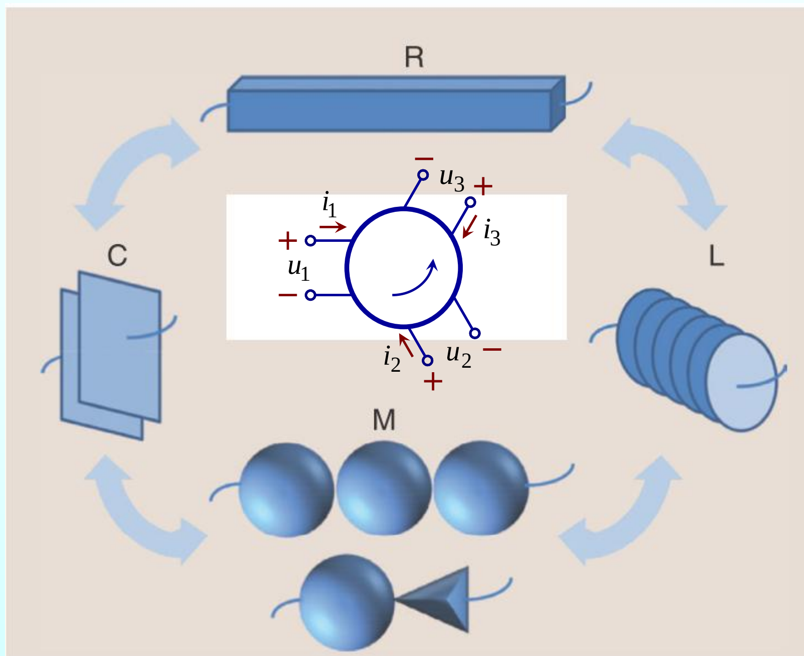
Практикум из рачунарске анализе кола



Милка Потребић

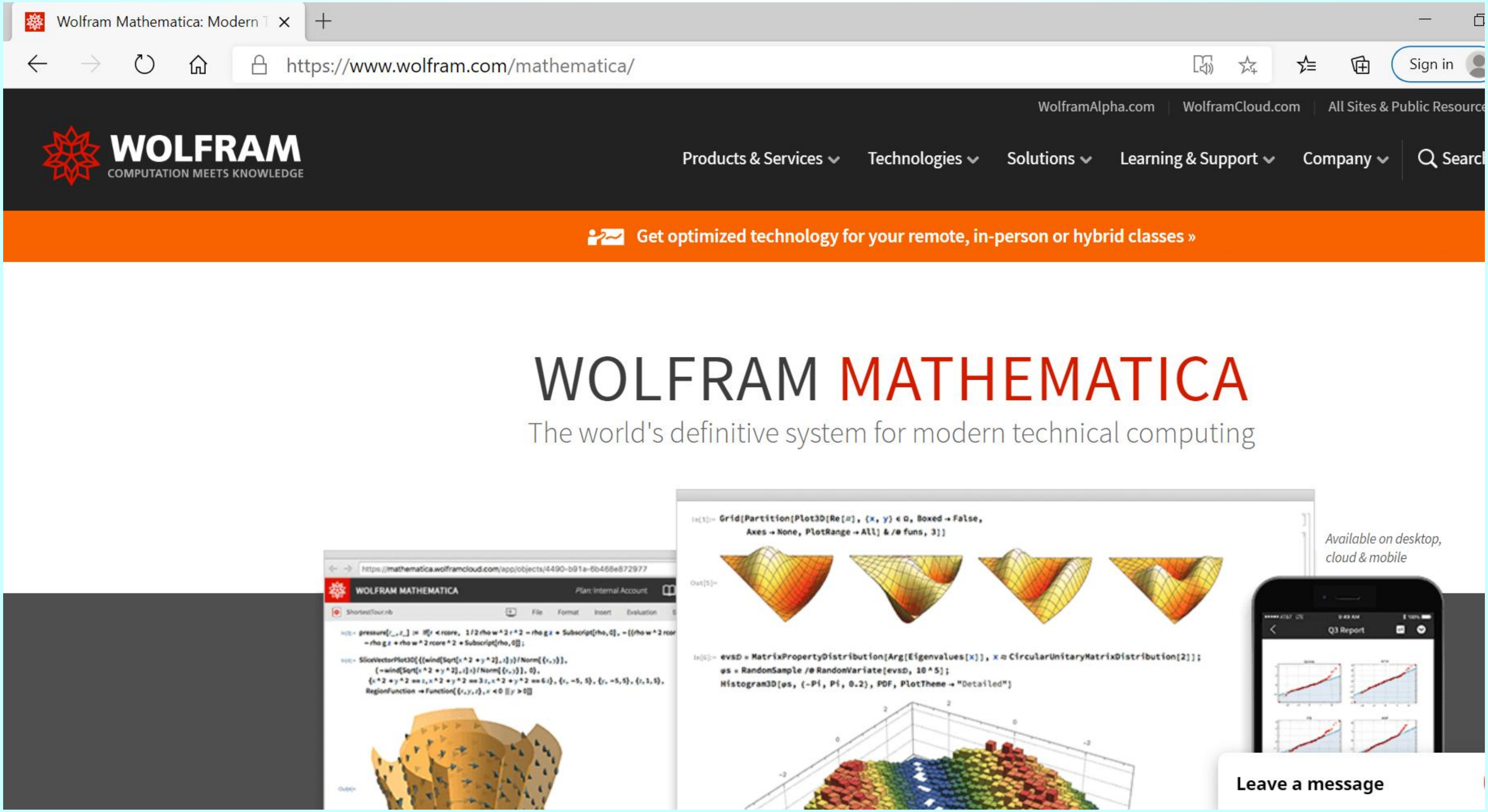
Рачунарски (софтверски) алати

- *Mathematica*, WolframAlpha, MuPAD, **Maxima**, **SymPy**, **SymPy Live**, **SymPy Gamma**
- MATLAB, **Scilab**, **Octave**, **FreeMat**, **Julia**
- LTspice, **QucsStudio**, **ngspice**, **Xyce**, **XCircuit**
- **Python**, MathCAD, MAPLE, GeoGebra
- Symbolab, SpeQ Mathematics, meta-calculator, Desmos, …

Free/Libre Open Source Software (FLOSS)

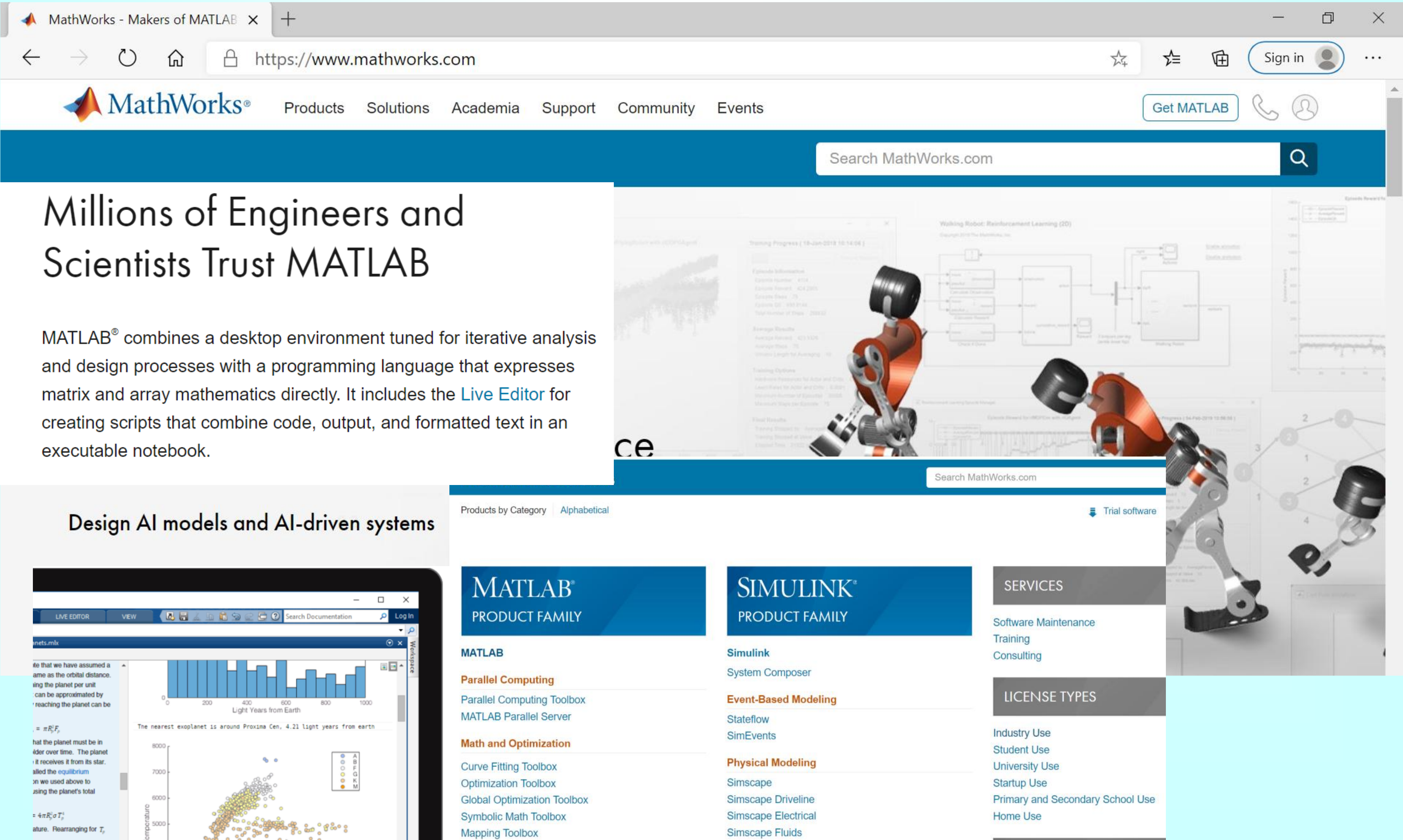
Mathematica

https://www.wolfram.com/mathematica/



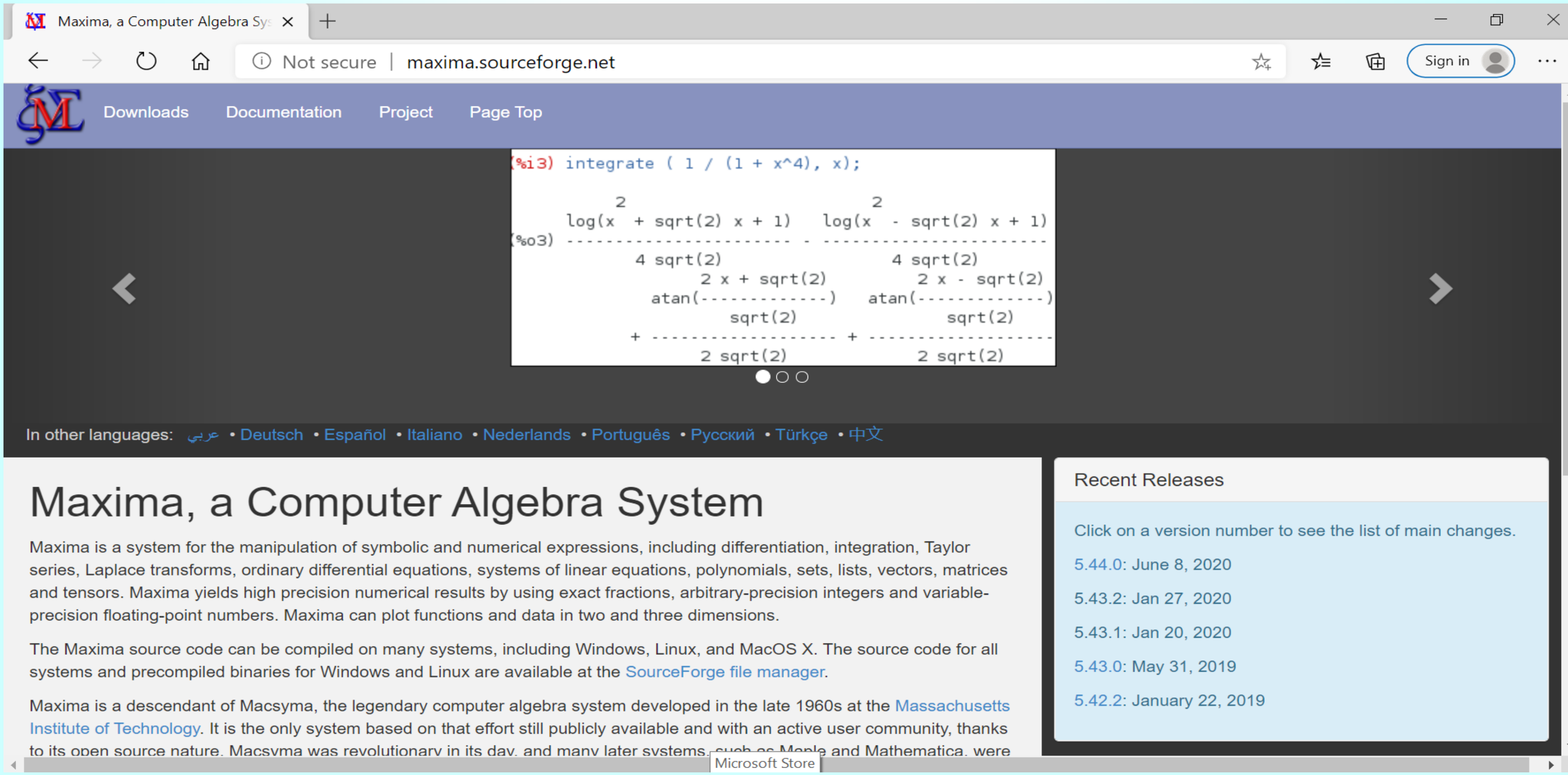
http://www.mathworks.com/

MATLAB



Maxima

http://maxima.sourceforge.net/



Maxima on line

http://maxima.cesga.es/

Servicio proporcionado por CESGA

Maxima on line

Help: Español, English Galego

```
expand((x-2)^3*(x+1/3)^2);

solve(x^2-x+2=0);

invert(matrix([2,3,1], [a,0,0], [1,4,8]));

integrate(x * sin(x), x);

draw3d(explicit(x^2+y^2,x,-1,1,y,-1,1));
```

Clic Clear

AVISO LEGAL

(%i1) expand((x-2)^3*(x+1/3)^2);

(%o1) $x^5 - \frac{16\,x^4}{3} + \frac{73\,x^3}{9} - \frac{2\,x^2}{3} - 4\,x - \frac{8}{9}$

(%i2) solve(x^2-x+2=0);

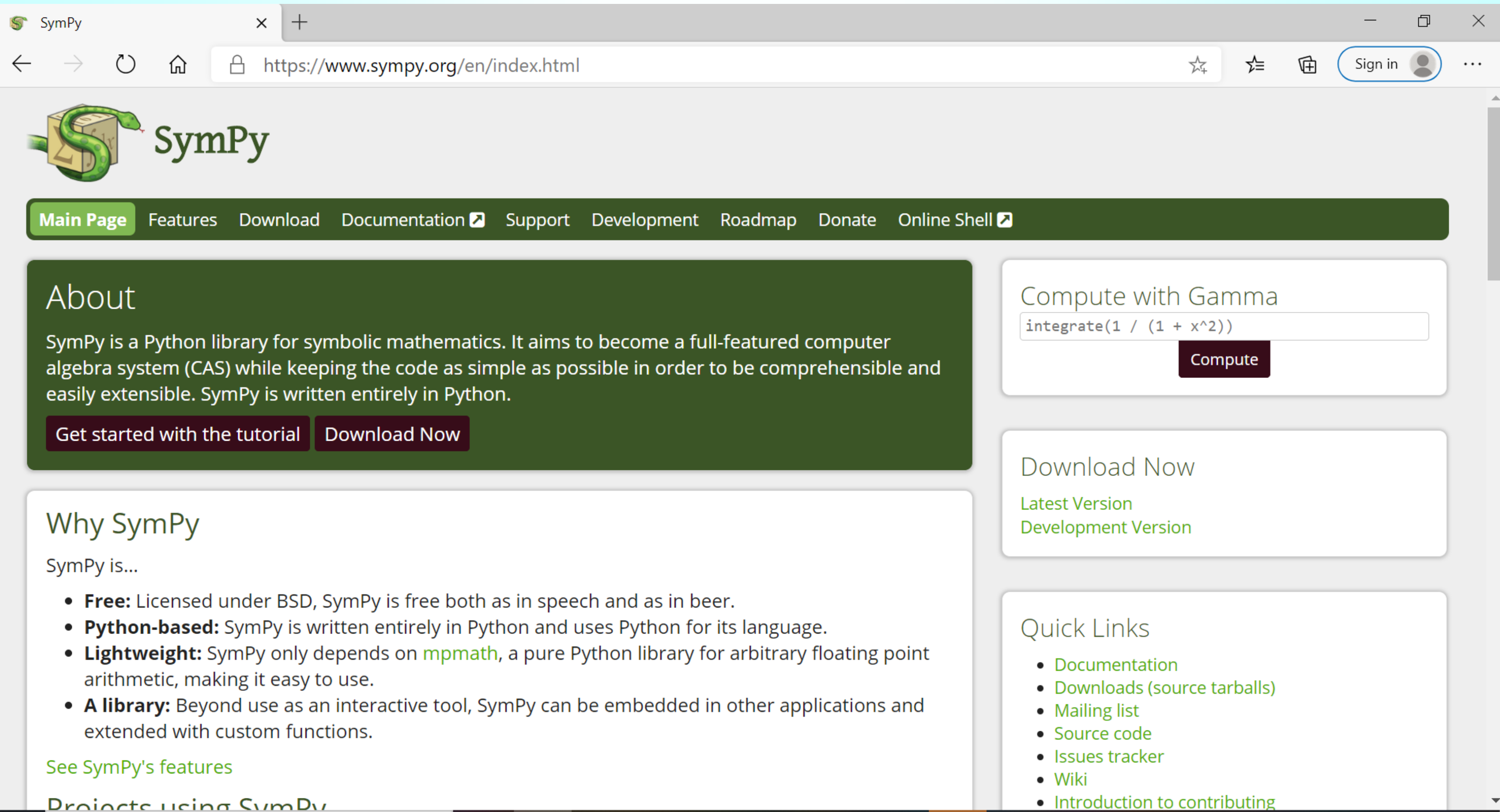
(%o2) $\left[x = -\frac{\sqrt{7}\,i-1}{2}, x = \frac{\sqrt{7}\,i+1}{2}\right]$

(%i3) invert(matrix([2,3,1], [a,0,0], [1,4,8]));

(%o3) $\begin{pmatrix} 0 & \frac{1}{a} & 0 \\ \frac{2}{5} & -\frac{3}{4\,a} & -\frac{1}{20} \\ -\frac{1}{5} & \frac{1}{4\,a} & \frac{3}{20} \end{pmatrix}$

