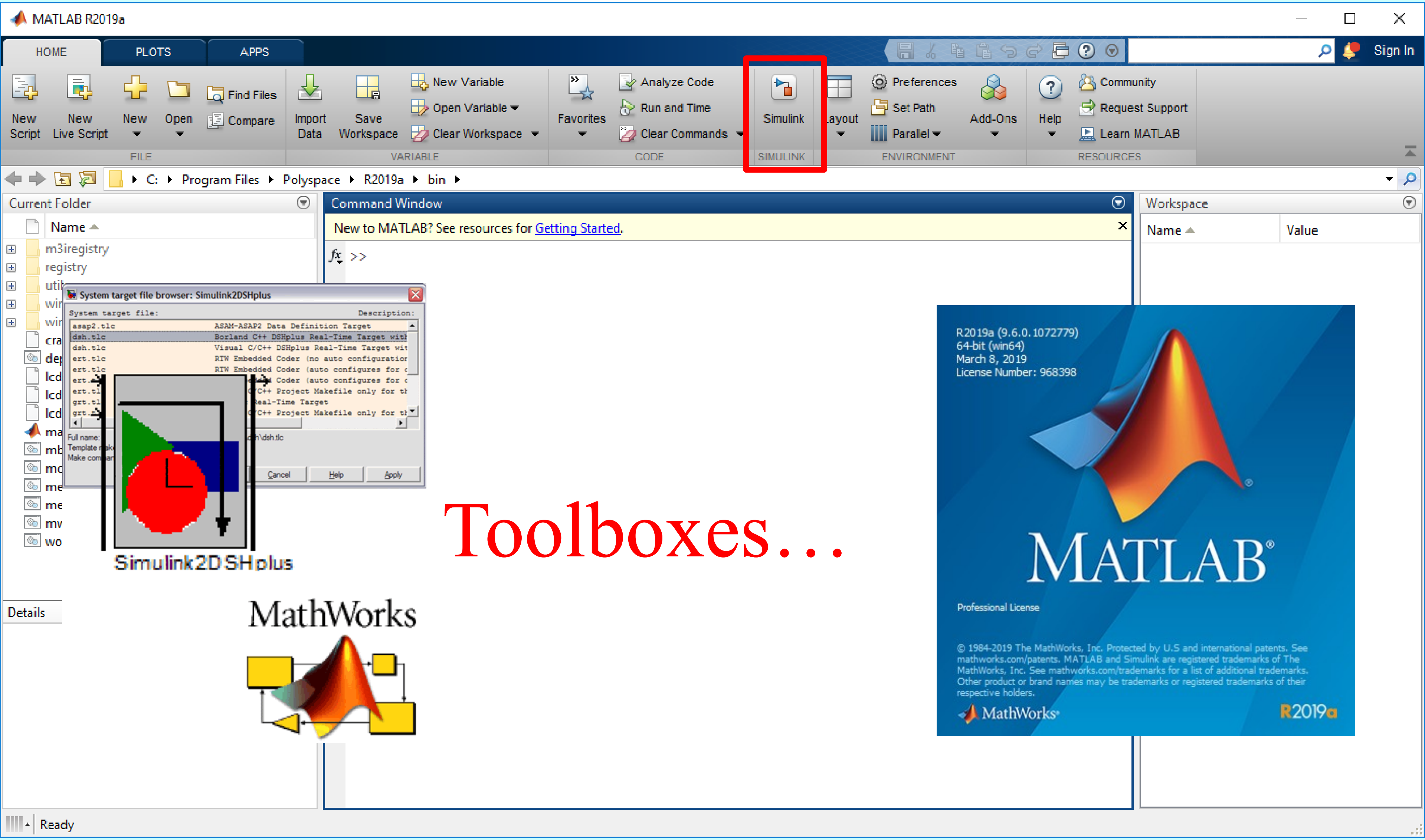
Рачунарски (софтверски) алати

- *Mathematica*, MuPAD, **Maxima**, **SymPy**
- MATLAB, **Scilab**, **Octave**, **FreeMat**
- LTspice, **ngspice**, **QucsStudio**, **XCircuit**
- **Python**, MathCAD, MAPLE, SpeQ Mathematics…

Free/Libre Open Source Software (FLOSS)

MATLAB


http://www.mathworks.com/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New Variable
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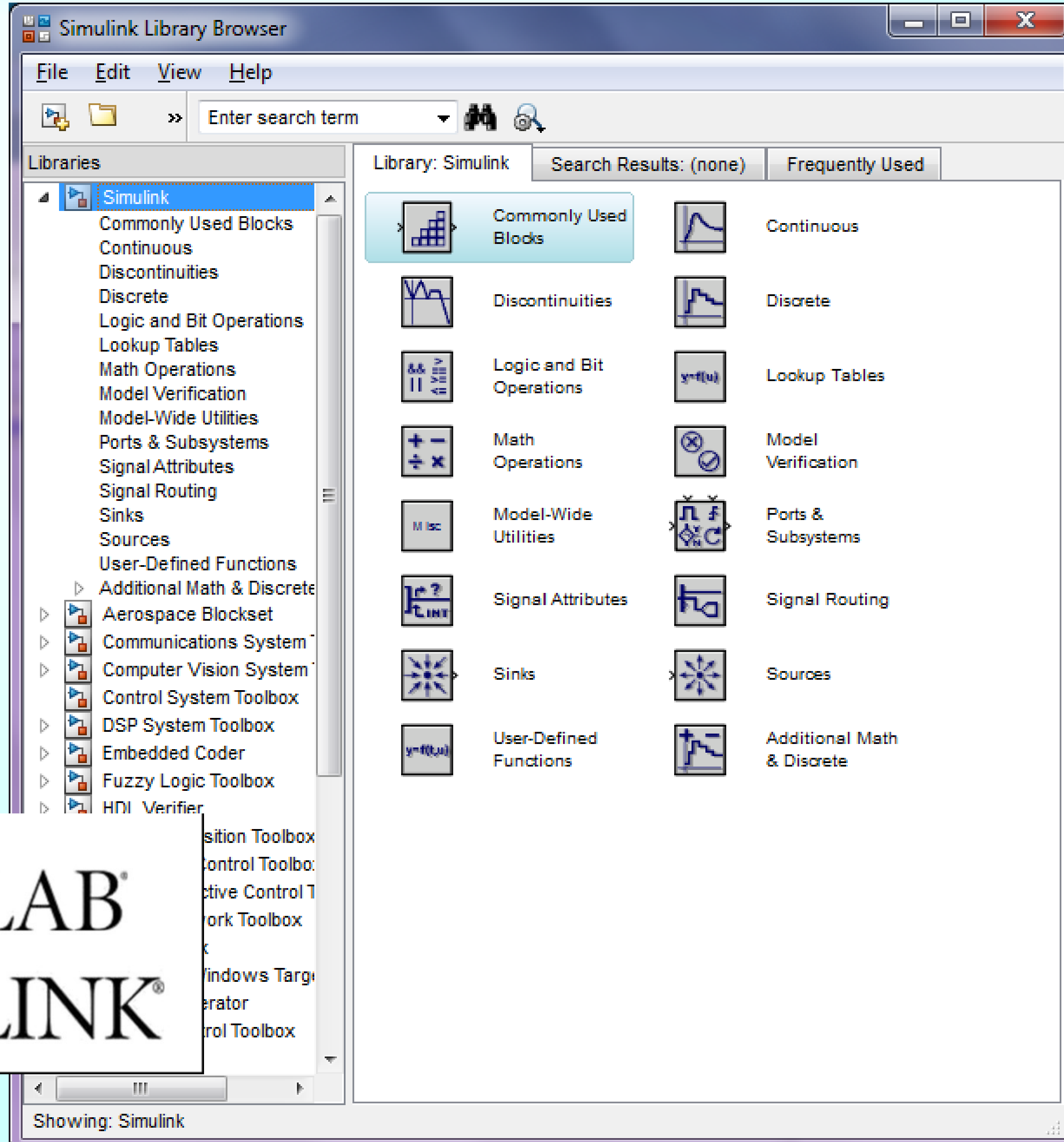
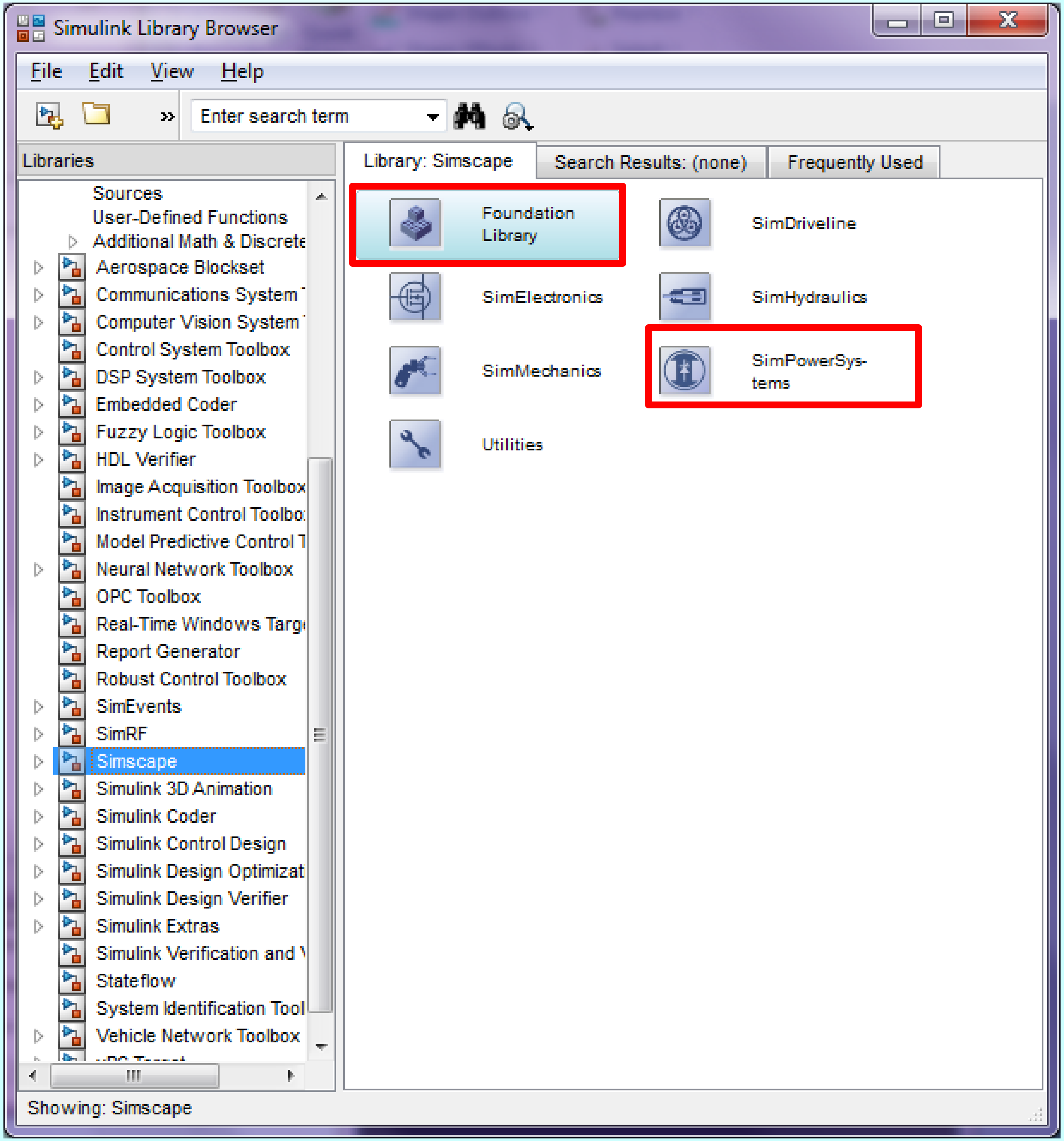
Simulink



MATLAB SIMULINK

Simscape


Simulink Library Browser
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Libraries
Library: Simscape
Search Results: (none)
Frequently Used
Sources
User-Defined Functions
Additional Math & Discrete
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Communications System
Computer Vision System
Control System Toolbox
DSP System Toolbox
Embedded Coder
Fuzzy Logic Toolbox
HDL Verifier
Image Acquisition Toolbox
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Neural Network Toolbox
OPC Toolbox
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SimRF
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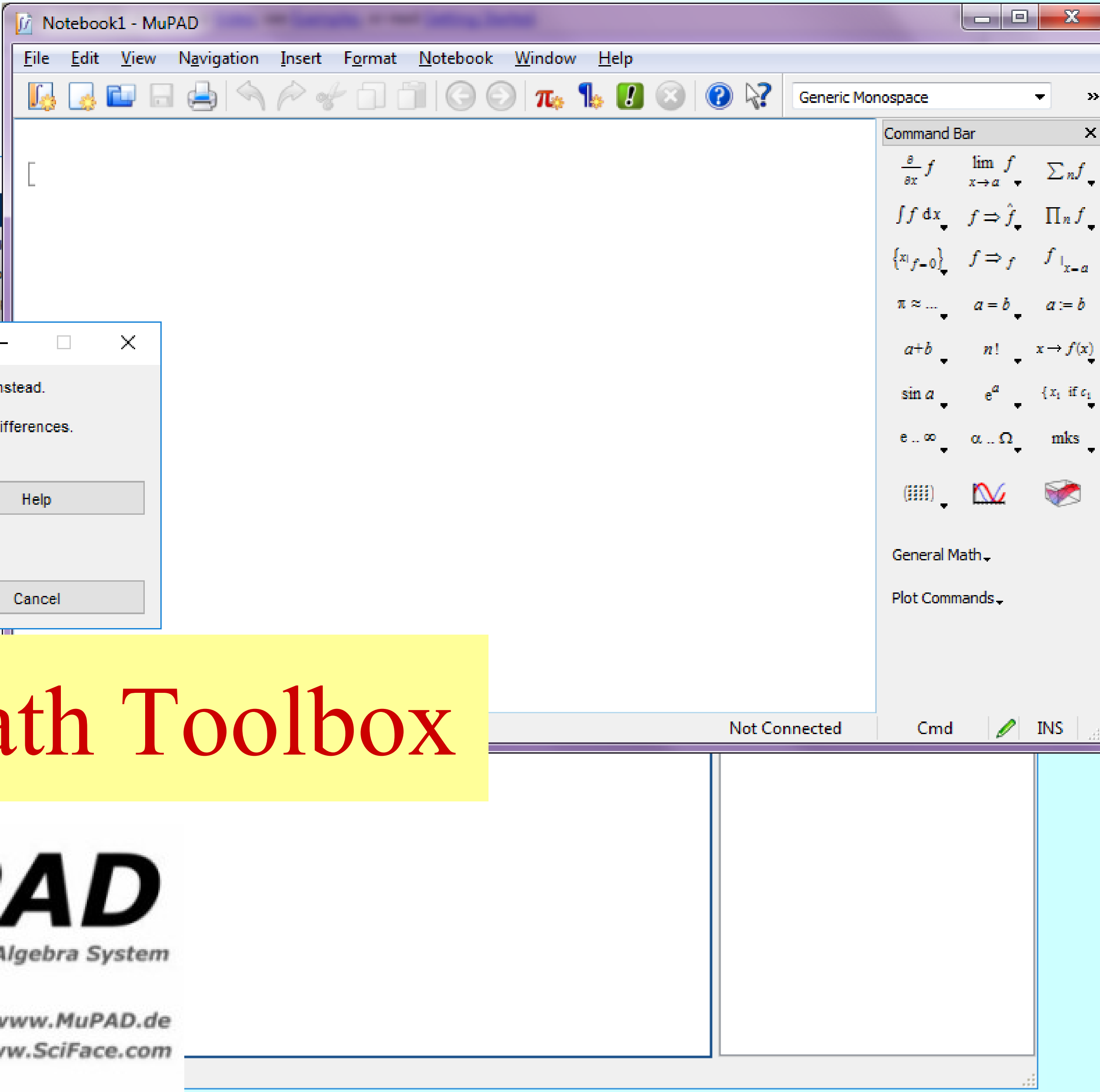
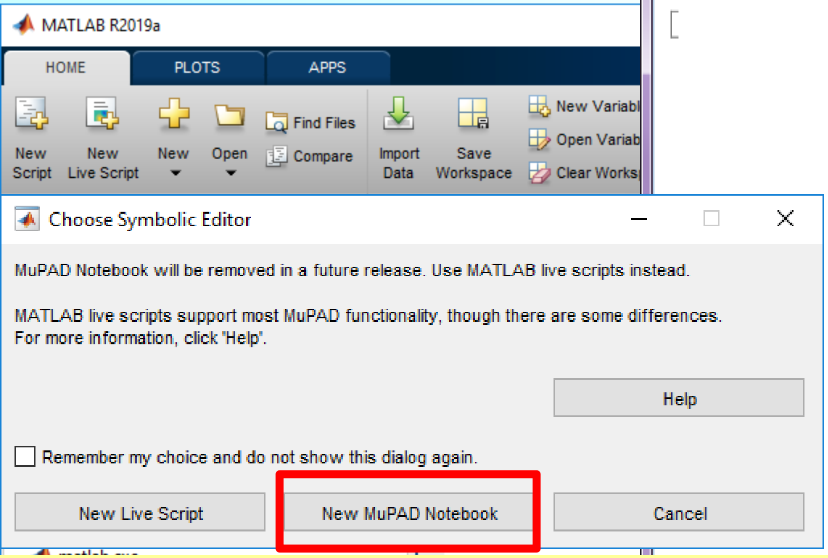
Simulink Coder
Simulink Control Design
Simulink Design Optimizat
Simulink Design Verifier
Simulink Extras
Simulink Verification and
Stateflow
System Identification Tool
Vehicle Network Toolbox
Foundation Library
SimDriveline
SimElectronics
SimHydraulics
SimMechanics
SimPowerSys-tems
Utilities
Showing: Simscape

