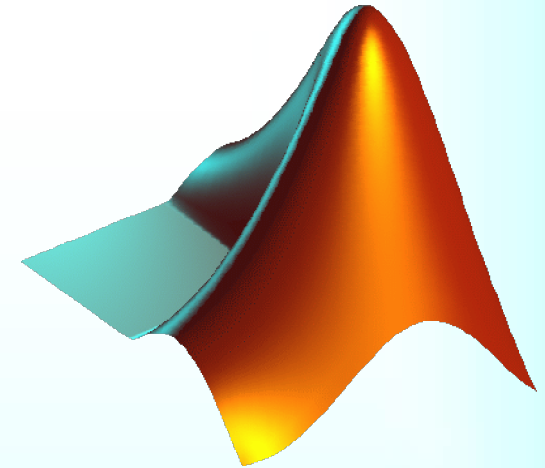
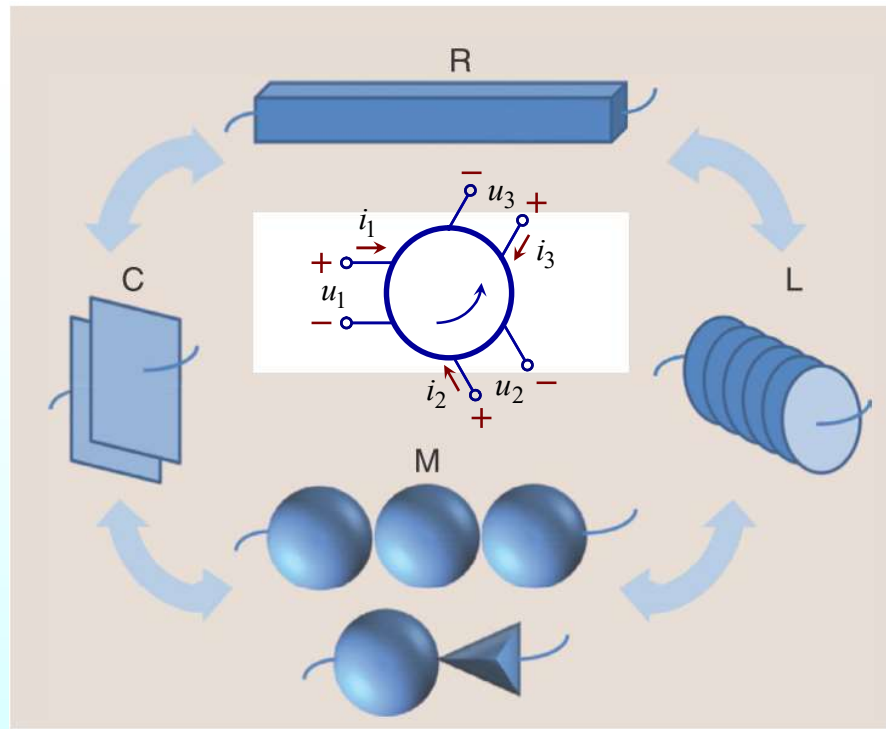


Практикум из рачунарске анализе кола

1. Увод



Милка Потребих Иваниш
Никола Баста

Практикум из рачунарске анализе кола

13E072PRK3, 19E072PRK

- **Настава се изводи према текућем студијском програму који је Електротехнички факултет акредитовао** <http://www.etf.bg.ac.rs>
- Студијски програм: **Електротехника и рачунарство**
- Изборно подручје (модул): **Физичка електроника, Сигнали и системи, Телекомуникације и информационе технологије**
- **Сарджај:** Рачунарске симулације електричних кола помоћу програма MATLAB/Simulink или Scilab/Xcos, LTspice и QucsStudio. Симболичко решавање кола програмима MATLAB/Symbolic Math или Symbolic Python и Maxima.
- **Наставници.** Др **Милка Потребих Иваниш**, редовни професор, соба 64 (milka_potrebic@etf.rs);
Др **Никола Баста**, доцент, соба 80 (nbasta@etf.rs).
- **Сарадници:** мс. инж. **Ања Ковачевић**, асистент, дипл. инж. **Анђела Нинковић**, сарадник у настави*.
- Белешке са предавања и лаб. вежби, примери испитних задатака и питања, <http://tek.etf.rs>
- Додатни материјали и консултације биће организовани преко канала на MS Teams платформи (линкови за канале су на адреси <http://tek.etf.rs>)
- **Начин одржавања наставе.** Рачунски центар.
- **Пратити** званично представљање предмета и објављивање општих службених порука на адреси <http://tek.etf.rs/>