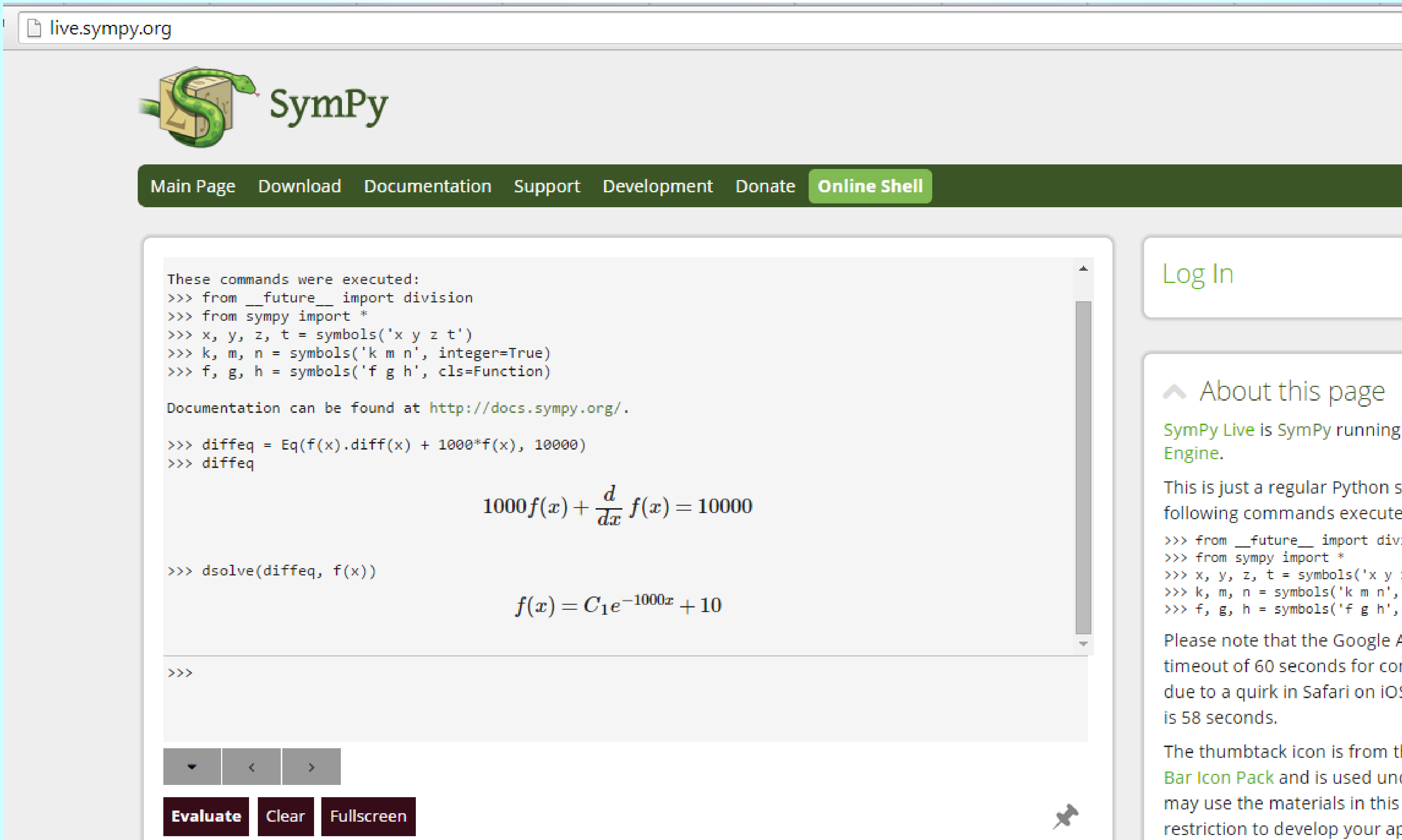
SymPy

www.sympy.org/



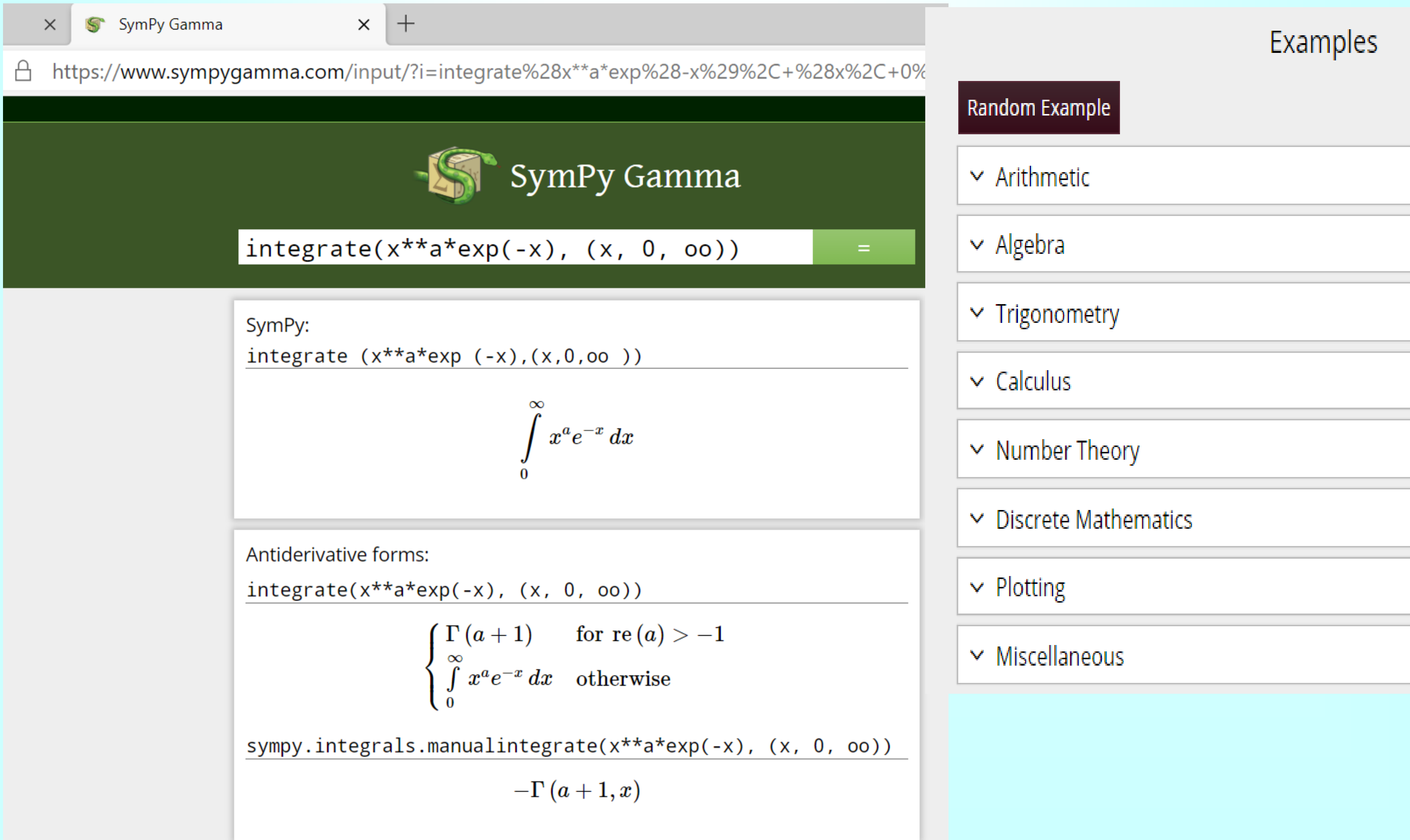
SymPy live

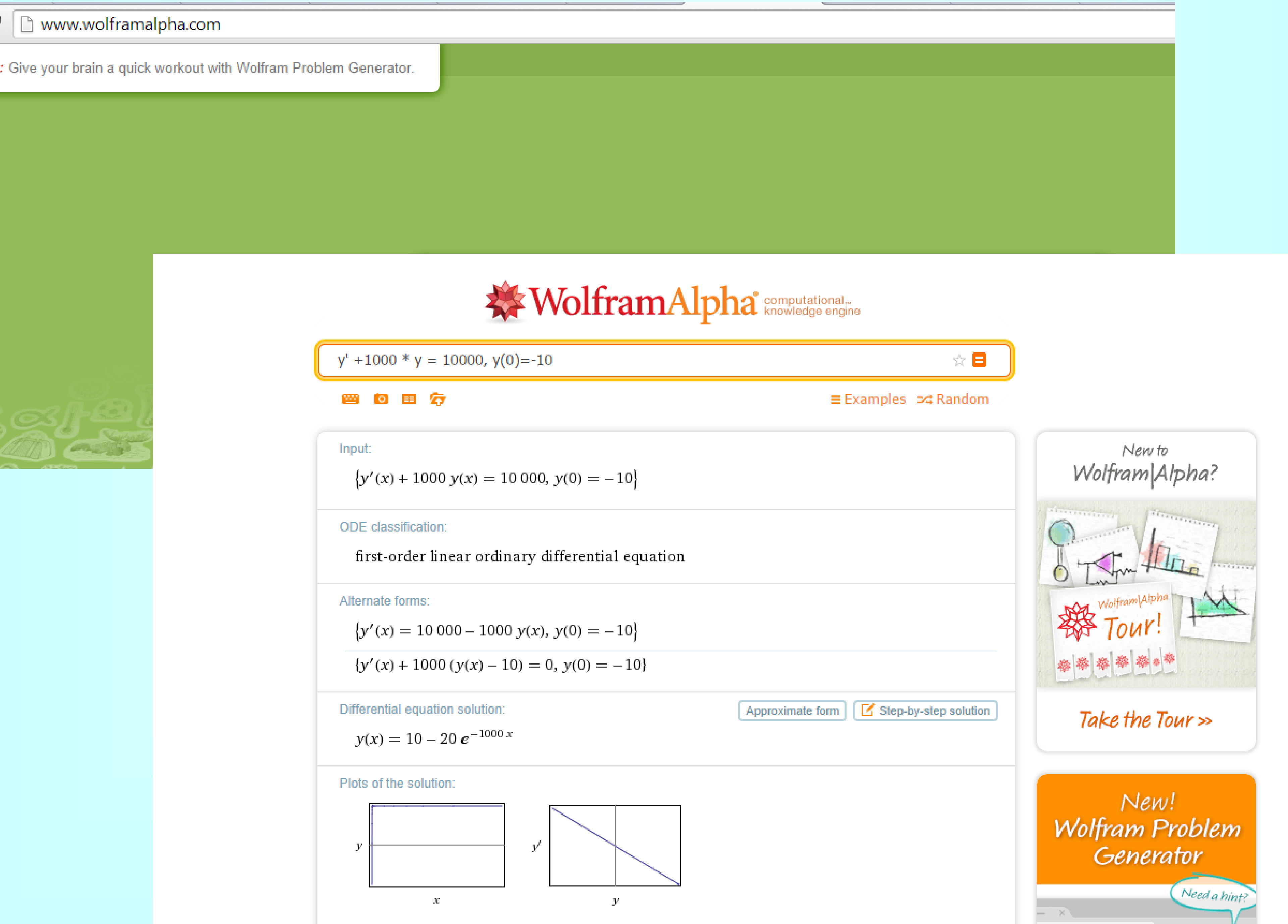
live.sympy.org



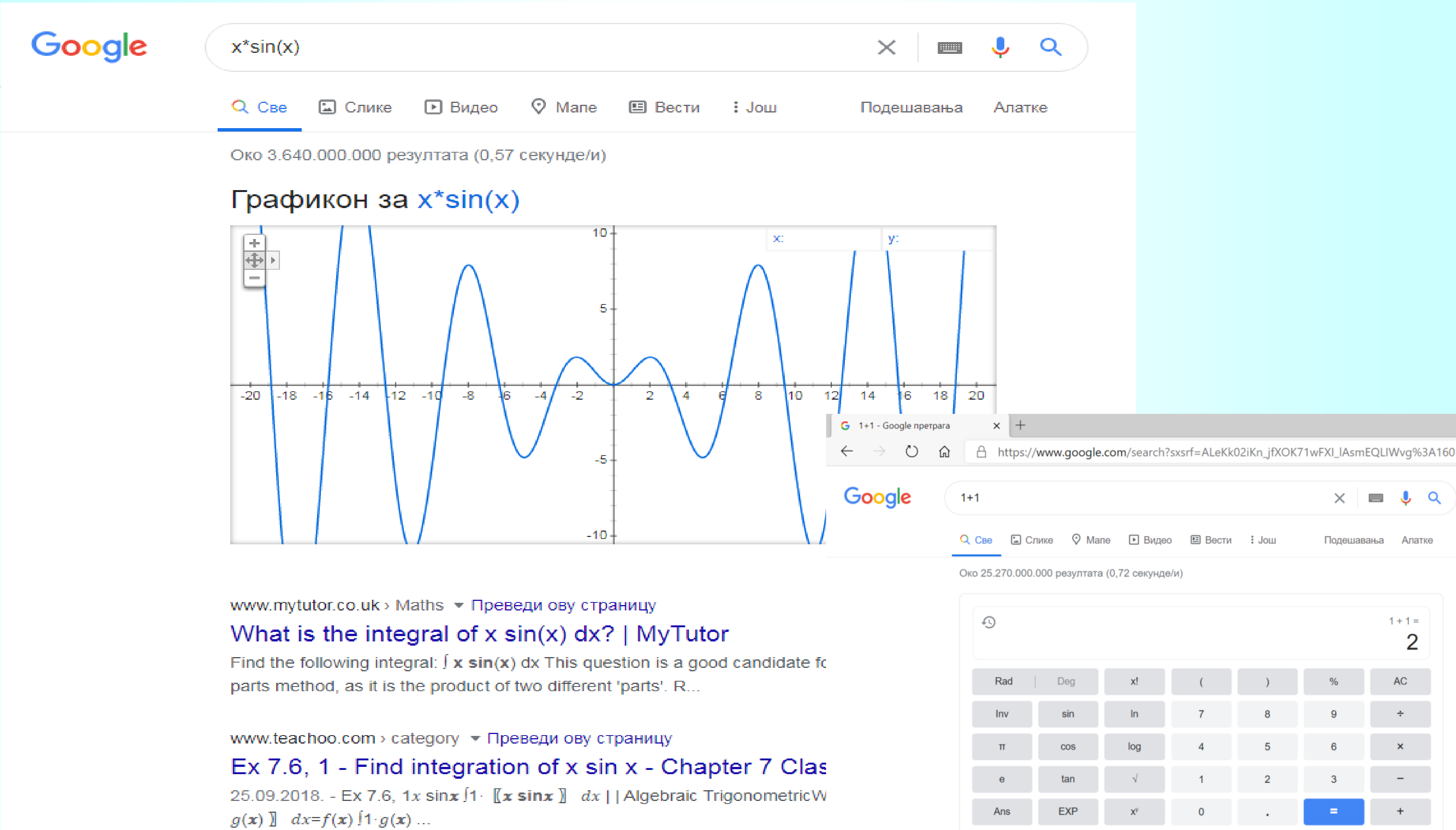
SymPy Gamma

https://www.sympygamma.com/



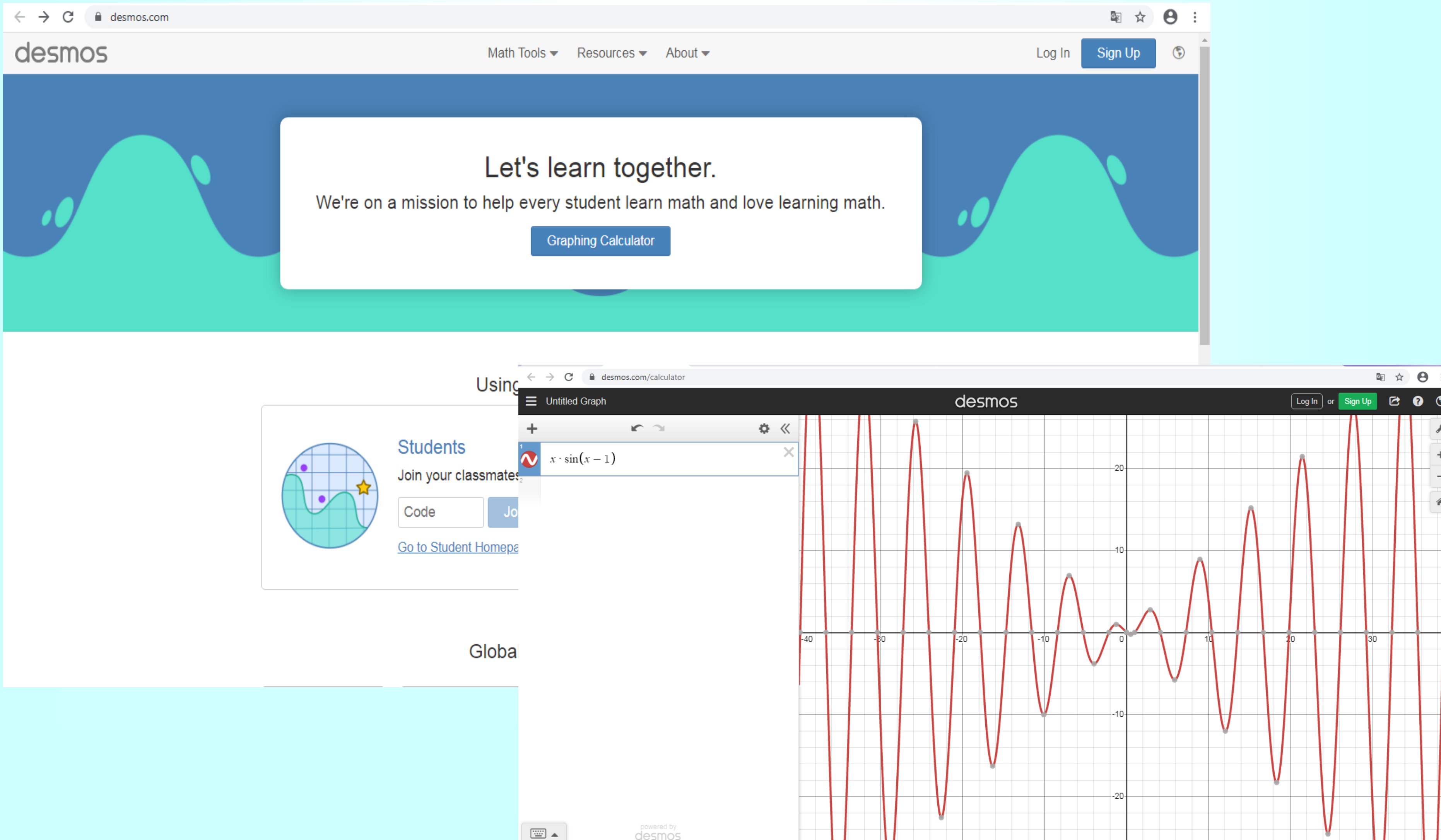

www.wolframalpha.com
Give your brain a quick workout with Wolfram Problem Generator.
WolframAlpha computational... knowledge engine
y' +1000 * y = 10000, y(0)=-10
Examples
Random
Input:
$\{y'(x) + 1000\, y(x) = 10\,000,\ y(0) = -10\}$
ODE classification:
first-order linear ordinary differential equation
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:
y
x
y'
y
New to Wolfram|Alpha?
Wolfram|Alpha Tour!
Take the Tour >>
New! Wolfram Problem Generator
Need a hint?

Google kalkulator



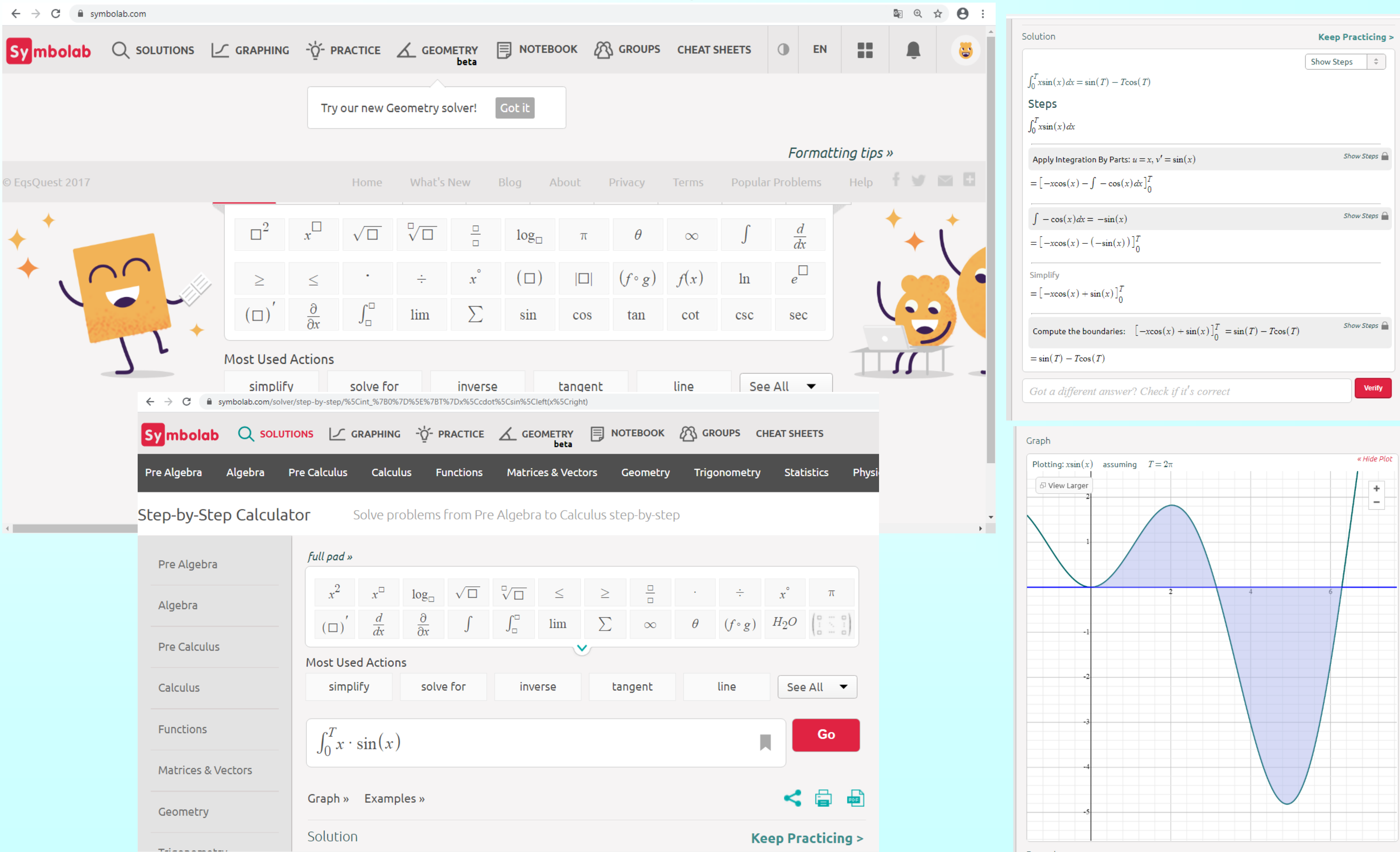
Graphing Calculator – Desmos

https://www.desmos.com/calculator



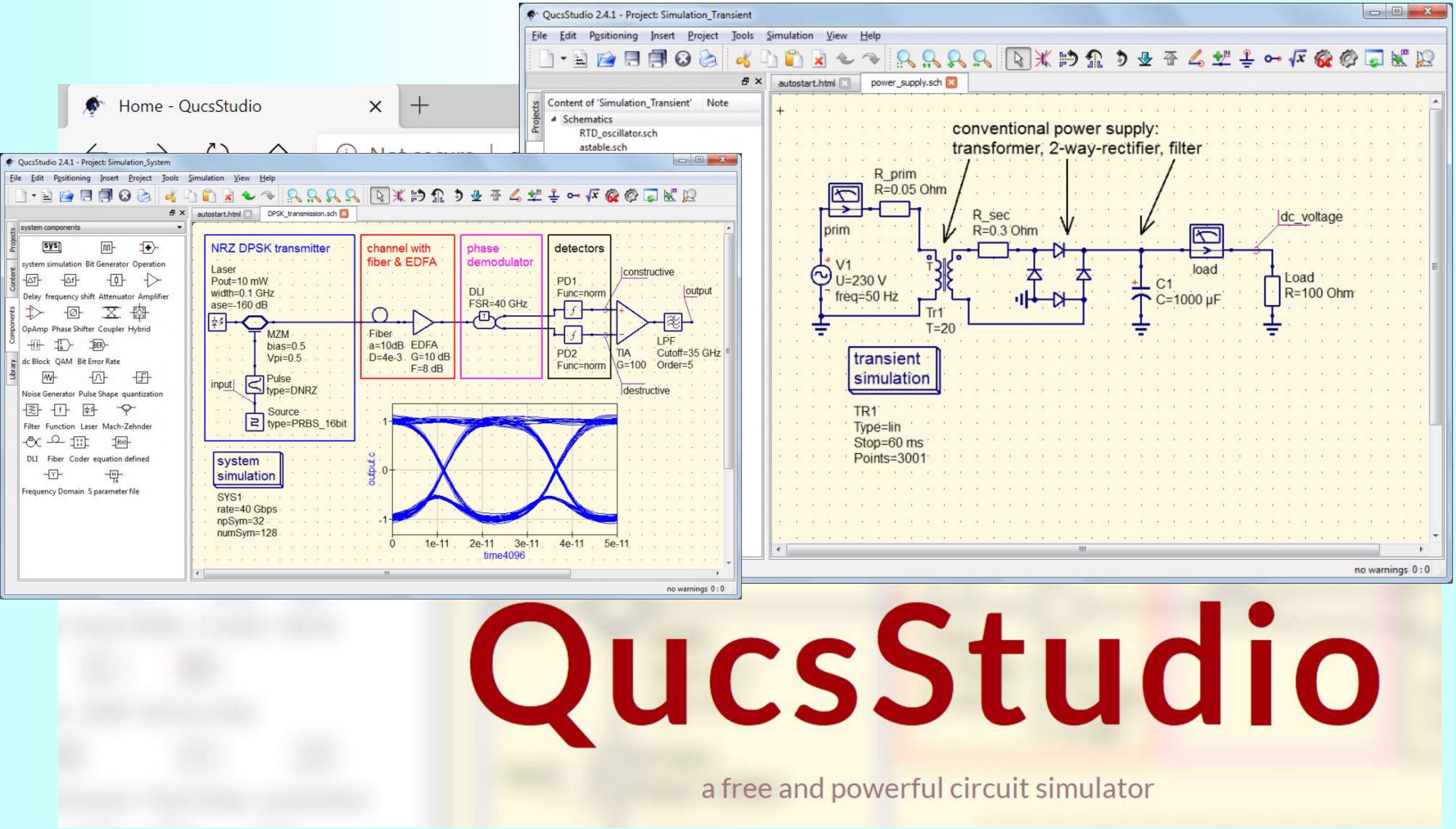
Symbolab Math Solver - Step by Step calculator