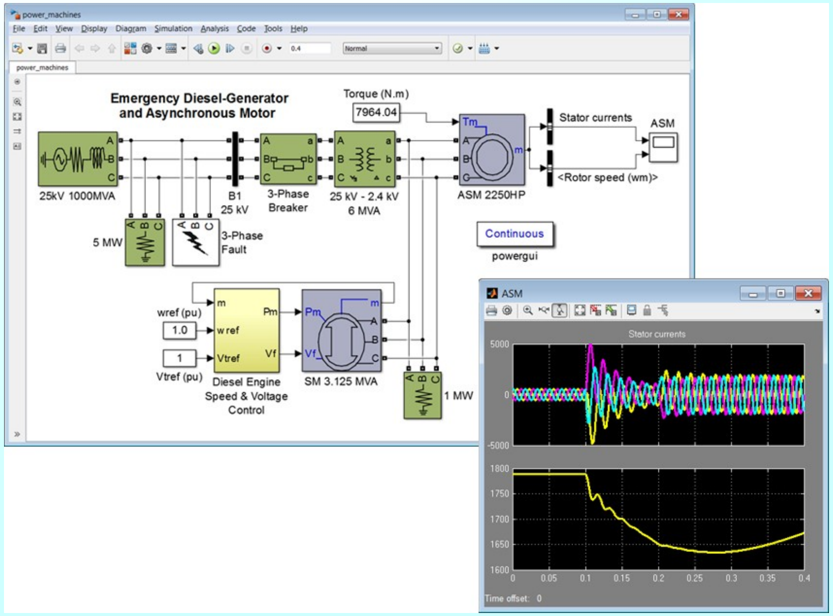
MuPAD

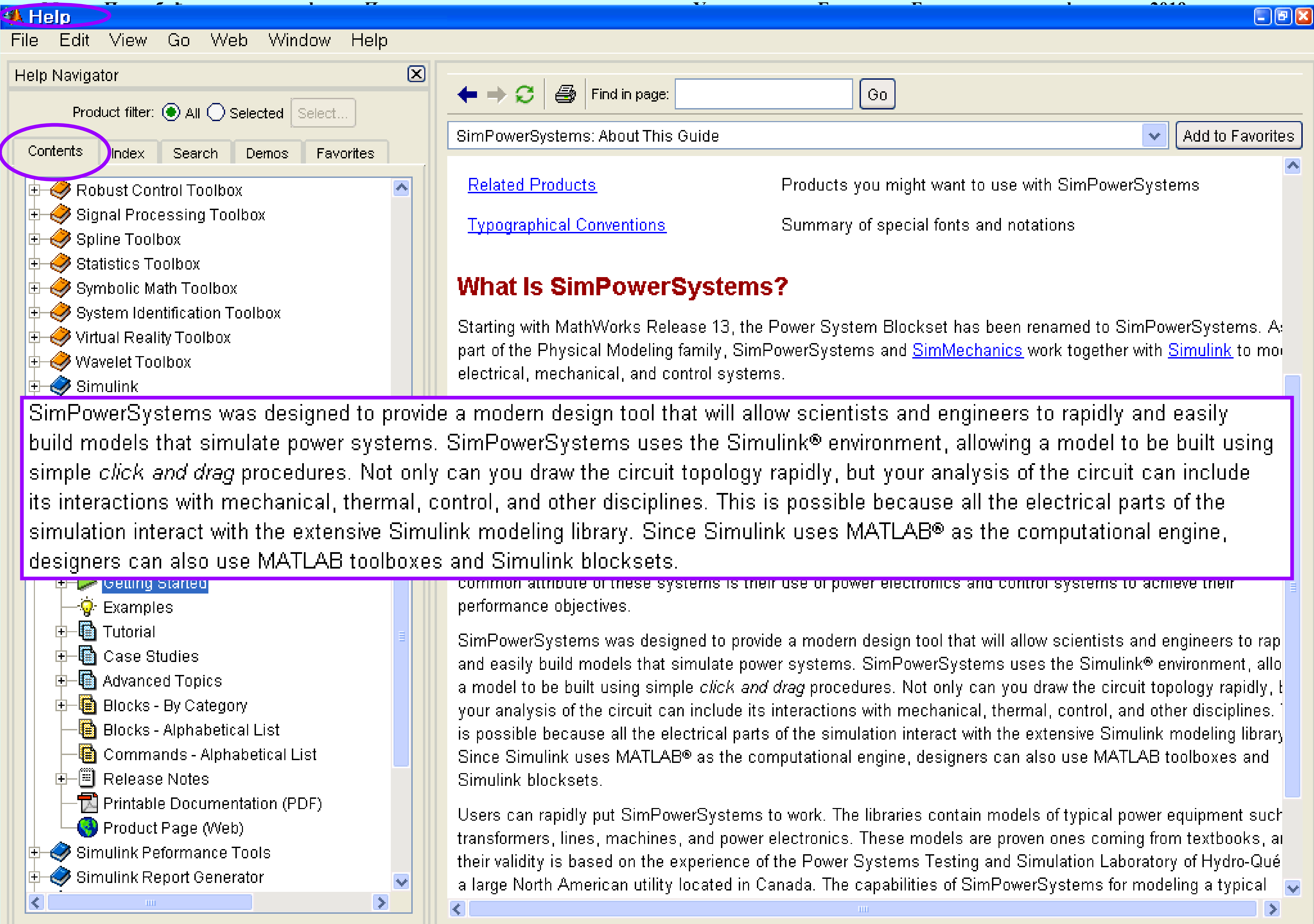




Symbolic Math Toolbox

SimPowerSystems

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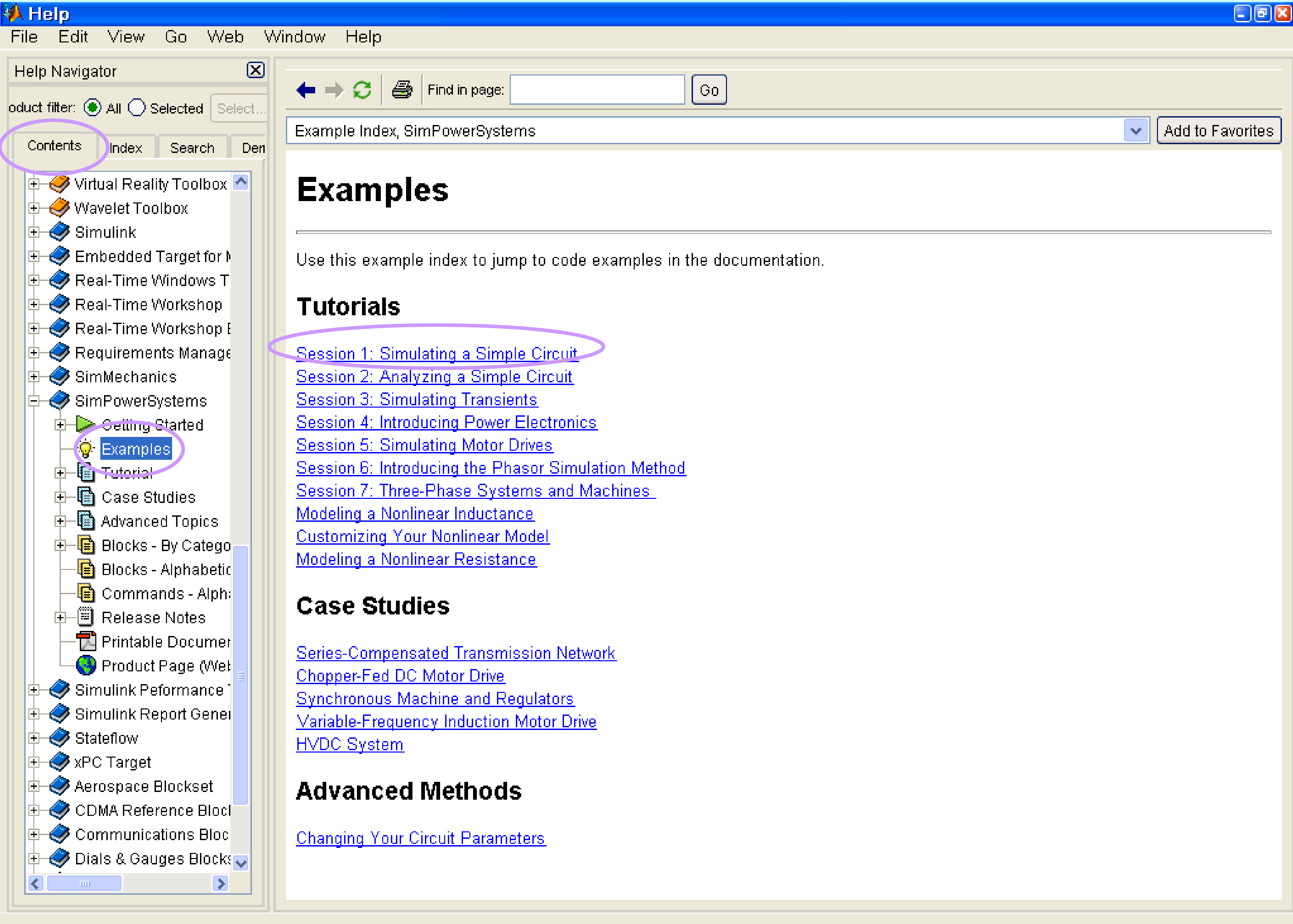
Blocks - Alphabetical List
Commands - Alphabetical List
Release Notes
Printable Documentation (PDF)
Product Page (Web)
Simulink Peformance Tools
Simulink Report Generator
Find in page: Go
SimPowerSystems: About This Guide
Add to Favorites
Related Products
Products you might want to use with SimPowerSystems
Typographical Conventions
Summary of special fonts and notations
What Is SimPowerSystems?
Starting with MathWorks Release 13, the Power System Blockset has been renamed to SimPowerSystems. As part of the Physical Modeling family, SimPowerSystems and SimMechanics work together with Simulink to mo electrical, mechanical, and control systems.
SimPowerSystems was designed to provide a modern design tool that will allow scientists and engineers to rapidly and easily build models that simulate power systems. SimPowerSystems uses the Simulink® environment, allowing a model to be built using simple *click and drag* procedures. Not only can you draw the circuit topology rapidly, but your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library. Since Simulink uses MATLAB® as the computational engine, designers can also use MATLAB toolboxes and Simulink blocksets.
performance objectives.
SimPowerSystems was designed to provide a modern design tool that will allow scientists and engineers to rap and easily build models that simulate power systems. SimPowerSystems uses the Simulink® environment, allo a model to be built using simple *click and drag* procedures. Not only can you draw the circuit topology rapidly, your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library Since Simulink uses MATLAB® as the computational engine, designers can also use MATLAB toolboxes and Simulink blocksets.
Users can rapidly put SimPowerSystems to work. The libraries contain models of typical power equipment such transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, a their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Qué a large North American utility located in Canada. The capabilities of SimPowerSystems for modeling a typical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Use this example index to jump to code examples in the documentation.
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Session 1: Simulating a Simple Circuit
Session 2: Analyzing a Simple Circuit
Session 3: Simulating Transients
Session 4: Introducing Power Electronics
Session 5: Simulating Motor Drives
Session 6: Introducing the Phasor Simulation Method
Session 7: Three-Phase Systems and Machines
Modeling a Nonlinear Inductance
Customizing Your Nonlinear Model
Modeling a Nonlinear Resistance
Case Studies
Series-Compensated Transmission Network
Chopper-Fed DC Motor Drive
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SimPowerSystems

Session 1: Simulating a Simple Circuit

The Power System Blockset allows you to build and simulate electrical circuits containing linear and nonlinear elements. During Sessions 1 through 3 you will build, analyze, and simulate the following circuit.

In this session you

- Explore the **powerlib** library of the Power System Blockset
- Learn how to build a simple circuit from the **powerlib** library
- Interconnect Simulink blocks with your circuit

The circuit below represents an equivalent power system feeding a 300 km transmission line. The line is compensated by a shunt inductor at its receiving end. A circuit breaker allows energizing and deenergizing of the line. In order to simplify matters, only one of the three phases is represented. The parameters shown in the figure are typical of a 735 kV power system.

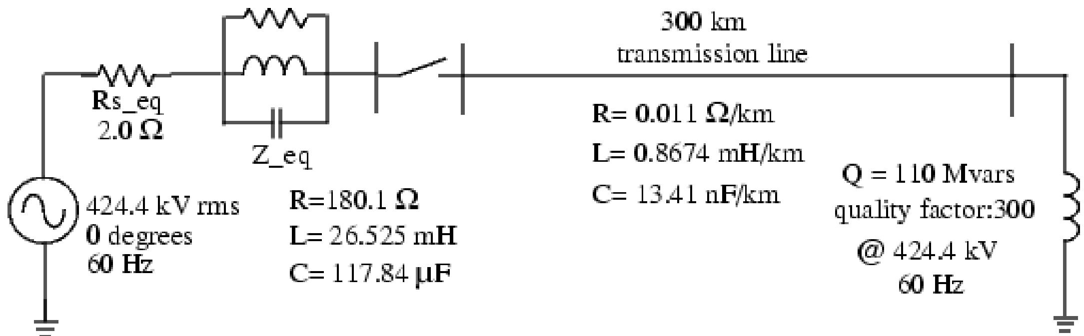
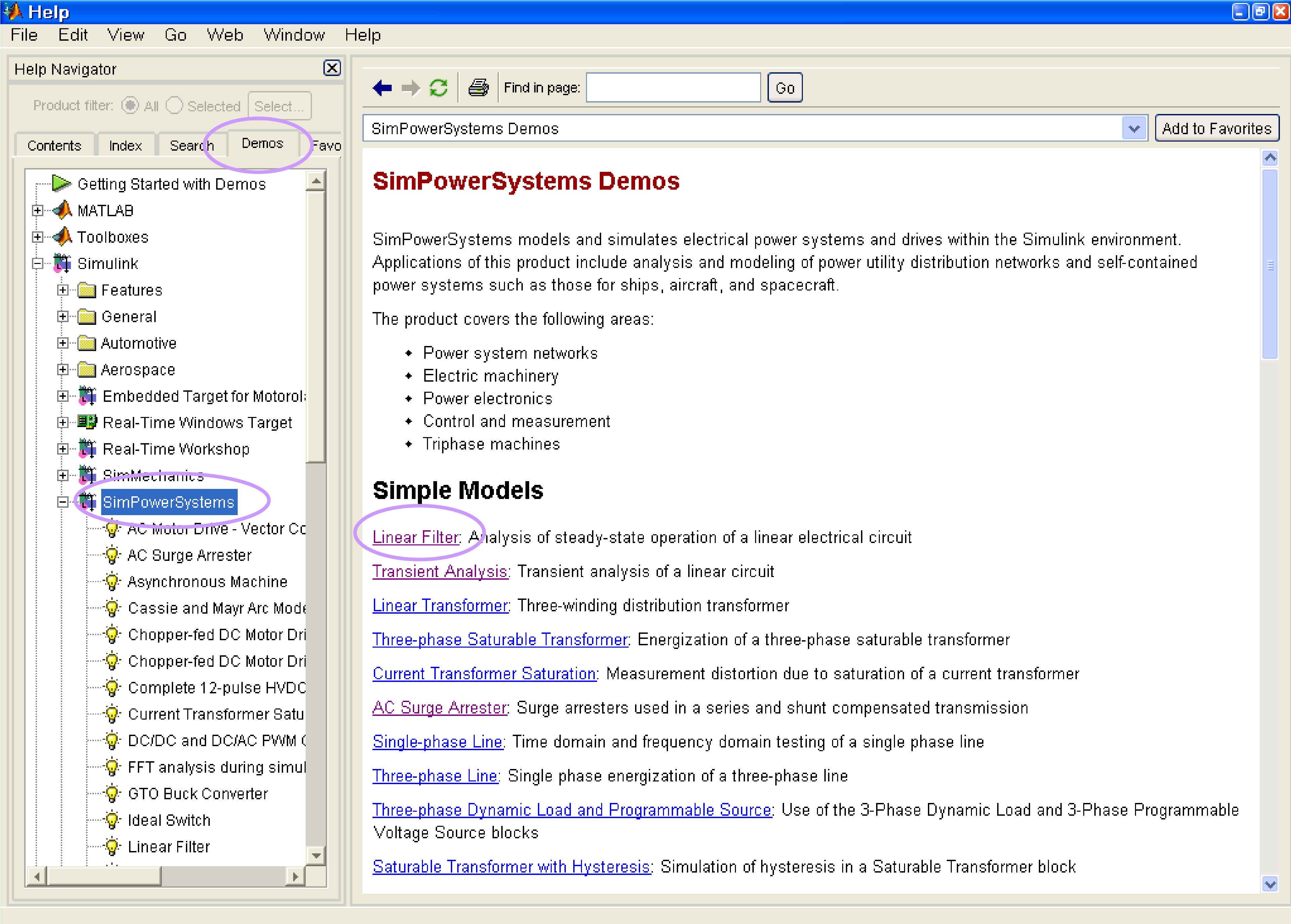


Figure 1-1: Circuit to Be Modeled with the Power System Blockset

Tutorial | Building the Electrical Circuit with powerlib Library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AC Surge Arrester
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GTO Buck Converter
Ideal Switch
Linear Filter
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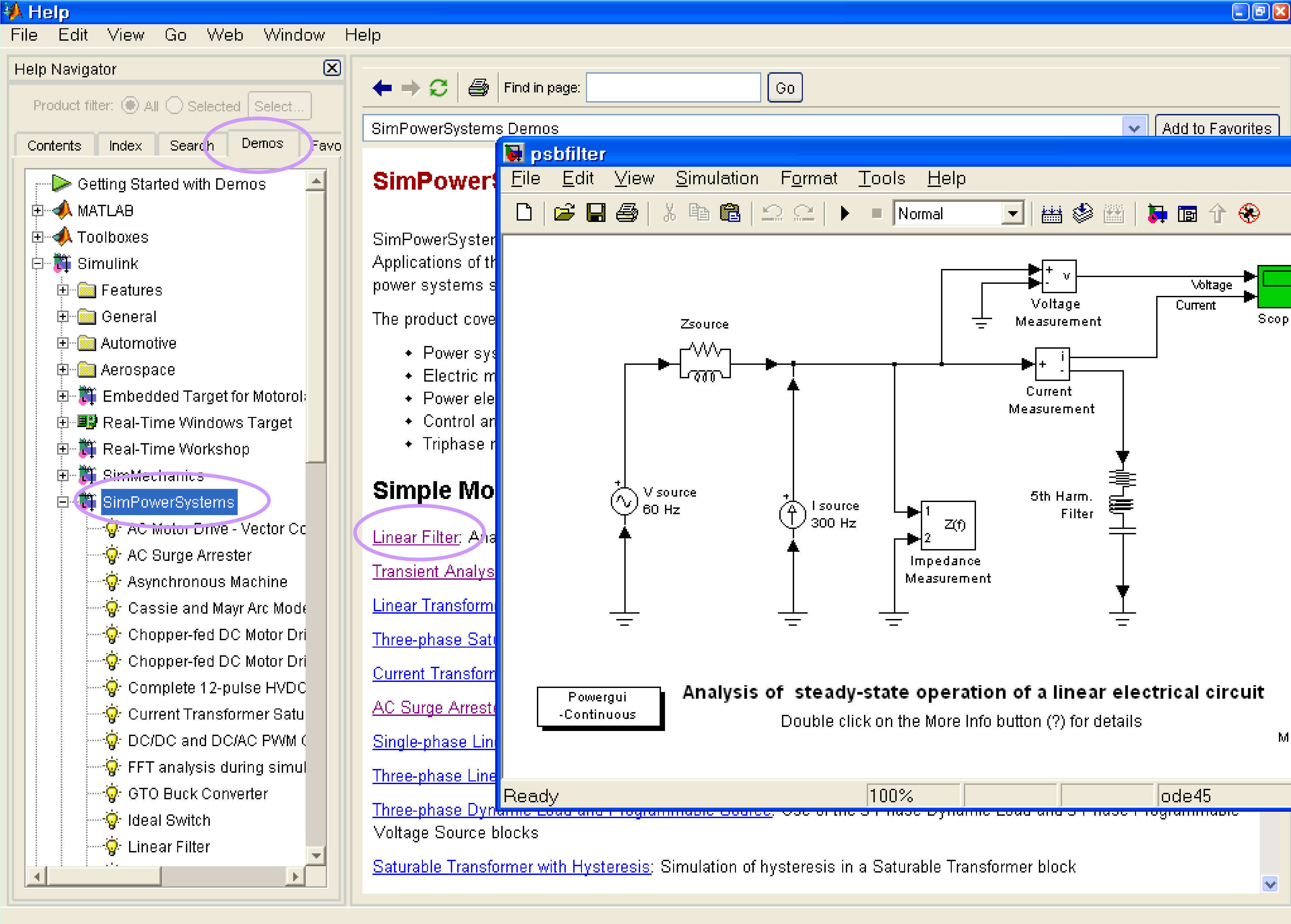
SimPowerSystems Demos
SimPowerSystems models and simulates electrical power systems and drives within the Simulink environment. Applications of this product include analysis and modeling of power utility distribution networks and self-contained power systems such as those for ships, aircraft, and spacecraft.
The product covers the following areas:
Power system networks
Electric machinery
Power electronics
Control and measurement
Triphase machines
Simple Models
Linear Filter: Analysis of steady-state operation of a linear electrical circuit
Transient Analysis: Transient analysis of a linear circuit
Linear Transformer: Three-winding distribution transformer
Three-phase Saturable Transformer: Energization of a three-phase saturable transformer
Current Transformer Saturation: Measurement distortion due to saturation of a current transformer
AC Surge Arrester: Surge arresters used in a series and shunt compensated transmission
Single-phase Line: Time domain and frequency domain testing of a single phase line
Three-phase Line: Single phase energization of a three-phase line
Three-phase Dynamic Load and Programmable Source: Use of the 3-Phase Dynamic Load and 3-Phase Programmable Voltage Source blocks
Saturable Transformer with Hysteresis: Simulation of hysteresis in a Saturable Transformer block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Voltage Source blocks
Saturable Transformer with Hysteresis: Simulation of hysteresis in a Saturable Transformer block
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Analysis of steady-state operation of a linear electrical circuit
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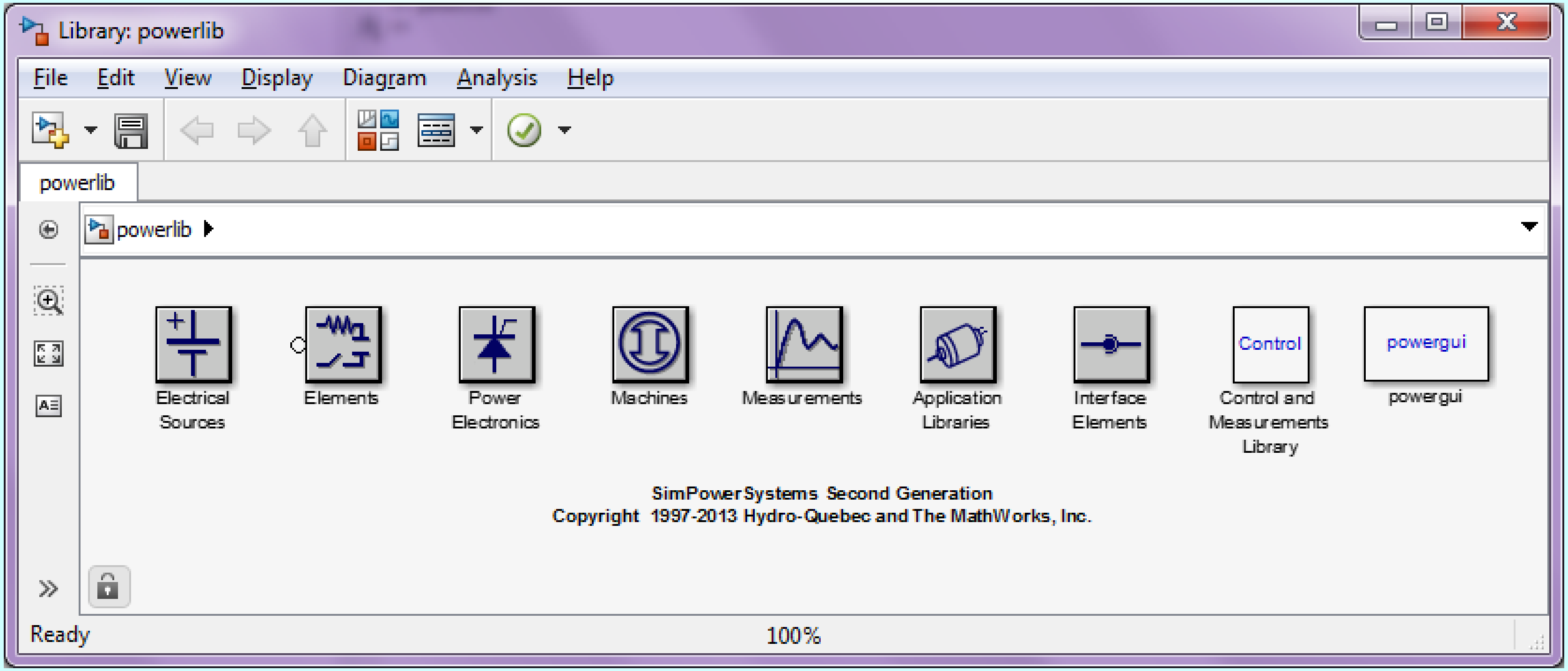
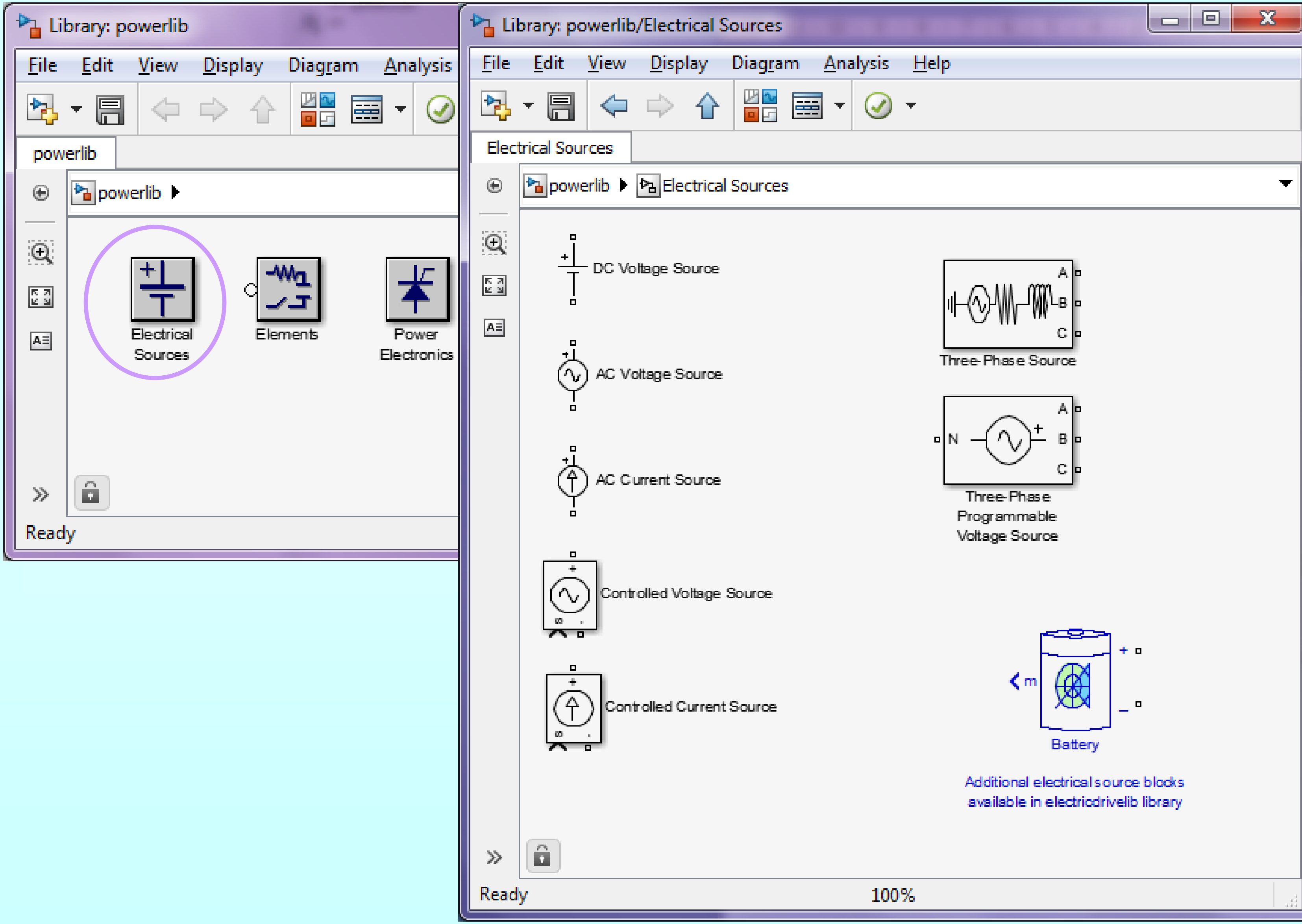
Симулација електричних кола