Начин полагања

- **ПРЕДИСПИТНЕ ОБАВЕЗЕ (70%) + ИСПИТ (30%) = УКУПНО (100%)**
- **Предиспитне обавезе (MATLAB)** реализују се полагањем колоквијума у РЦ, израдом домаћег задатка са усменом одбраном, или поенима освојеним кроз активности на часу – израда једноставнијих задатака у вредности од 5 до 10 испитних поена.
- Добровољна израда **MATLAB Onramp** теста (самостални пролазак кроз основни MATLAB курс у слободно време) носи додатних 5 бонус поена.
- Поени са свих активности се сабирају и максимално се може освојити 70%.
- **Испит** подразумева израду пројекта и његову одбрану, укупно 30%.
- Одбрана пројекта може се реализовати у свим испитним роковима. Израда пројекта се може реализовати у наведеним алтернативним софтверским алатима.
- За заинтересоване студенте може се обезбедити предрок.
- Поред класичних тема за пројекте од ове године нове теме су: Симулатори кола на Интернету. Могућност примене вештачке интелигенције у решавању електричних кола.
- *Напомена: Домаћи задаци и пројекти се могу радити у тиму од два студента, али се бране индивидуално.*

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, Sage
- Symbolab, SpeQ Mathematics, meta-calculator, Desmos, ...
- Android apk: NCalc+, CalcES, SymJa CAS, Scientific Calculator Pro, CYZSoft Scientific Calculator Plus

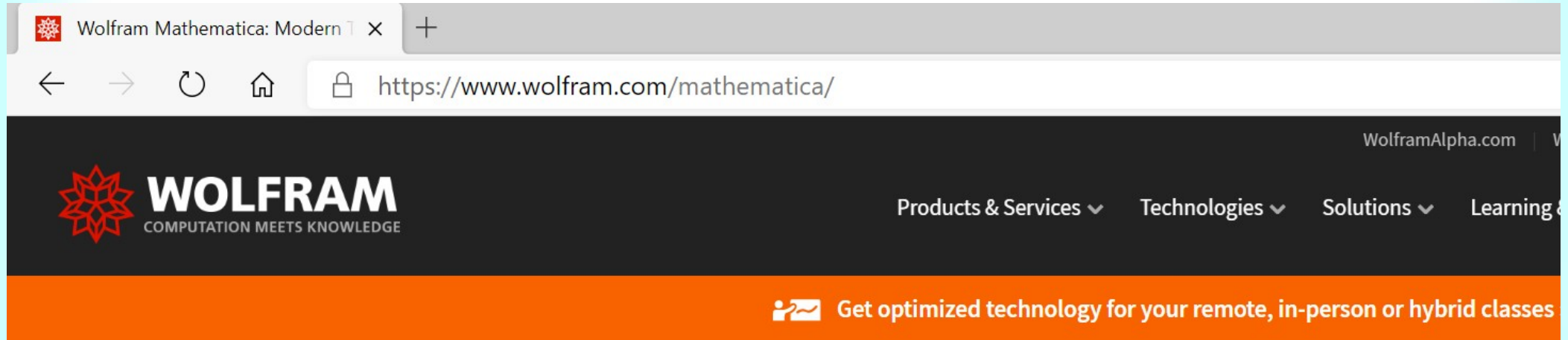
Free/Libre Open Source Software (FLOSS)

Моделовање електричних кола

- PSpice, ngSpice, TINA-TI, Micro-Cap, Plexim, 5SpiceXcos, SciLab, ...
- **Online Circuit Simulator:** DoCircuits, Circuit Lab, PartSim, EasyEda, Multisim, PartQuest (SystemVision Cloud)...
- **Android circuit simulator:** Electric Circuit Studio, Circuit Safari SPICE Simulator...

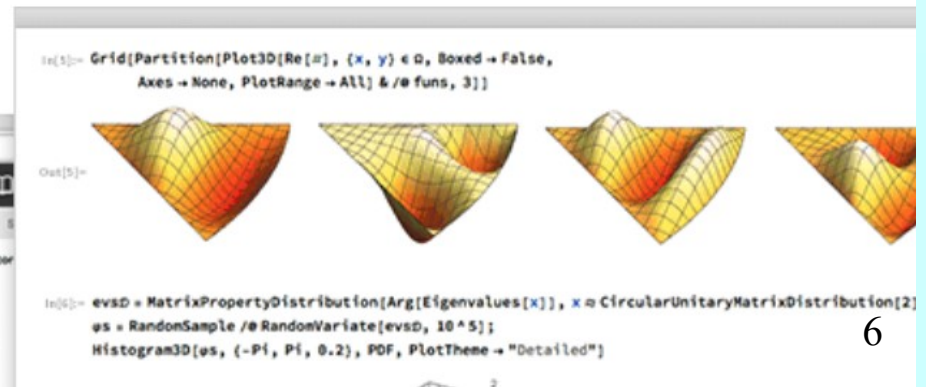
Mathematica

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



WOLFRAM MATHEMATICA

The world's definitive system for modern technical computing



Mathematica free on every Raspberry Pi!