https://www.symbolab.com/



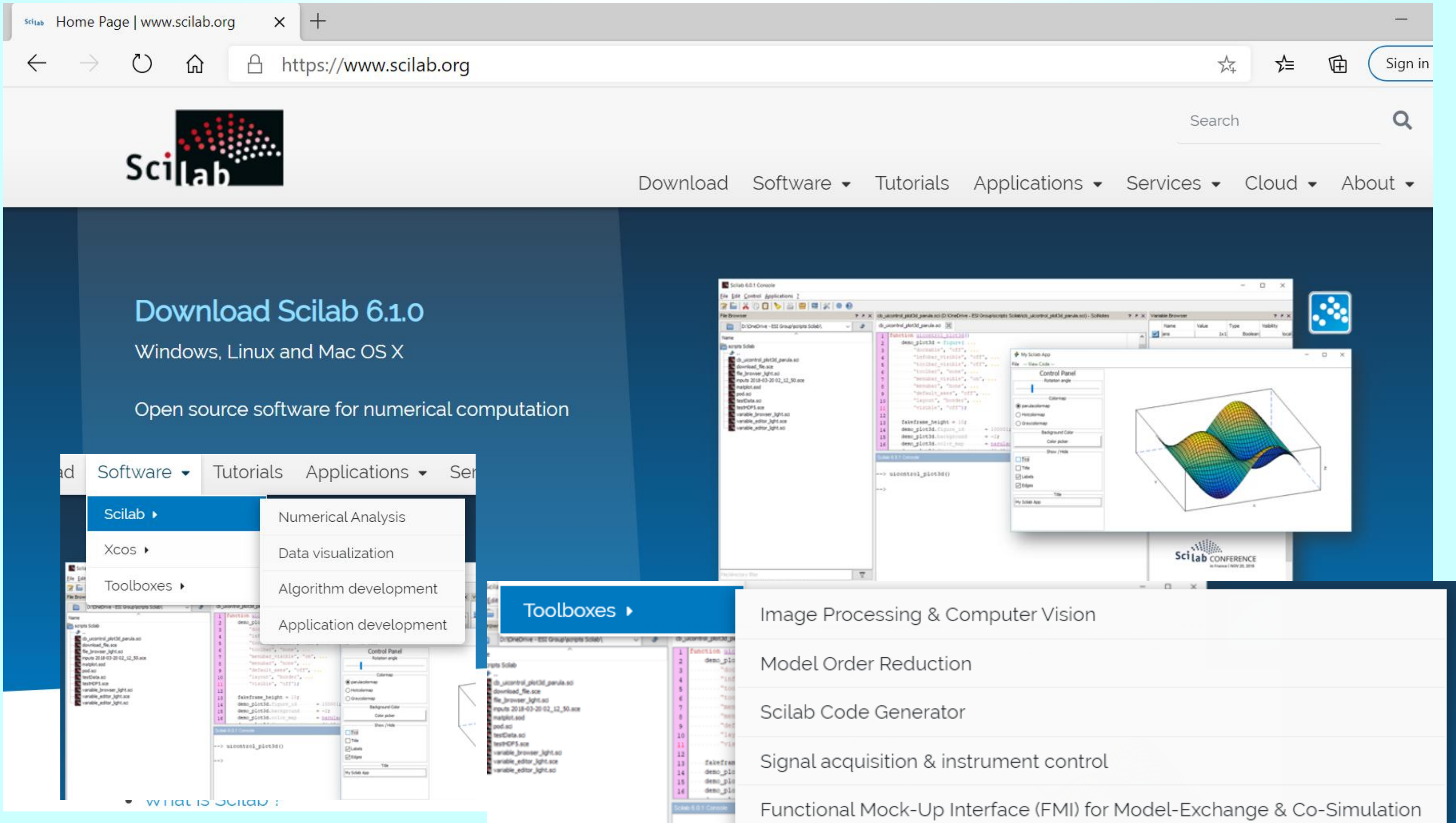
QucsStudio

http://qucsstudio.de/



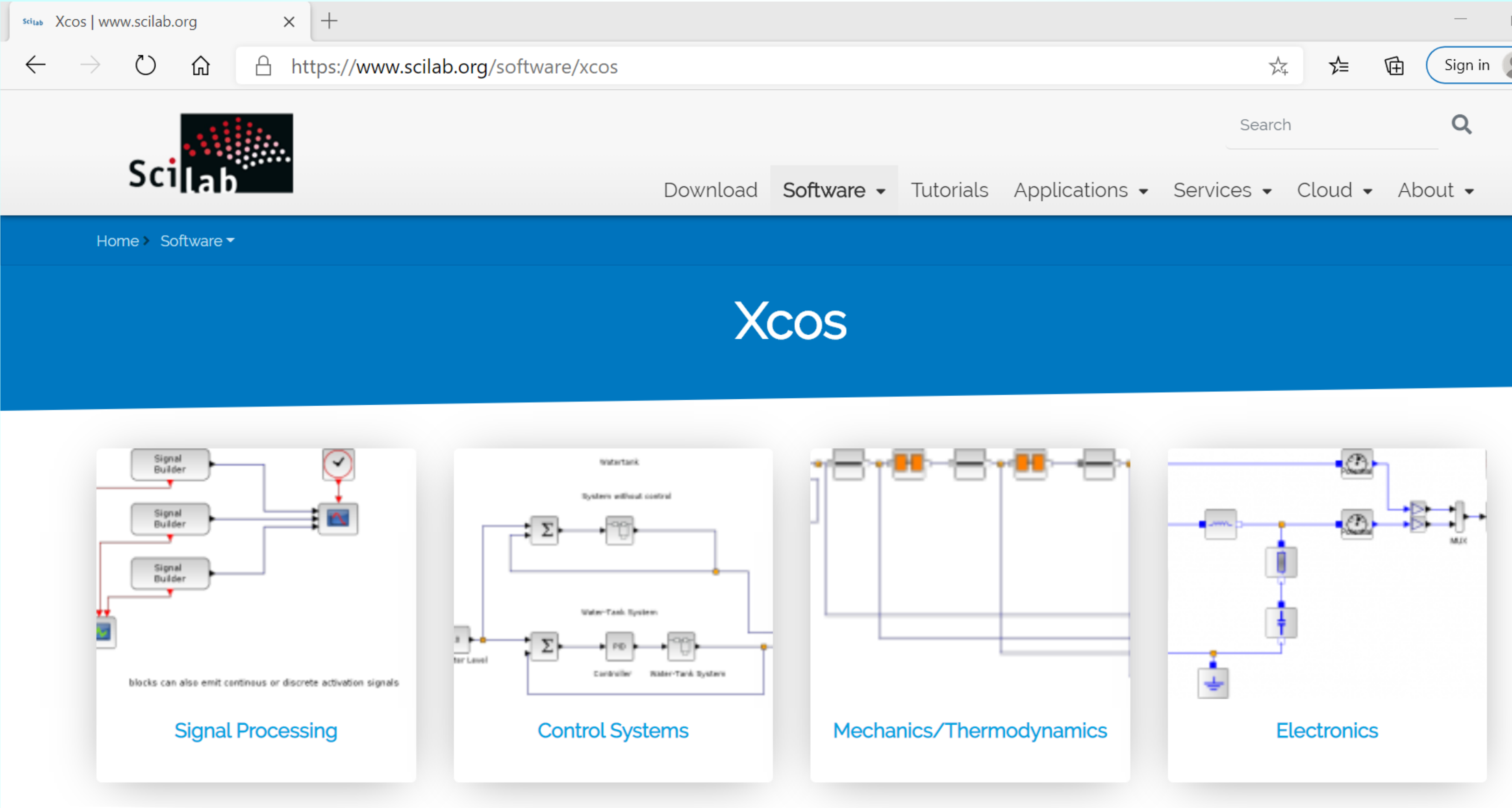
SciLab

https://www.scilab.org/



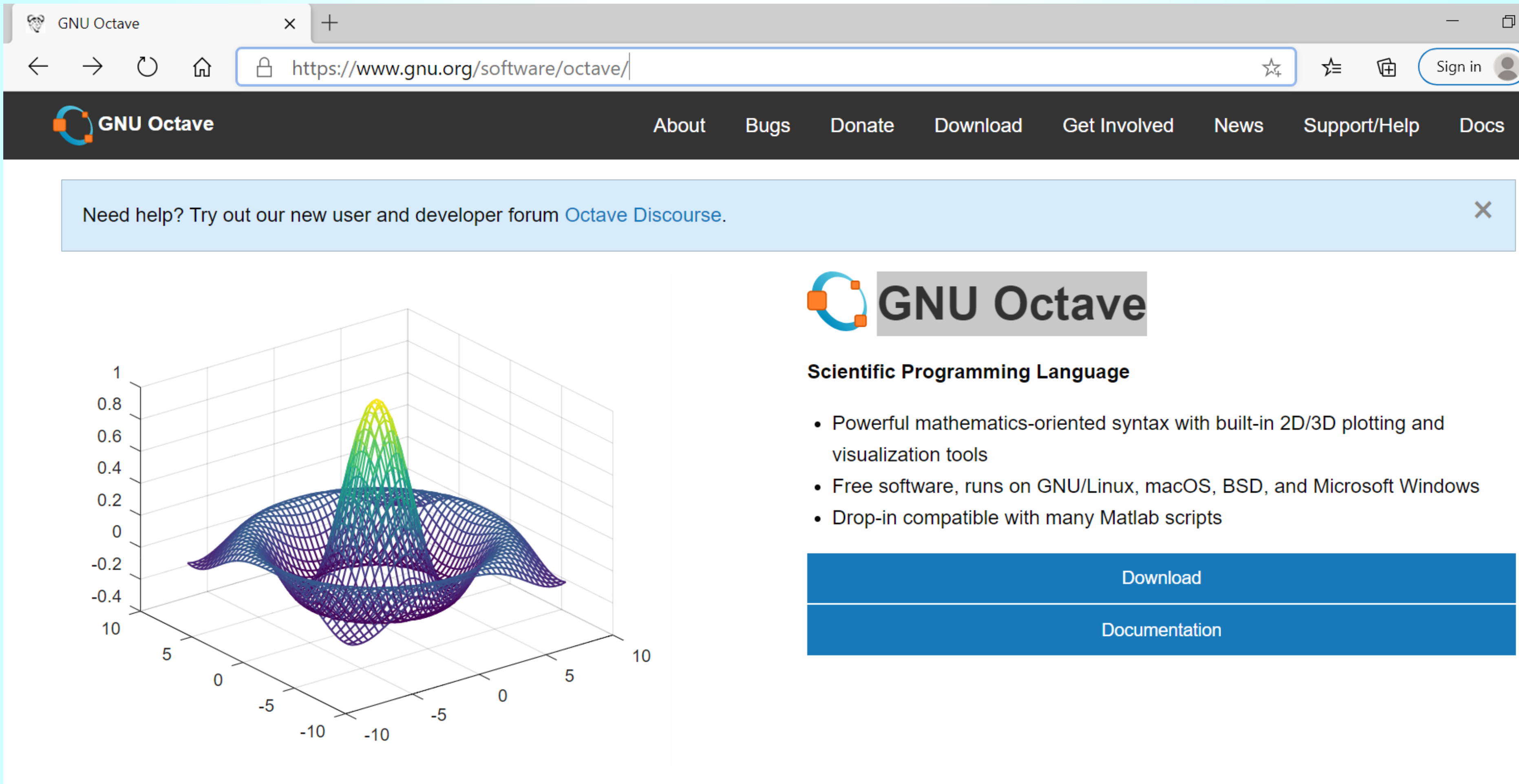
Xcos

https://www.scilab.org/software/xcos



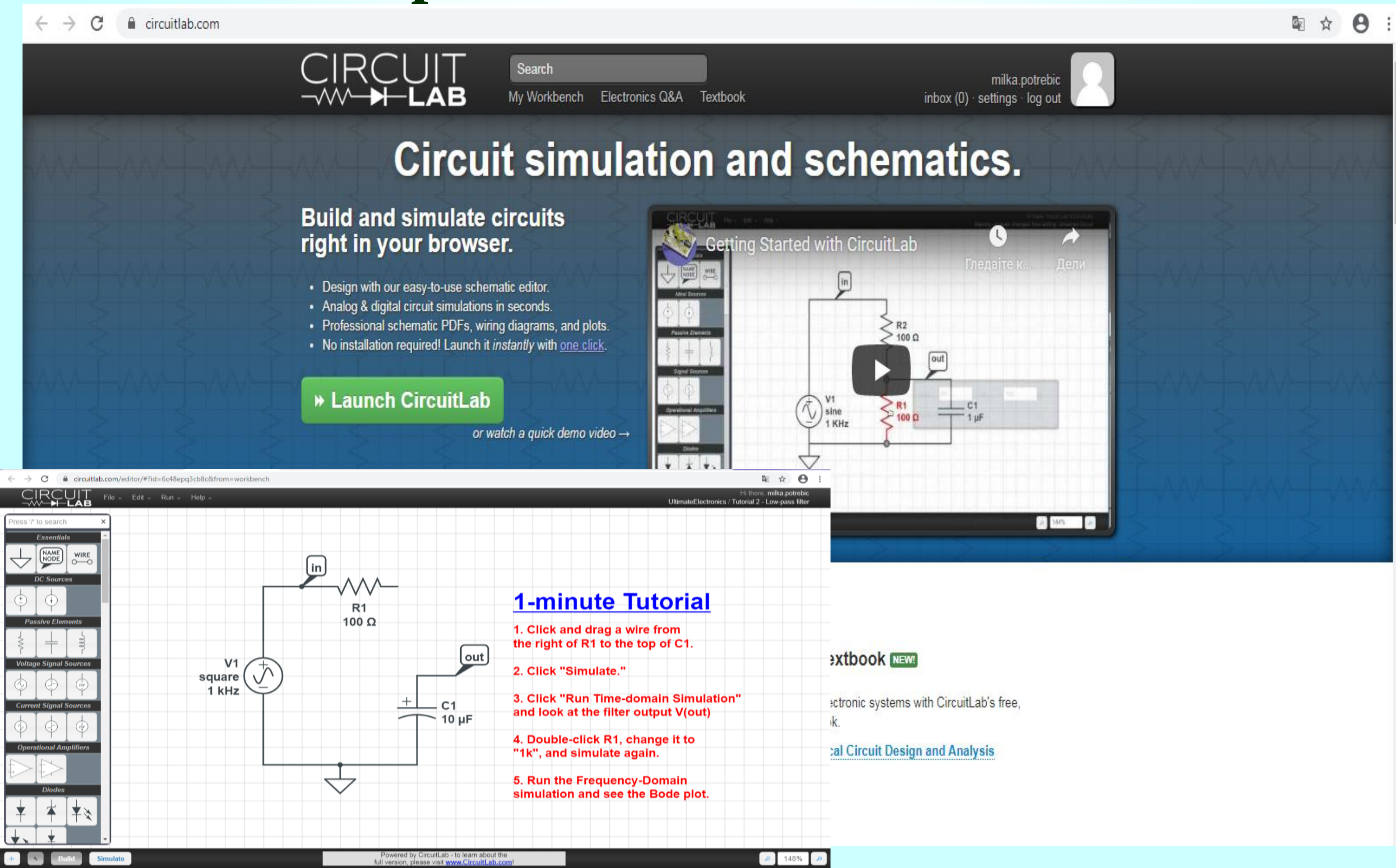
GNU Octave

https://www.gnu.org/software/octave/



CircuitLab

https://www.circuitlab.com/



DoCircuits Circuit Simulator

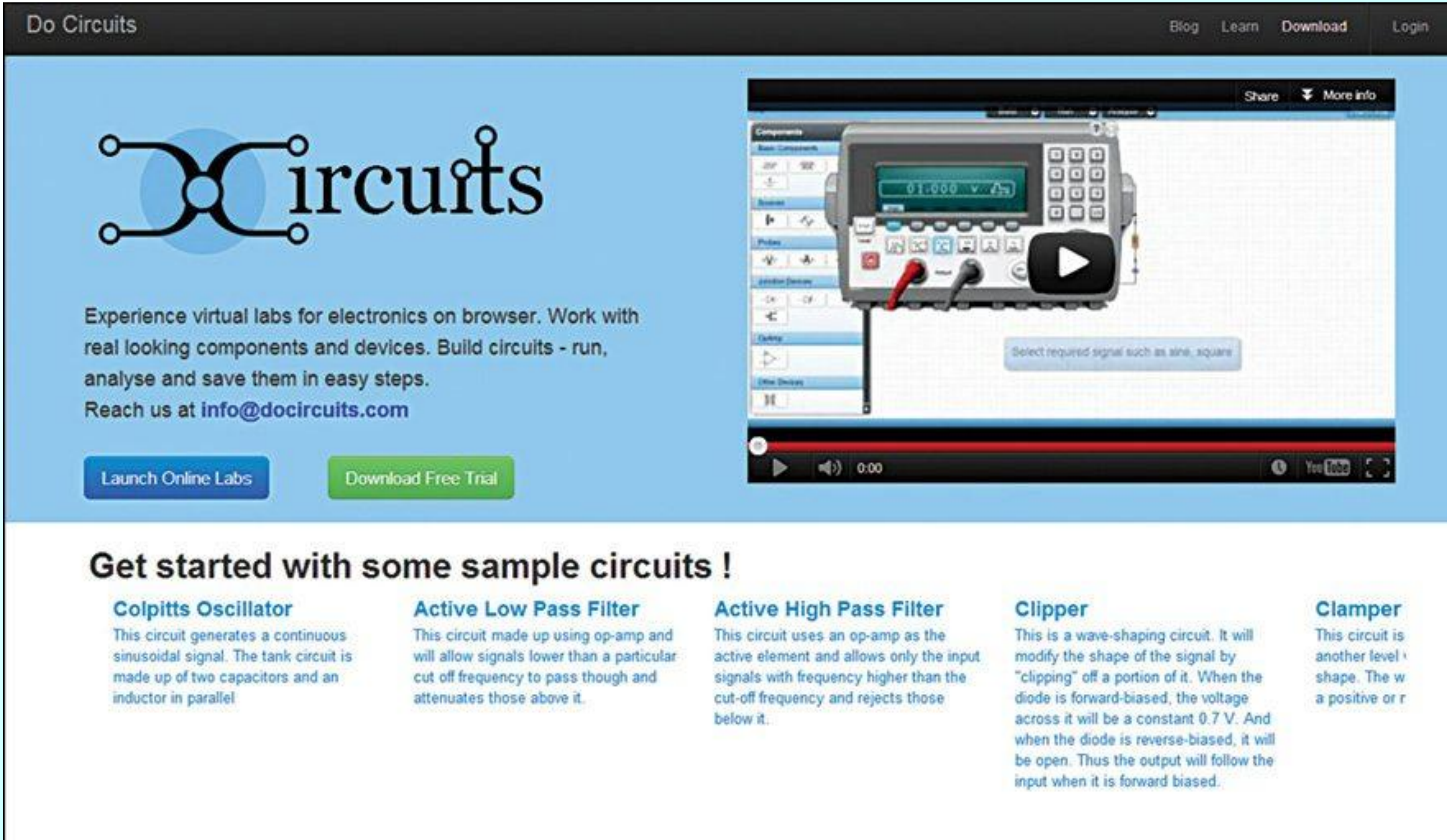
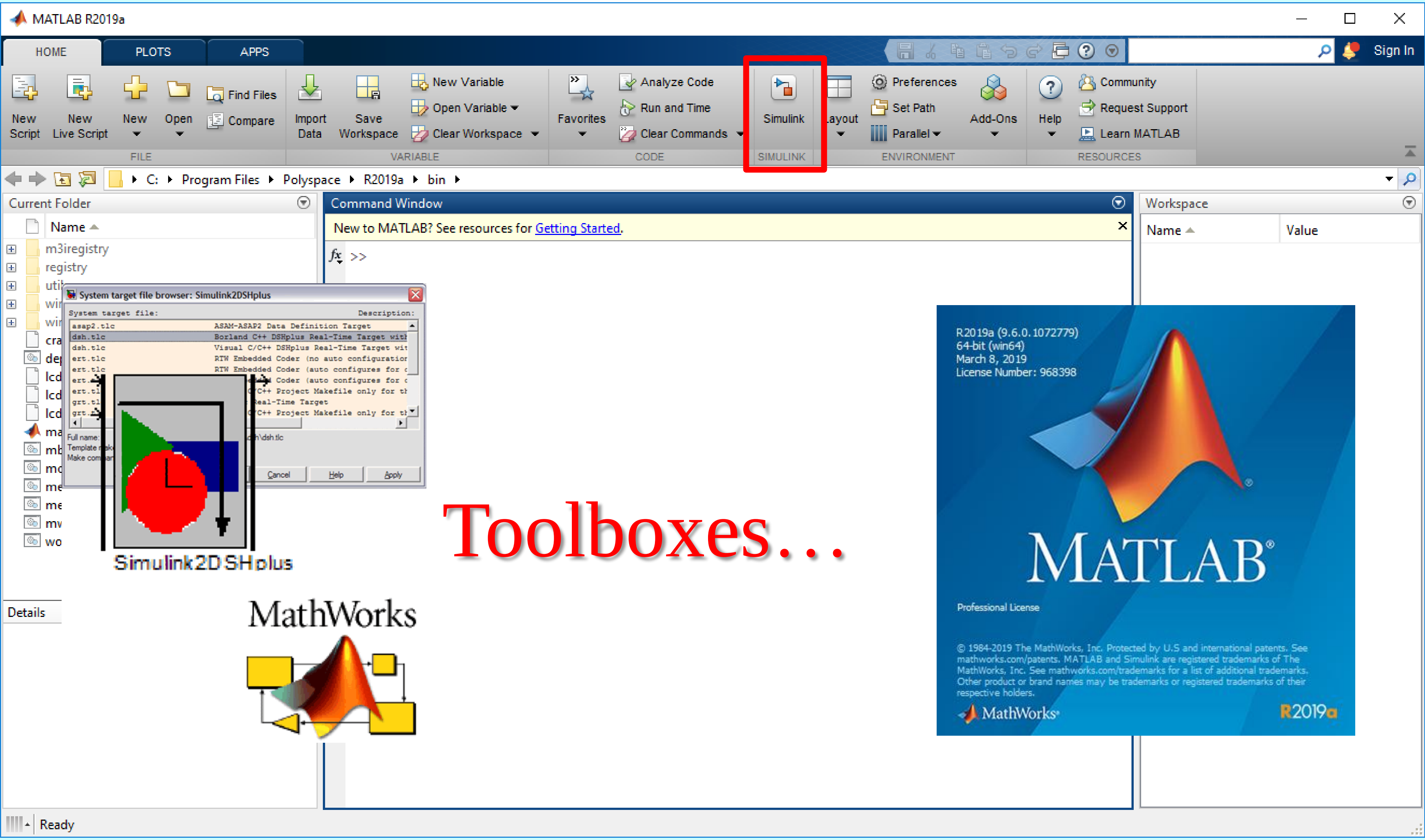


Fig. 1: DoCircuits - Home

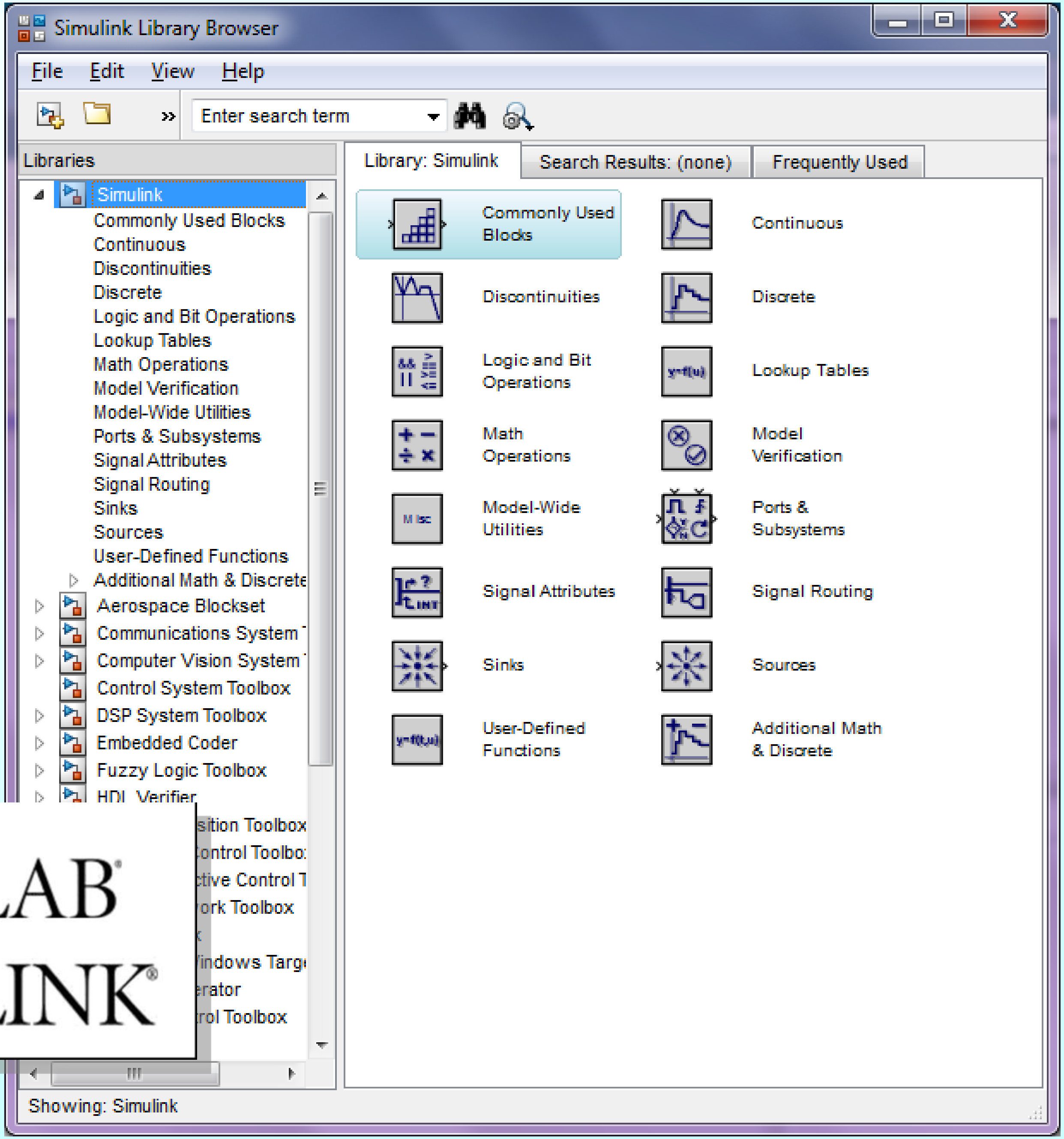
http://www.mathworks.com/

MATLAB



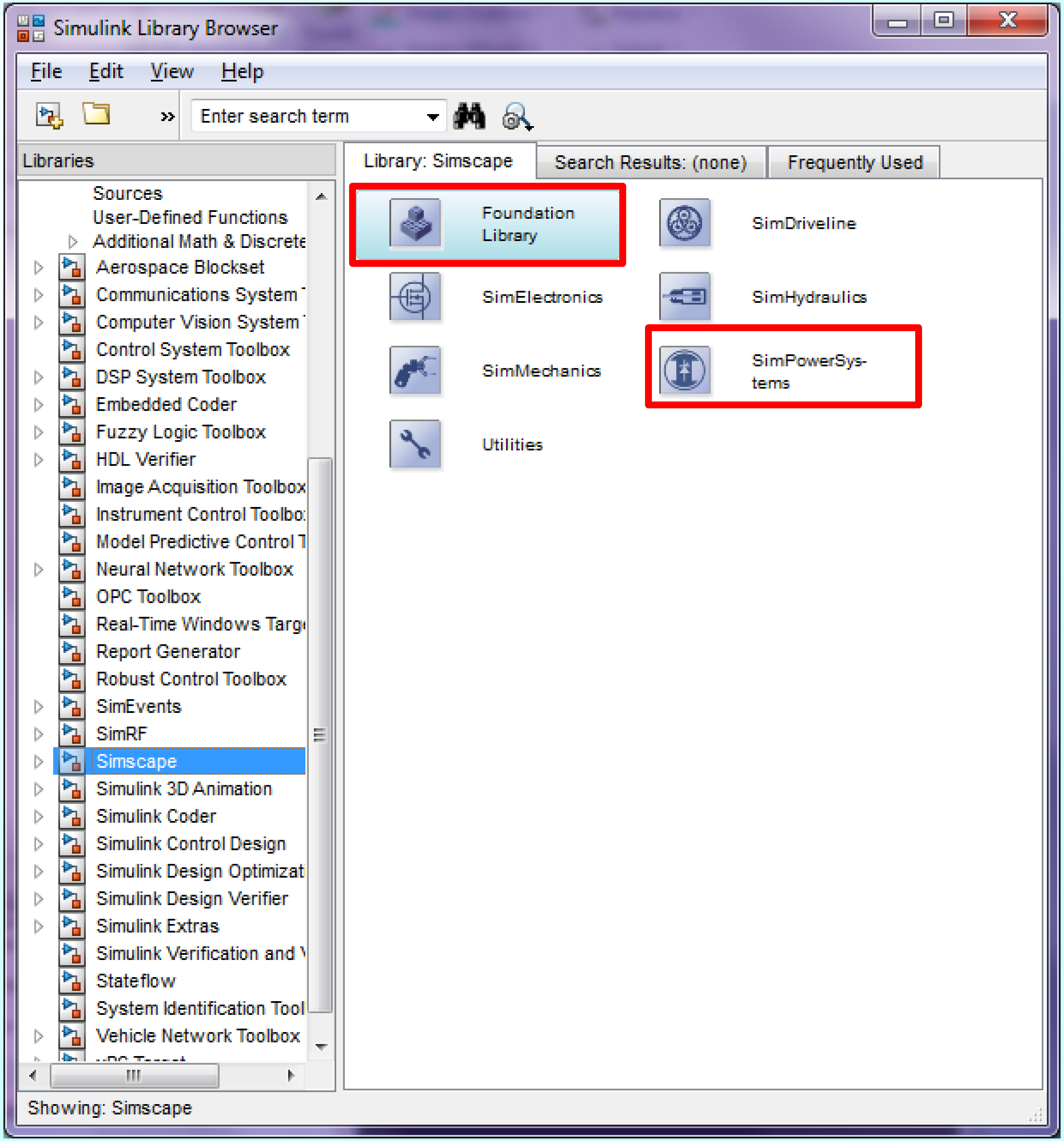
Toolboxes…

Simulink

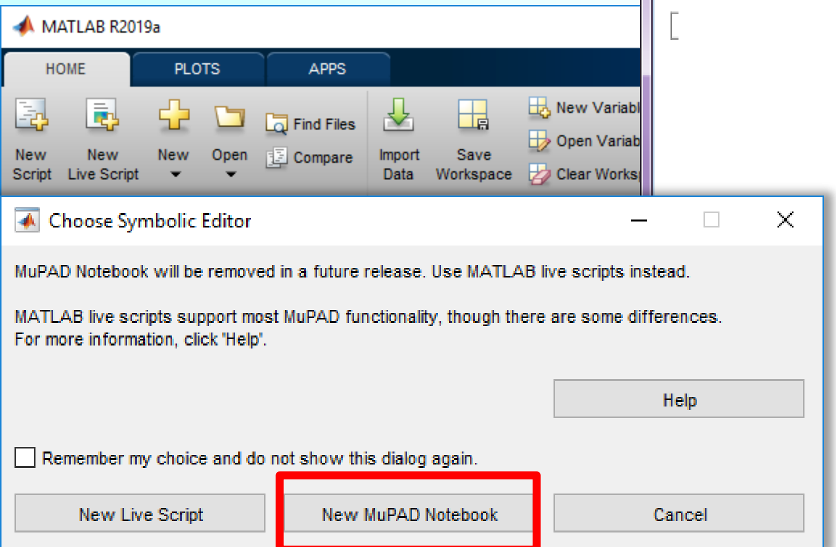


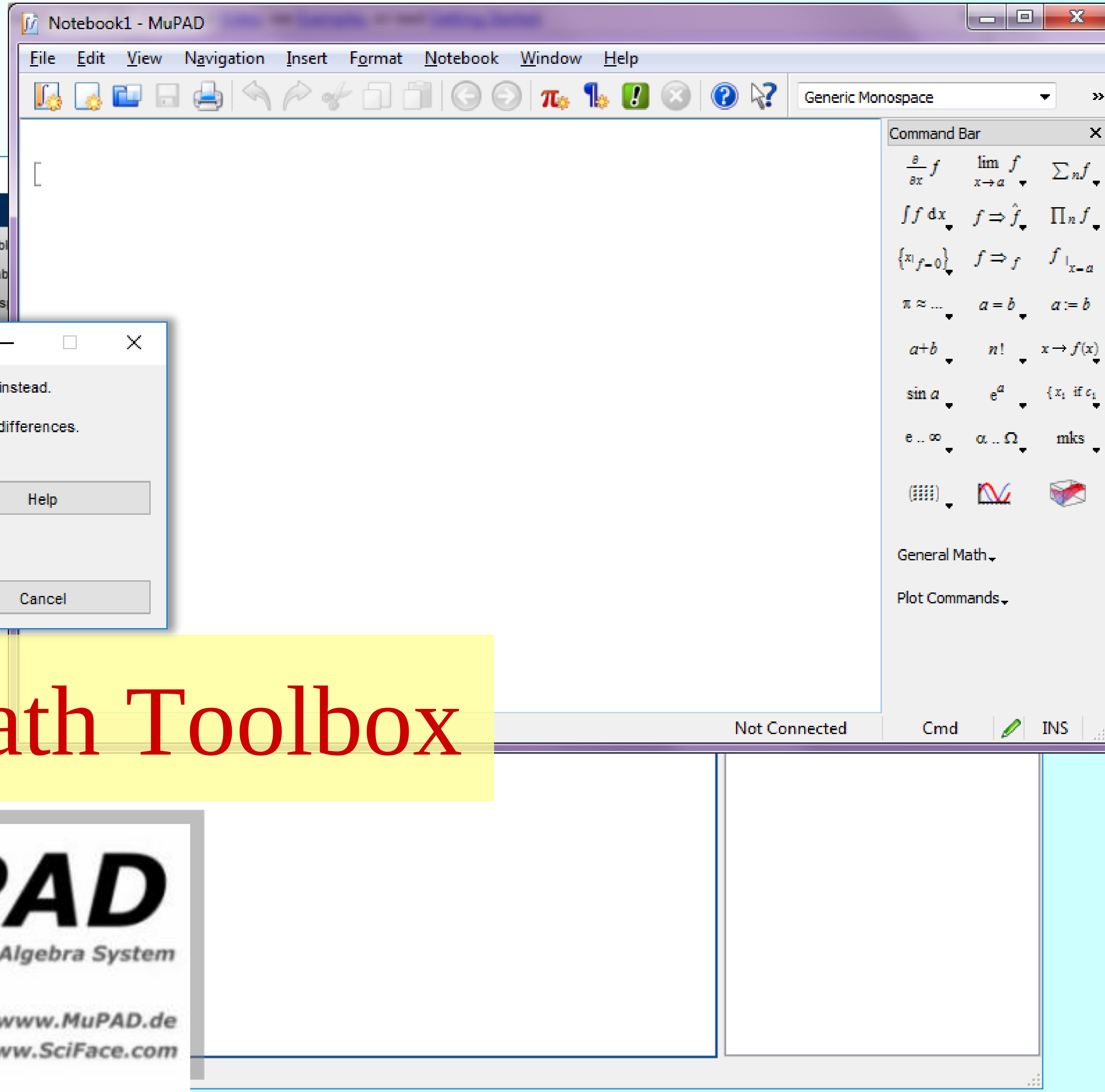
MATLAB SIMULINK

Simscape


Simulink Library Browser
File Edit View Help
Enter search term
Libraries
Library: Simscape
Search Results: (none)
Frequently Used
Sources
User-Defined Functions
Additional Math & Discrete
Aerospace Blockset
Communications System
Computer Vision System
Control System Toolbox
DSP System Toolbox
Embedded Coder
Fuzzy Logic Toolbox
HDL Verifier
Image Acquisition Toolbox
Instrument Control Toolbo
Model Predictive Control T
Neural Network Toolbox
OPC Toolbox
Real-Time Windows Targe
Report Generator
Robust Control Toolbox
SimEvents
SimRF
Simscape
Simulink 3D Animation
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
SimPowerSystems
Utilities
Showing: Simscape