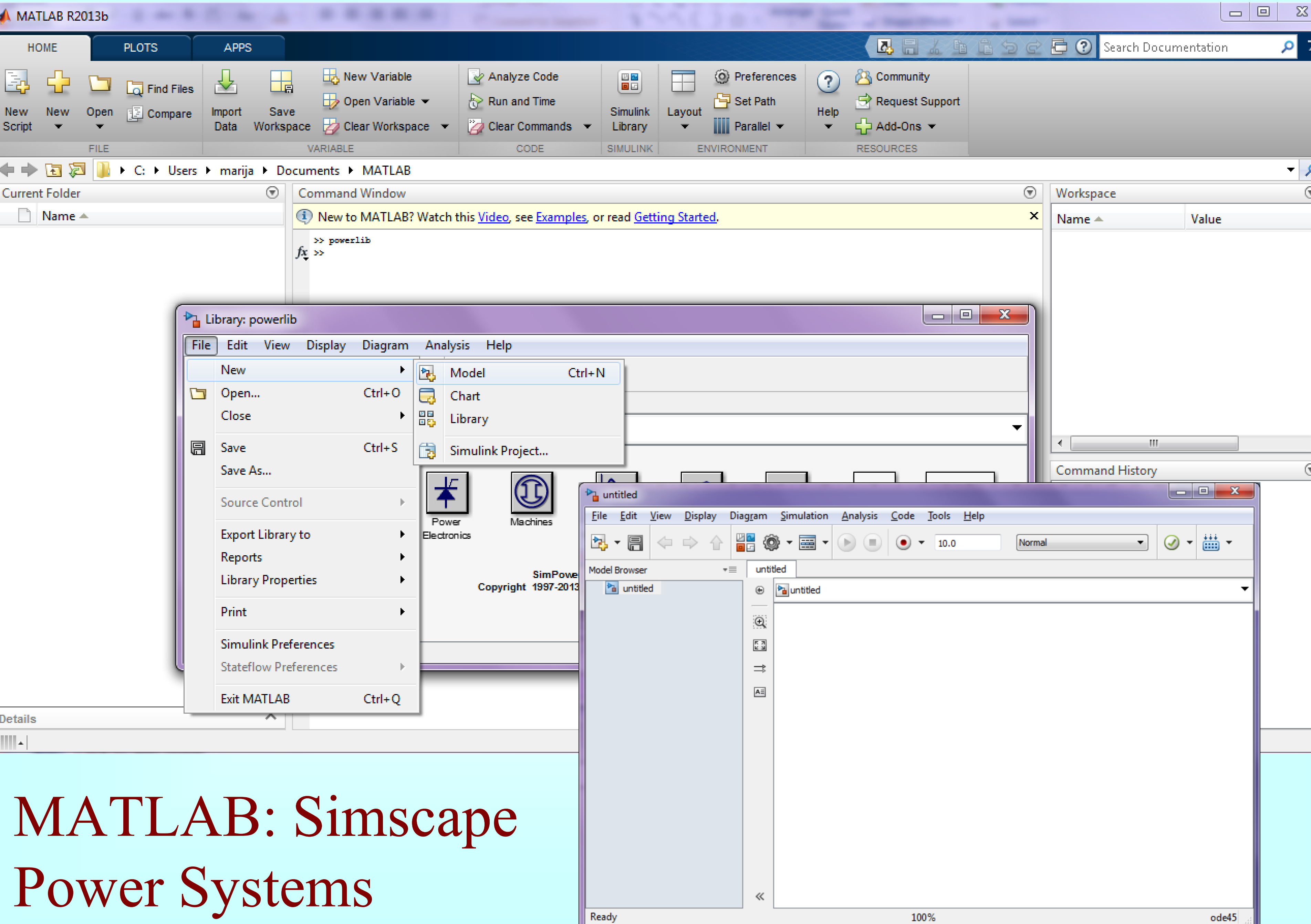
powerlib



Симулација електричних кола

powerlib

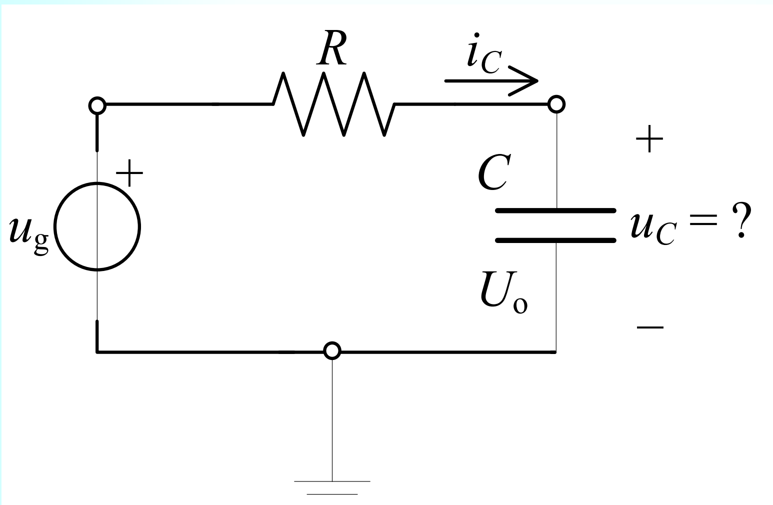




MATLAB: Simscape Power Systems

Пример анализе ел. кола

коло је образовано у тренутку $t_0 = 0$

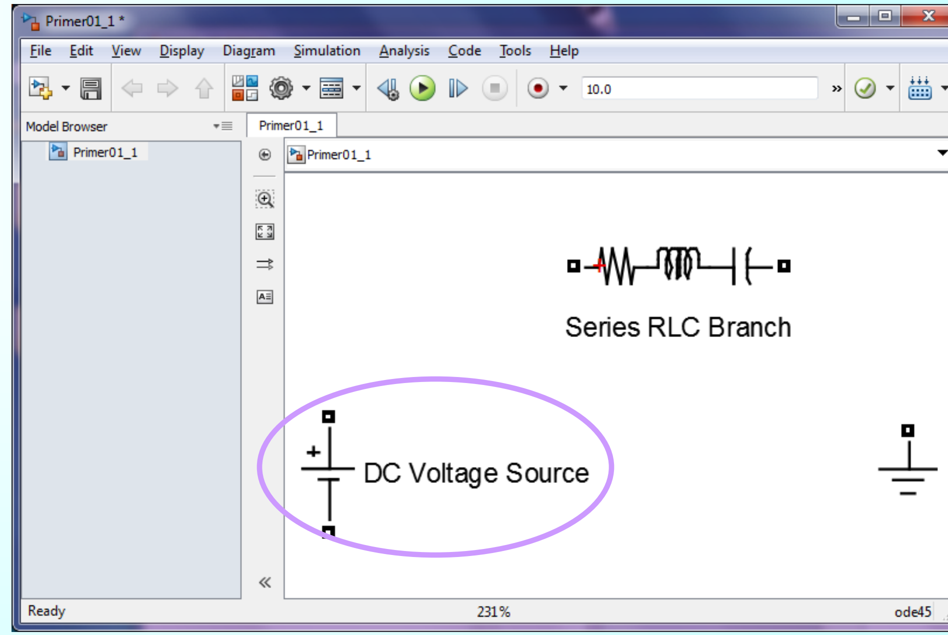


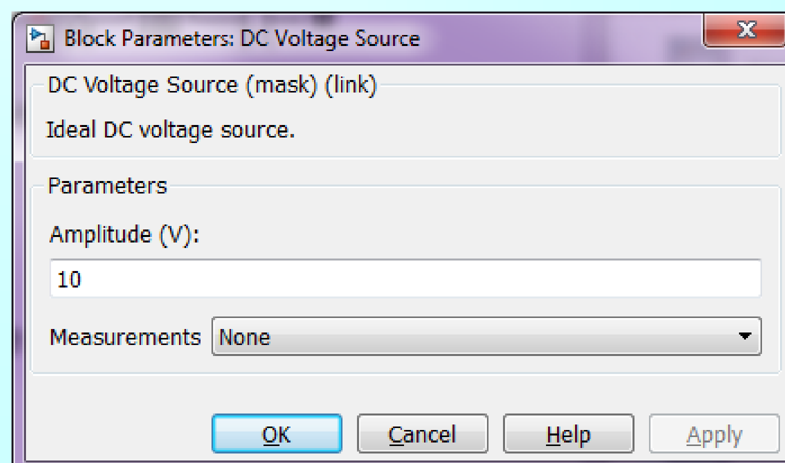
$R = 1\,\mathrm{k\Omega}$

$C = 1\,\mu\mathrm{F}$

$u_g(t) = U\,h(t), U = 10\ \mathrm{V}$

$u(t_0^-) = U_0 = -10\ \mathrm{V}$

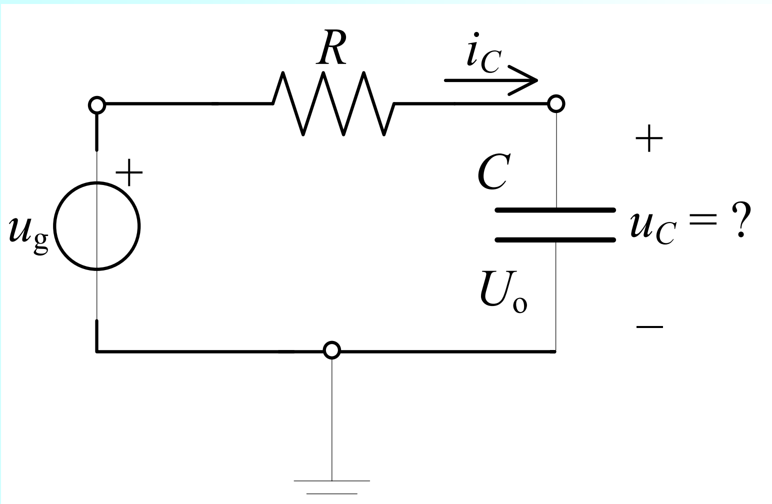




MATLAB: Simscape Power Systems

Подешавање параметара ел. кола

коло је образовано у тренутку $t_0 = 0$

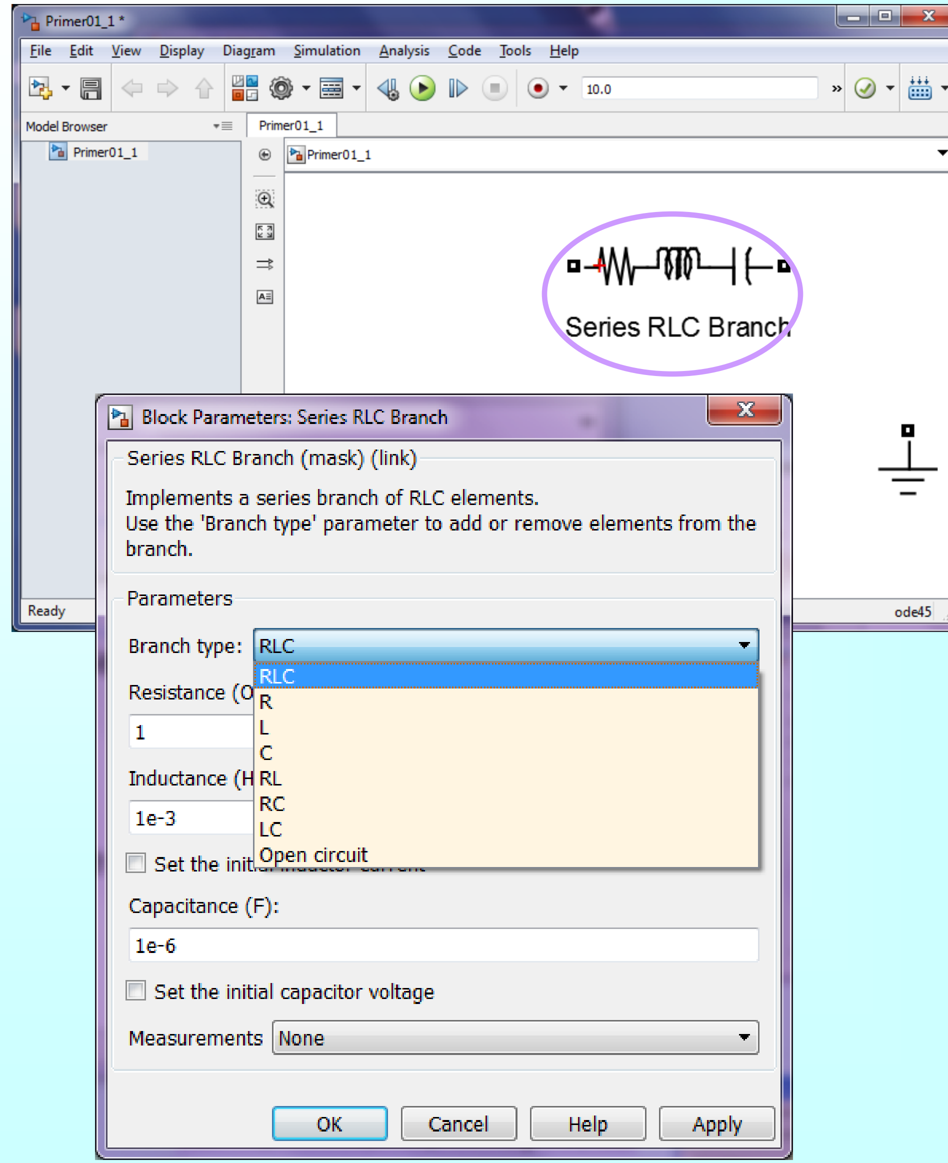


$R = 1\,\mathrm{k}\Omega$

$C = 1\,\mu\mathrm{F}$

$u_g(t) = U\,h(t), U = 10\ \mathrm{V}$

$u(t_0^-) = U_0 = -10\ \mathrm{V}$



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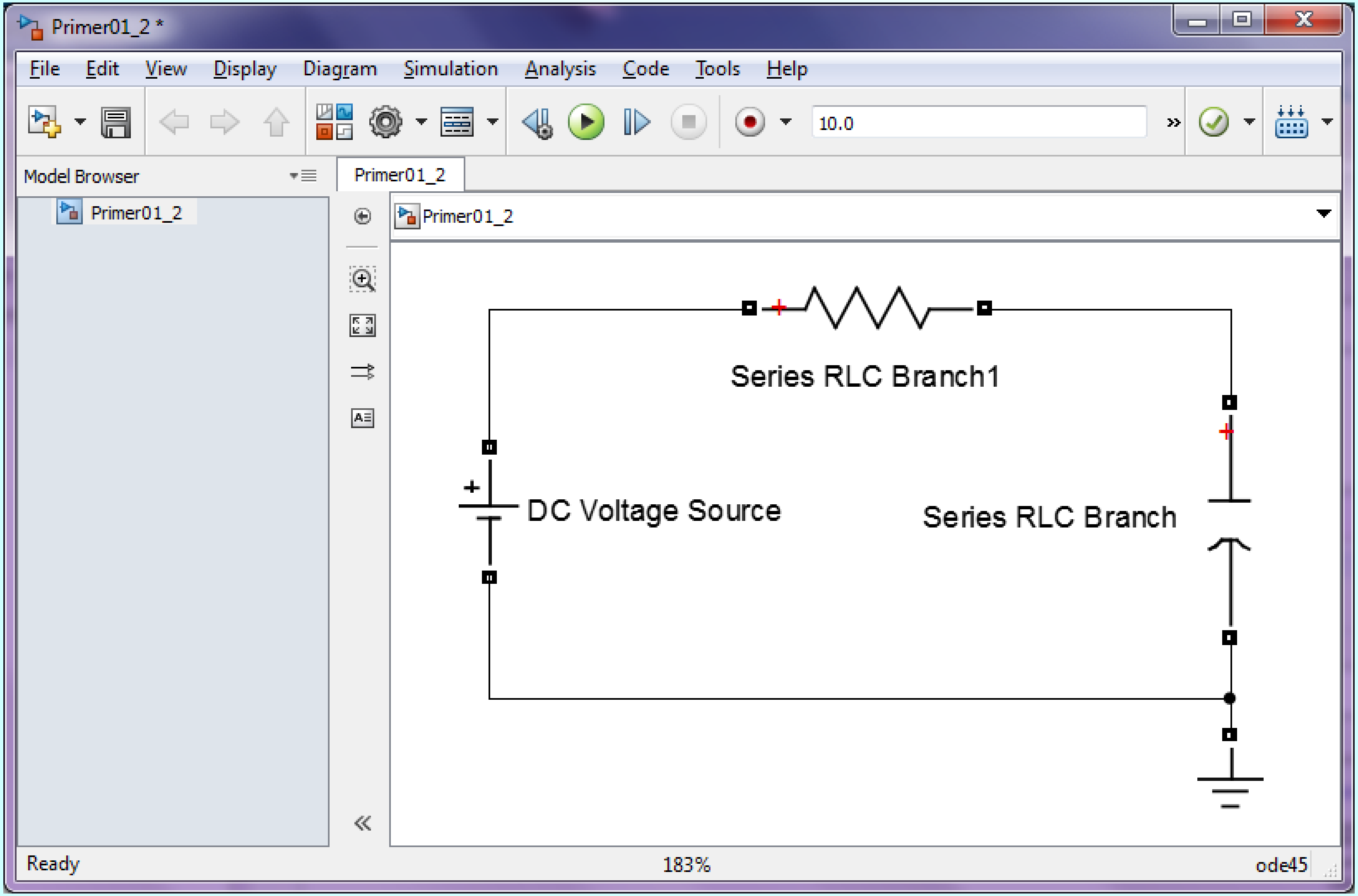
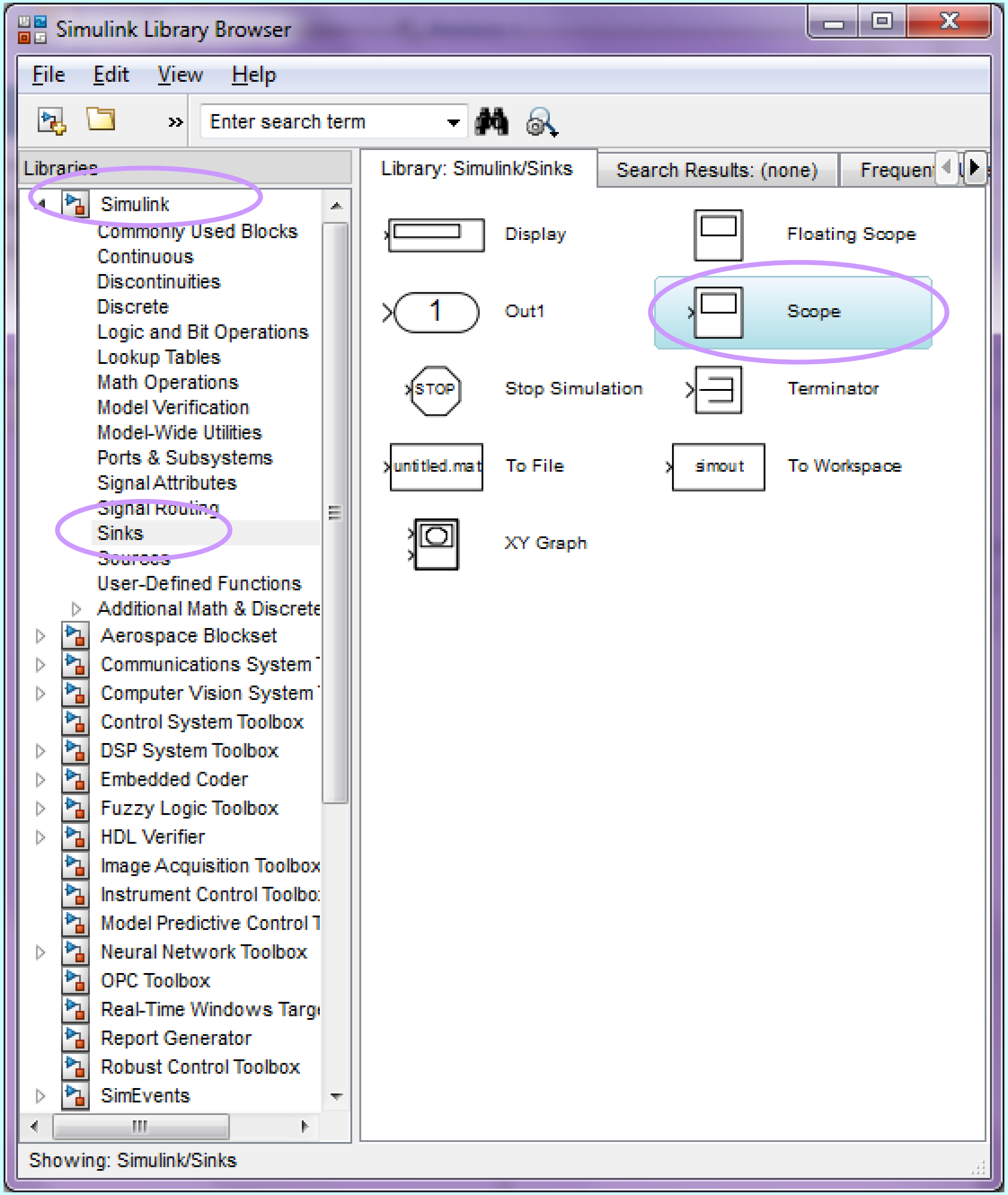
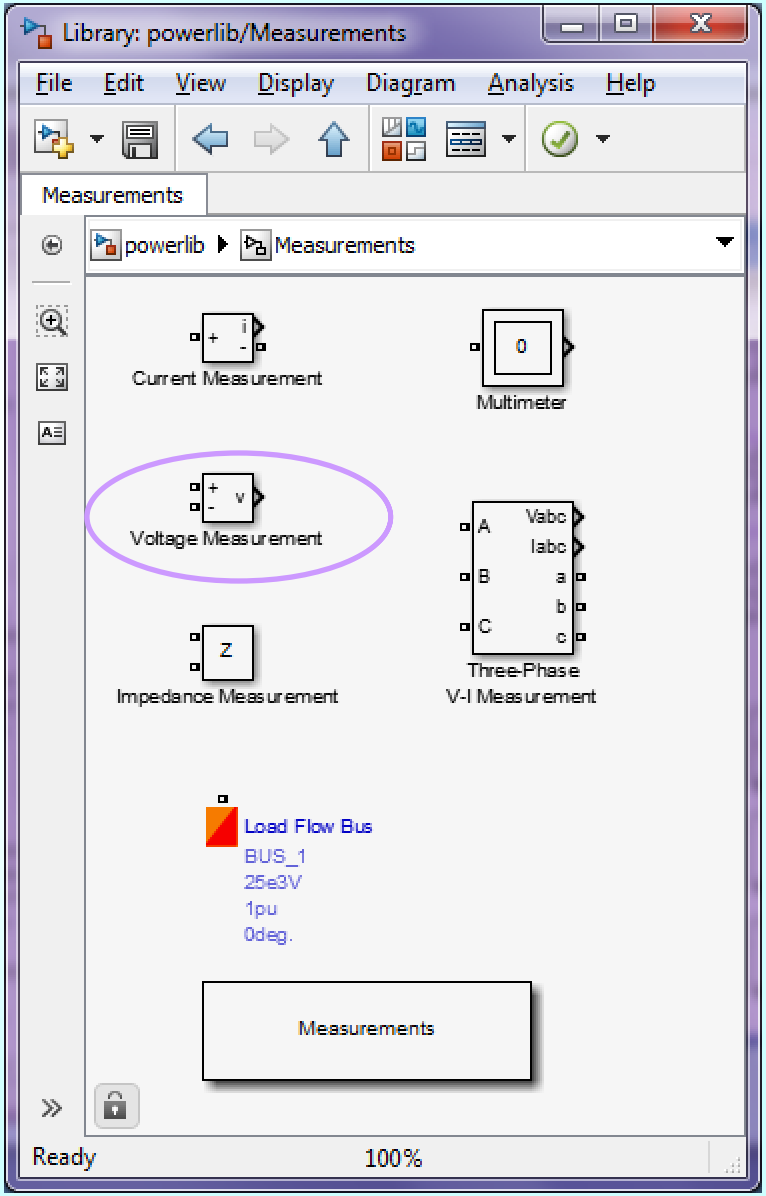