<https://www.wolfram.com/raspberry-pi/>



www.wolframalpha.com

Give your brain a quick workout with Wolfram Problem Generator.



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



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:

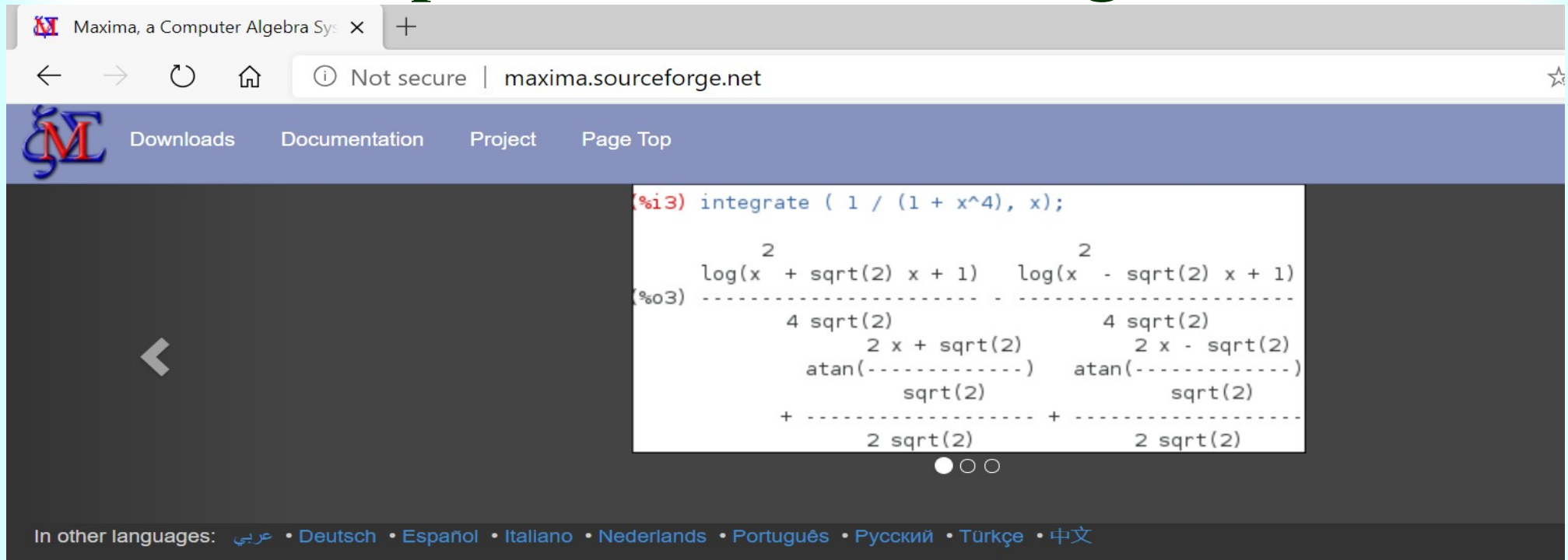
Approximate form

Step-by-step solution

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

Maxima

<http://maxima.sourceforge.net/>



The screenshot shows a web browser window with the address bar displaying "http://maxima.sourceforge.net/". The page title is "Maxima, a Computer Algebra System". The navigation bar includes links for "Downloads", "Documentation", "Project", and "Page Top". The main content area displays a Maxima session with the input command `(%i3) integrate ( 1 / (1 + x^4), x);` and the resulting output `(%o3)` showing a complex symbolic expression for the integral of $1/(1+x^4)$. The output is a sum of logarithmic and arctangent terms. At the bottom of the browser window, there is a language selection bar with options: "In other languages: عربي • Deutsch • Español • Italiano • Nederlands • Português • Русский • Türkçe • 中文".

Maxima, a Computer Algebra System

Maxima is a system for the manipulation of symbolic and numerical expressions, including differentiation, integration, Taylor series, Laplace transforms, ordinary differential equations, systems of linear equations, polynomials, sets, lists, vectors, matrices and tensors. Maxima yields high precision numerical results by using exact fractions, arbitrary-precision integers and variable-precision floating-point numbers. Maxima can plot functions and data in two and three dimensions.