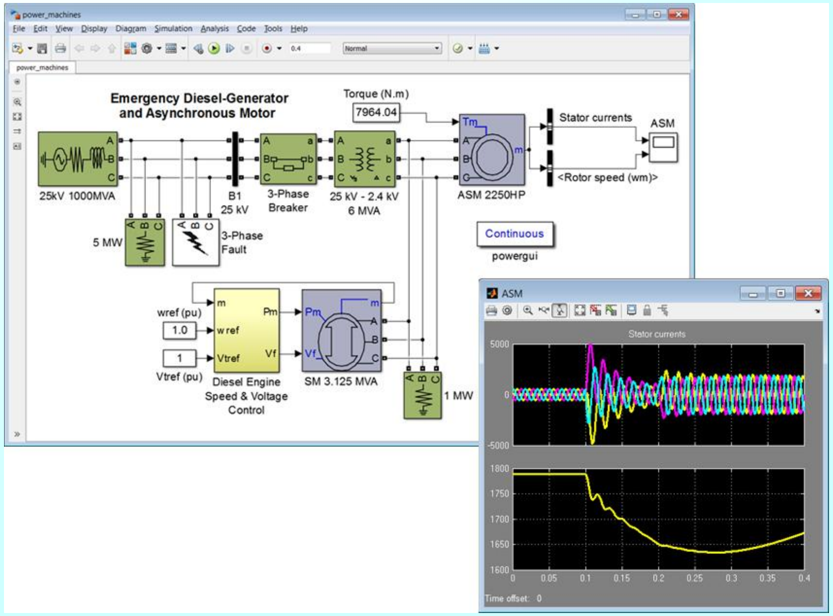
MuPAD

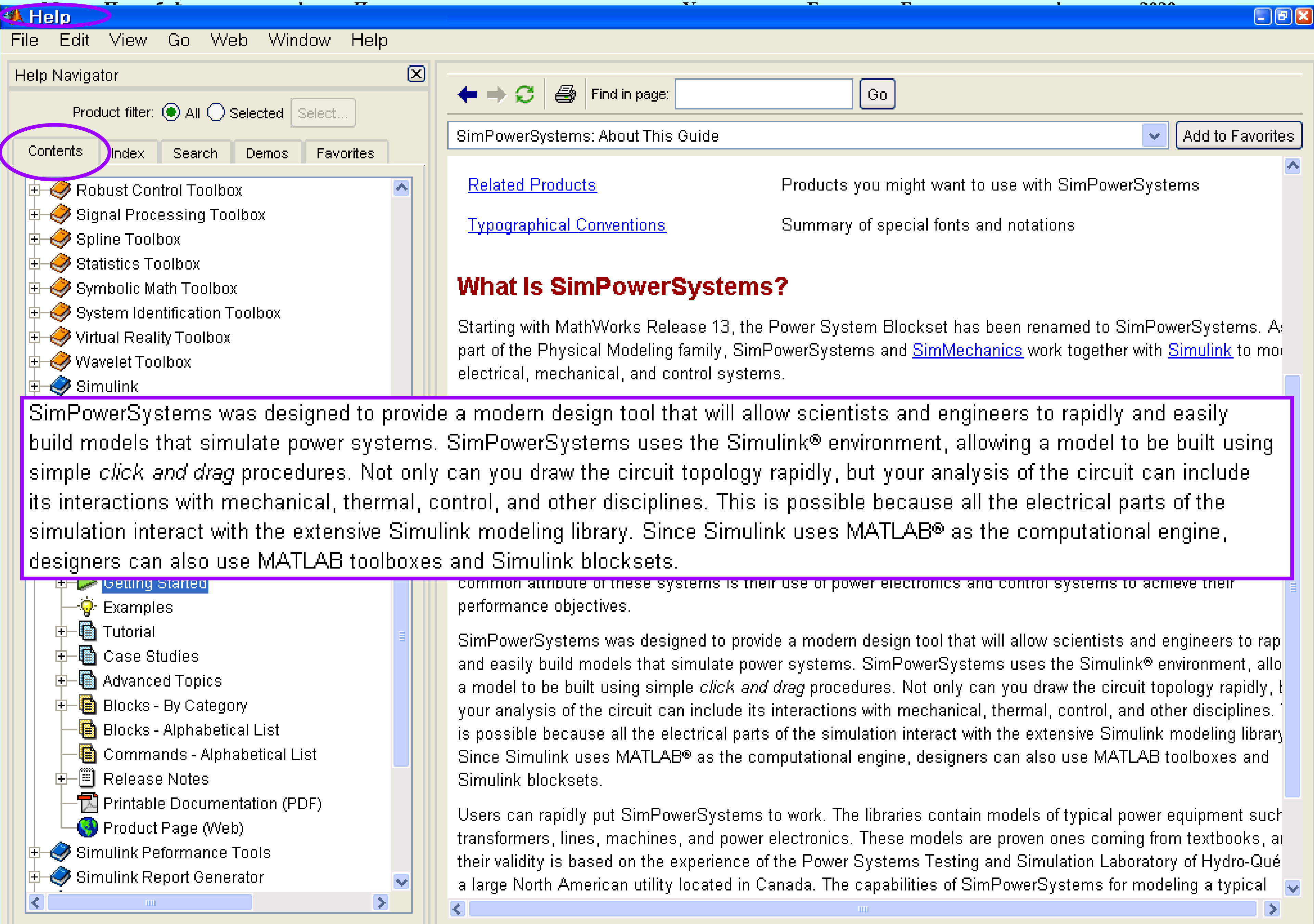


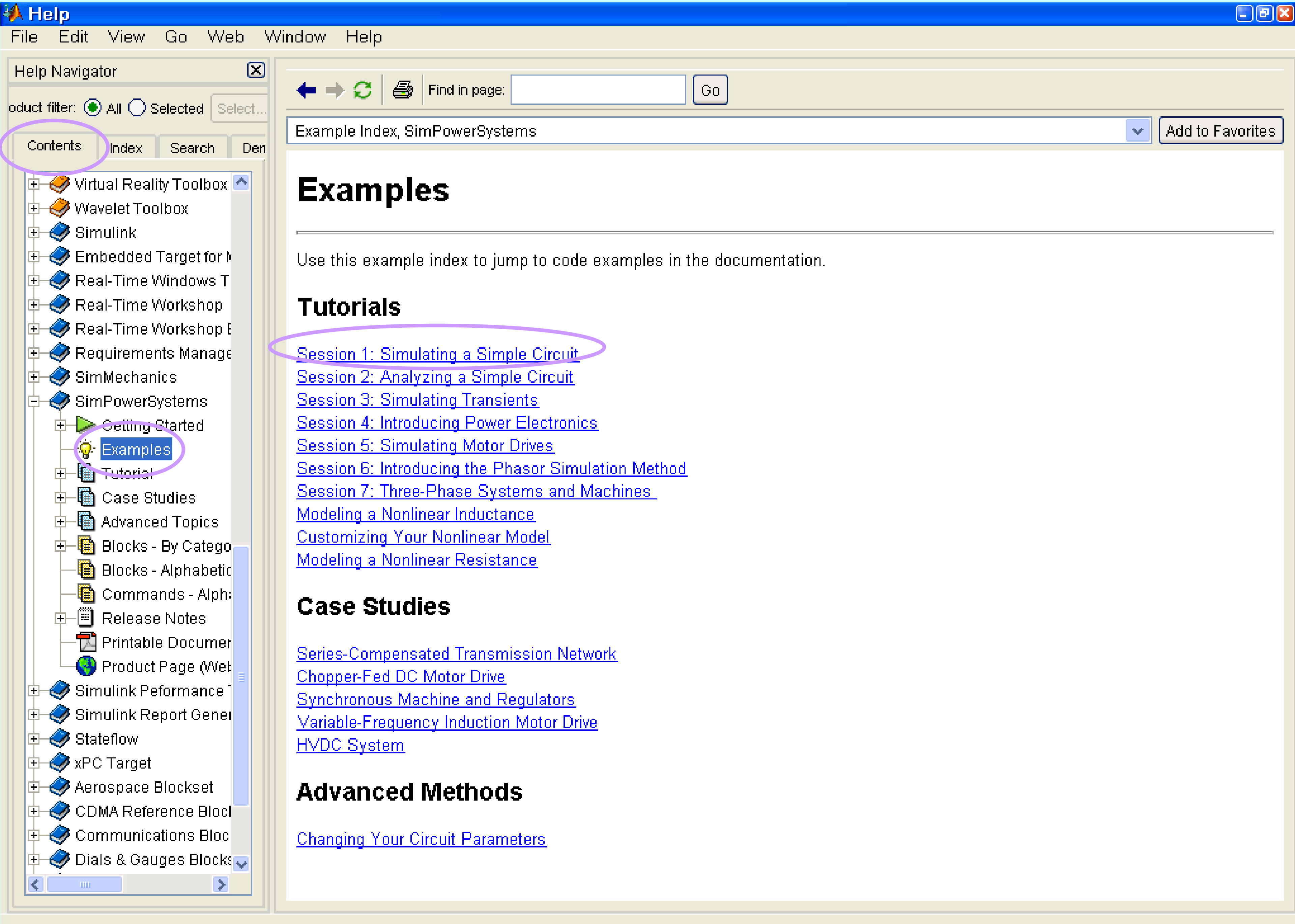


Symbolic Math Toolbox

SimPowerSystems




Help
File Edit View Go Web Window Help
Help Navigator
Product filter: All Selected Select...
Contents Index Search Demos Favorites
Robust Control Toolbox
Signal Processing Toolbox
Spline Toolbox
Statistics Toolbox
Symbolic Math Toolbox
System Identification Toolbox
Virtual Reality Toolbox
Wavelet Toolbox
Simulink
Getting Started
Examples
Tutorial
Case Studies
Advanced Topics
Blocks - By Category
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.
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


Help
File Edit View Go Web Window Help
Help Navigator
oduct filter: All Selected Select...
Contents
Index
Search
Den
Virtual Reality Toolbox
Wavelet Toolbox
Simulink
Embedded Target for M
Real-Time Windows T
Real-Time Workshop
Real-Time Workshop E
Requirements Manage
SimMechanics
SimPowerSystems
Getting Started
Examples
Tutorial
Case Studies
Advanced Topics
Blocks - By Catego
Blocks - Alphabetic
Commands - Alph
Release Notes
Printable Documen
Product Page (Wel
Simulink Peformance
Simulink Report Gene
Stateflow
xPC Target
Aerospace Blockset
CDMA Reference Bloc
Communications Bloc
Dials & Gauges Block
Find in page:
Go
Example Index, SimPowerSystems
Add to Favorites
Examples
Use this example index to jump to code examples in the documentation.
Tutorials
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
Synchronous Machine and Regulators
Variable-Frequency Induction Motor Drive
HVDC System
Advanced Methods
Changing Your Circuit Parameters

Help

File Edit View Go Web Window Help

Help Navigator

oduct filter: All Selected Select...

Contents | Index | Search | Den

Find in page: Go

Example Index, SimPowerSystems | Add to Favorites

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.

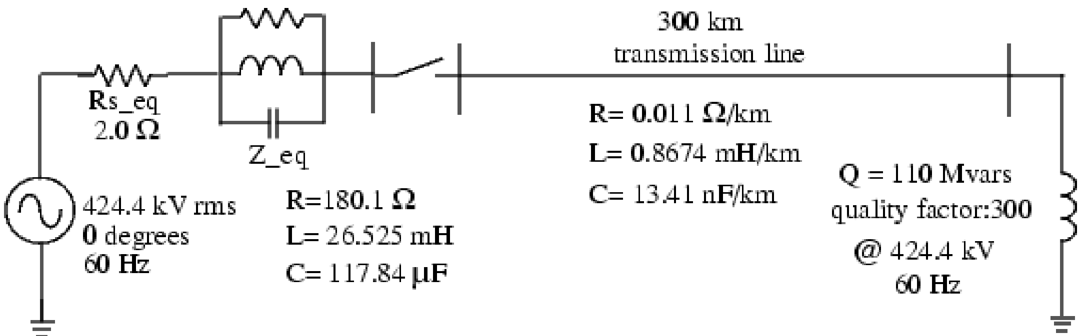
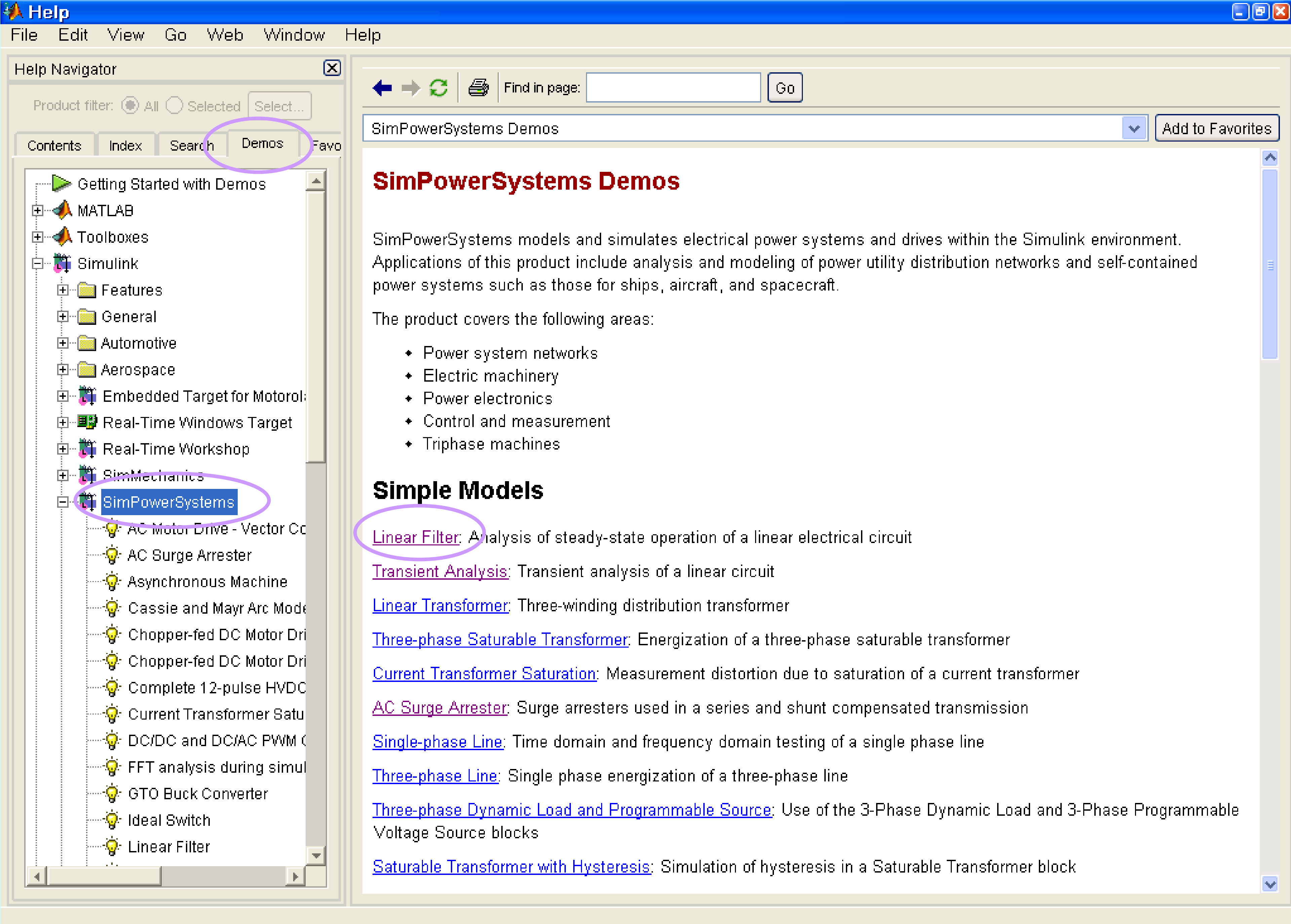
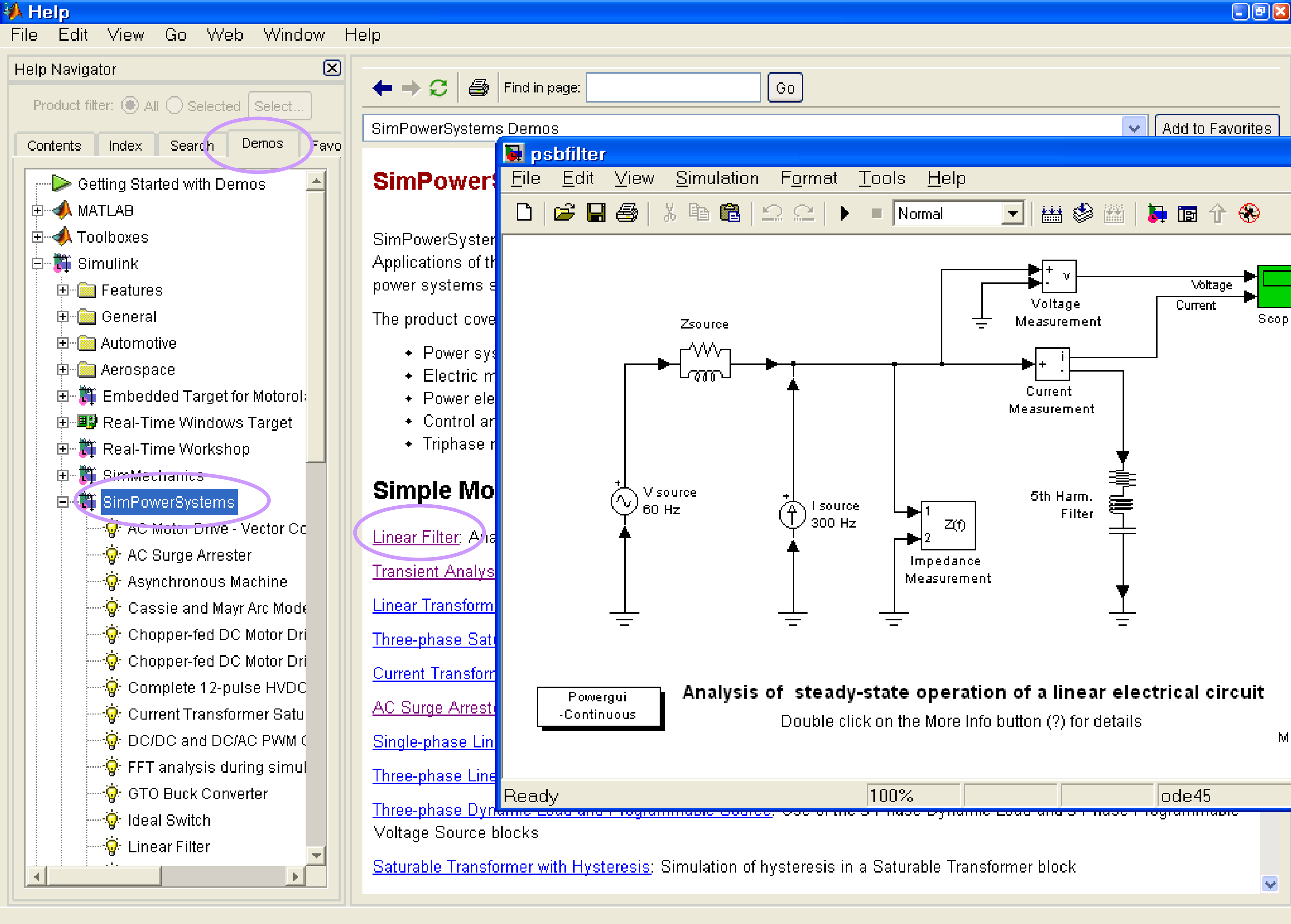


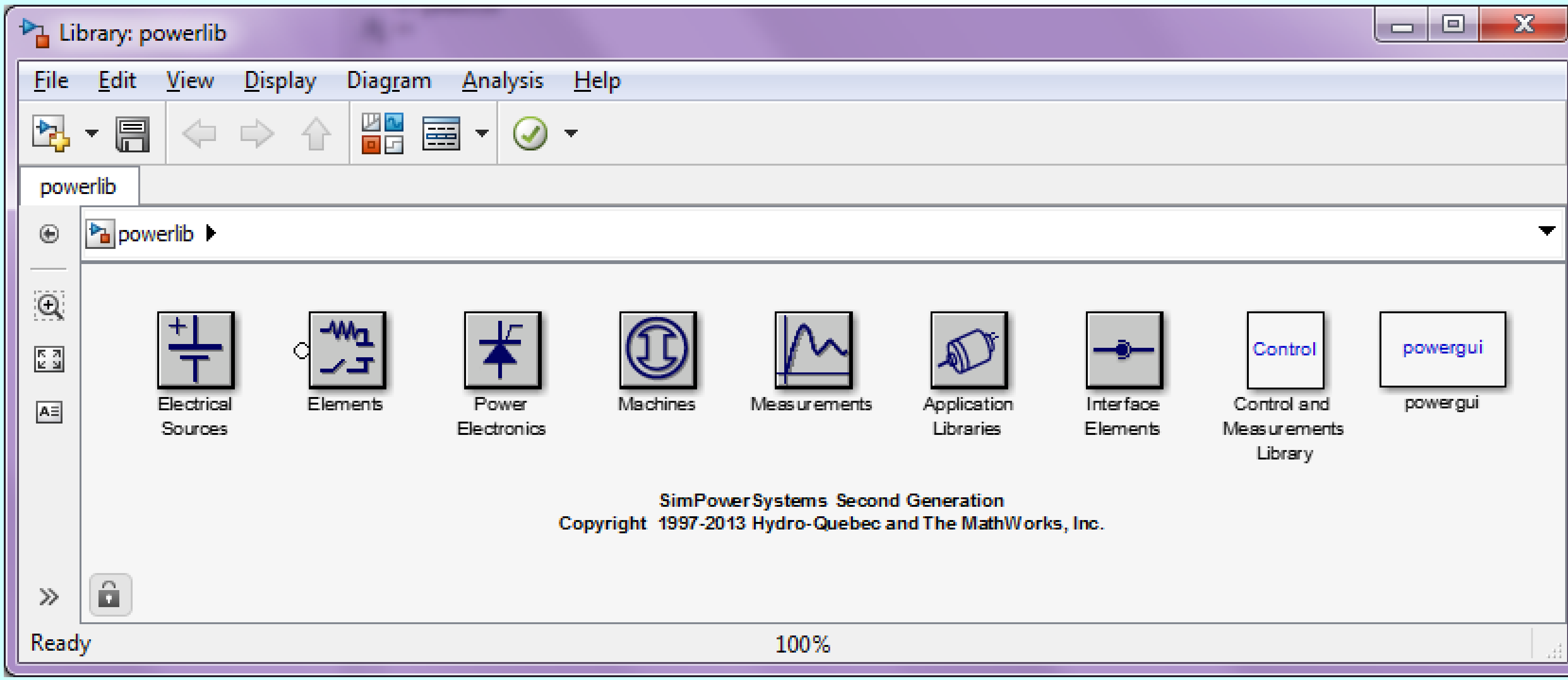
Figure 1-1: Circuit to Be Modeled with the Power System Blockset


Help
File Edit View Go Web Window Help
Help Navigator
Product filter: All Selected Select...
Contents Index Search Demos Favo
Getting Started with Demos
MATLAB
Toolboxes
Simulink
Features
General
Automotive
Aerospace
Embedded Target for Motorol
Real-Time Windows Target
Real-Time Workshop
SimMechanics
SimPowerSystems
AC Motor Drive - Vector Cc
AC Surge Arrester
Asynchronous Machine
Cassie and Mayr Arc Mode
Chopper-fed DC Motor Dri
Chopper-fed DC Motor Dri
Complete 12-pulse HVDC
Current Transformer Satu
DC/DC and DC/AC PWM (
FFT analysis during simul
GTO Buck Converter
Ideal Switch
Linear Filter
Find in page: Go
SimPowerSystems Demos
Add to Favorites
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


Help
File Edit View Go Web Window Help
Help Navigator
Product filter: All Selected Select...
Contents Index Search Demos Favo
Getting Started with Demos
MATLAB
Toolboxes
Simulink
Features
General
Automotive
Aerospace
Embedded Target for Motorol
Real-Time Windows Target
Real-Time Workshop
SimMechanics
SimPowerSystems
AC Motor Drive - Vector Co
AC Surge Arrester
Asynchronous Machine
Cassie and Mayr Arc Mode
Chopper-fed DC Motor Dri
Chopper-fed DC Motor Dri
Complete 12-pulse HVDC
Current Transformer Satu
DC/DC and DC/AC PWM
FFT analysis during simul
GTO Buck Converter
Ideal Switch
Linear Filter
Find in page: Go
SimPowerSystems Demos
Add to Favorites
SimPower
SimPowerSyster
Applications of th
power systems s
The product cove
Power sys
Electric m
Power ele
Control ar
Triphase r
Simple Mo
Linear Filter: Ana
Transient Analys
Linear Transform
Three-phase Satu
Current Transform
AC Surge Arreste
Single-phase Lin
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
psbfilter
File Edit View Simulation Format Tools Help
Normal
Zsource
Voltage Measurement
Voltage
Current
Scop
Current Measurement
V source 60 Hz
I source 300 Hz
Z(f)
Impedance Measurement
5th Harm. Filter
Powergui -Continuous
Analysis of steady-state operation of a linear electrical circuit
Double click on the More Info button (?) for details
Ready
100%
ode45