MATLAB: Simscape
Power Systems

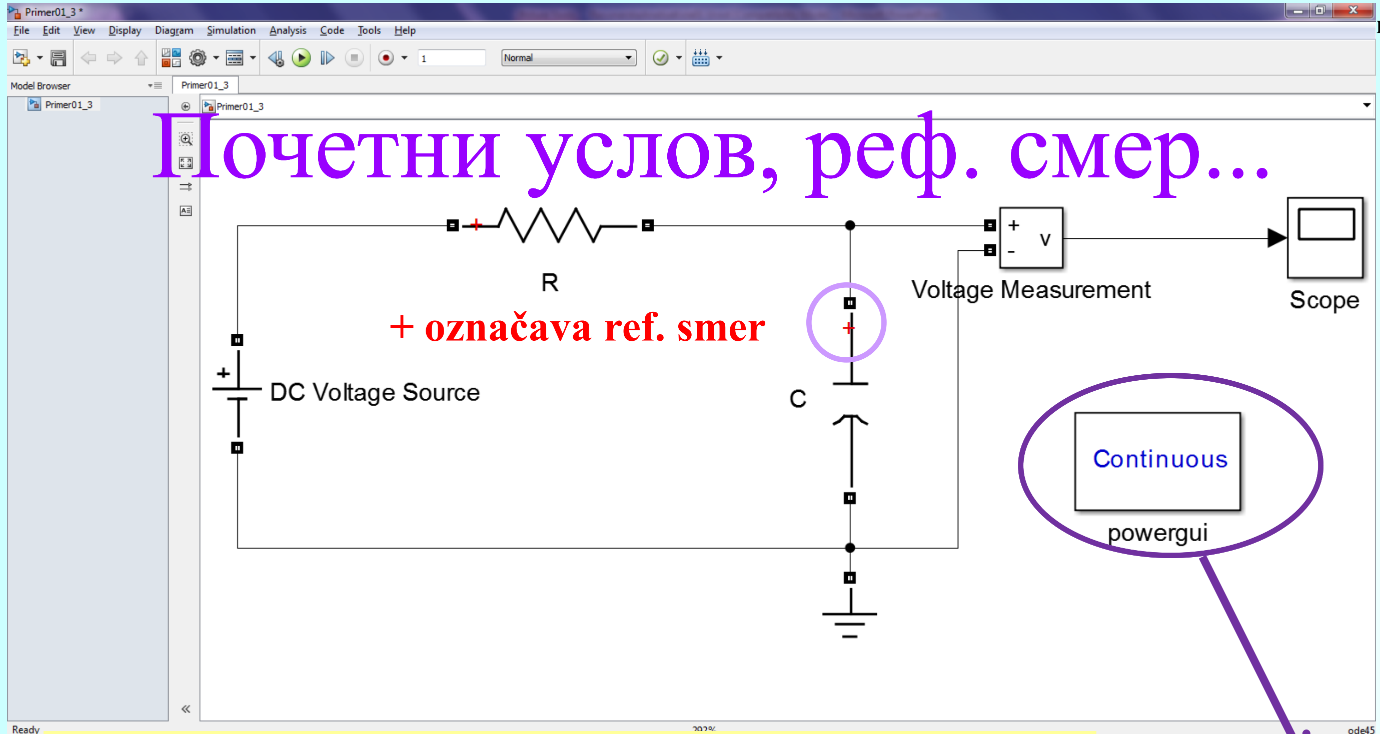
Како се мери напон???

MATLAB: Simscape Power Systems





Почетни услов, реф. смер...



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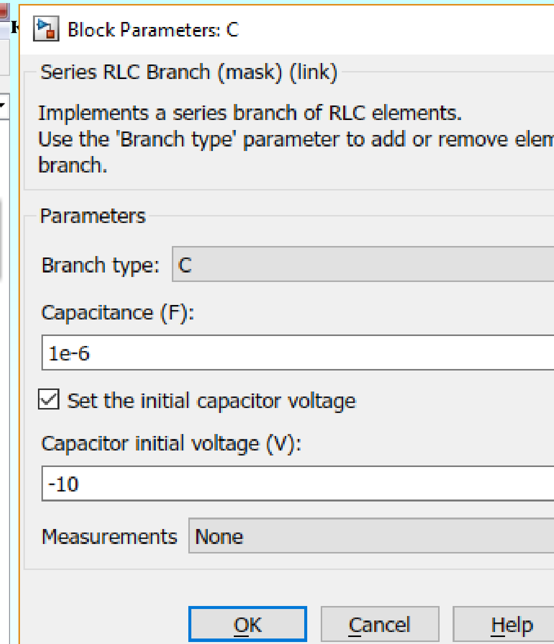

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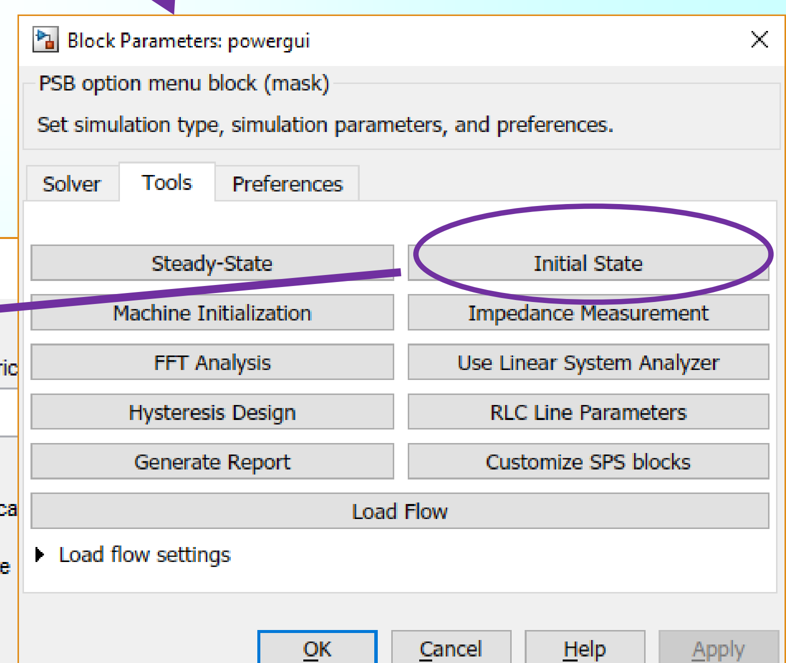
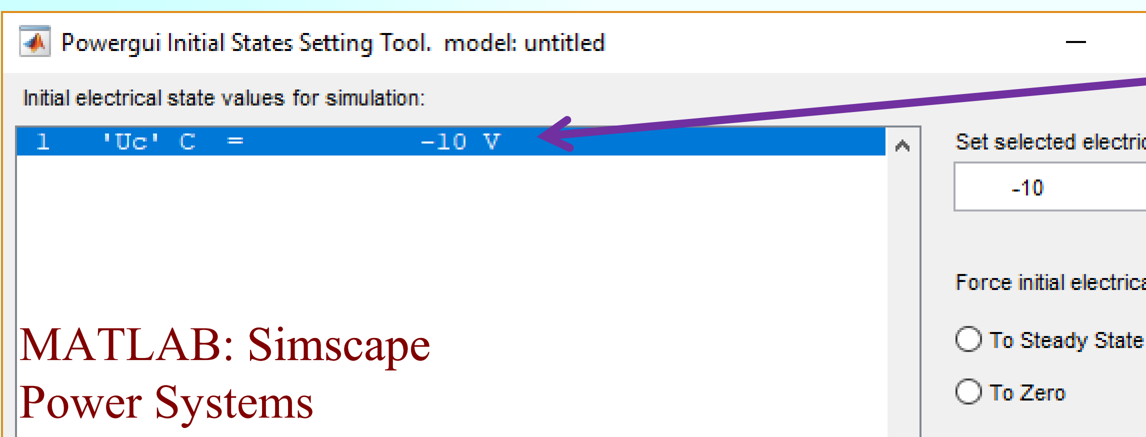
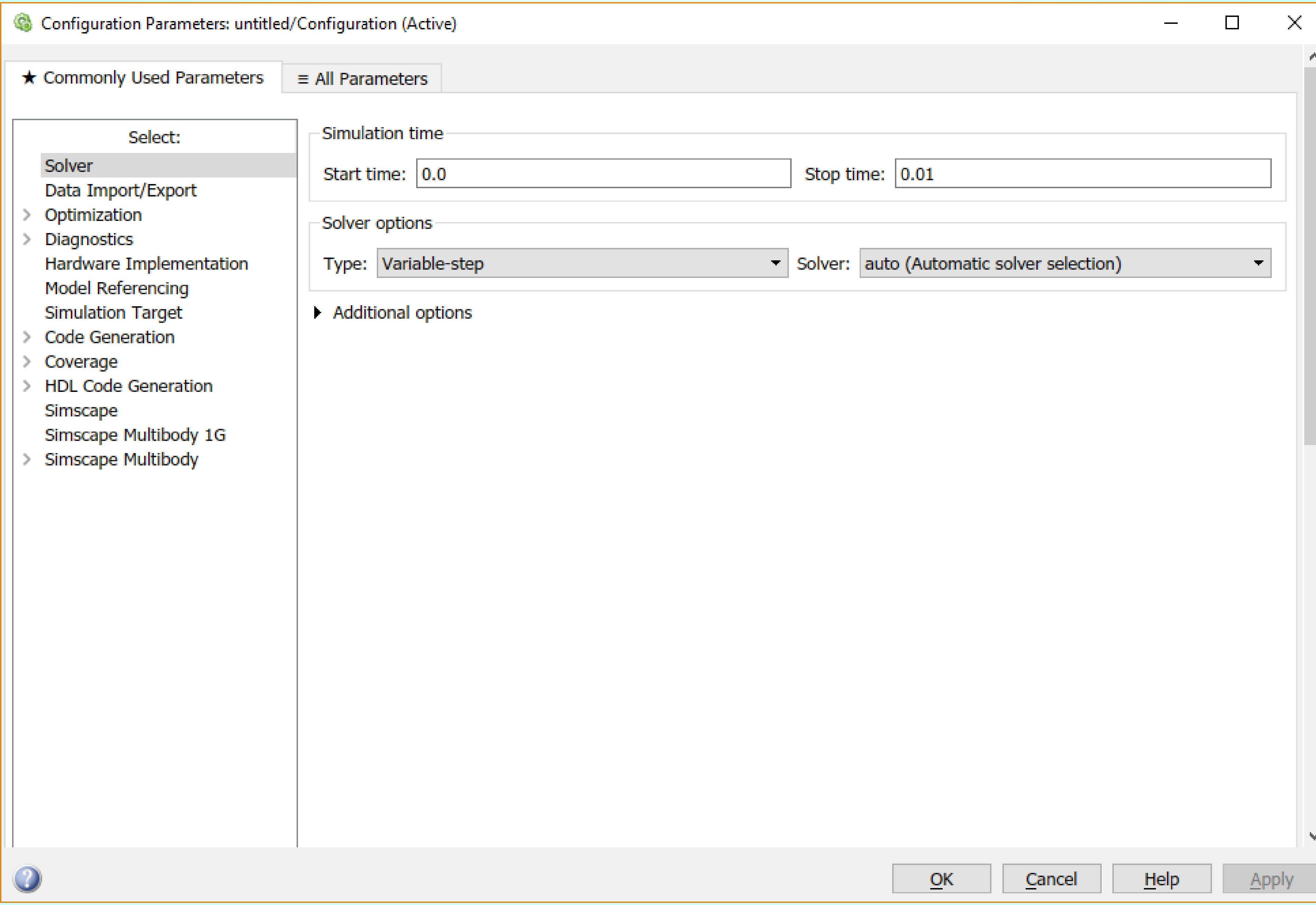




MATLAB: Simscape Power Systems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Commonly Used Parameters
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Hardware Implementation
Model Referencing
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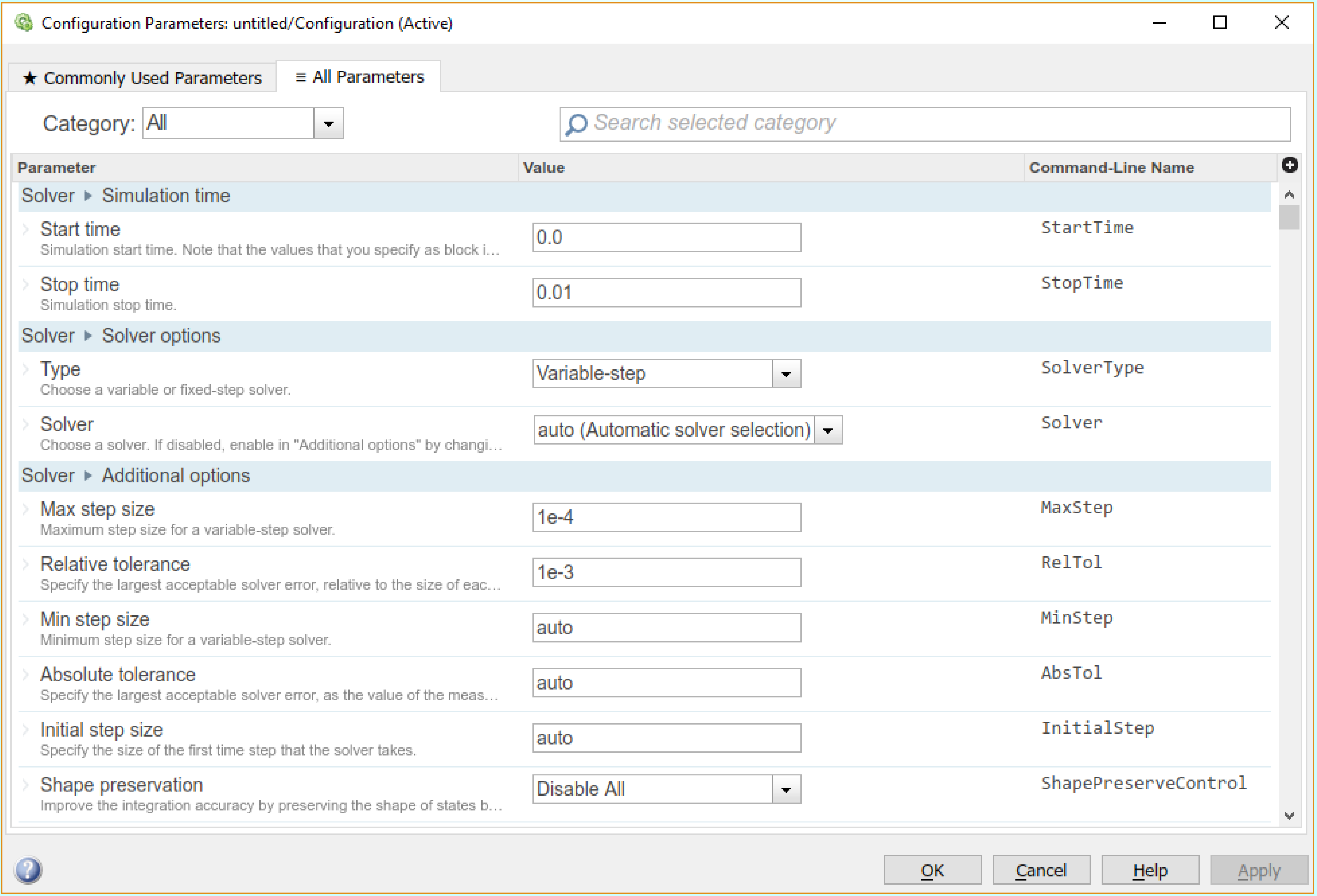
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MaxStep
Relative tolerance
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1e-3
RelTol
Min step size
Minimum step size for a variable-step solver.
auto
MinStep
Absolute tolerance
Specify the largest acceptable solver error, as the value of the meas…
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AbsTol
Initial step size
Specify the size of the first time step that the solver takes.
auto
InitialStep
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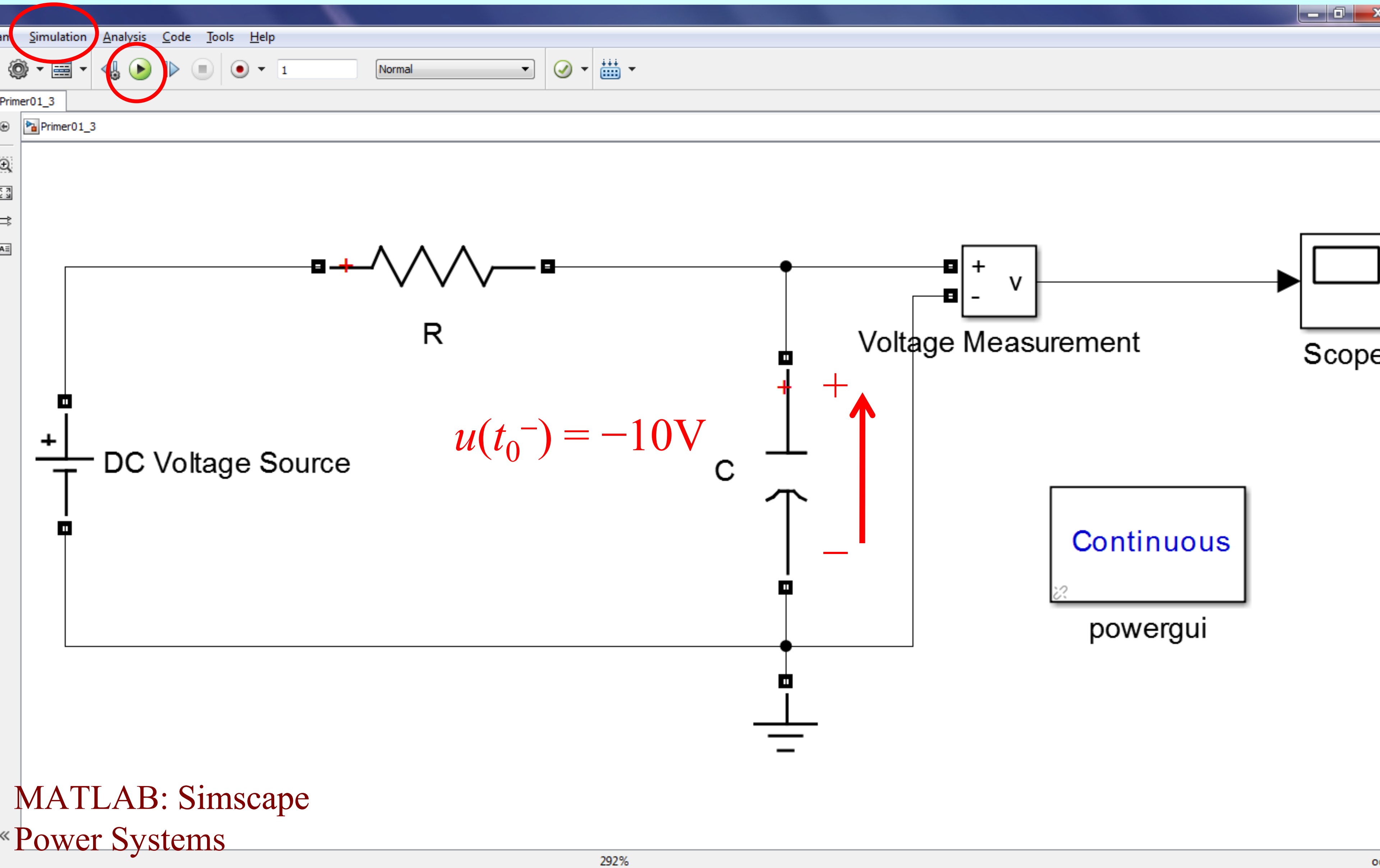
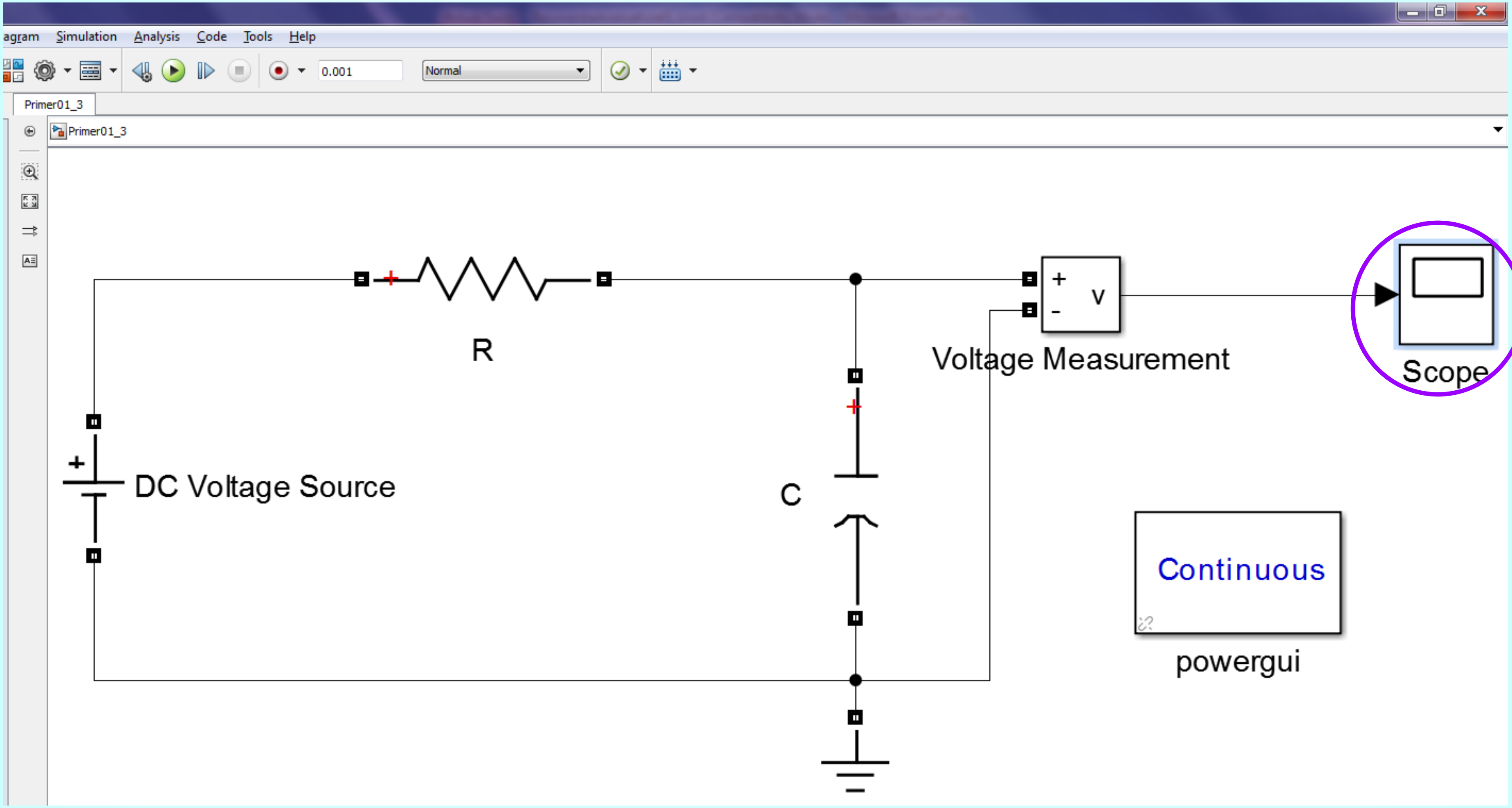
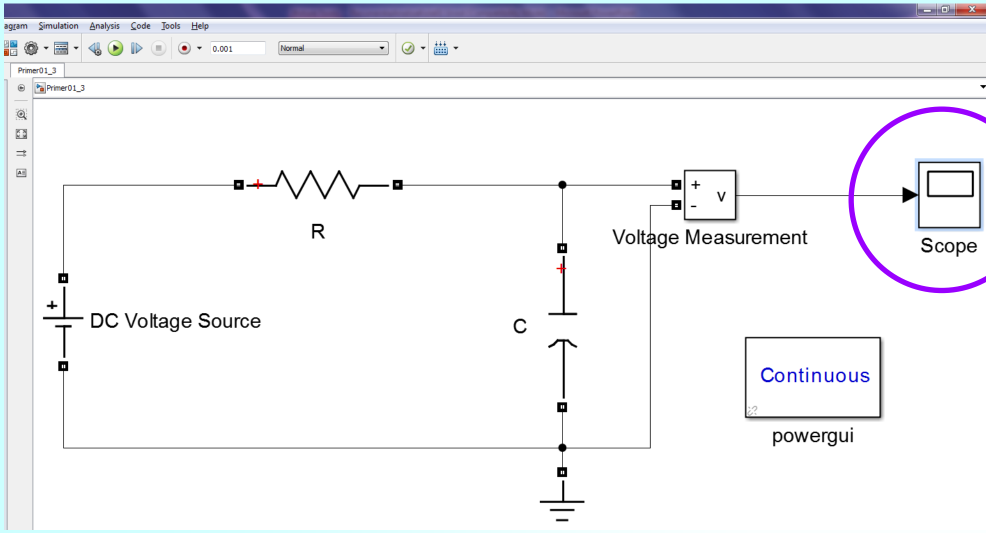