Recent Releases

Click on a version number

5.44.0: June 8, 2020

5.43.2: Jan 27, 2020

Maxima on line

<http://maxima.cesga.es/>

Serv

Maxima on line

```
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));
```

ClickClear

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

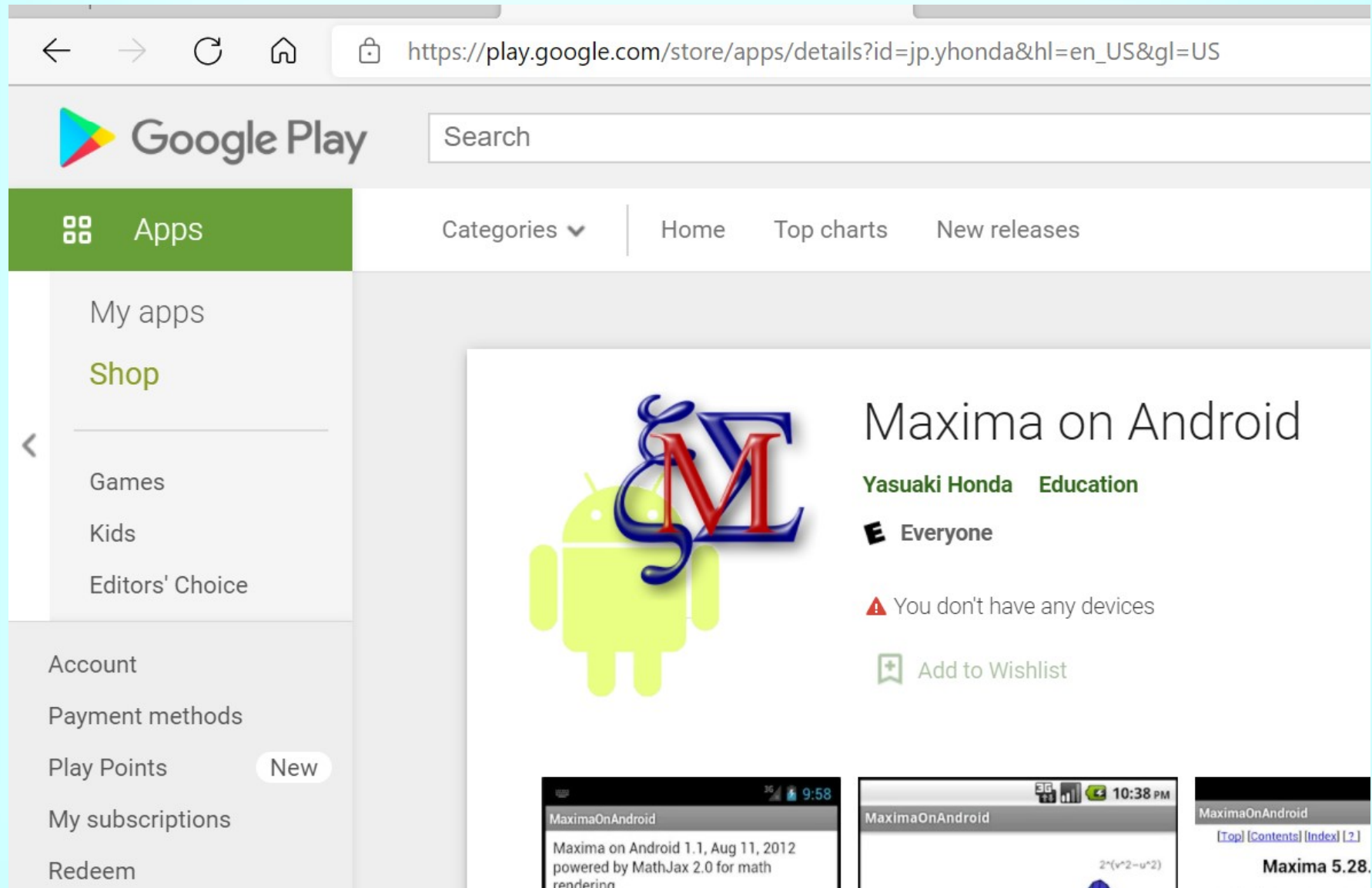
(%o1) $x^5 - \frac{16x^4}{3} + \frac{73x^3}{9} - \frac{2x^2}{3} - 4x - \frac{8}{9}$