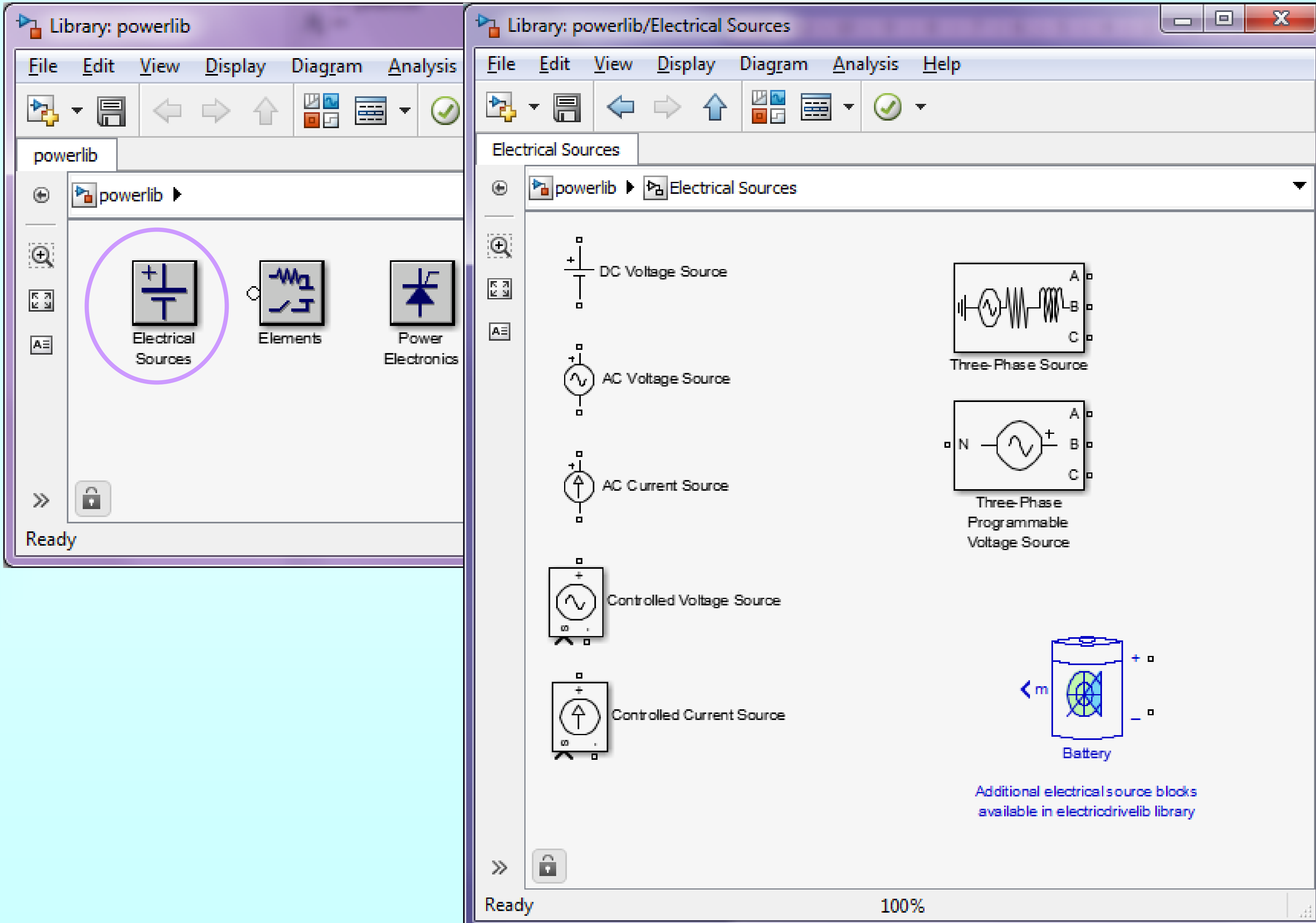
Симулација електричних кола

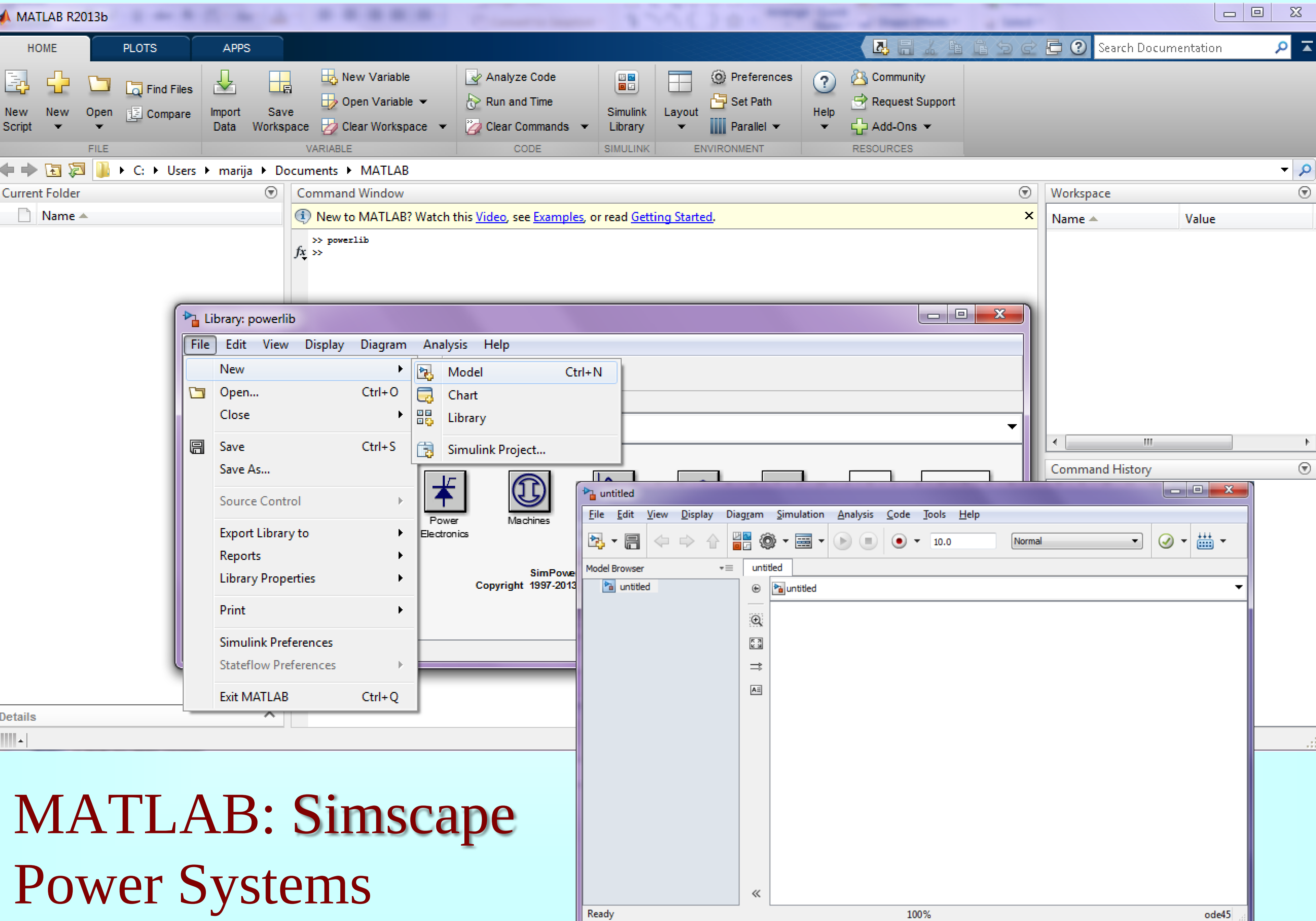
powerlib



Симулација електричних кола

powerlib

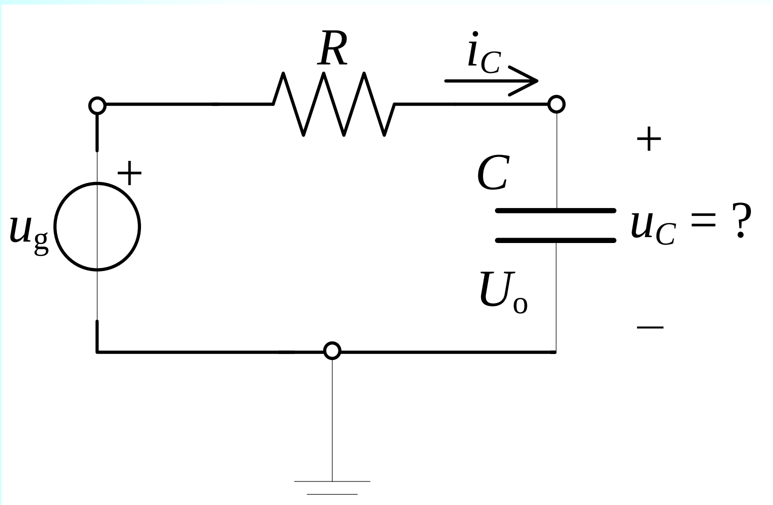




MATLAB: Simscape Power Systems

Пример анализе ел. кола

коло је образовано у тренутку $t_0 = 0$

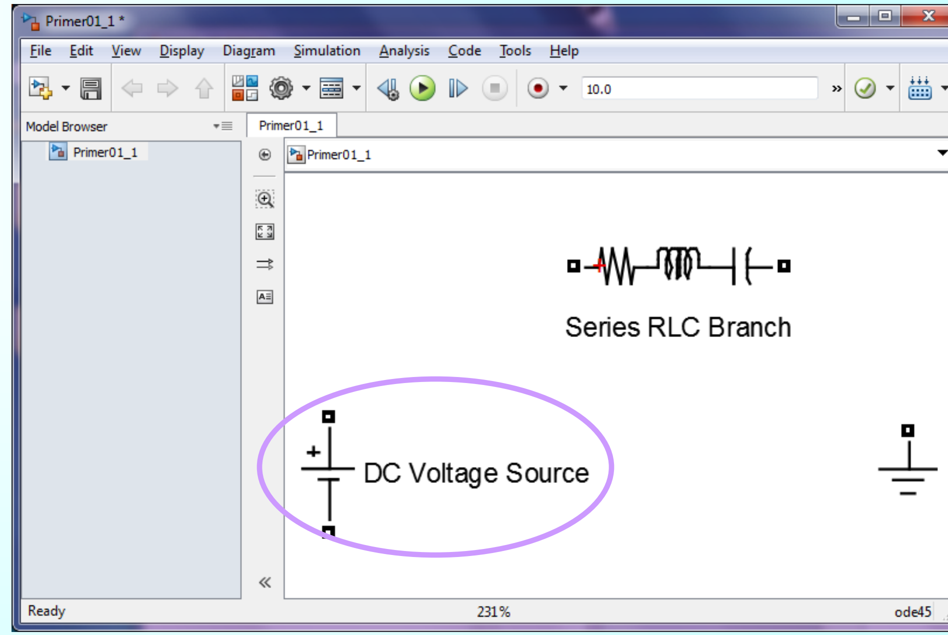


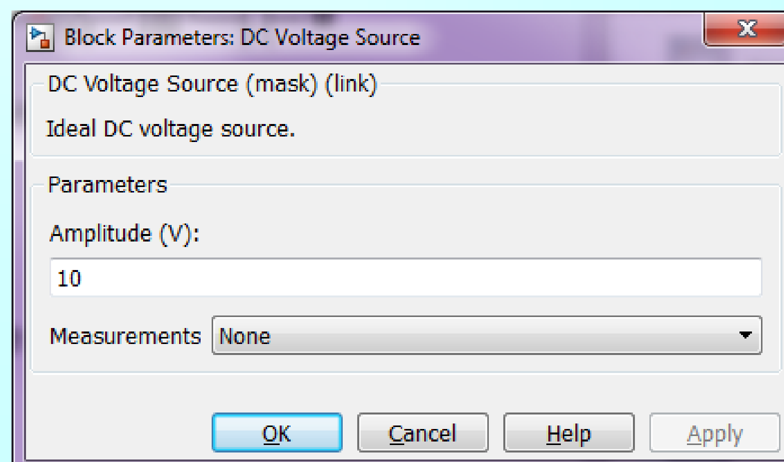
$R = 1\,\mathrm{k}\Omega$

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

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

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

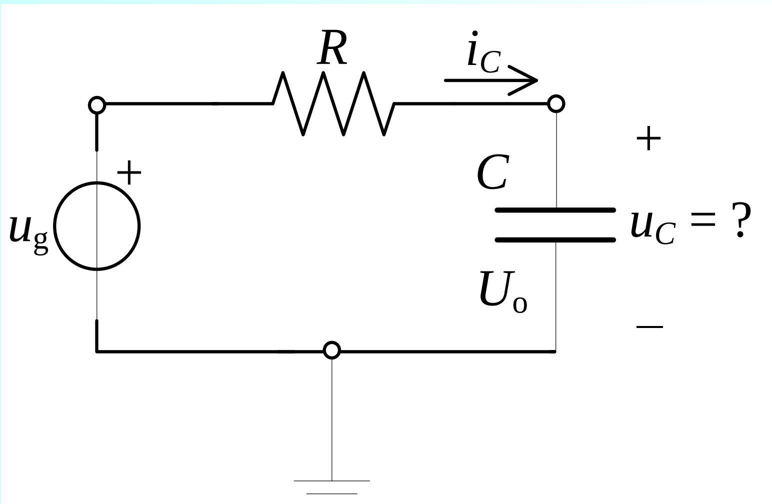




MATLAB: Simscape Power Systems

Подешавање параметара ел. кола

коло је образовано у тренутку $t_0 = 0$

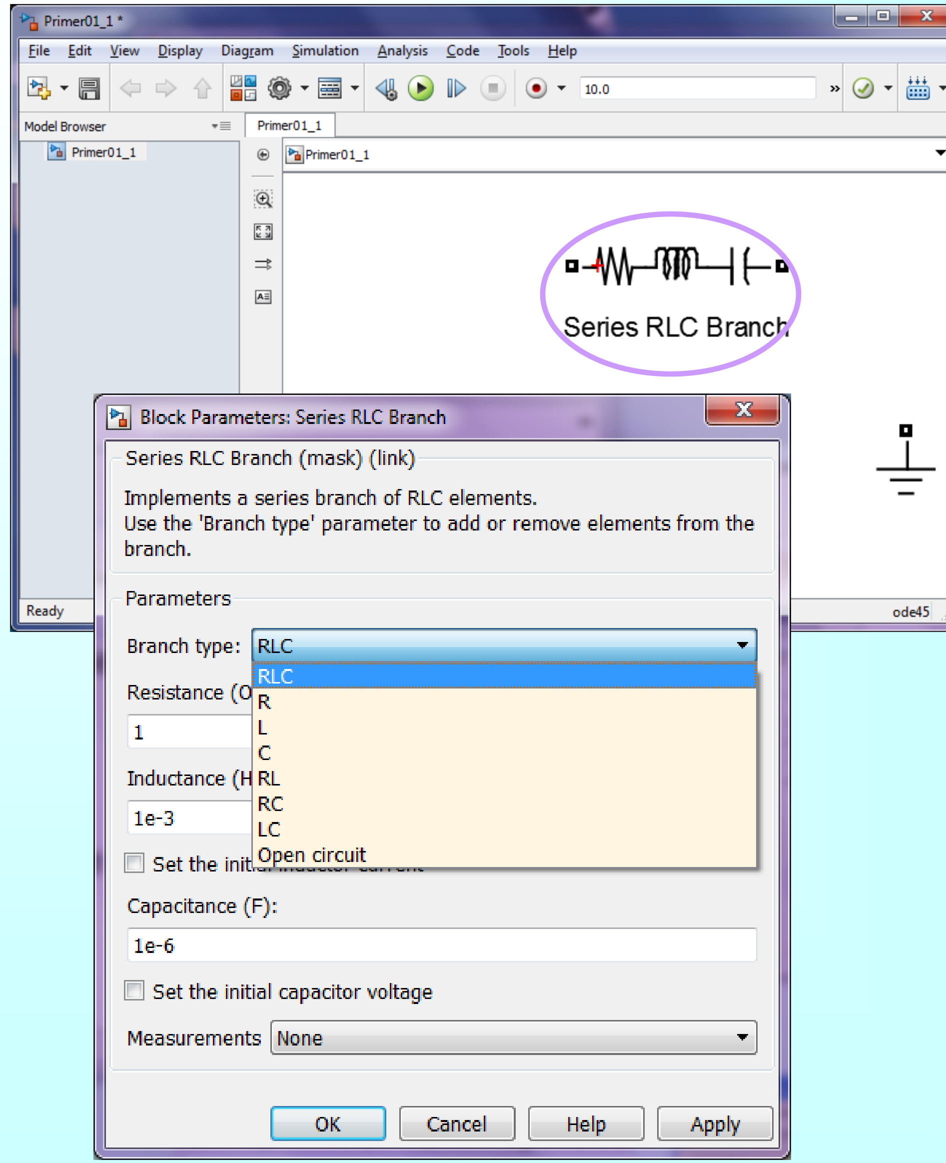


$R = 1\,\mathrm{k\Omega}$

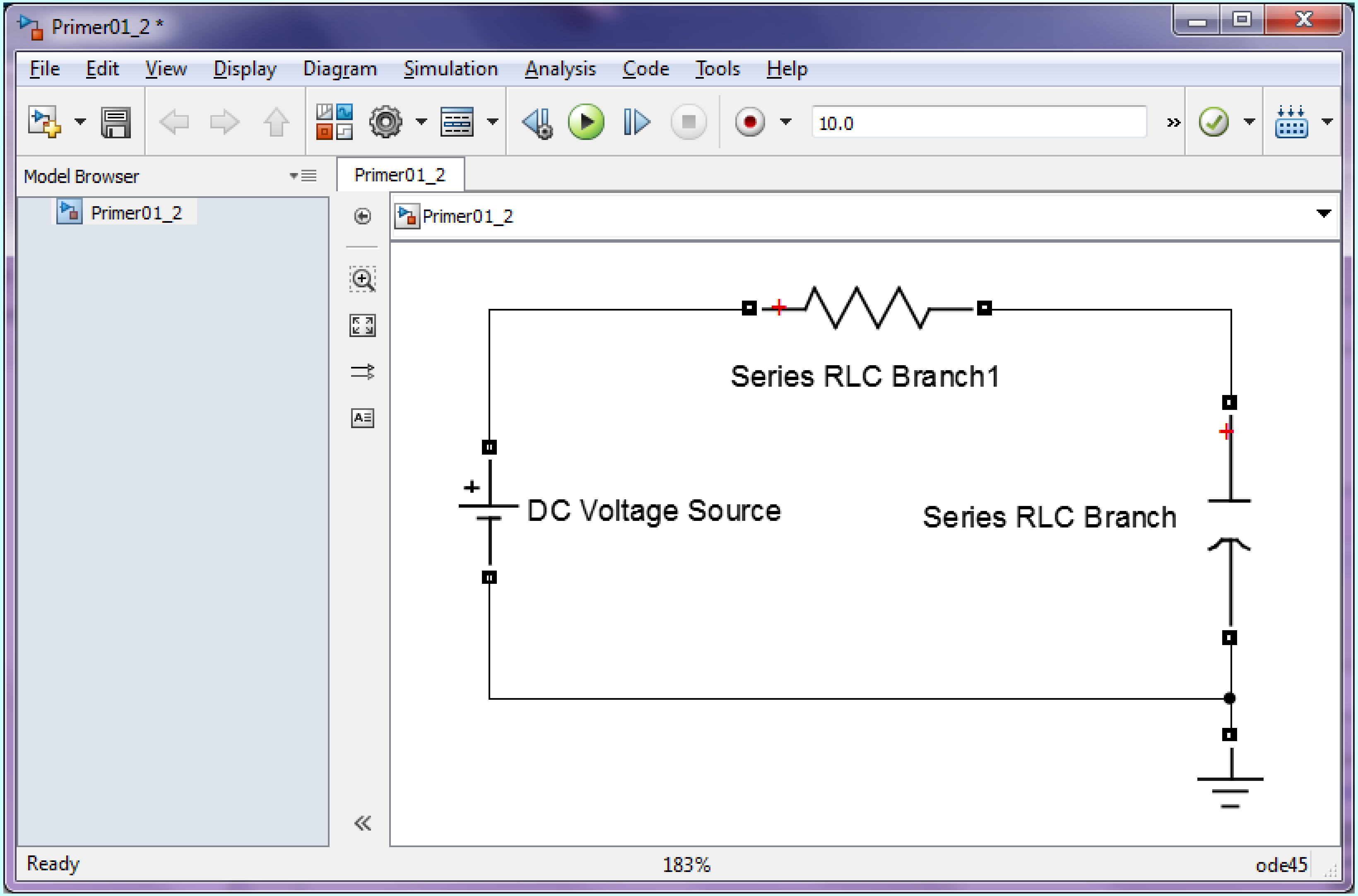
$C = 1\,\mu\mathrm{F}$

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

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



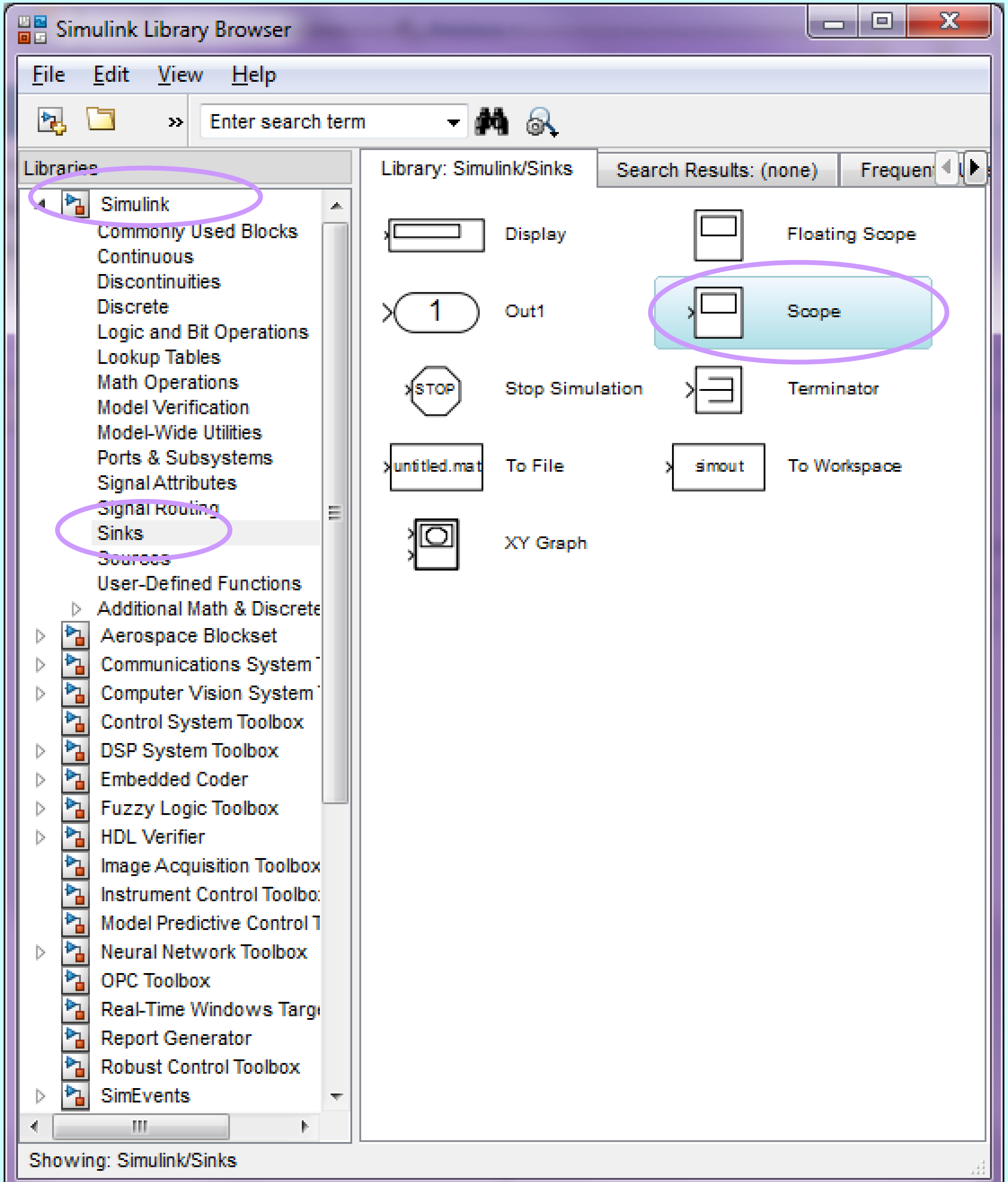
MATLAB: Simscape Power Systems

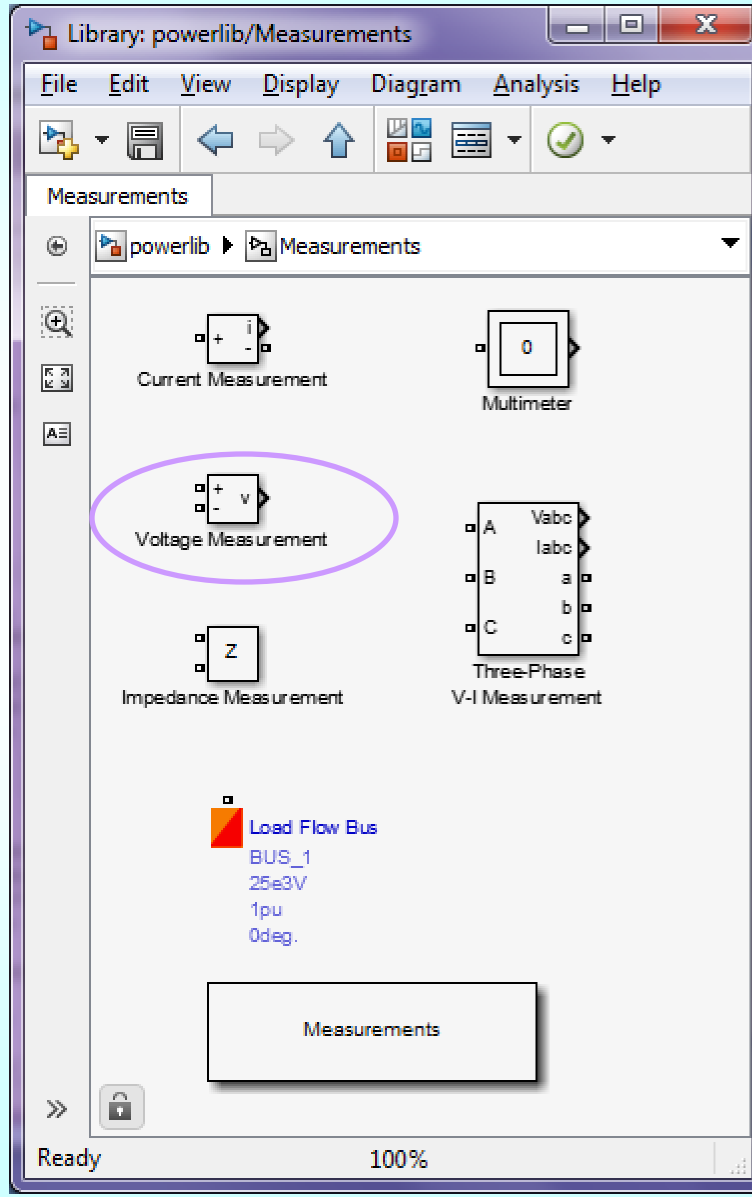


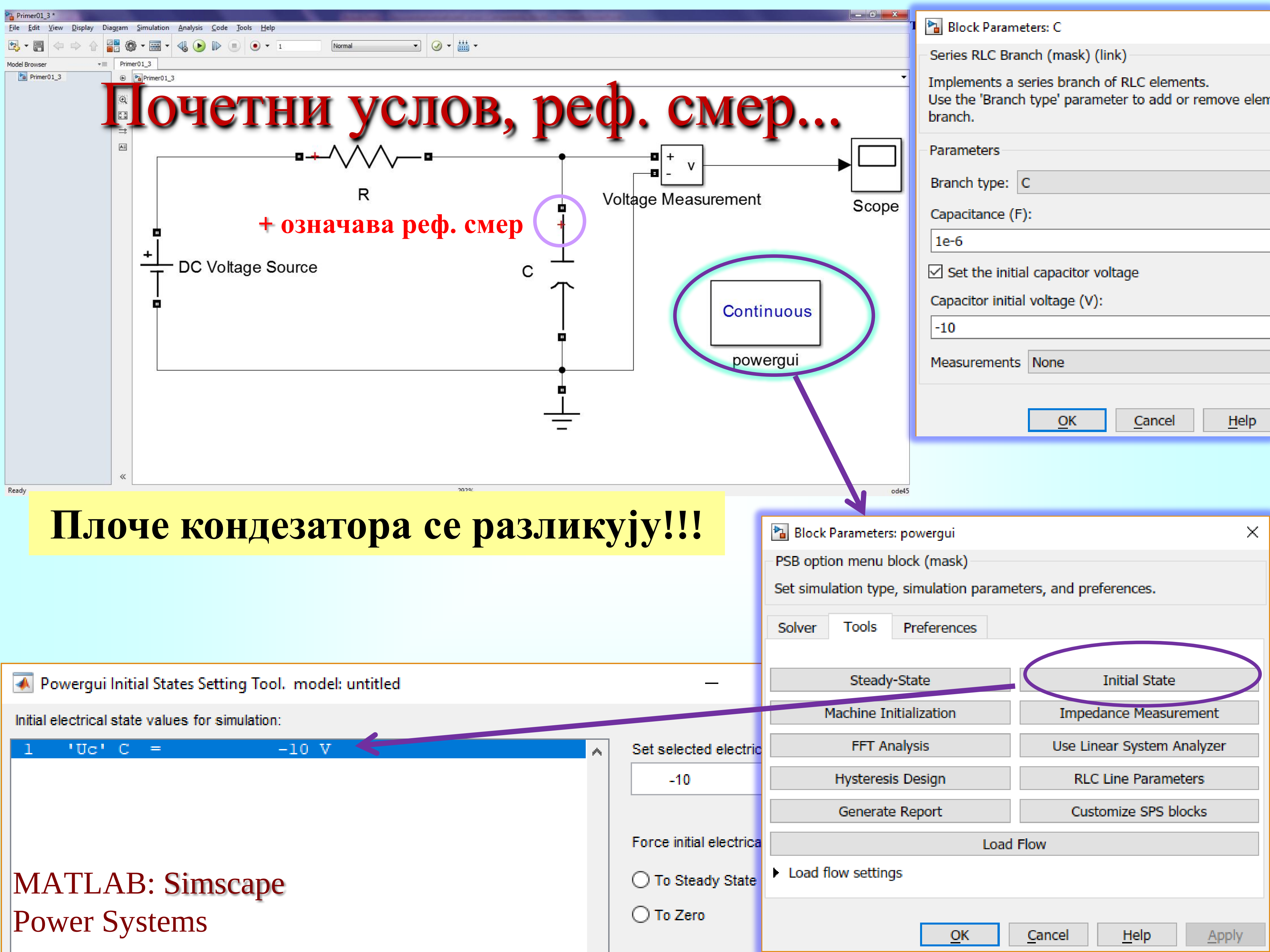
MATLAB: Simscape Power Systems

Како се мери напон???