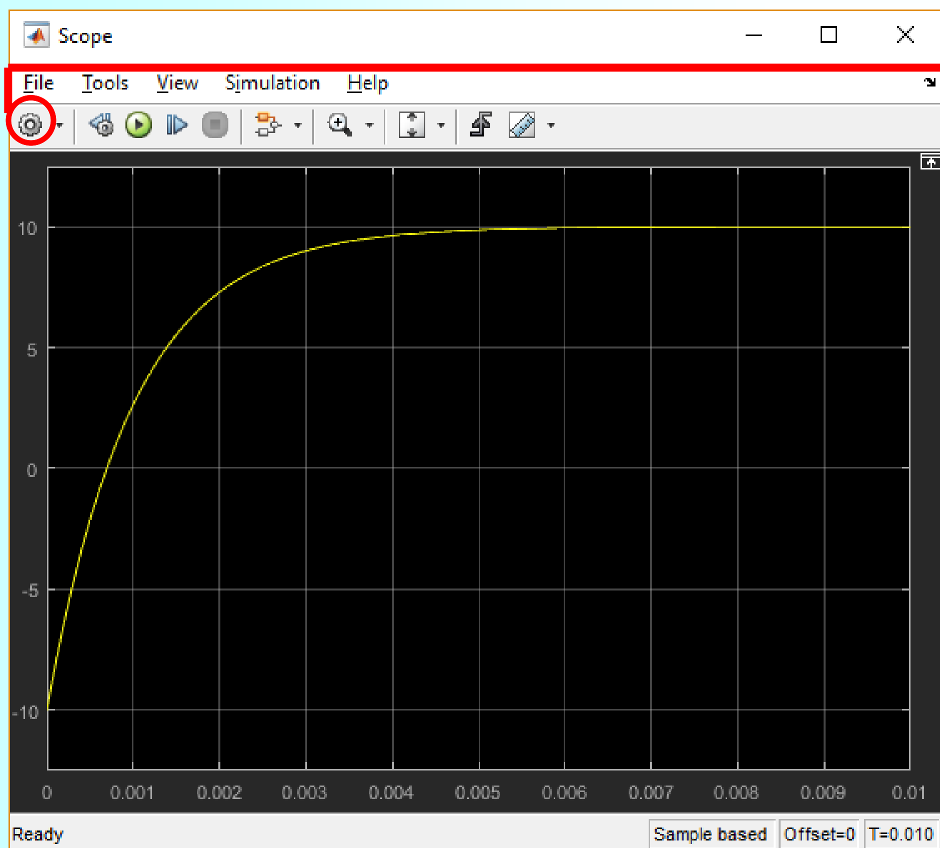
MATLAB: Simscape Power Systems

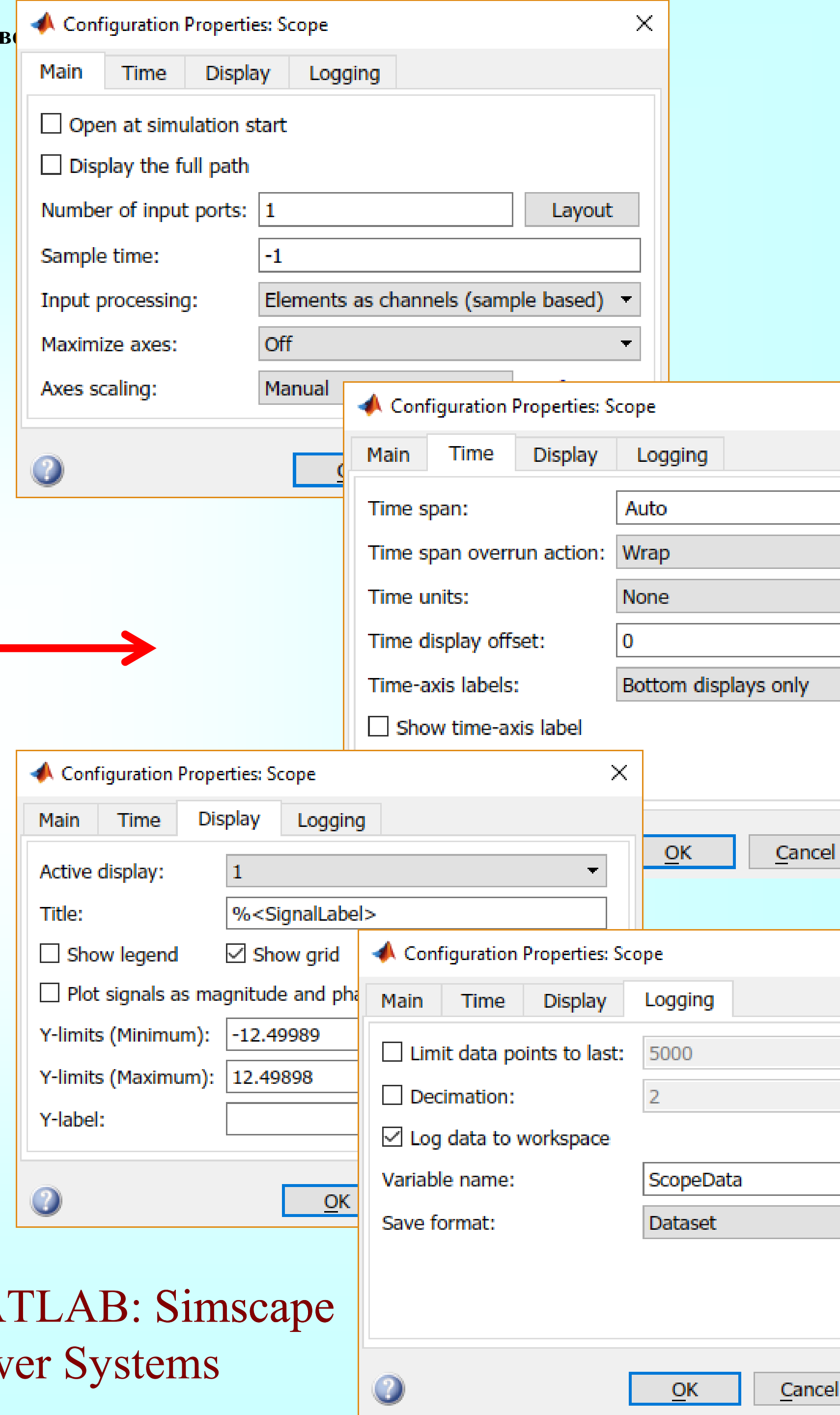
Налажење одзива... Осцилоскоп



MATLAB: Simscape
Power Systems







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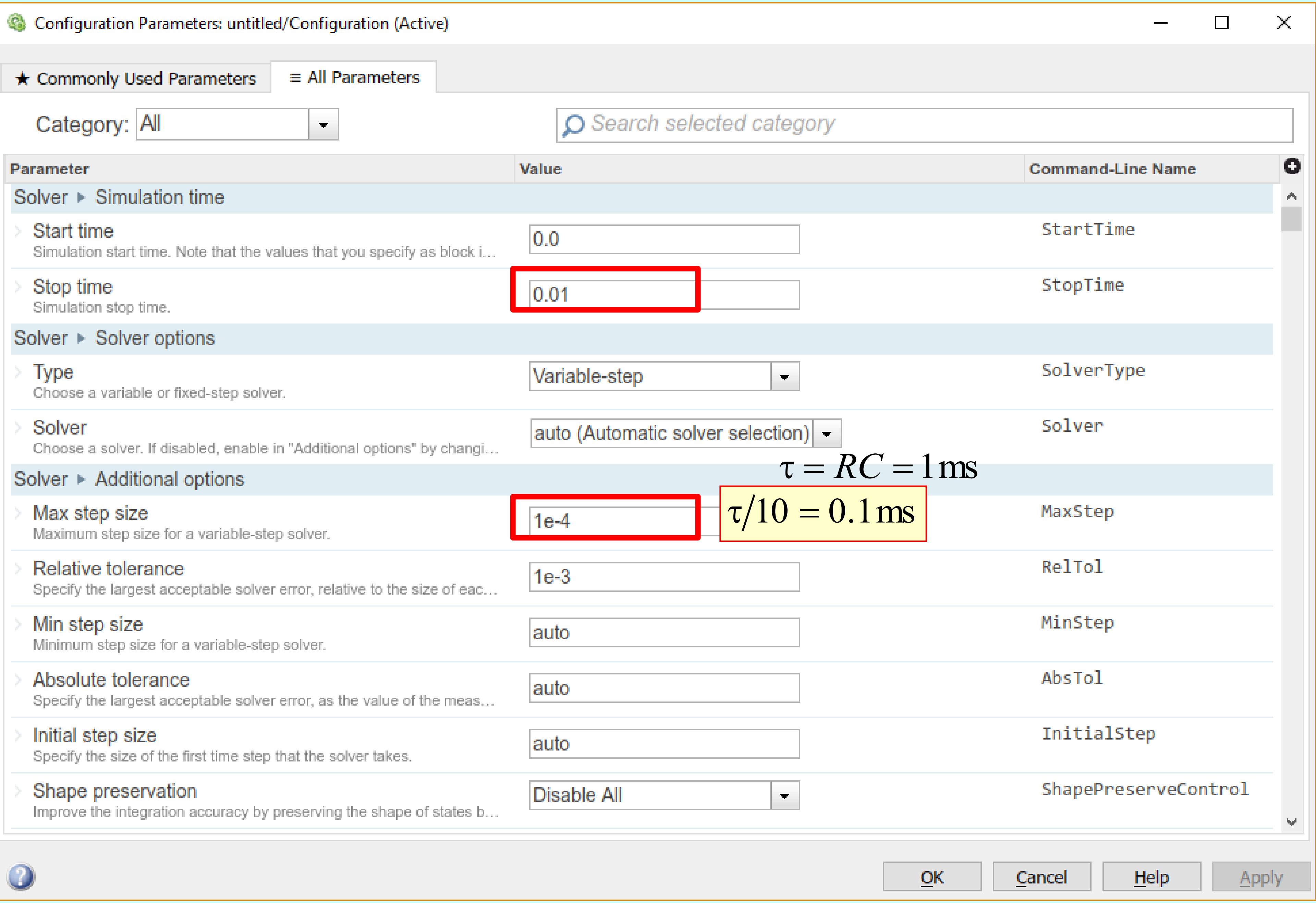
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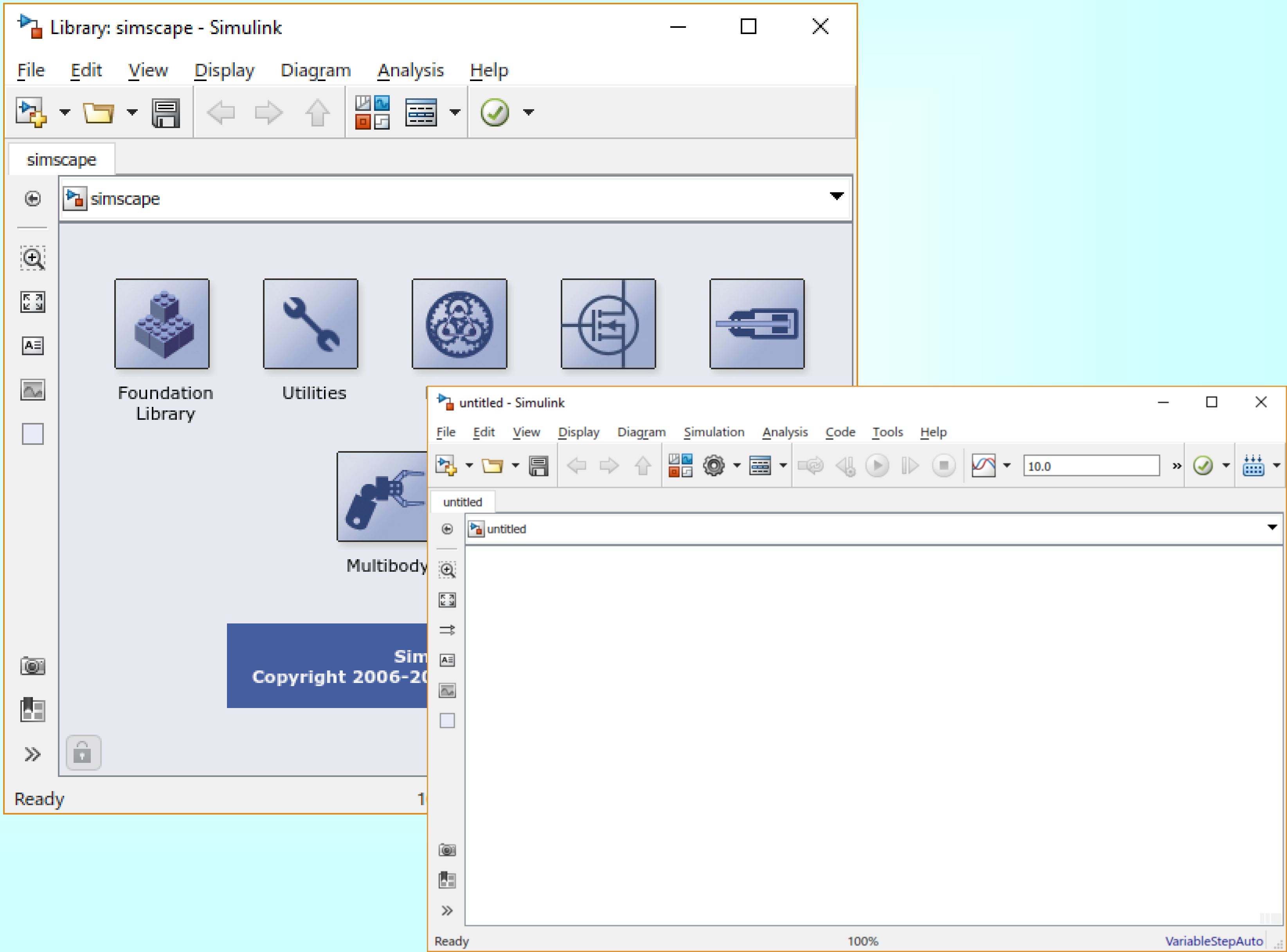
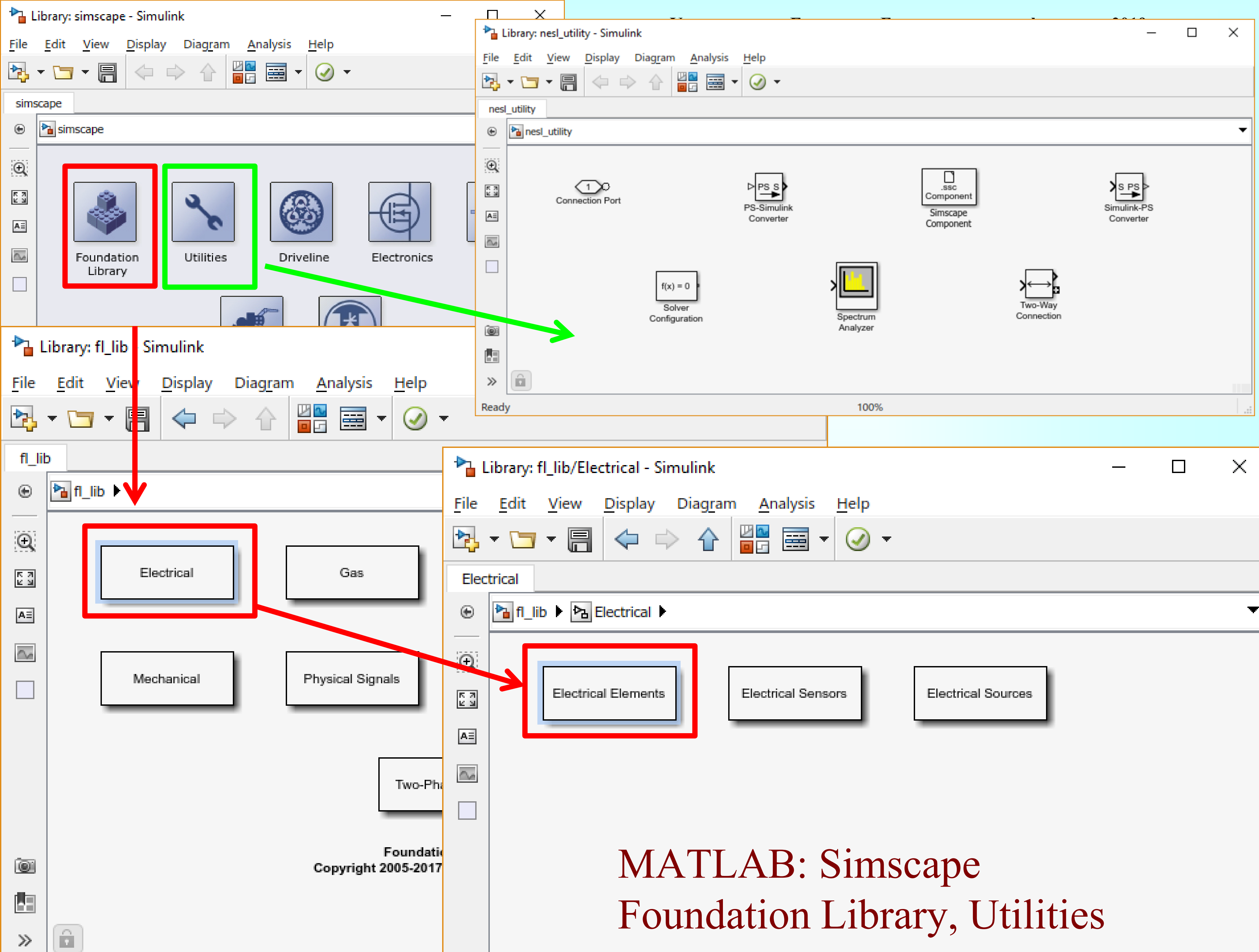
Stop time
Simulation stop time.
0.01
StopTime
Solver ▸ Solver options
Type
Choose a variable or fixed-step solver.
Variable-step
SolverType
Solver
Choose a solver. If disabled, enable in "Additional options" by changi...
auto (Automatic solver selection)
Solver
Solver ▸ Additional options
Max step size
Maximum step size for a variable-step solver.
1e-4
MaxStep
τ = RC = 1 ms
τ/10 = 0.1 ms
Relative tolerance
Specify the largest acceptable solver error, relative to the size of eac...
1e-3
RelTol
Min step size
Minimum step size for a variable-step solver.
auto
MinStep
Absolute tolerance
Specify the largest acceptable solver error, as the value of the meas...
auto
AbsTol
Initial step size
Specify the size of the first time step that the solver takes.
auto
InitialStep
Shape preservation
Improve the integration accuracy by preserving the shape of states b...
Disable All
ShapePreserveControl
OK
Cancel
Help
Apply