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

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

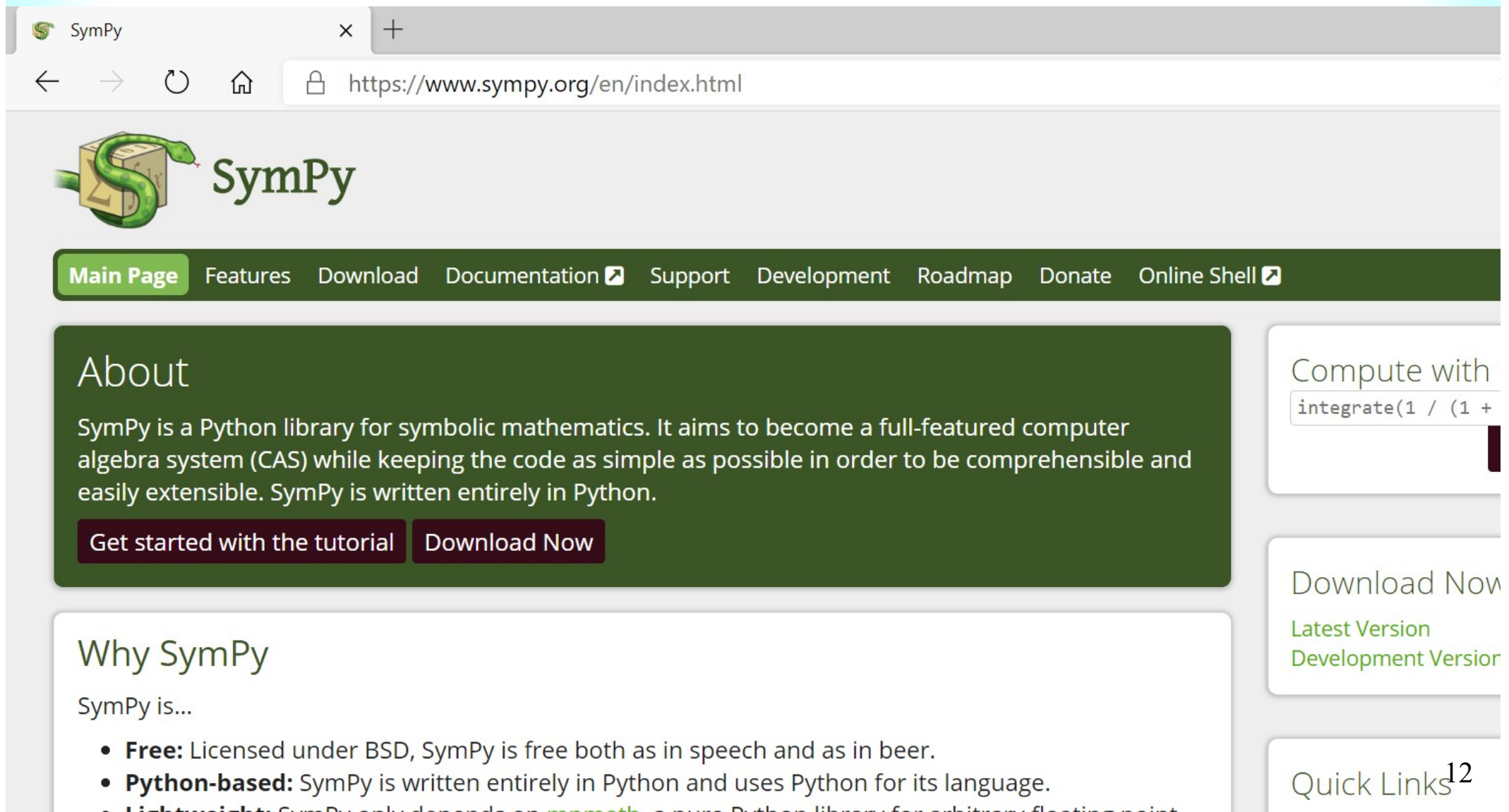
Maxima on Android

https://play.google.com/store/apps/details?id=jp.yhonda&hl=en_US&gl=US



SymPy

www.sympy.org/



The screenshot shows the SymPy website homepage. At the top, there's a browser window with the URL `https://www.sympy.org/en/index.html`. Below the browser window, the SymPy logo (a green snake coiled around a yellow cube) is visible. A dark green navigation bar contains links: Main Page, Features, Download, Documentation, Support, Development, Roadmap, Donate, and Online Shell. The main content area has a dark green background with the heading "About" and a paragraph describing SymPy as a Python library for symbolic mathematics. Below this are two buttons: "Get started with the tutorial" and "Download Now". To the right, there's a white box with the text "Compute with" and a code input field containing `integrate(1 / (1 +`. Below this is another white box with the text "Download Now" and links for "Latest Version" and "Development Version". At the bottom left, there's a white box with the heading "Why SymPy" and the text "SymPy is...". Below this is a list of bullet points: "Free", "Python-based", and "Lightweight".

About

SymPy is a Python library for symbolic mathematics. It aims to become a full-featured computer algebra system (CAS) while keeping the code as simple as possible in order to be comprehensible and easily extensible. SymPy is written entirely in Python.

[Get started with the tutorial](#) [Download Now](#)

Why SymPy

SymPy is...