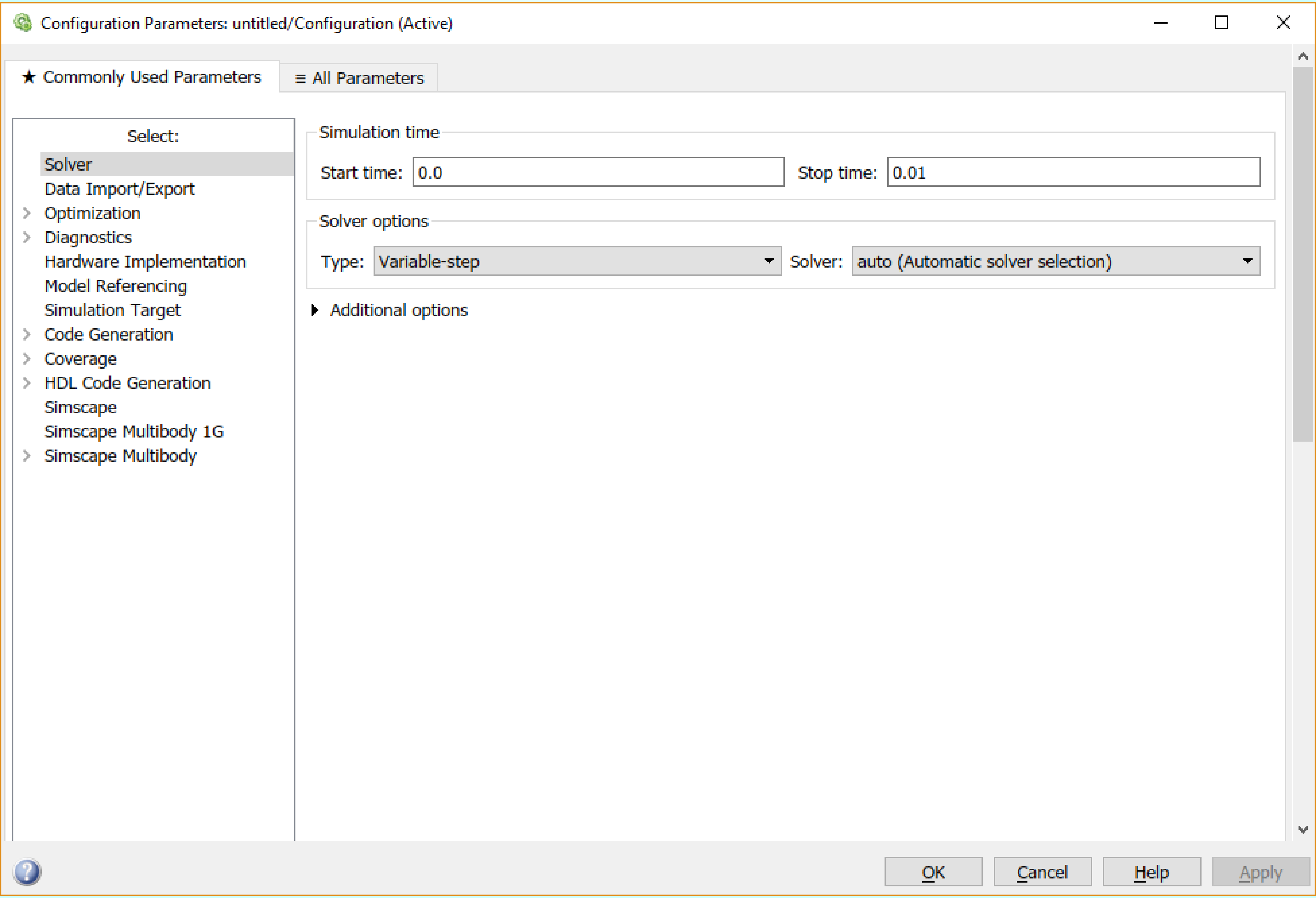
MATLAB: Simscape Power Systems

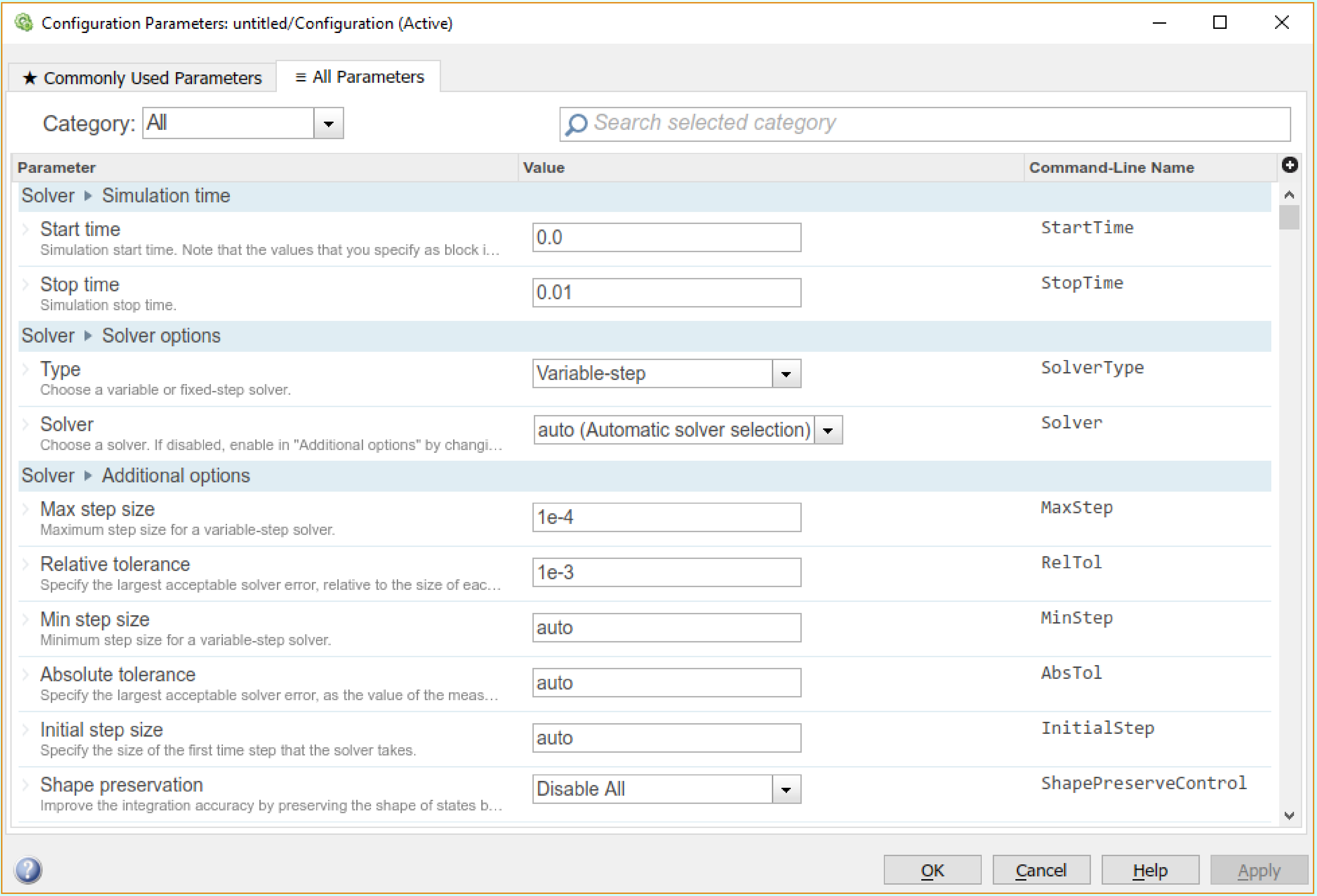




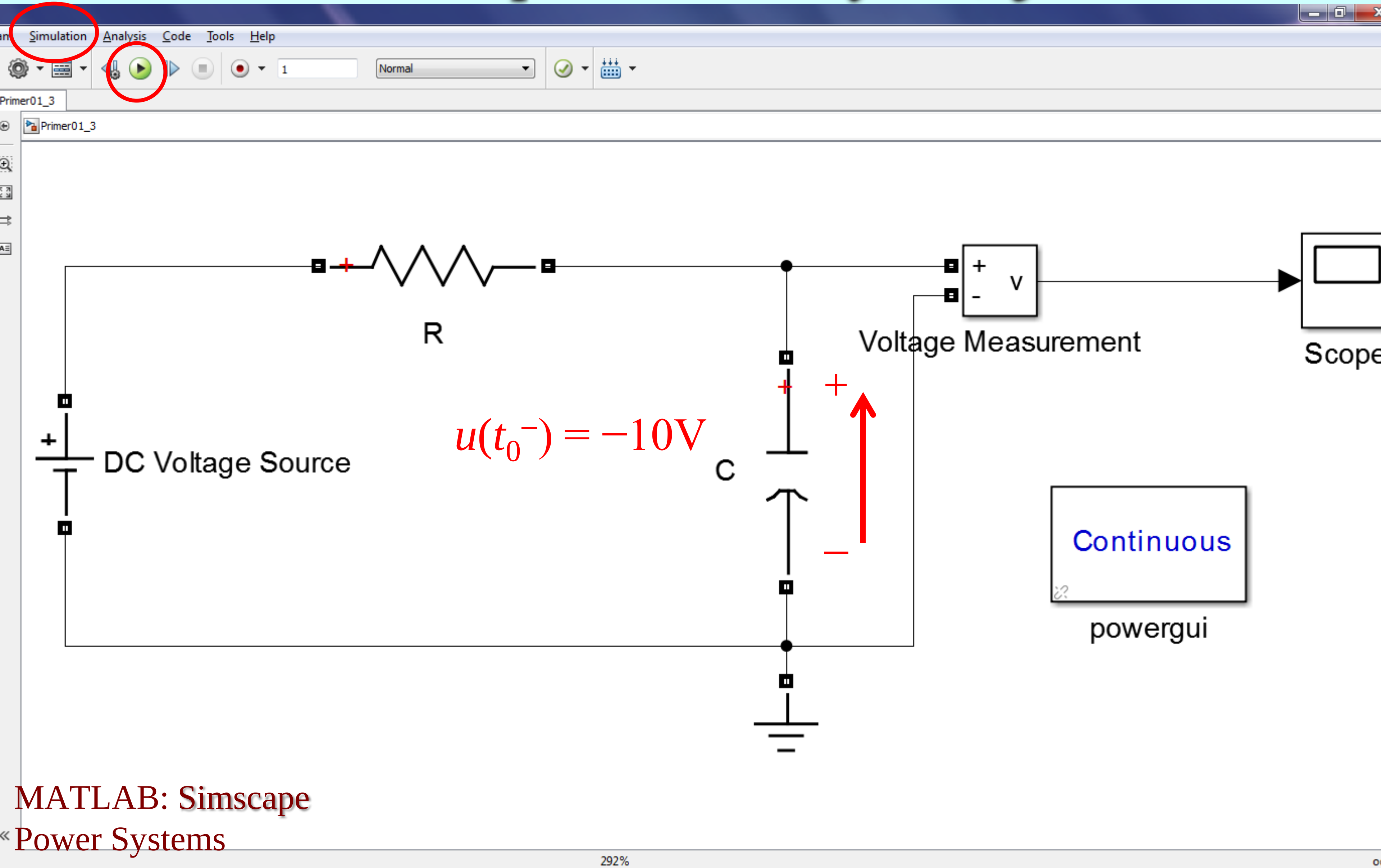


Почетни услов, реф. смер...
Primer01_3 *
File Edit View Display Diagram Simulation Analysis Code Tools Help
Normal
Model Browser
Primer01_3
R
+ означава реф. смер
Voltage Measurement
Scope
DC Voltage Source
C
Continuous
powergui
Ready
ode45
Плоче кондезатора се разликују!!!
Block Parameters: C
Series RLC Branch (mask) (link)
Implements a series branch of RLC elements.
Use the 'Branch type' parameter to add or remove elem
branch.
Parameters
Branch type: C
Capacitance (F):
1e-6
Set the initial capacitor voltage
Capacitor initial voltage (V):
-10
Measurements None
OK
Cancel
Help
Block Parameters: powergui
PSB option menu block (mask)
Set simulation type, simulation parameters, and preferences.
Solver
Tools
Preferences
Steady-State
Initial State
Machine Initialization
Impedance Measurement
FFT Analysis
Use Linear System Analyzer
Hysteresis Design
RLC Line Parameters
Generate Report
Customize SPS blocks
Load Flow
Load flow settings
OK
Cancel
Help
Apply
Powergui Initial States Setting Tool. model: untitled
Initial electrical state values for simulation:
1 'Uc' C = -10 V
Set selected electric
-10
Force initial electrica
To Steady State
To Zero
MATLAB: Simscape
Power Systems


Configuration Parameters: untitled/Configuration (Active)
Commonly Used Parameters
All Parameters
Select:
Solver
Data Import/Export
Optimization
Diagnostics
Hardware Implementation
Model Referencing
Simulation Target
Code Generation
Coverage
HDL Code Generation
Simscape
Simscape Multibody 1G
Simscape Multibody
Simulation time
Start time: 0.0
Stop time: 0.01
Solver options
Type: Variable-step
Solver: auto (Automatic solver selection)
Additional options
OK
Cancel
Help
Apply


Configuration Parameters: untitled/Configuration (Active)
★ Commonly Used Parameters
≡ All Parameters
Category: All
Search selected category
Parameter
Value
Command-Line Name
Solver ▸ Simulation time
Start time
Simulation start time. Note that the values that you specify as block i...
0.0
StartTime
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
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

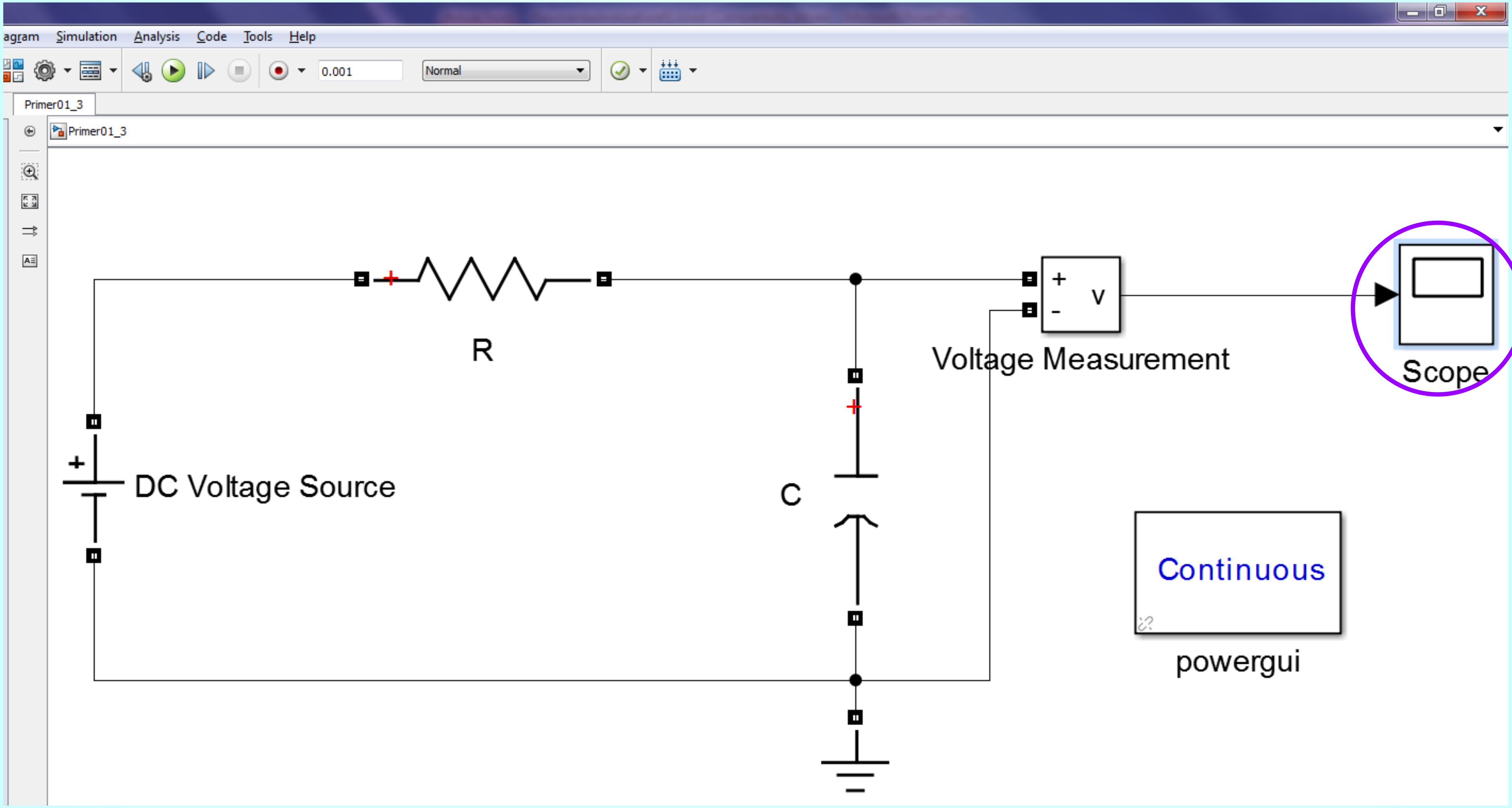
Покретање симулације...