Simscape – Foundation Library, Utilities

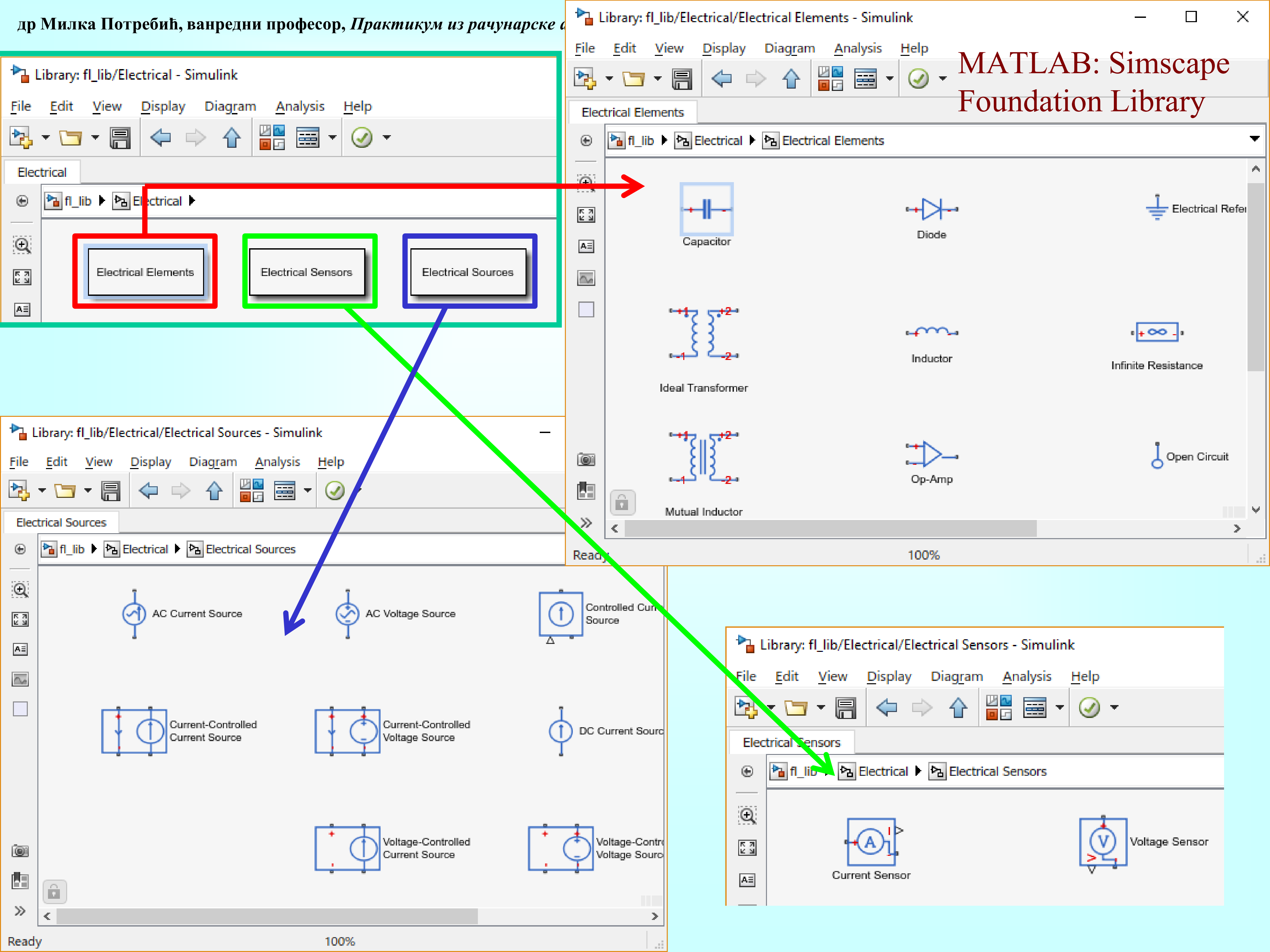
simscape



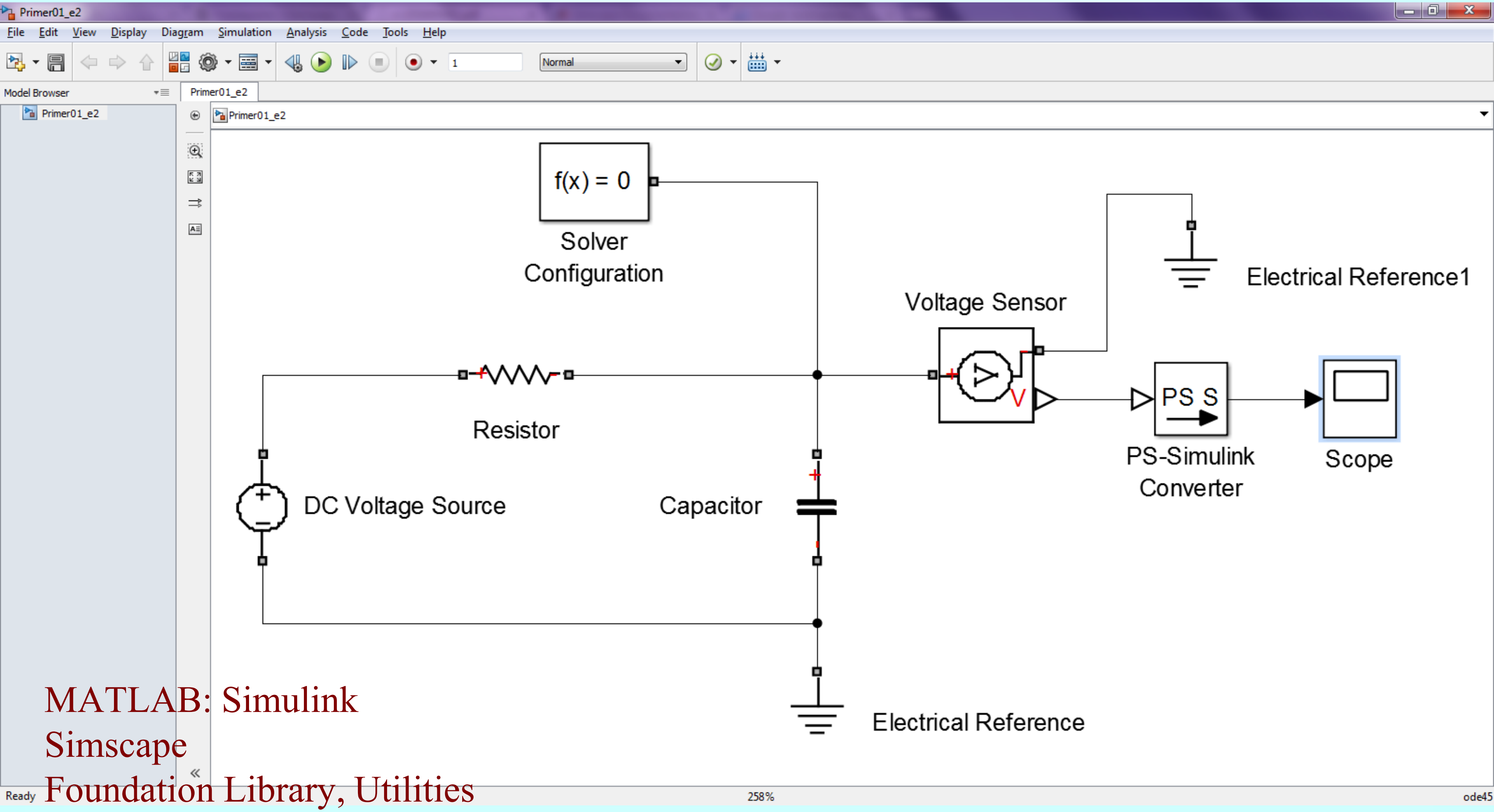


MATLAB: Simscape Foundation Library, Utilities

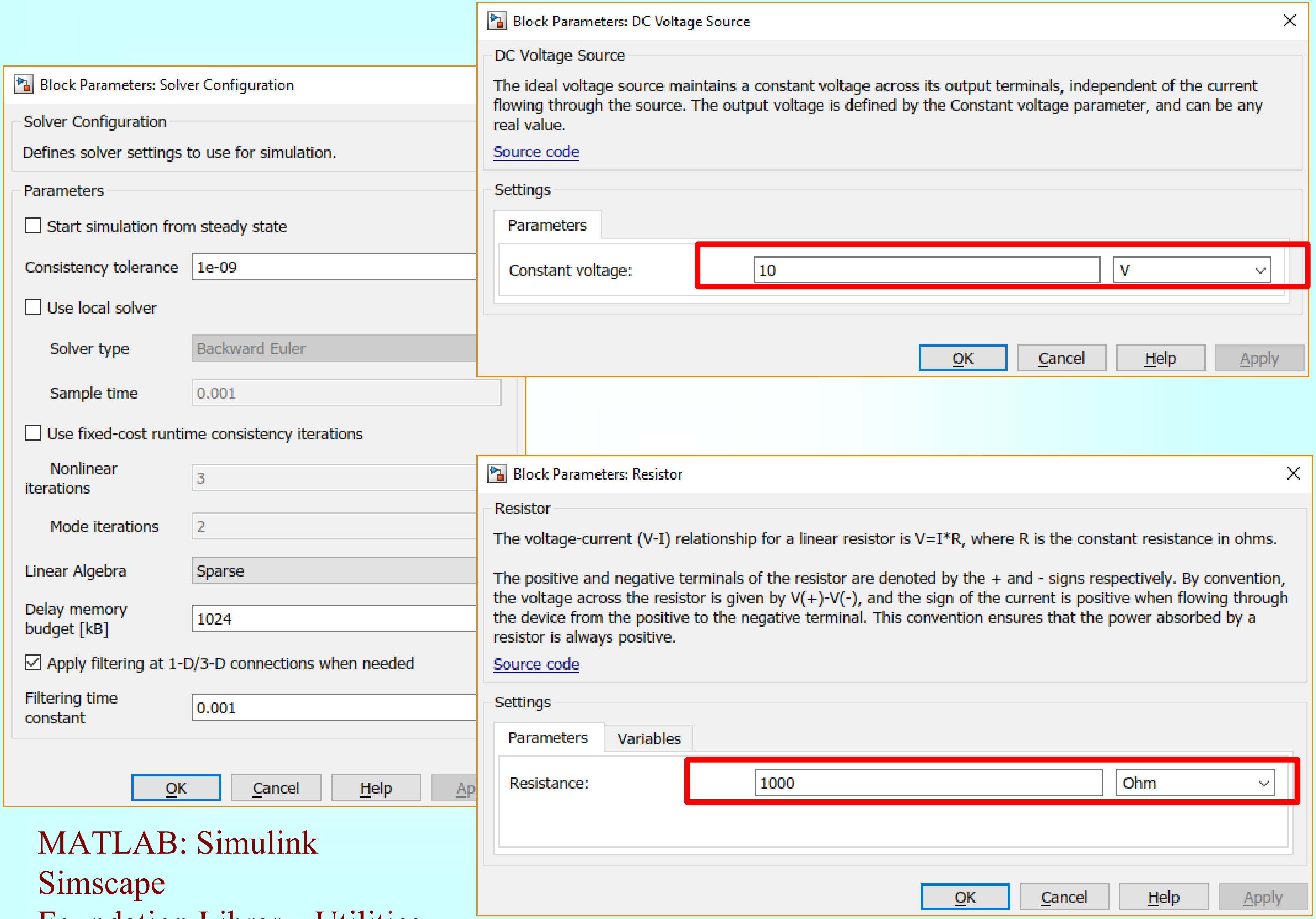
MATLAB: Simscape Foundation Library



Анализа електричног кола

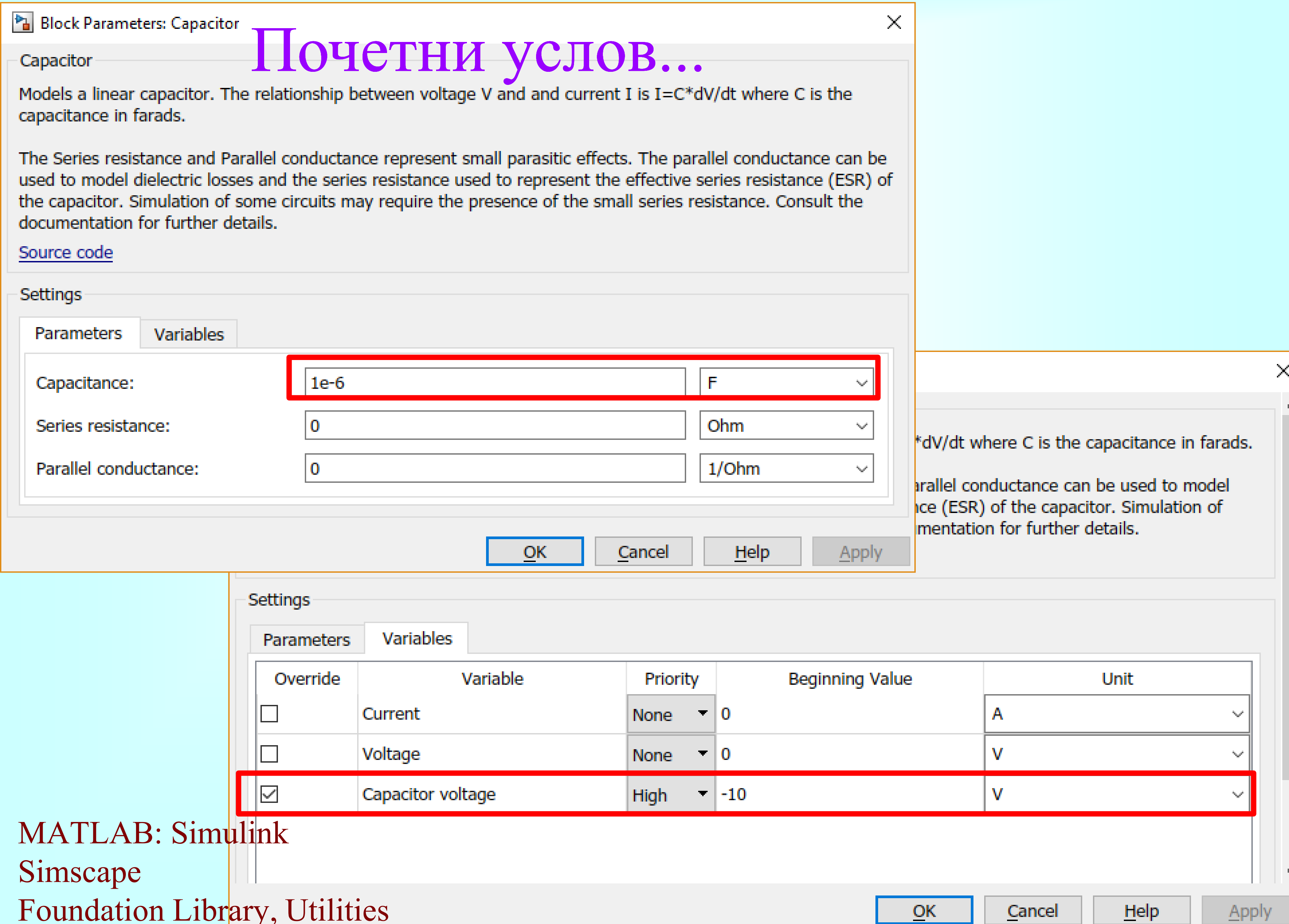


MATLAB: Simulink
Simscape
Foundation Library, Utilities



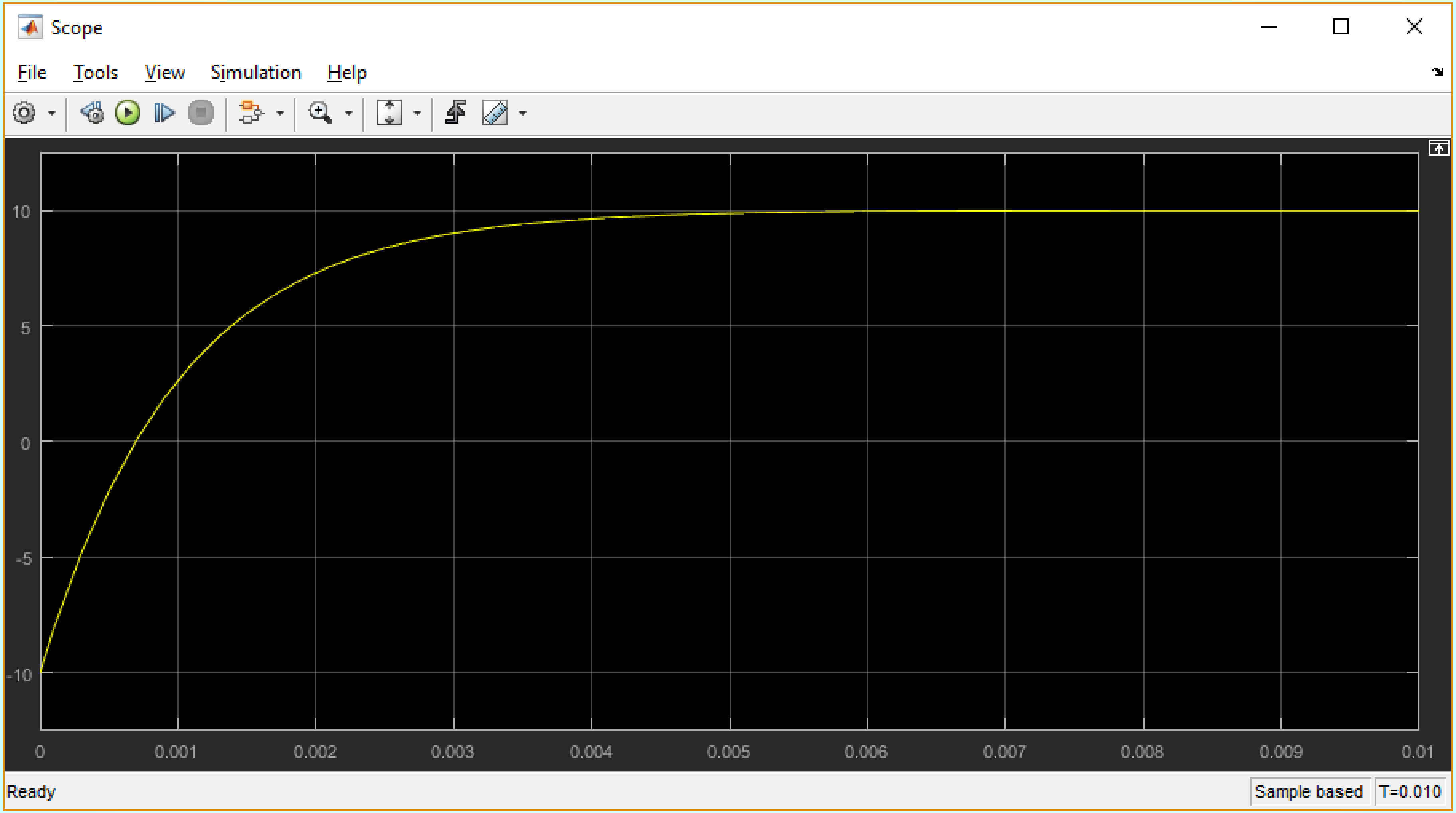
MATLAB: Simulink
Simscape
Foundation Library, Utilities

Почетни услов...