- **Free:** Licensed under BSD, SymPy is free both as in speech and as in beer.
- **Python-based:** SymPy is written entirely in Python and uses Python for its language.
- **Lightweight:** SymPy only depends on `mpmath`, a pure Python library for arbitrary floating point

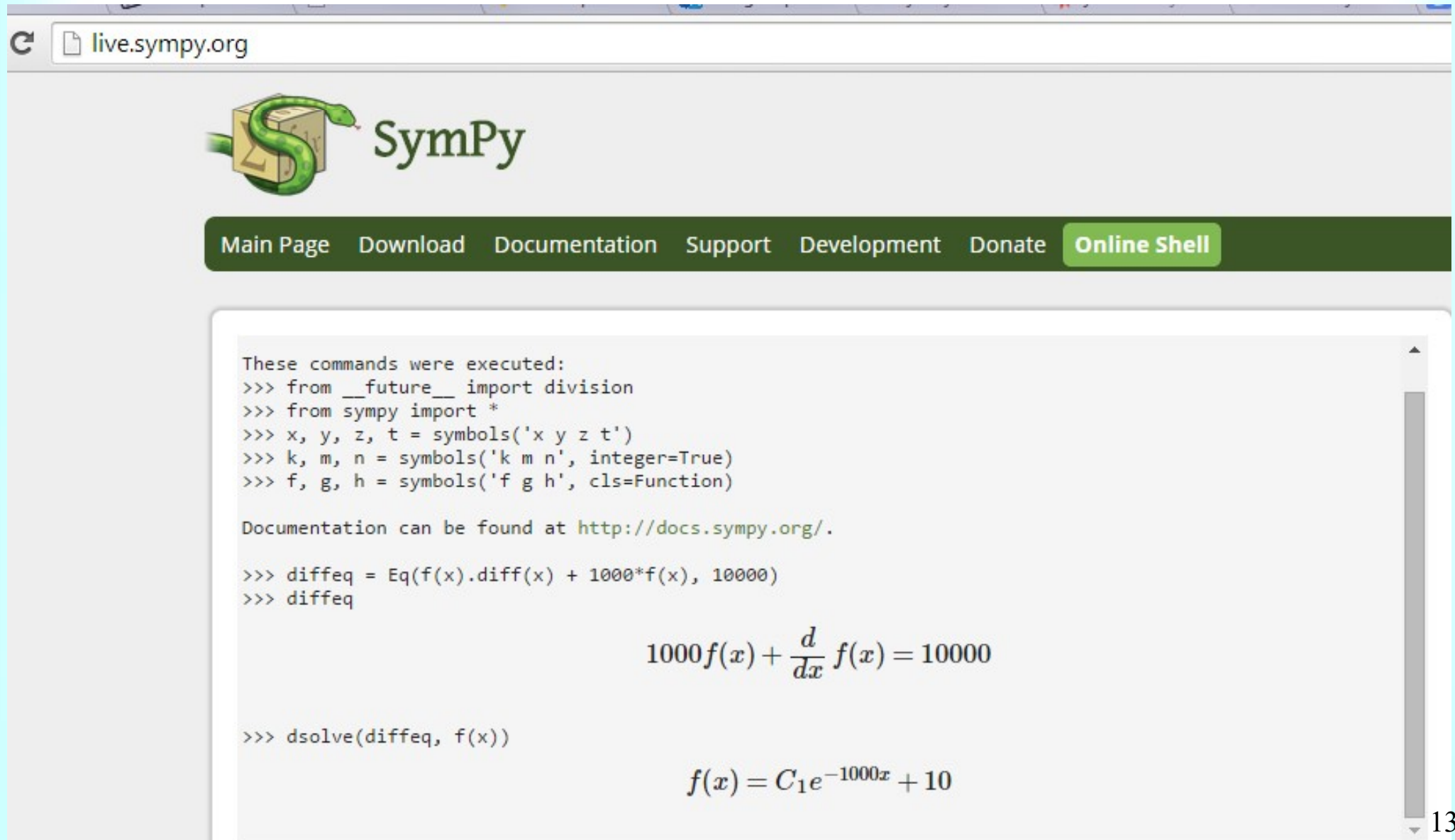
Compute with
`integrate(1 / (1 +`

Download Now
Latest Version
Development Version

Quick Links¹²

SymPy live

live.sympy.org



The screenshot shows the SymPy live web interface. At the top, there is a navigation bar with links: Main Page, Download, Documentation, Support, Development, Donate, and Online Shell. Below the navigation bar, a terminal window displays the following commands and output:

```
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
```