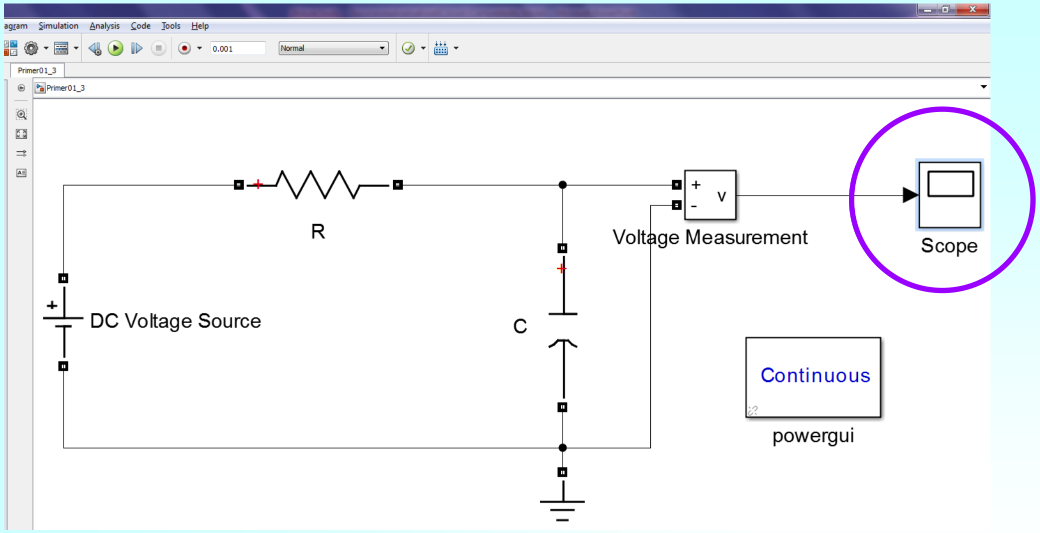
$$u(t_0^-) = -10\text{V}$$

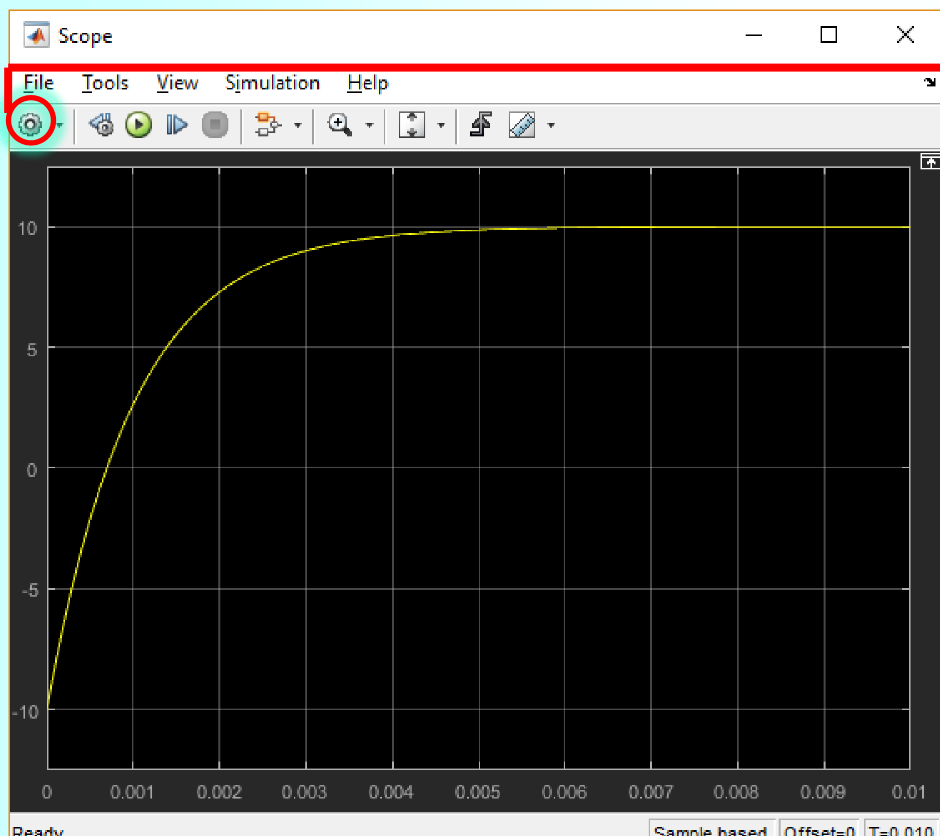
MATLAB: Simscape Power Systems

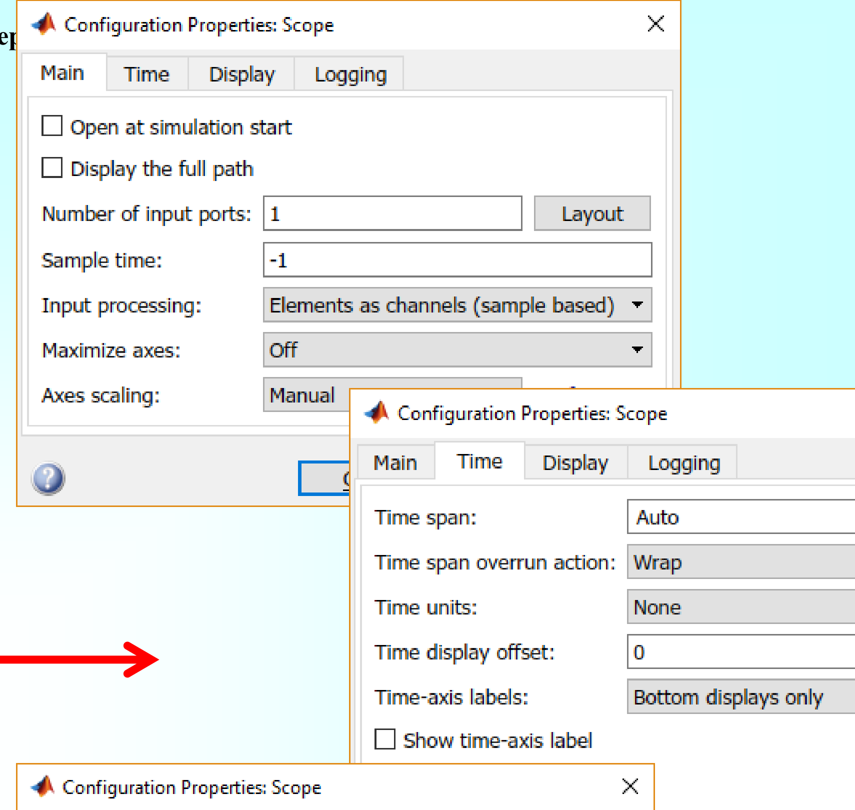
Налажење одзива... Осцилоскоп

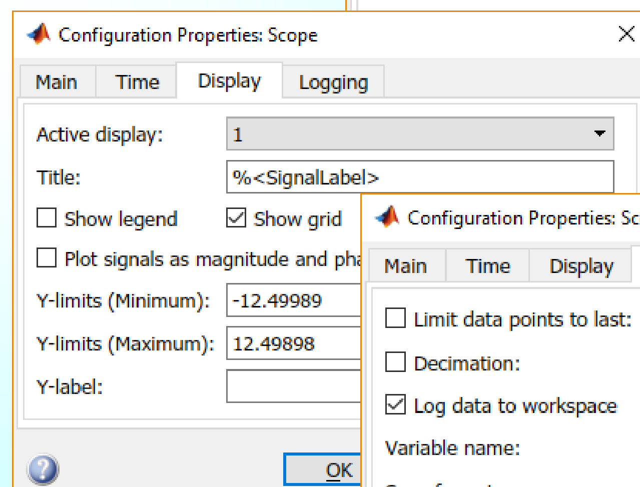


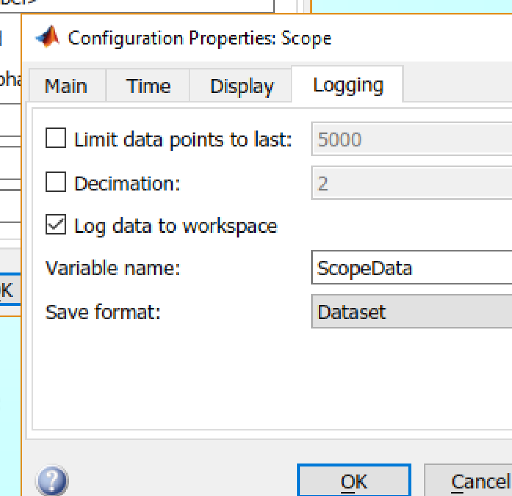
MATLAB: Simscape
Power Systems



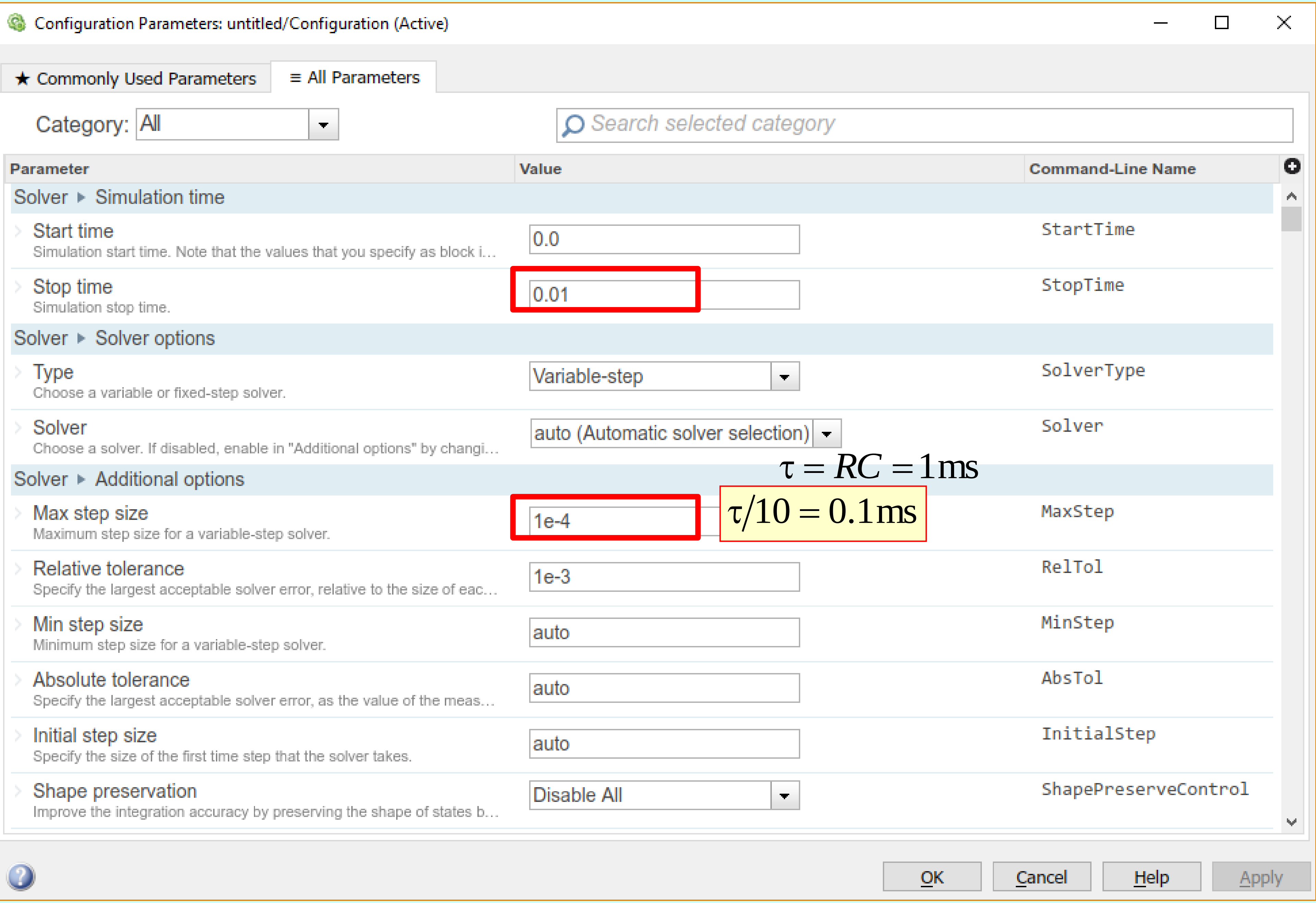








MATLAB: Simscape Power Systems

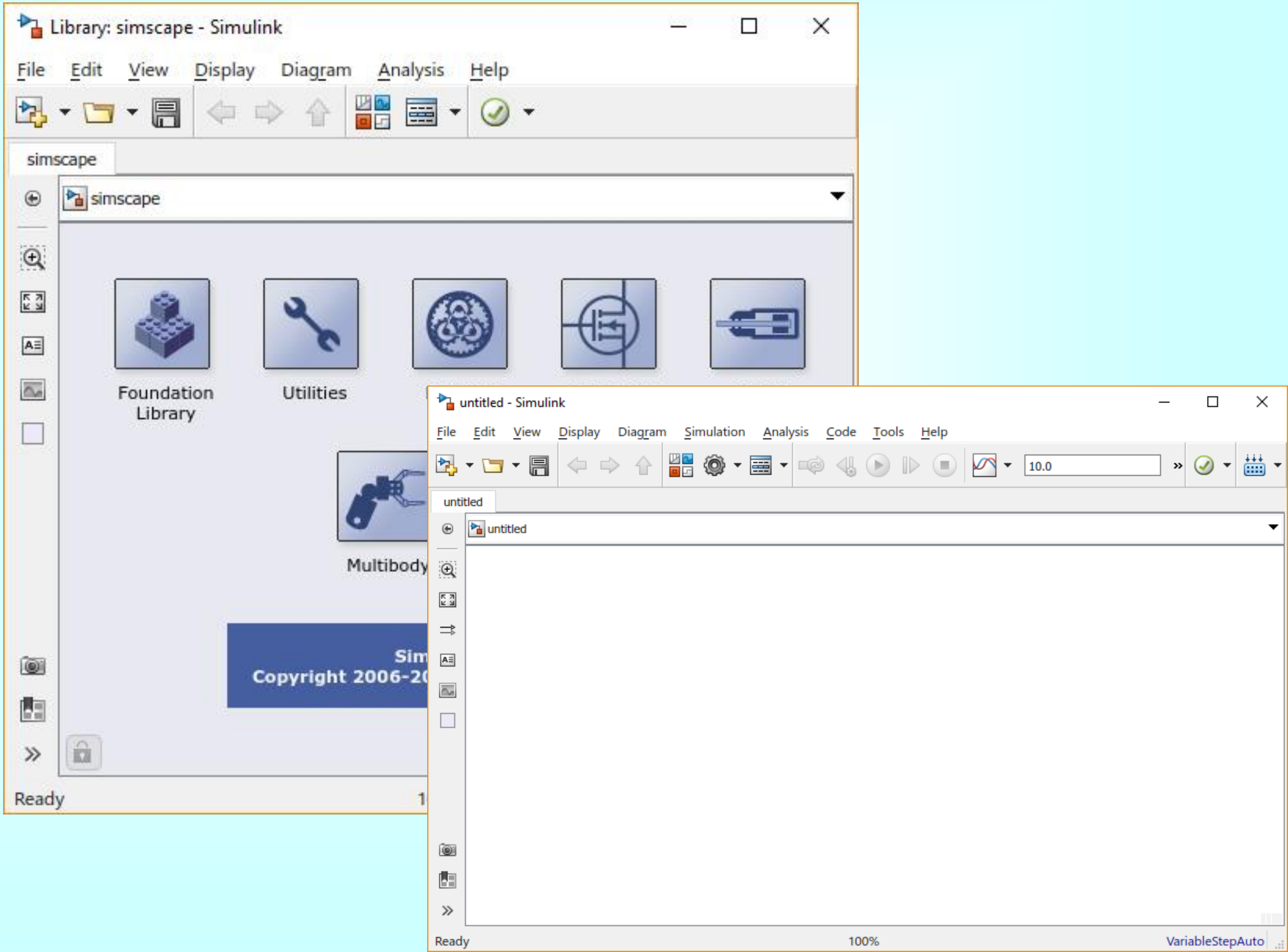


$$\tau = RC = 1\,\mathrm{ms}$$

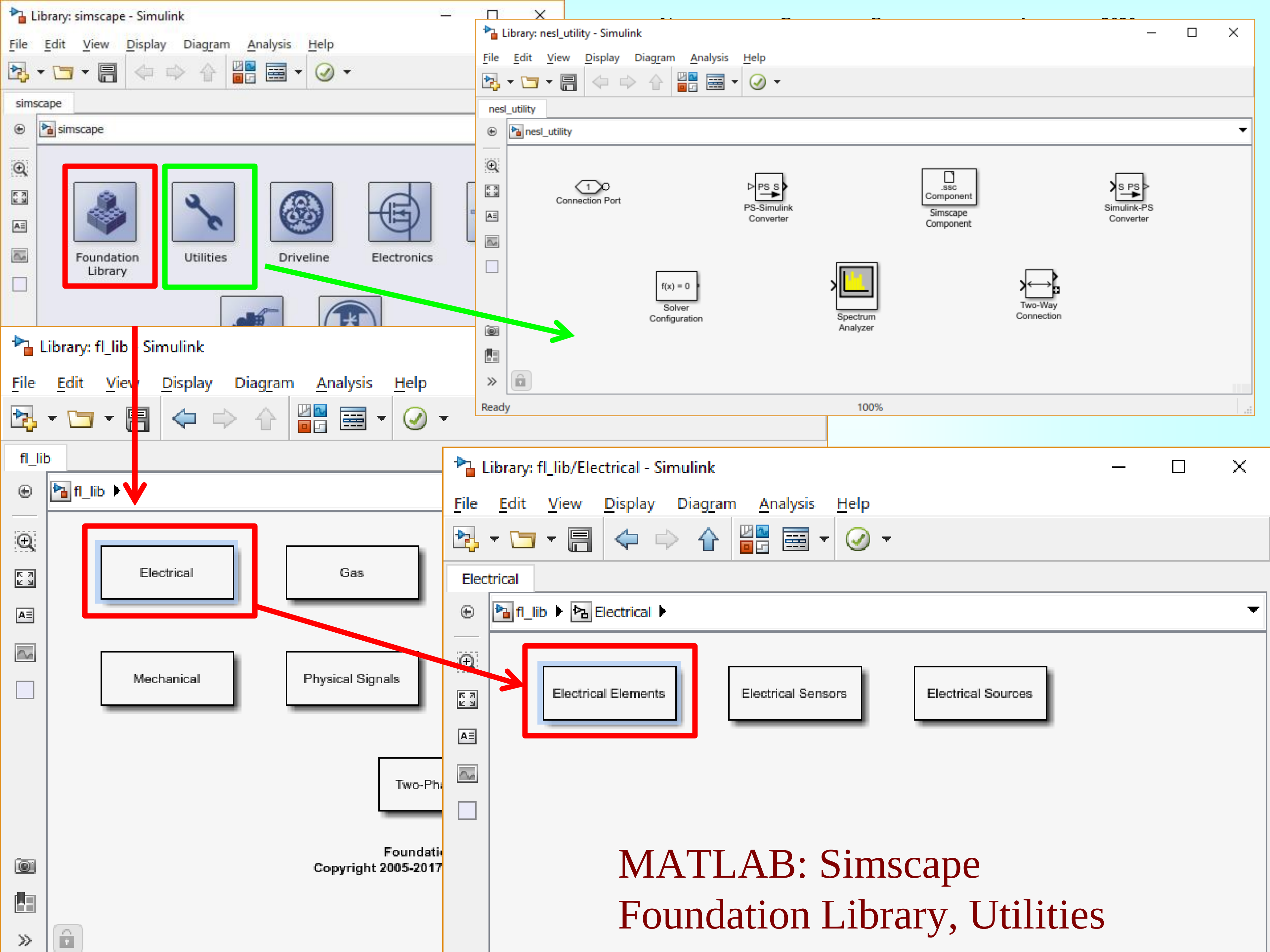
$$\tau/10 = 0.1\,\mathrm{ms}$$

Simscape – Foundation Library, Utilities

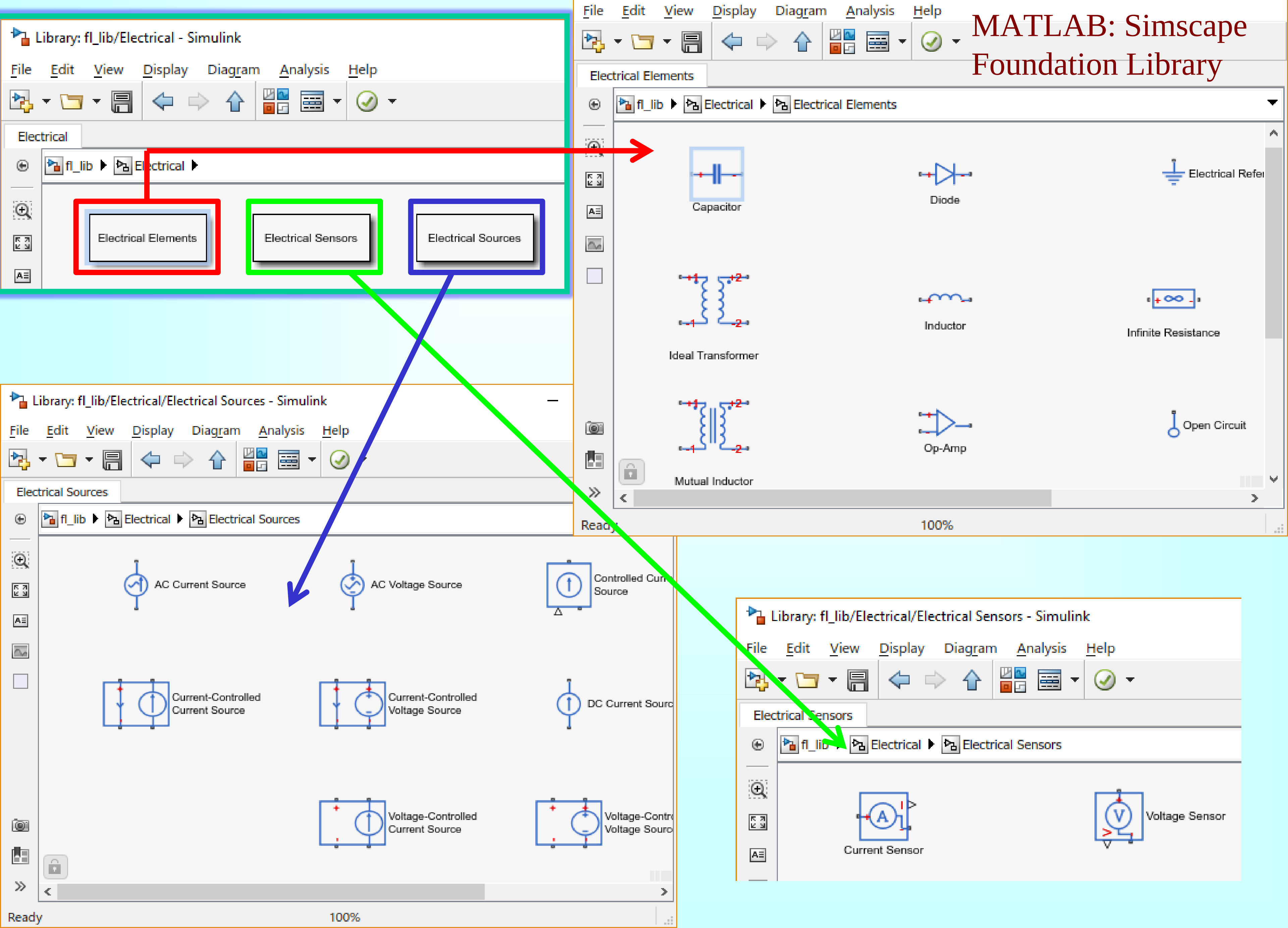
simscape



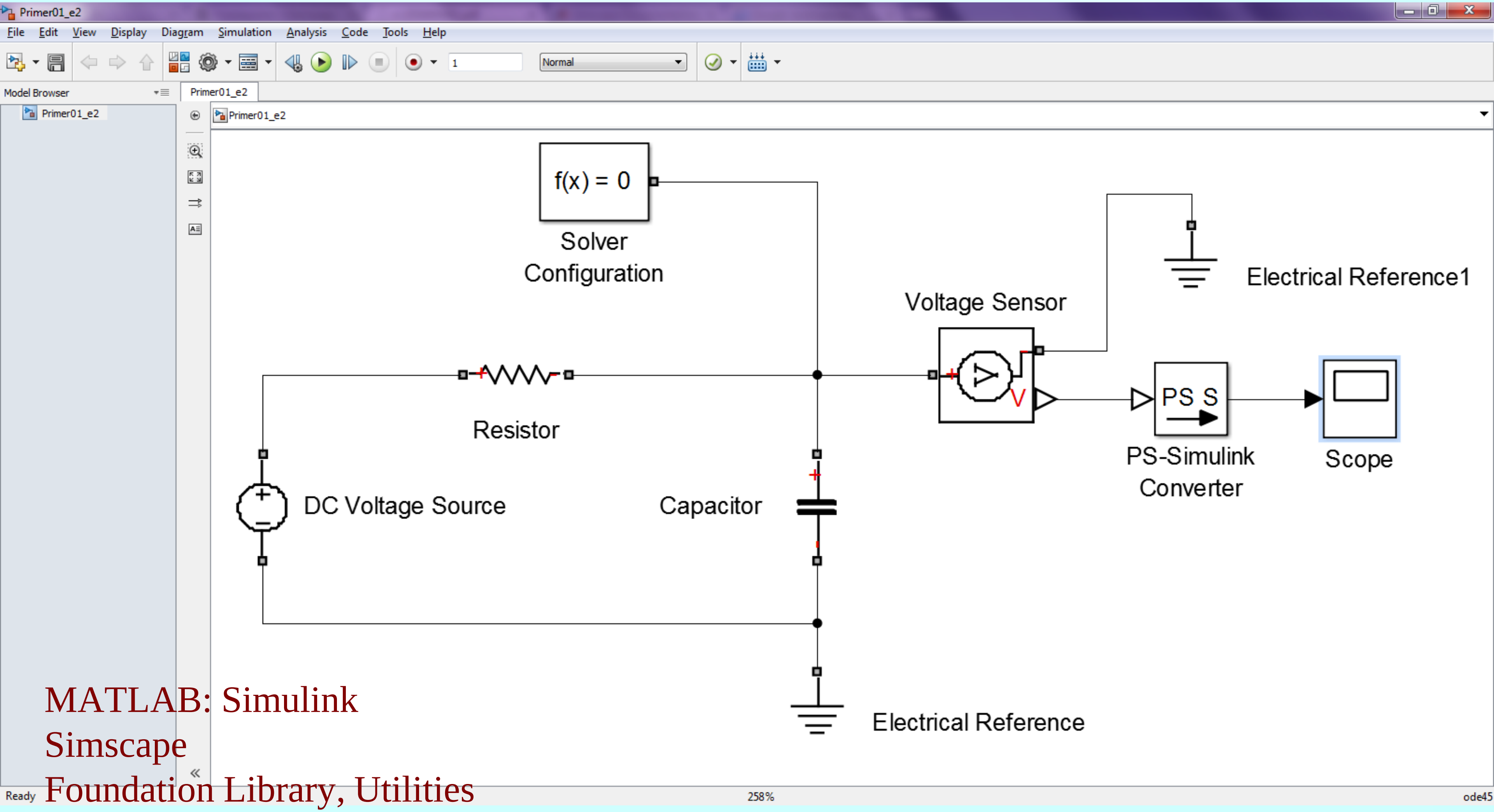
MATLAB: Simscape Foundation Library, Utilities



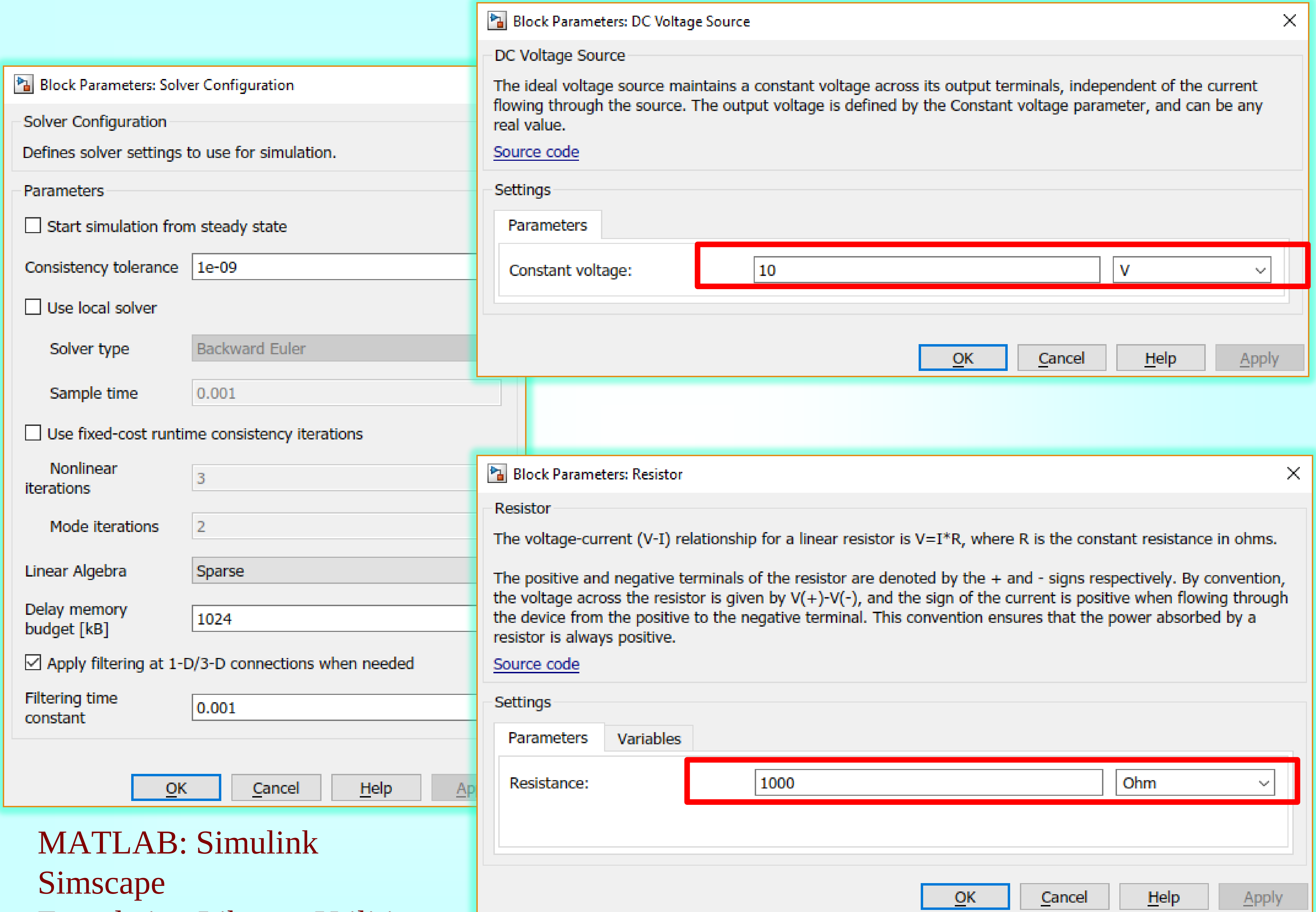
MATLAB: Simscape Foundation Library



Анализа електричног кола

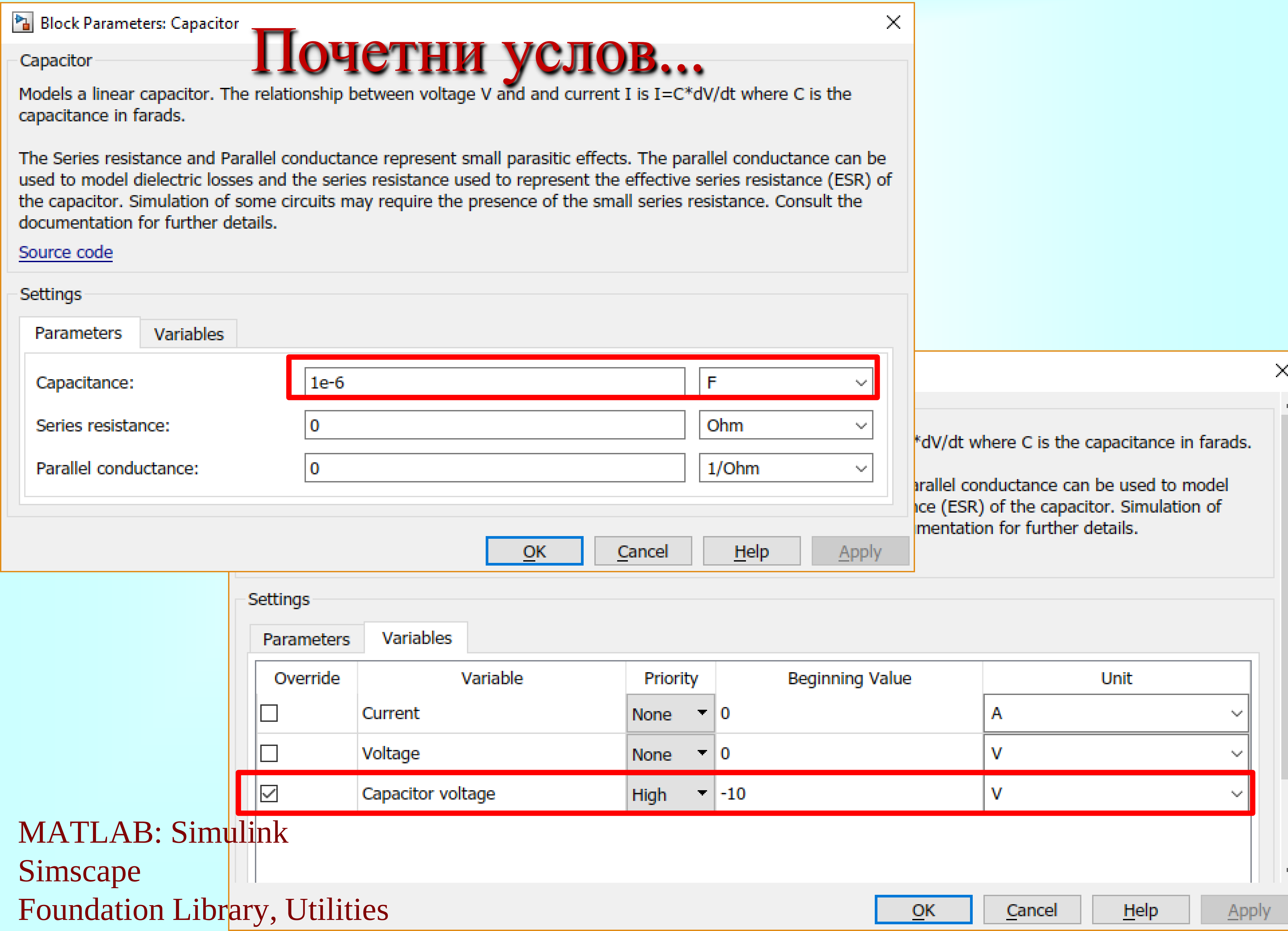


MATLAB: Simulink
Simscape
Foundation Library, Utilities



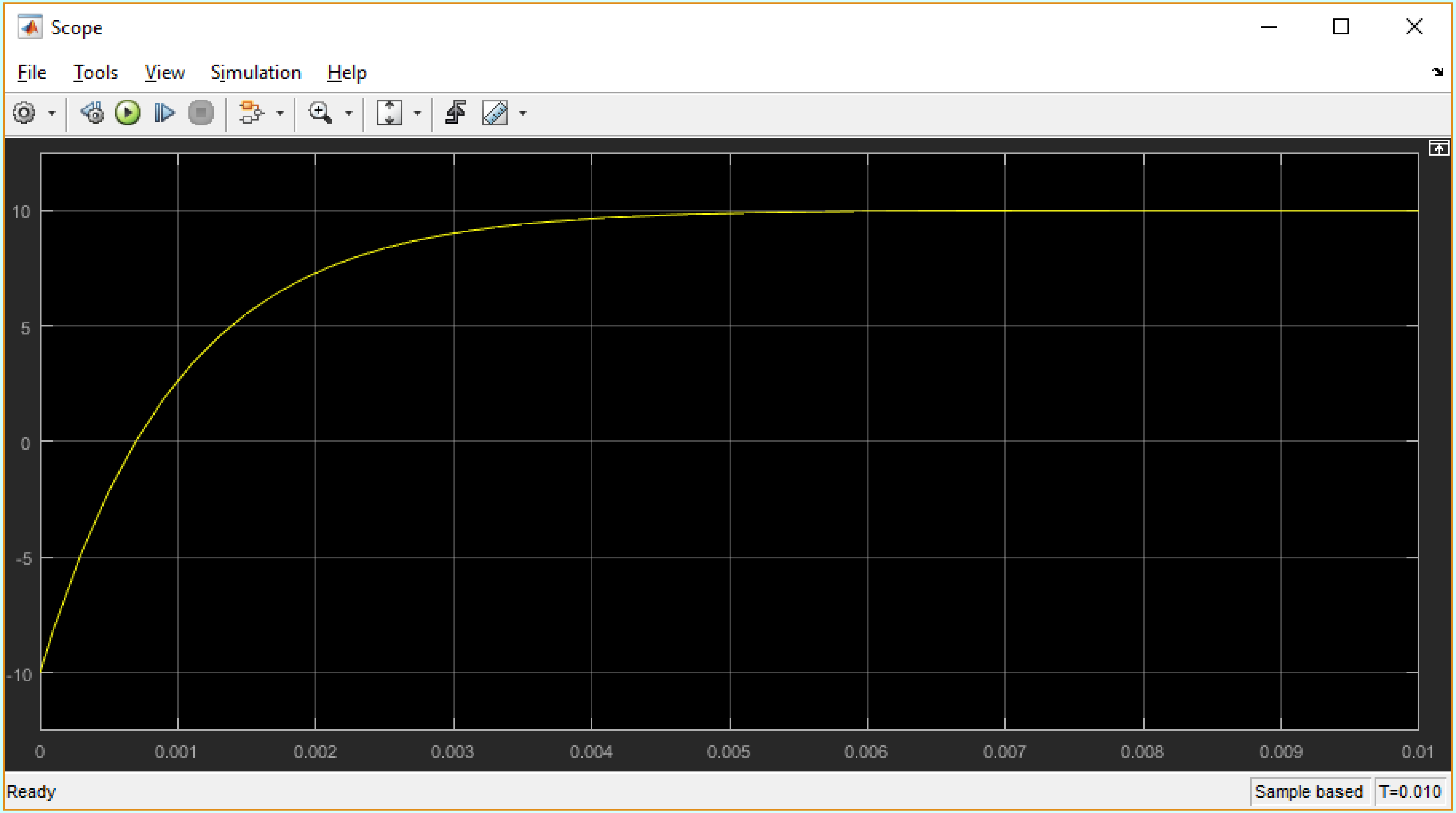
MATLAB: Simulink
Simscape
Foundation Library, Utilities

Почетни услов...