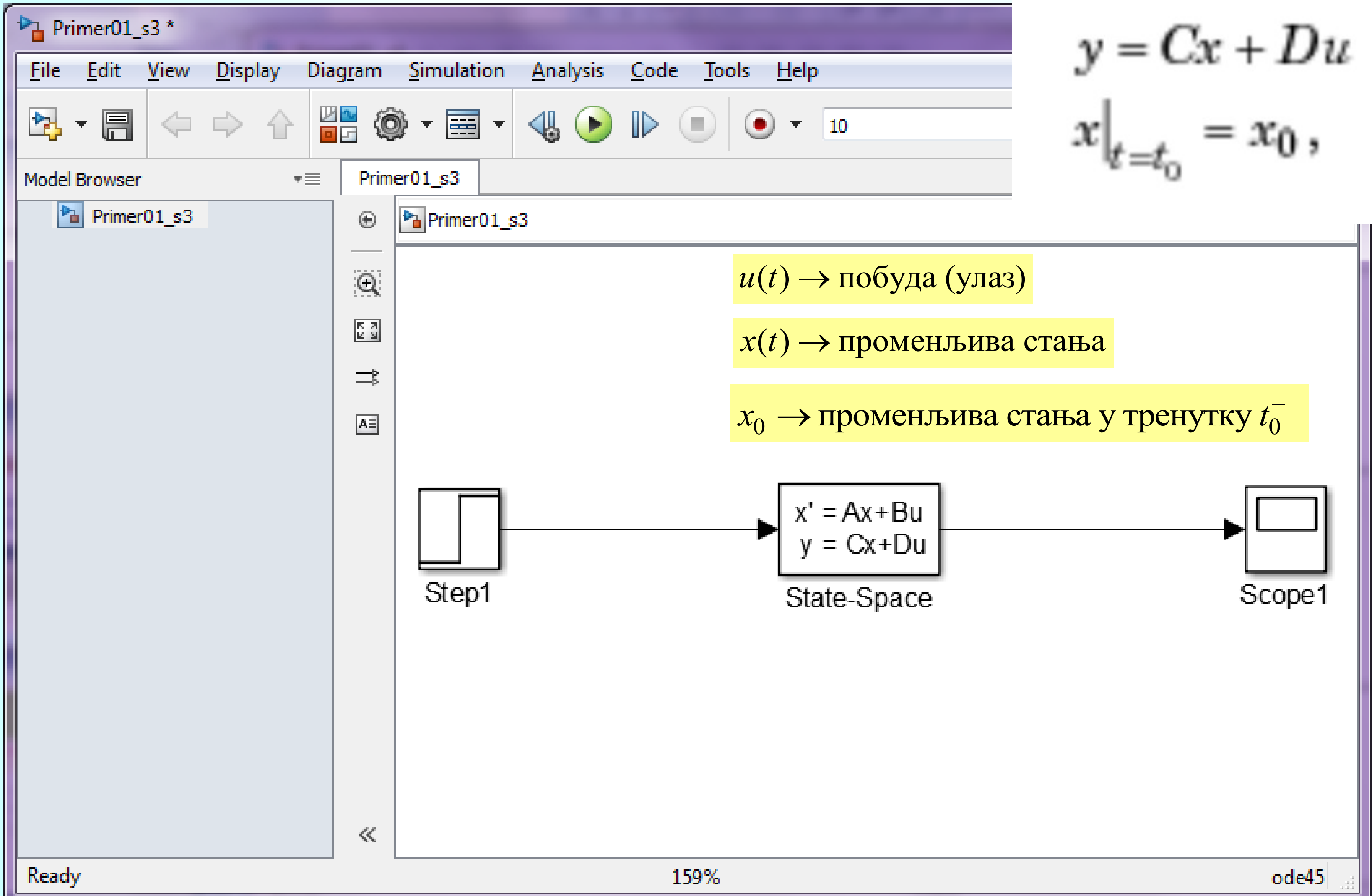
MATLAB: Simulink
Simscape
Foundation Library, Utilities

Налажење одзива...



Simulink

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$
$$x\big|_{t=t_0} = x_0\,,$$



$u(t) \rightarrow$ побуда (улаз)

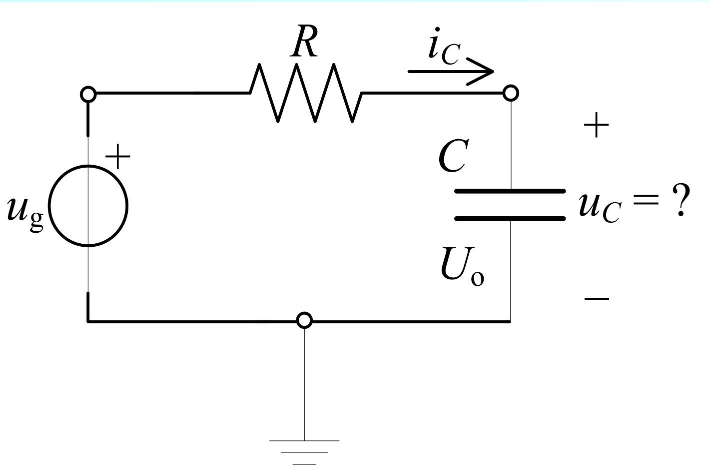
$x(t) \rightarrow$ променљива стања

$x_0 \rightarrow$ променљива стања у тренутку t_0^-

коло је образовано у тренутку $t_0 = 0$

Simulink

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$
$$x\big|_{t=t_0} = x_0 \,,$$



$u = u_g(t) \rightarrow$ побуда (улаз)

$x = u_C(t) \rightarrow$ напон кондензатора (променљива стања и одзив - излаз)

$x(t_0^-) = U_0 \rightarrow$ напон кондензатора у тренутку t_0^-

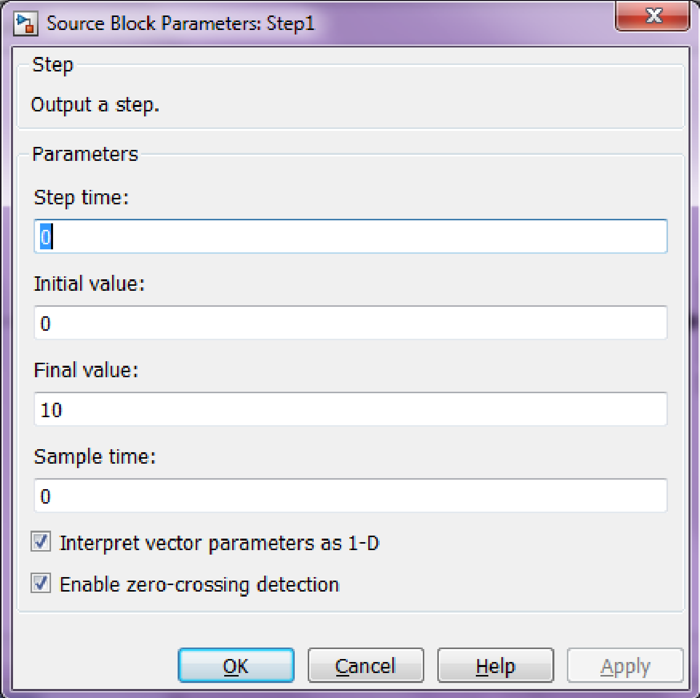
$$u_g(t) = Ri_C + u_C(t)$$
$$i_C = C\frac{du_C}{dt}$$
$$u_C(t_0^-) = U_0 = -10 \text{ V}$$

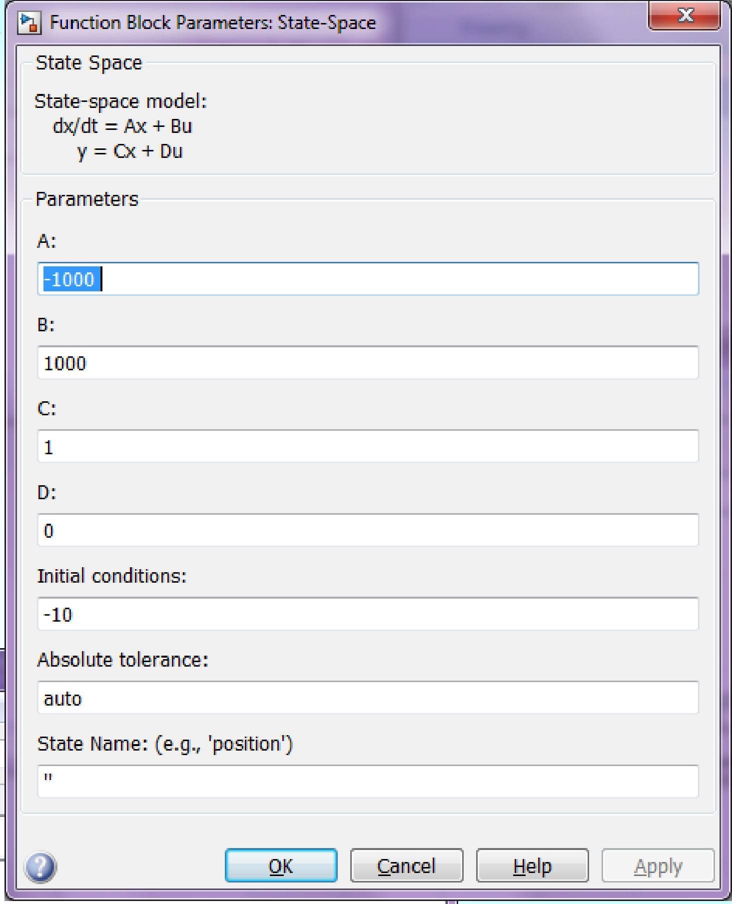
$$R = 1\,\text{k}\Omega$$
$$C = 1\,\mu\text{F}$$
$$u_g(t) = U\,h(t), U = 10 \text{ V}$$
$$u_C(t_0^-) = U_0 = -10 \text{ V}$$

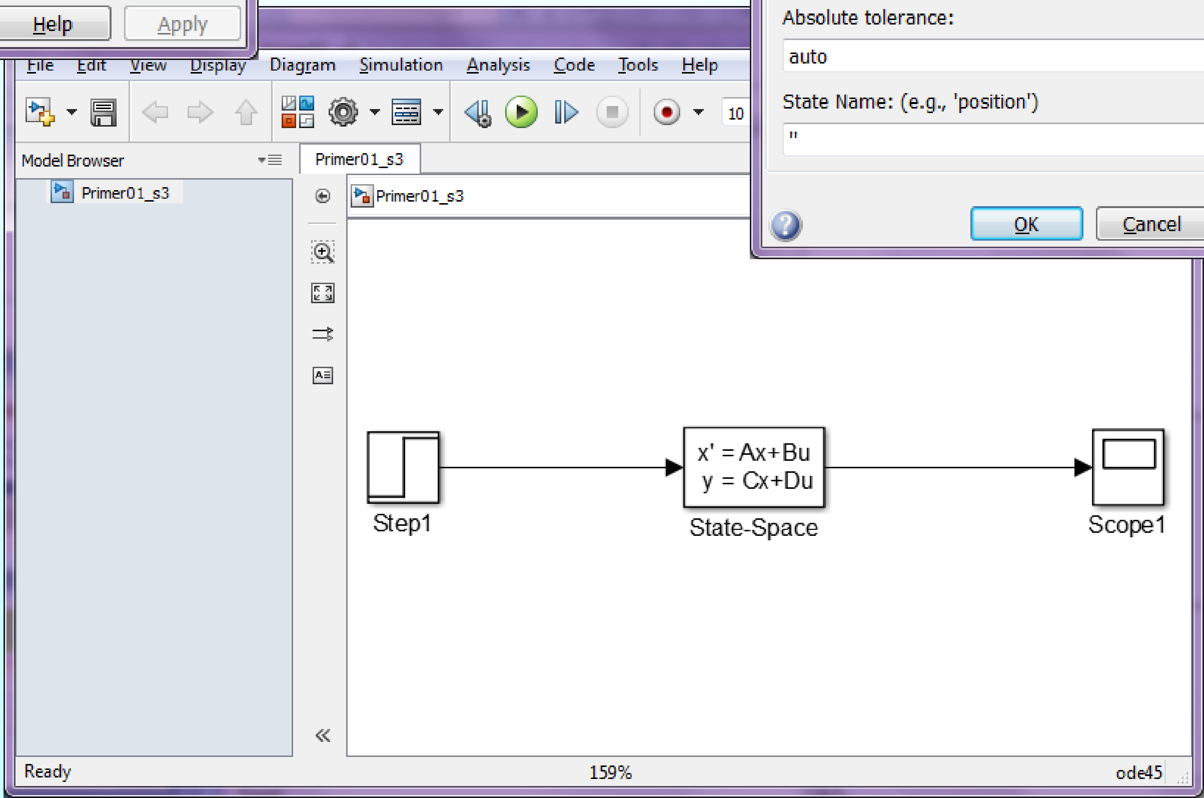
$$\frac{du_C(t)}{dt} = \frac{i_C}{C} = \frac{u_g(t) - u_C(t)}{RC} = -\frac{u_C(t)}{RC} + \frac{u_g(t)}{RC}$$
$$u_C(t_0^-) = U_0 = -10 \text{ V}$$

$$\frac{du_C(t)}{dt} = Au_C(t) + Bu_g(t) \Rightarrow A = -\frac{1}{RC} = -1000 \,, B = 1000$$
$$u_C(t) = Cu_C(t) \Rightarrow C = 1, D = 0$$
$$u_C(t_0^-) = U_0 = -10 \text{ V}$$

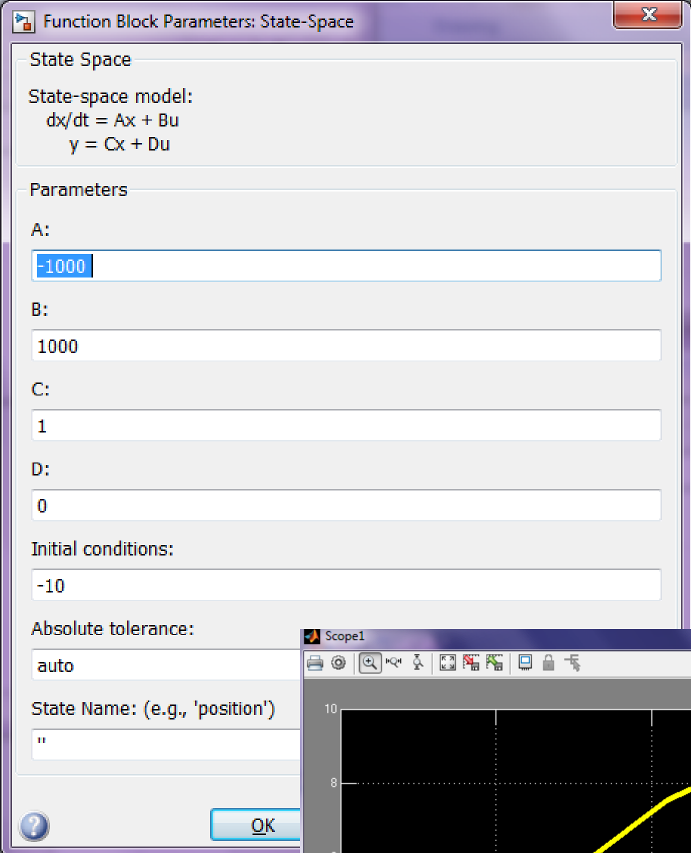
Simulink

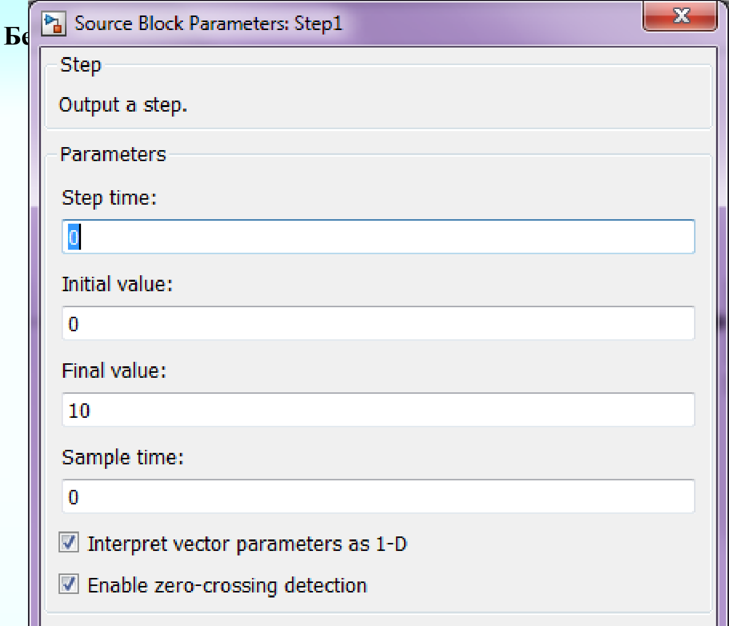

Source Block Parameters: Step1
Step
Output a step.
Parameters
Step time:
0
Initial value:
0
Final value:
10
Sample time:
0
Interpret vector parameters as 1-D
Enable zero-crossing detection
OK
Cancel
Help
Apply

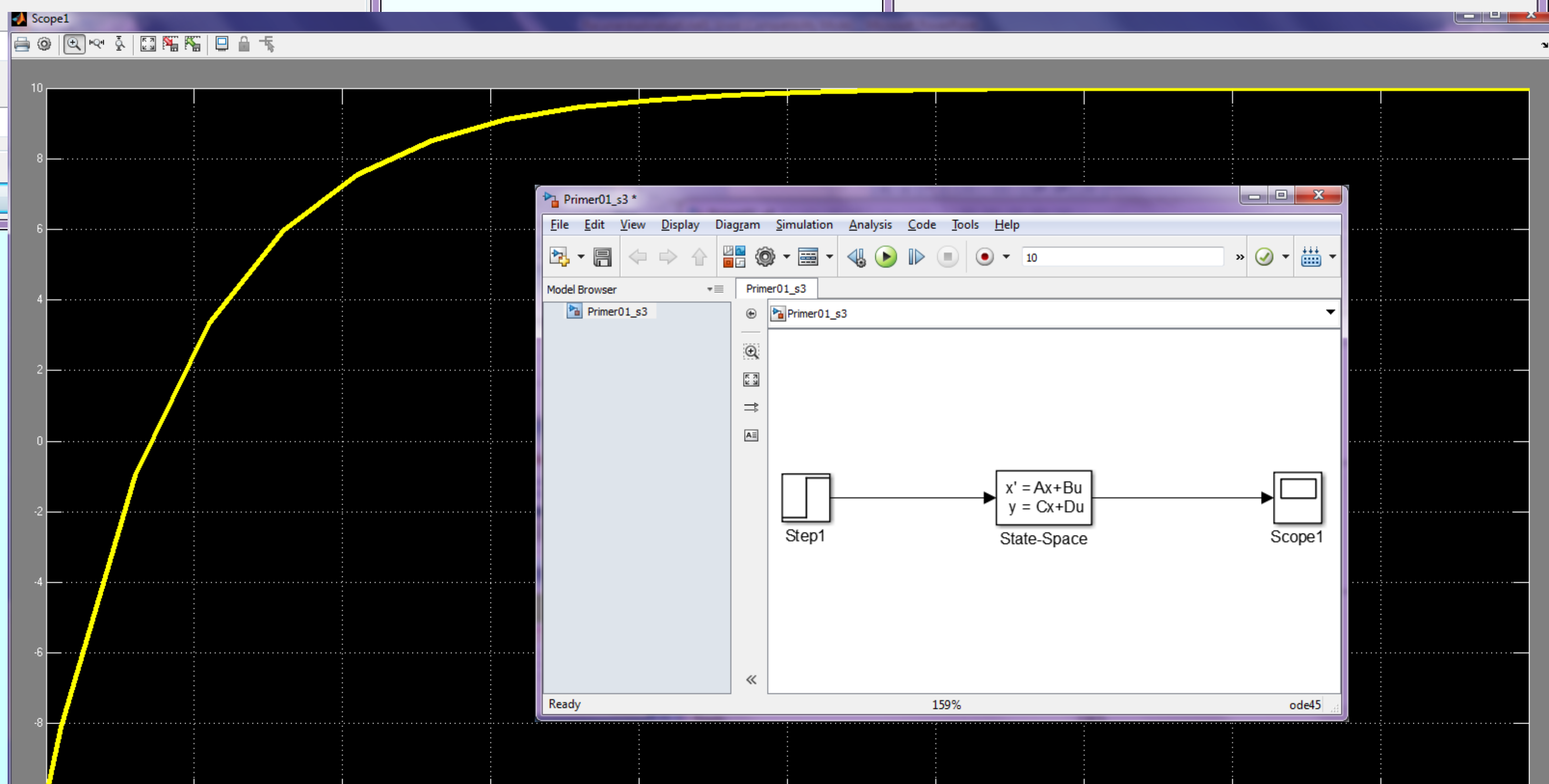

Function Block Parameters: State-Space
State Space
State-space model:
dx/dt = Ax + Bu
y = Cx + Du
Parameters
A:
-1000
B:
1000
C:
1
D:
0
Initial conditions:
-10
Absolute tolerance:
auto
State Name: (e.g., 'position')
''
OK
Cancel
Help
Apply


File Edit View Display Diagram Simulation Analysis Code Tools Help
10
Model Browser
Primer01_s3
Primer01_s3
Primer01_s3
x' = Ax+Bu
y = Cx+Du
Step1
State-Space
Scope1
Ready
159%
ode45

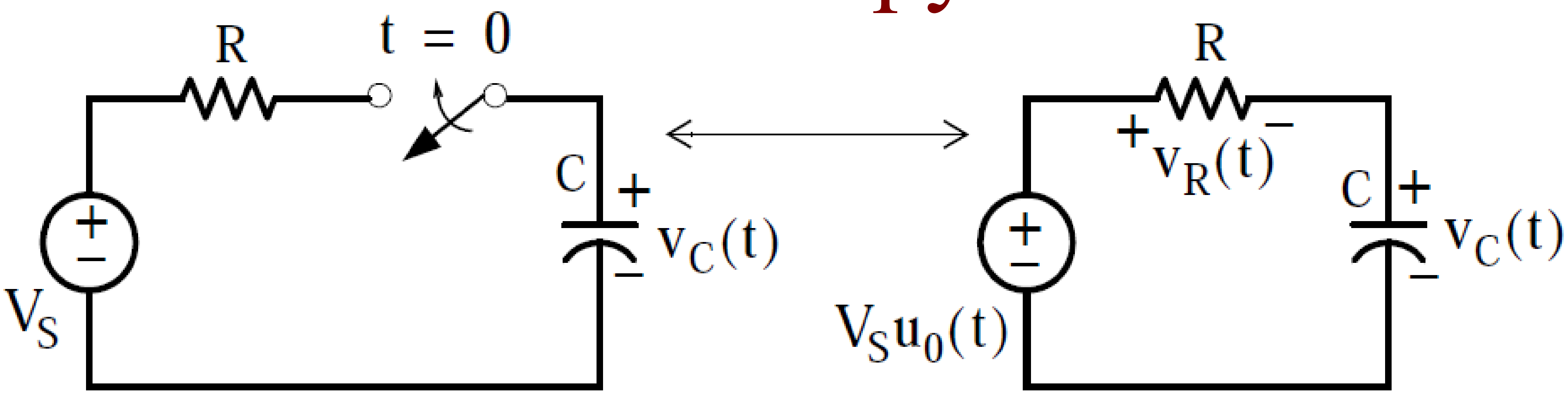
Simulink


Function Block Parameters: State-Space
State Space
State-space model:
dx/dt = Ax + Bu
y = Cx + Du
Parameters
A:
-1000
B:
1000
C:
1
D:
0
Initial conditions:
-10
Absolute tolerance:
auto
State Name: (e.g., 'position')
''
OK