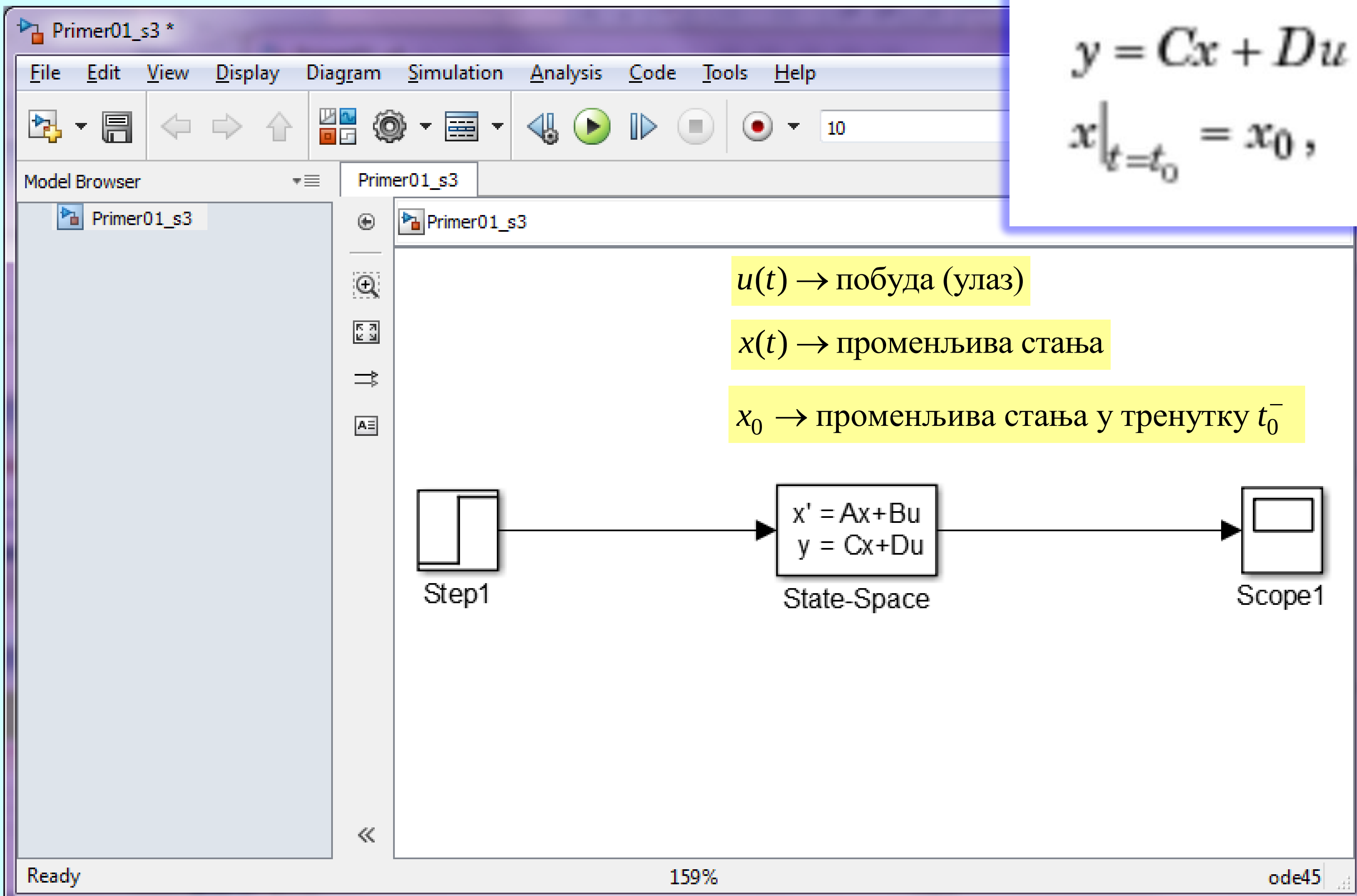
MATLAB: Simulink
Simscape
Foundation Library, Utilities

Налажење одзива...



Simulink

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



$u(t) \rightarrow$ побуда (улаз)

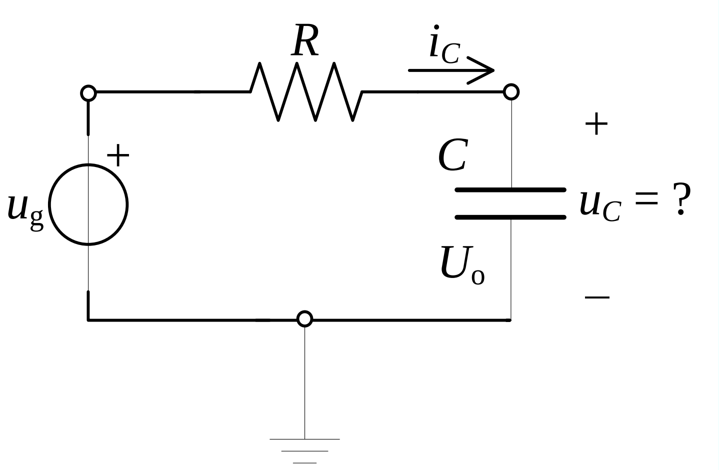
$x(t) \rightarrow$ променљива стања

$x_0 \rightarrow$ 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)

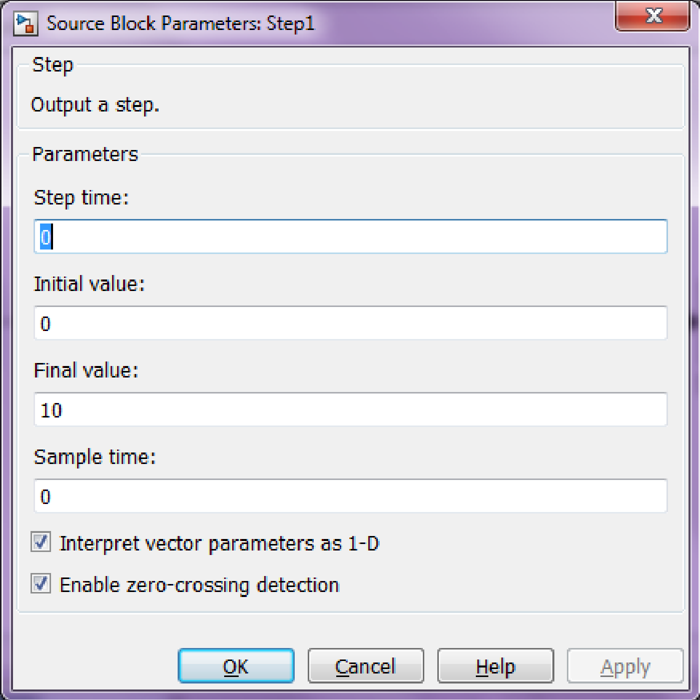
$x(t_0^-) = U_0 \rightarrow$ напон кондензатора у тренутку t_0^-

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

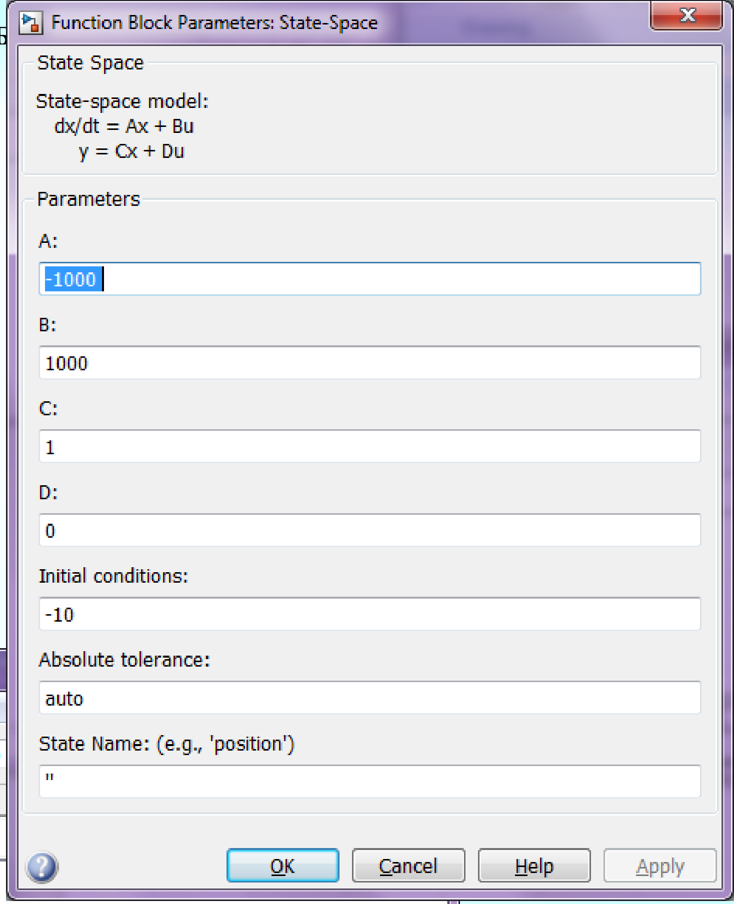
$$R = 1\,\mathrm{k\Omega}$$
$$C = 1\,\mu\mathrm{F}$$
$$u_g(t) = U\,h(t), U = 10\,\mathrm{V}$$
$$u_C(t_0^-) = U_0 = -10\,\mathrm{V}$$

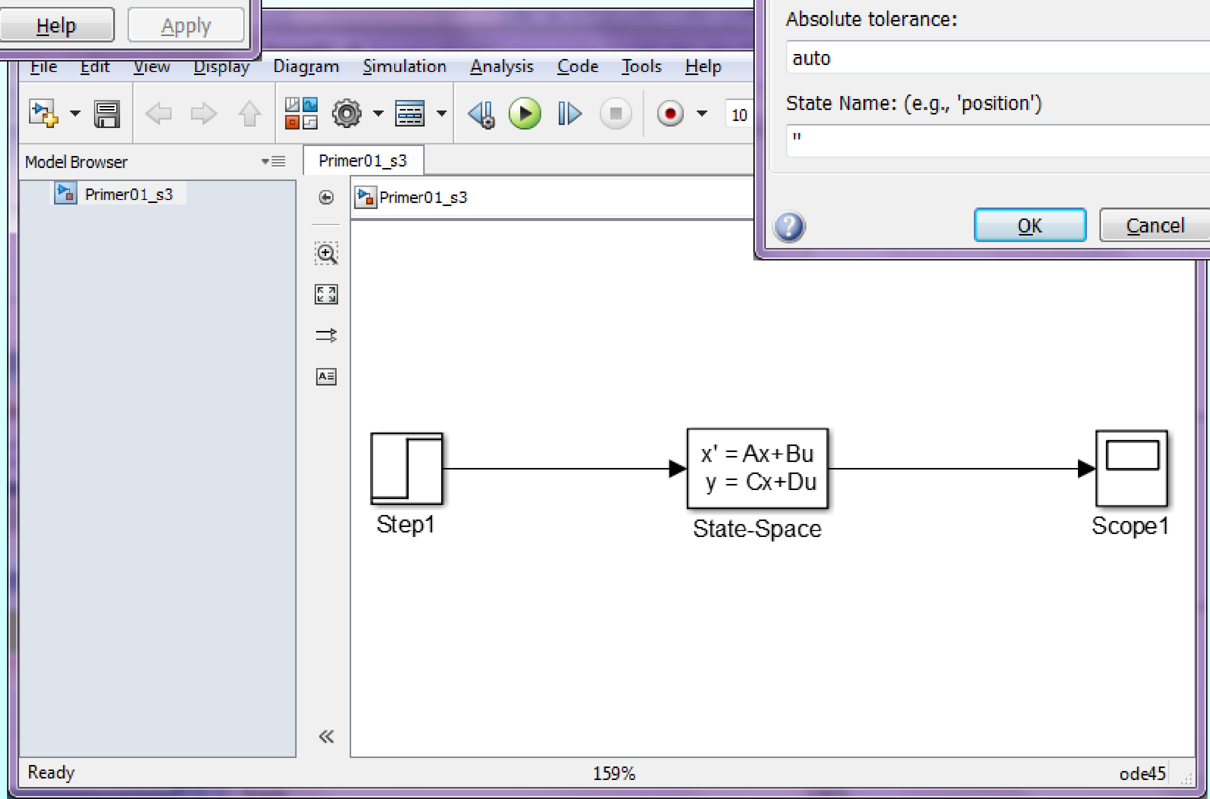
$$\frac{du_C(t)}{dt} = \frac{i_C}{C} = \frac{u_g(t) - u_C(t)}{RC} = -\frac{u_C(t)}{RC} + \frac{u_g(t)}{RC}$$
$$u_C(t_0^-) = U_0 = -10\,\mathrm{V}$$

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

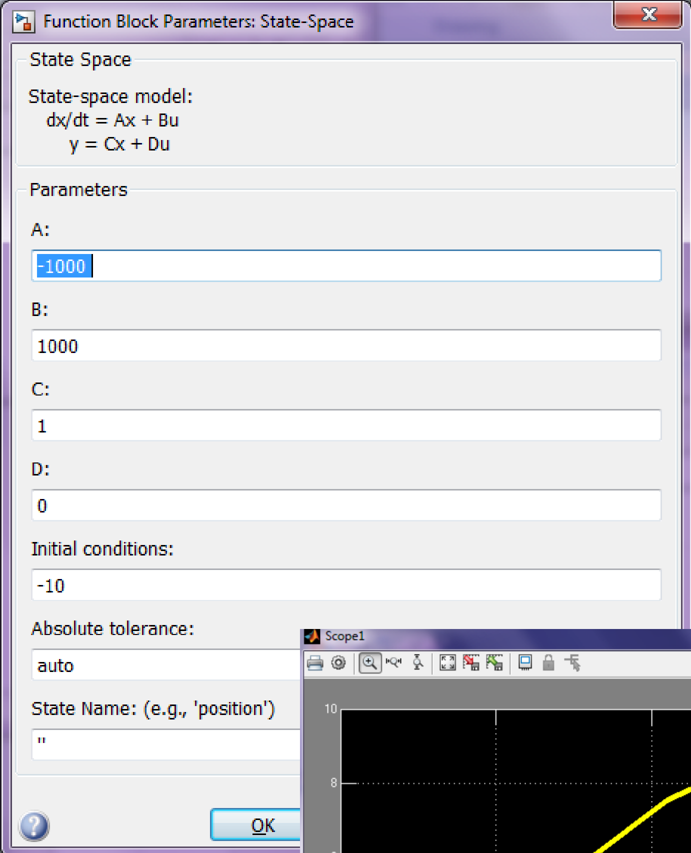

Source Block Parameters: Step1
Step
Output a step.
Parameters
Step time:
0
Initial value:
0
Final value:
10
Sample time:
0
Interpret vector parameters as 1-D
Enable zero-crossing detection
OK
Cancel
Help
Apply

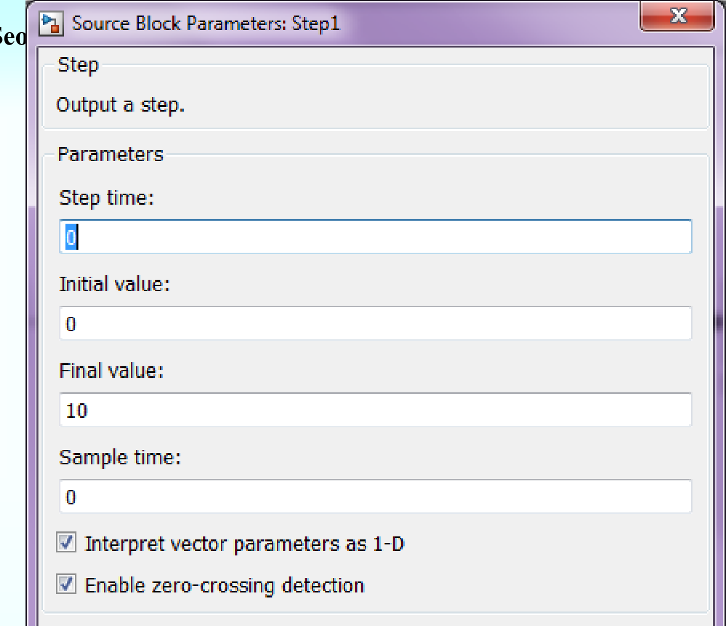
Simulink

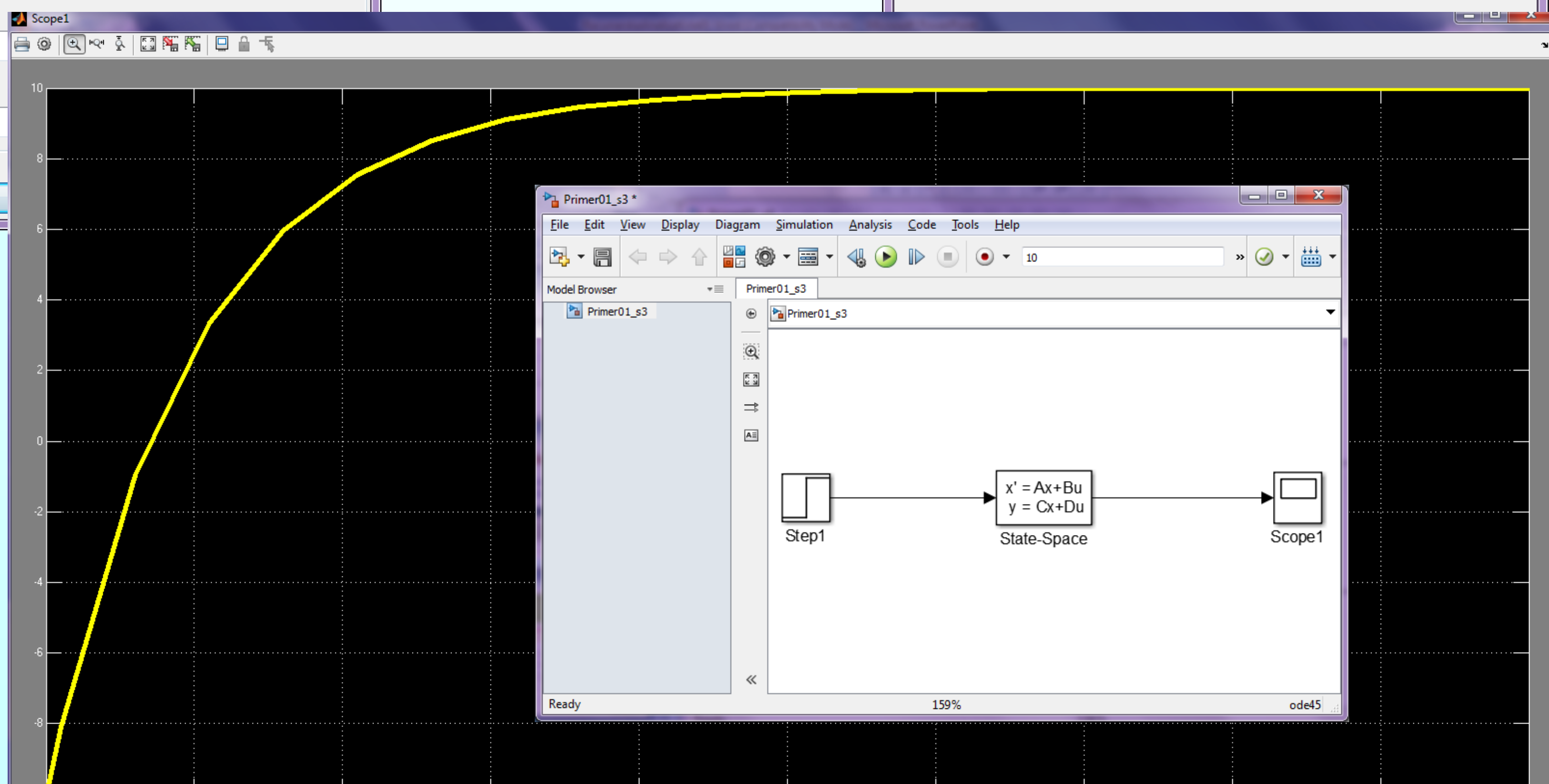

Function Block Parameters: State-Space
State Space
State-space model:
dx/dt = Ax + Bu
y = Cx + Du
Parameters
A:
-1000
B:
1000
C:
1
D:
0
Initial conditions:
-10
Absolute tolerance:
auto
State Name: (e.g., 'position')
''
OK
Cancel
Help
Apply


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

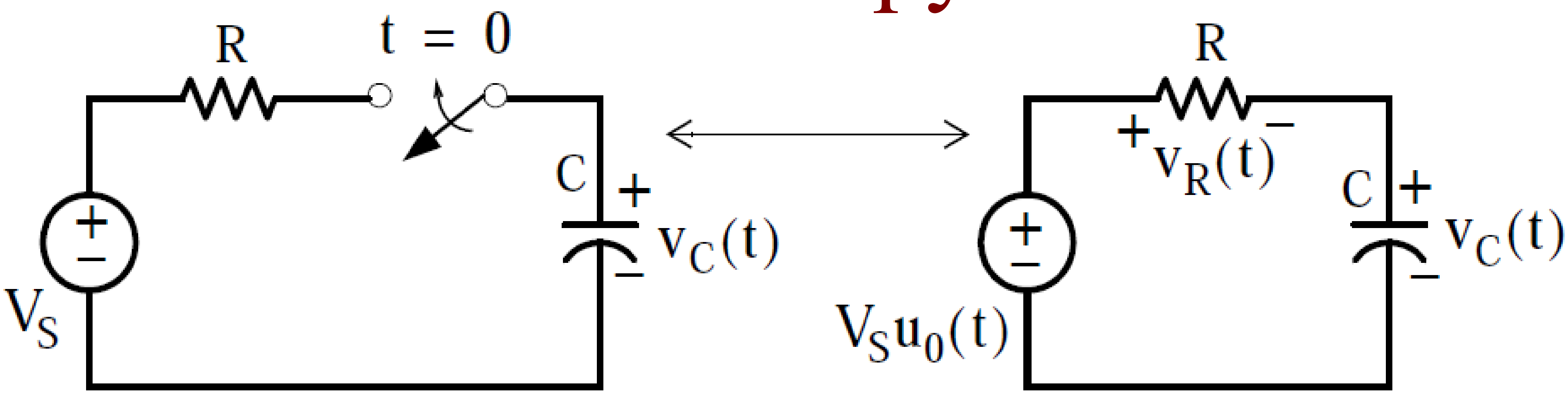
Simulink


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”



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

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

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

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

$$t > 0$$

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

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

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

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

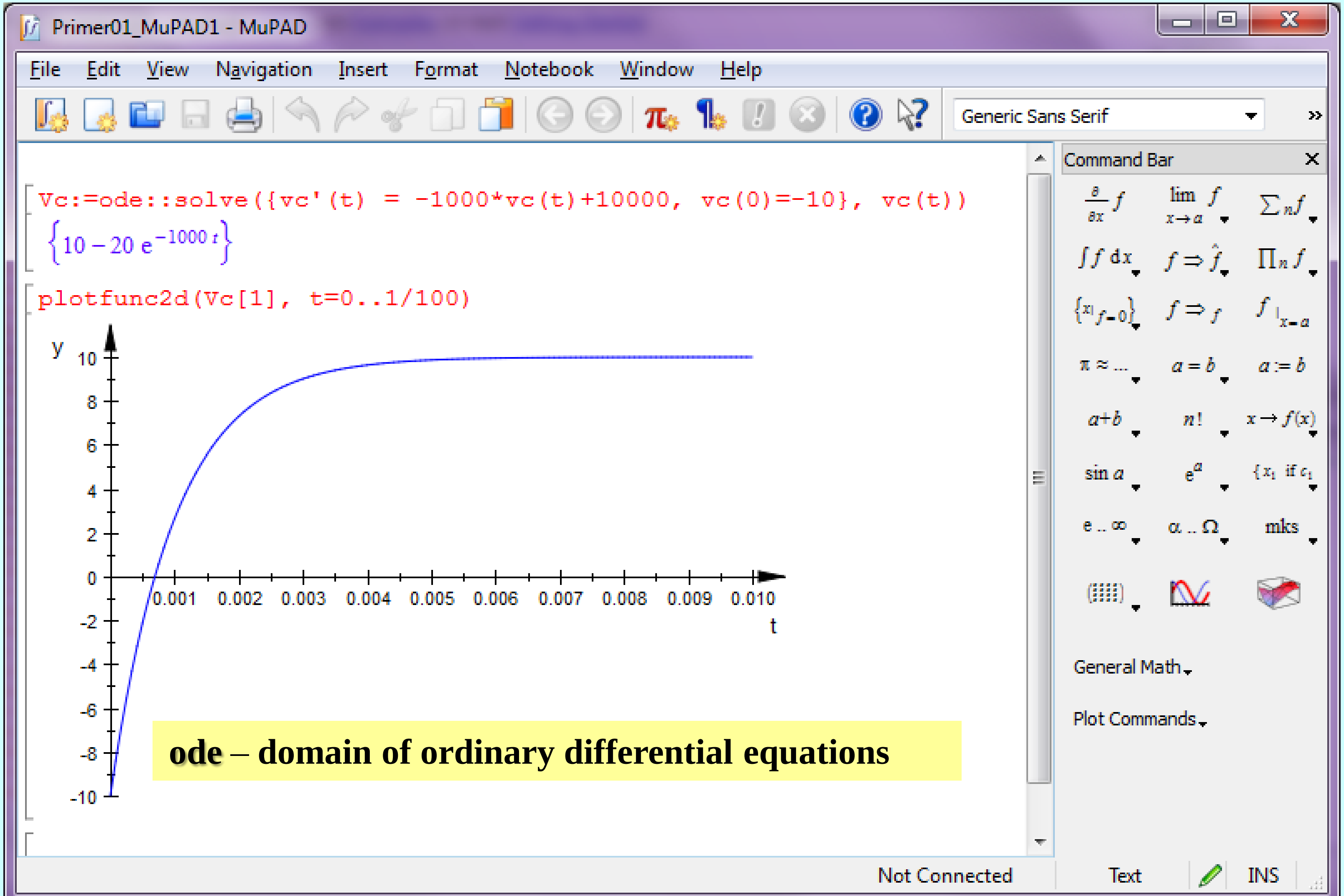
$u_g(t) = U\,h(t), U = 10\,\mathrm{V}$

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

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])