Source Block Parameters: Step1
Step
Output a step.
Parameters
Step time:
0
Initial value:
0
Final value:
10
Sample time:
0
Interpret vector parameters as 1-D
Enable zero-crossing detection


Scope1
10
8
6
4
2
0
-2
-4
-6
-8
Primer01_s3 *
File Edit View Display Diagram Simulation Analysis Code Tools Help
10
Model Browser
Primer01_s3
x' = Ax+Bu
y = Cx+Du
Step1
State-Space
Scope1
Ready
159%
ode45

Решимо “ручно”



$$v_R + v_C = V_S u_0(t)$$

$$i = i_C = C\frac{dv_C}{dt}$$

$$v_R = Ri = RC\frac{dv_C}{dt}$$

$$RC\frac{dv_C}{dt} + v_C = V_S u_0(t)$$

$t > 0$

$$RC\frac{dv_C}{dt} + v_C = V_S$$

$$\boxed{v_C(t) = (V_S - V_S\, e^{-(1/RC)t})u_0(t)}$$

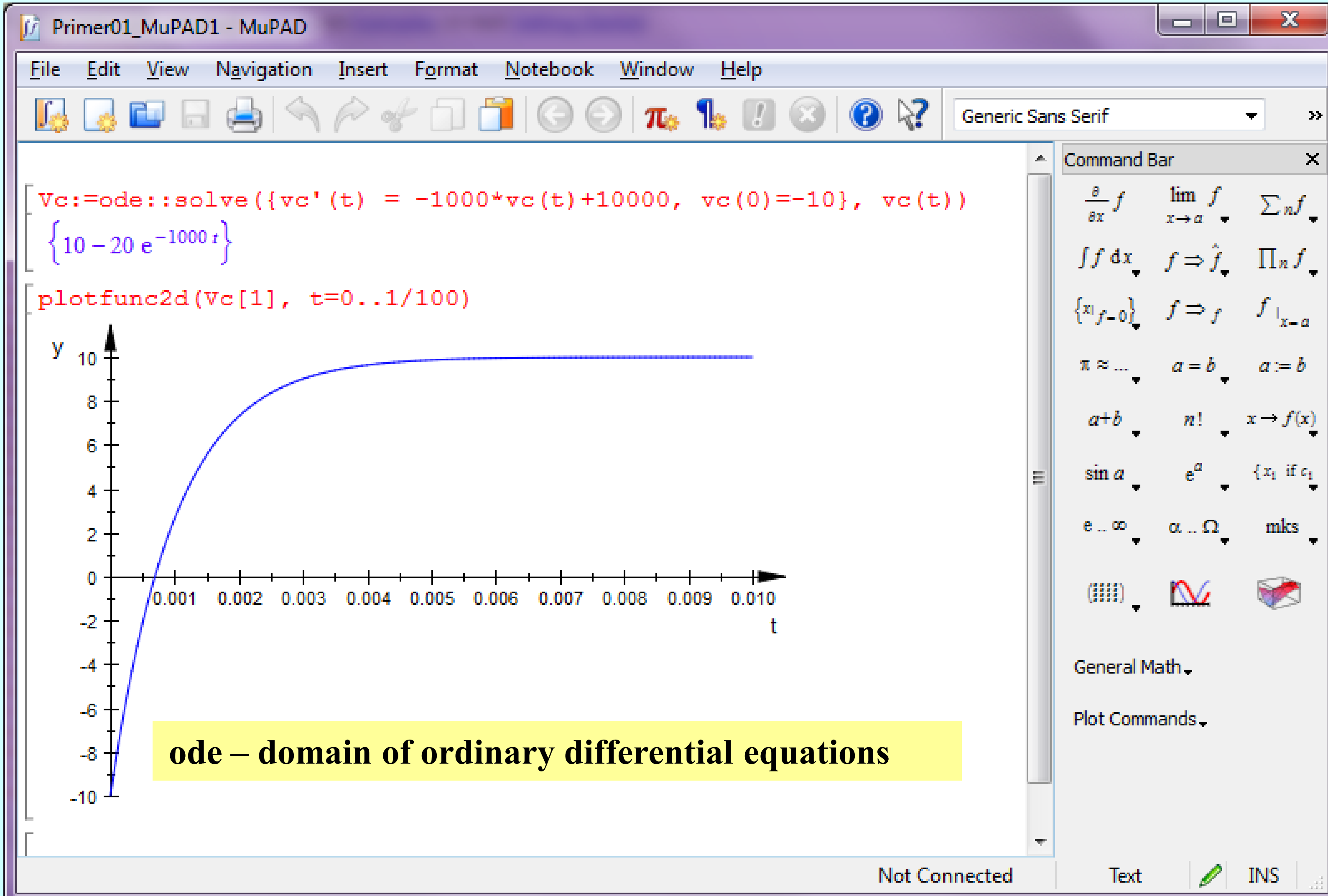
$$R = 1\,\mathrm{k\Omega}$$
$$C = 1\,\mu\mathrm{F}$$

$$u_g(t) = U\,h(t), U = 10\,\mathrm{V}$$
$$u_C(t_0^-) = U_0 = -10\,\mathrm{V}$$

MuPAD

$$\frac{du_C(t)}{dt} = Au_C(t) + Bu_g(t) \Rightarrow A = -\frac{1}{RC} = -1000, B = 1000$$

mupad



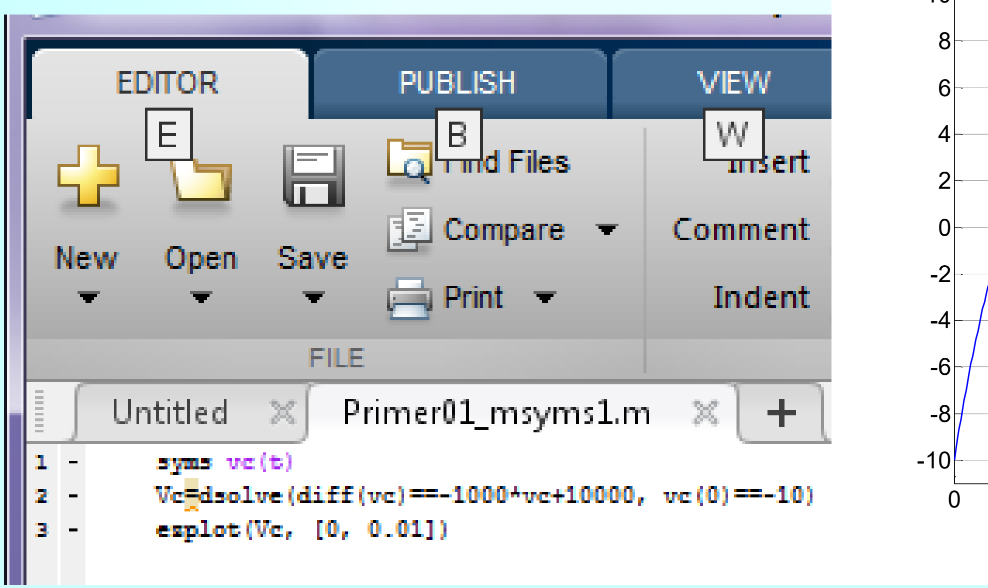
ode – domain of ordinary differential equations

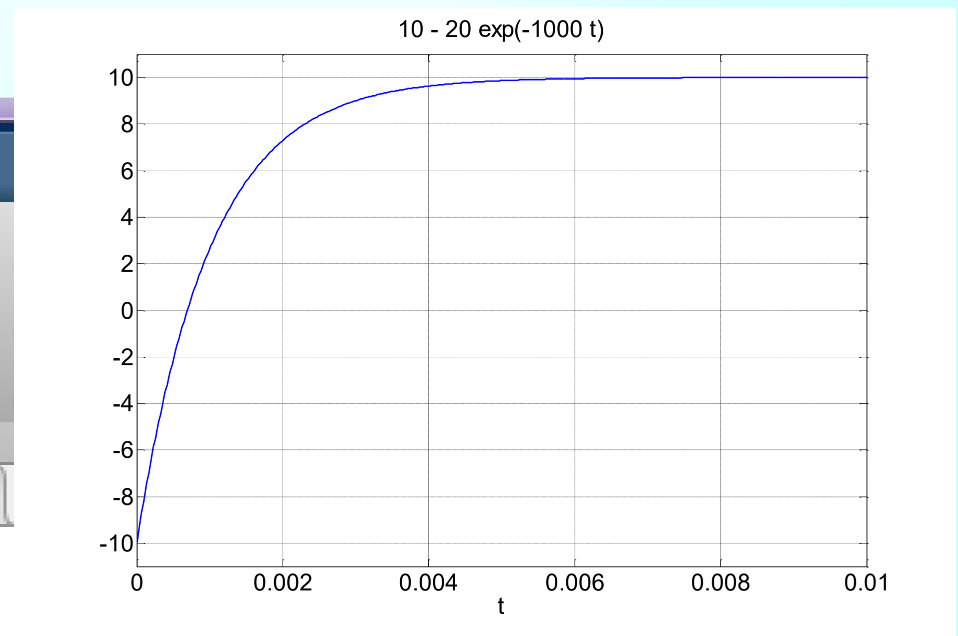
Symbolic Math Toolbox

syms vc(t)

Vc=dsolve(diff(vc)==-1000*vc+10000, vc(0)==-10)

ezplot(Vc, [0, 0.01])





www.wolframalpha.com

Give your brain a quick workout with Wolfram Problem Generator.

WolframAlpha computational... knowledge engine

y' +1000 * y = 10000, y(0)=-10

Examples Random

Input:

$\{y'(x) + 1000\, y(x) = 10\,000,\ y(0) = -10\}$

ODE classification:

first-order linear ordinary differential equation

Alternate forms:

$\{y'(x) = 10\,000 - 1000\, y(x),\ y(0) = -10\}$

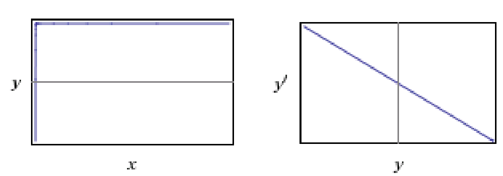
$\{y'(x) + 1000\,(y(x) - 10) = 0,\ y(0) = -10\}$

Differential equation solution:

Approximate form | Step-by-step solution

$y(x) = 10 - 20\, e^{-1000\, x}$

Plots of the solution:



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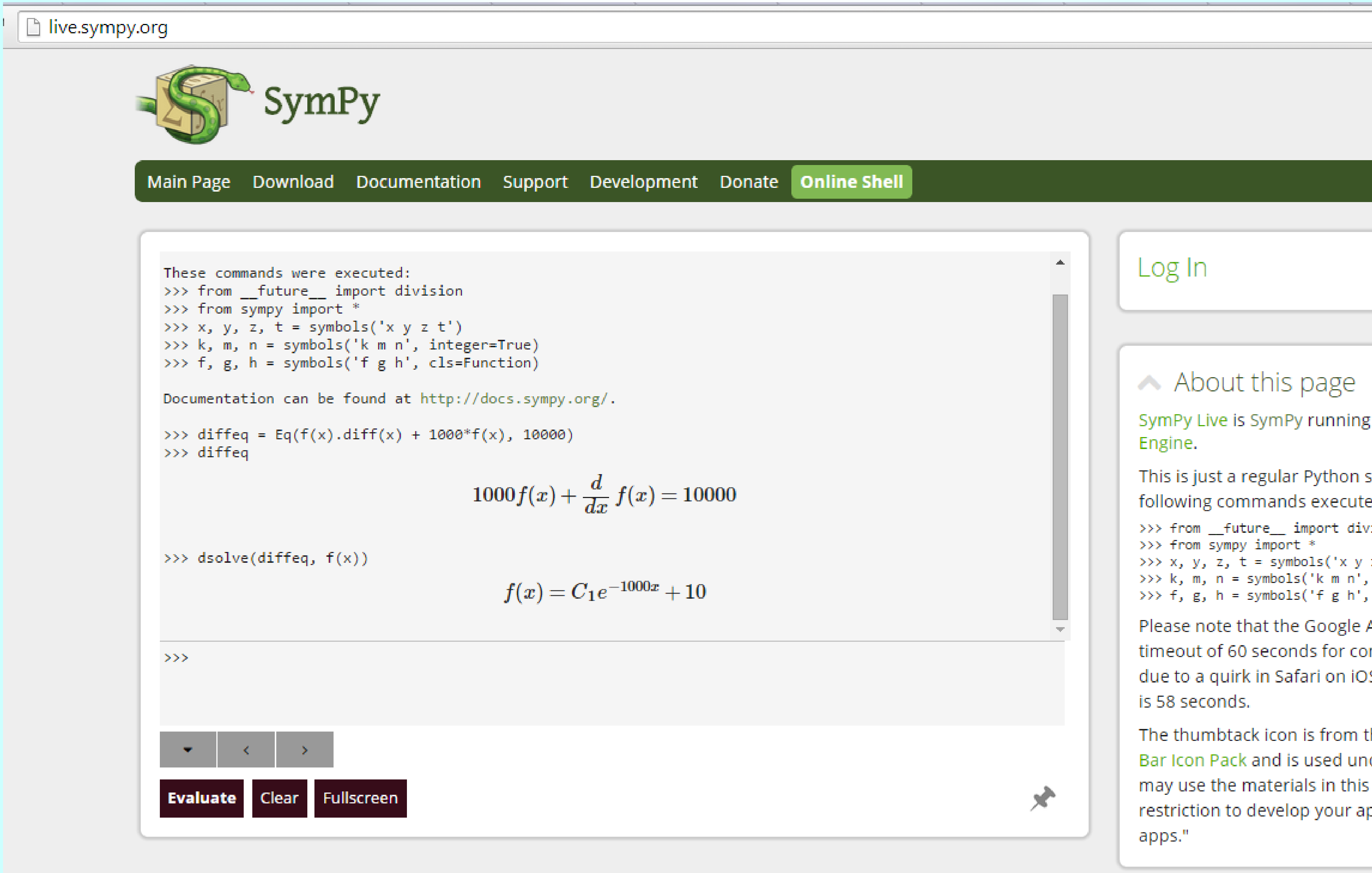
Wolfram|Alpha Tour!

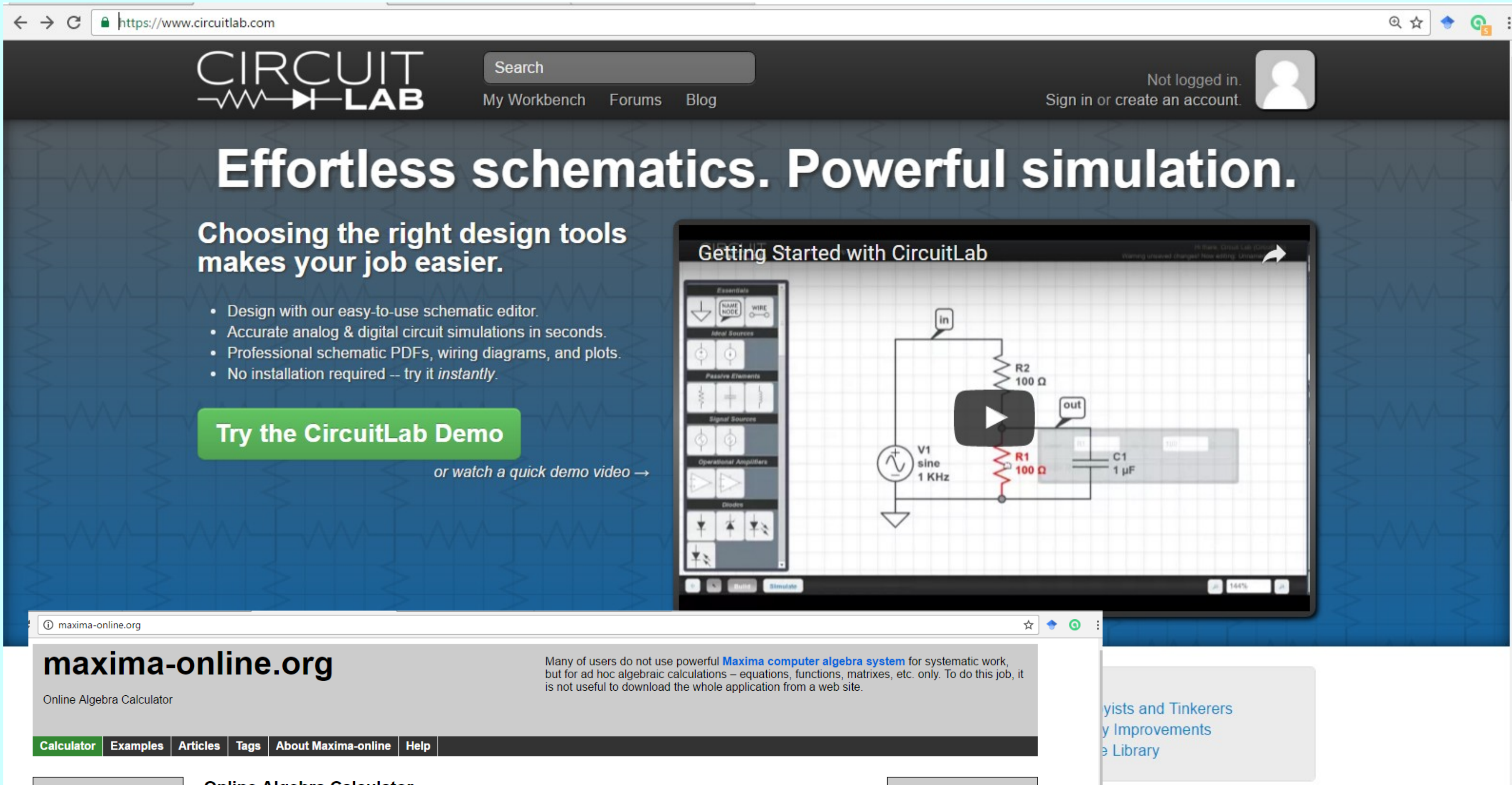
Take the Tour >>

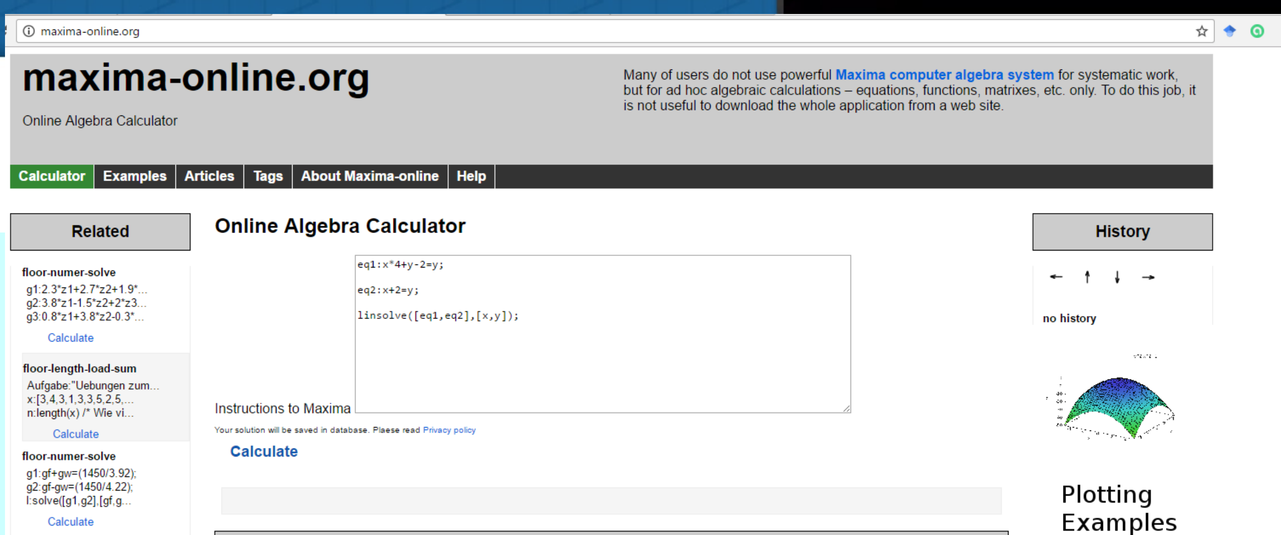
New! Wolfram Problem Generator

Need a hint?


live.sympy.org
SymPy
Main Page
Download
Documentation
Support
Development
Donate
Online Shell
These commands were executed:
>>> from __future__ import division
>>> from sympy import *
>>> x, y, z, t = symbols('x y z t')
>>> k, m, n = symbols('k m n', integer=True)
>>> f, g, h = symbols('f g h', cls=Function)
Documentation can be found at http://docs.sympy.org/.
>>> diffeq = Eq(f(x).diff(x) + 1000*f(x), 10000)
>>> diffeq
$1000 f(x) + \frac{d}{dx} f(x) = 10000$
>>> dsolve(diffeq, f(x))
$f(x) = C_1 e^{-1000x} + 10$
>>>
Evaluate
Clear
Fullscreen
Log In
About this page
SymPy Live is SymPy running o
Engine.
This is just a regular Python sh
following commands executed
>>> from __future__ import divis
>>> from sympy import *
>>> x, y, z, t = symbols('x y z
>>> k, m, n = symbols('k m n', i
>>> f, g, h = symbols('f g h', c
Please note that the Google Ap
timeout of 60 seconds for com
due to a quirk in Safari on iOS,
is 58 seconds.
The thumbtack icon is from the
Bar Icon Pack and is used unde
may use the materials in this fi
restriction to develop your app
apps."

CircuitLab, Maxima-online,…





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