$$1000f(x) + \frac{d}{dx} f(x) = 10000$$

```
>>> dsolve(diffeq, f(x))
```

$$f(x) = C_1 e^{-1000x} + 10$$

SymPy Gamma

<https://www.sympygamma.com/>

live

SymPy Gamma

`integrate(x**a*exp(-x), (x, 0, oo))`

SymPy:
`integrate (x**a*exp (-x),(x,0,oo ))`

$$\int_0^{\infty} x^a e^{-x} dx$$

Antiderivative forms:
`integrate(x**a*exp(-x), (x, 0, oo))`

$$\Gamma(a+1) \quad \text{for } \operatorname{re}(a) > -1$$

Random Example

- Arithmetic
- Algebra
- Trigonometry
- Calculus
- Number Theory



The image shows the Jupyter website homepage. The browser address bar displays `https://jupyter.org`. The Jupyter logo is prominently displayed on the left, with navigation links for 'Install', 'About Us', 'Community', 'Events', and 'Documentation' on the right. Below the navigation bar, a large Jupyter logo is centered, surrounded by various programming language logos including JavaScript, Python, Lua, Erlang, R, and C#. To the left of the logo, the text 'SymPy and the Jupyter Notebook for engineering calculations' is written in a large, bold, dark red serif font. Below the logo, a line of text reads: 'Project Jupyter exists to develop open-source software, open interactive computing across dozens of programn'.

Sympy and the Jupyter Notebook for engineering calculations

Project Jupyter exists to develop open-source software, open interactive computing across dozens of programn

```
[1]: from sympy import *  
x = symbols('x')  
import sympy; sympy.__version__
```

```
[1]: '1.4'
```

```
[2]: Integral(exp(-x**2), (x, -oo, oo))
```

```
[2]: 
$$\int_{-\infty}^{\infty} e^{-x^2} dx$$

```

```
[3]: _.doit()
```

```
[3]: 
$$\sqrt{\pi}$$

```

Google калкулатор

The image shows a Google search for the function $x \cdot \sin(x)$. The search results include a graph of the function, a snippet from mytutor.co.uk asking for the integral of $x \sin(x) dx$, and a Google calculator interface showing the calculation $1 + 1 = 2$.

Google Search Results for $x \cdot \sin(x)$

Око 3.640.000.000 резултата (0,57 секунде/и)

Графикон за $x \cdot \sin(x)$

The graph shows the function $y = x \cdot \sin(x)$ plotted against x . The x-axis ranges from -20 to 2, and the y-axis ranges from -10 to 10. The function is a blue curve that oscillates with increasing amplitude as $|x|$ increases.

Search Snippet:

www.mytutor.co.uk > Maths ▾ Преведи ову страницу
What is the integral of $x \sin(x) dx$? | My

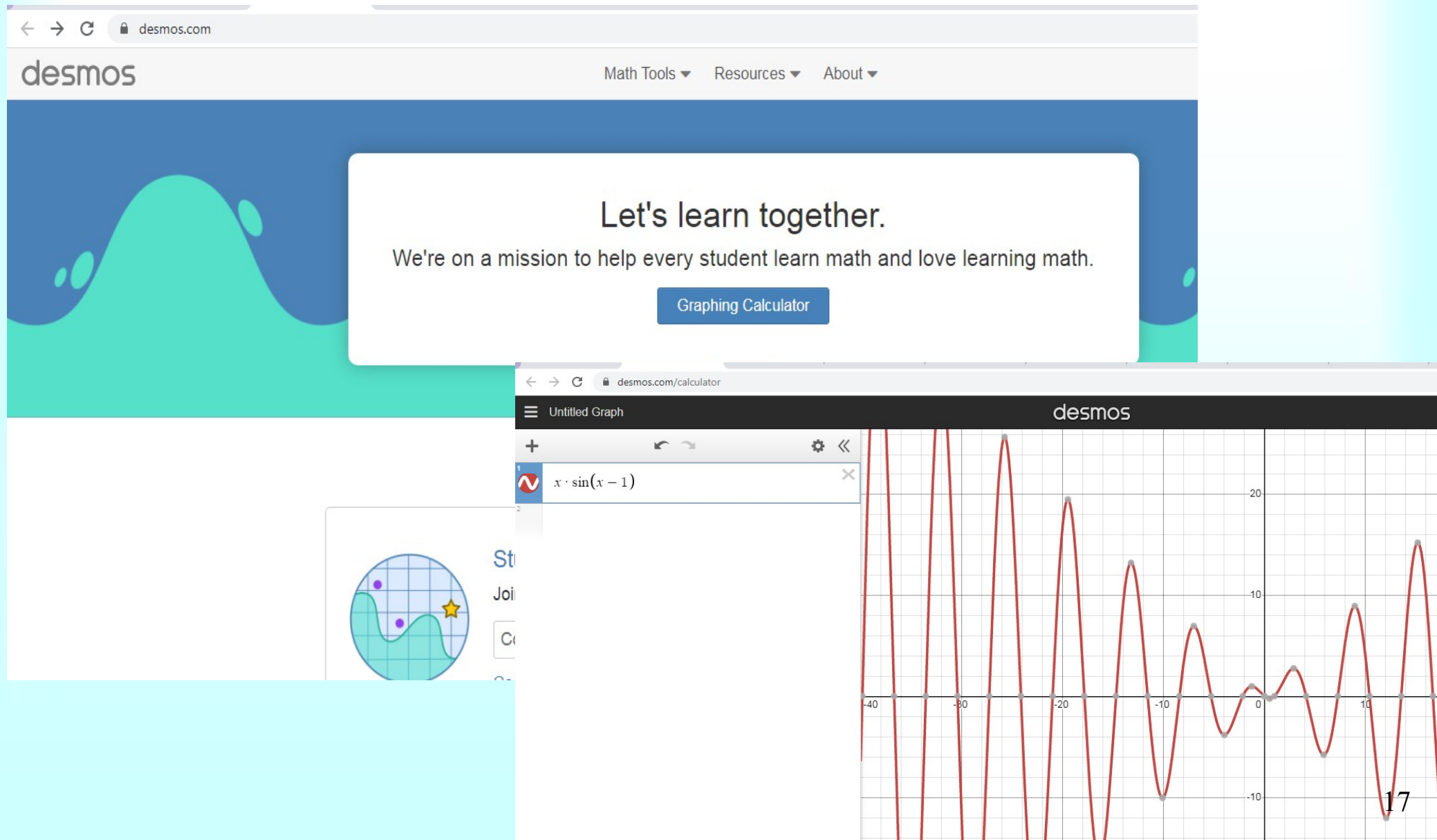
Google Calculator Interface:

1 + 1 = 2

Rad	Deg	x!	(	)	%	AC
Inv	sin	ln	7	8	9	÷
π	cos	log	4	5	6	×
e	tan	√	1	2	3	-
Ans	EXP	x ^y	0	.	=	+

Graphing Calculator – Desmos

<https://www.desmos.com/calculator>



Symbolab Math Solver - Step by Step calculator

<https://www.symbolab.com/>

The screenshot displays the Symbolab Math Solver website. The main navigation bar includes links for SOLUTIONS, GRAPHING, PRACTICE, GEOMETRY beta, NOTEBOOK, GROUPS, and CHEAT SHEETS. A prominent banner promotes the new Geometry solver. Below the navigation bar, a sidebar on the left lists various math topics: Pre Algebra, Algebra, Pre Calculus, Calculus, Functions, Matrices & Vectors, Geometry, and Trigonometry. The central area features a 'Step-by-Step Calculator' section with a 'full pad' of mathematical symbols and a 'Most Used Actions' bar containing buttons for simplify, solve for, inverse, tangent, and limit. The main content area shows the solution to the integral $\int_0^T x \sin(x) dx$. The solution is presented in a 'Solution' box, followed by a 'Steps' section that details the integration by parts process. A 'Graph' section at the bottom right shows a plot of $x \sin(x)$ for $T = 2\pi$, with the area under the curve shaded in blue.

Symbolab

SOLUTIONS GRAPHING PRACTICE GEOMETRY beta NOTEBOOK GROUPS CHEAT SHEETS

Try our new Geometry solver! Got it

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Step-by-Step Calculator Solve problems from Pre Algebra to Calculus step-by-step

Pre Algebra Algebra Pre Calculus Calculus Functions Matrices & Vectors Geometry Trigonometry

full pad »

x^2 $x^\square$ $\log_\square$ $\sqrt{\square}$ $\sqrt[\square]{\square}$ $\leq$ $\geq$ $\frac{\square}{\square}$ $\cdot$

$(\square)'$ $\frac{d}{dx}$ $\frac{\partial}{\partial x}$ $\int$ $\int_\square^\square$ $\lim$ $\sum$ ∞ θ $(\square)$

Most Used Actions

simplify solve for inverse tangent limit

$\int_0^T x \cdot \sin(x)$

Solution

$\int_0^T x \sin(x) dx = \sin(T) - T \cos(T)$

Steps

$\int_0^T x \sin(x) dx$

Apply Integration By Parts: $u = x, v' = \sin(x)$

$= [-x \cos(x) - \int -\cos(x) dx]_0^T$

$\int -\cos(x) dx = -\sin(x)$

$= [-x \cos(x) - (-\sin(x))]_0^T$

Simplify

$= [-x \cos(x) + \sin(x)]_0^T$

Compute the boundaries: $[-x \cos(x) + \sin(x)]^T_0 = \sin(T) - T \cos(T)$

Graph

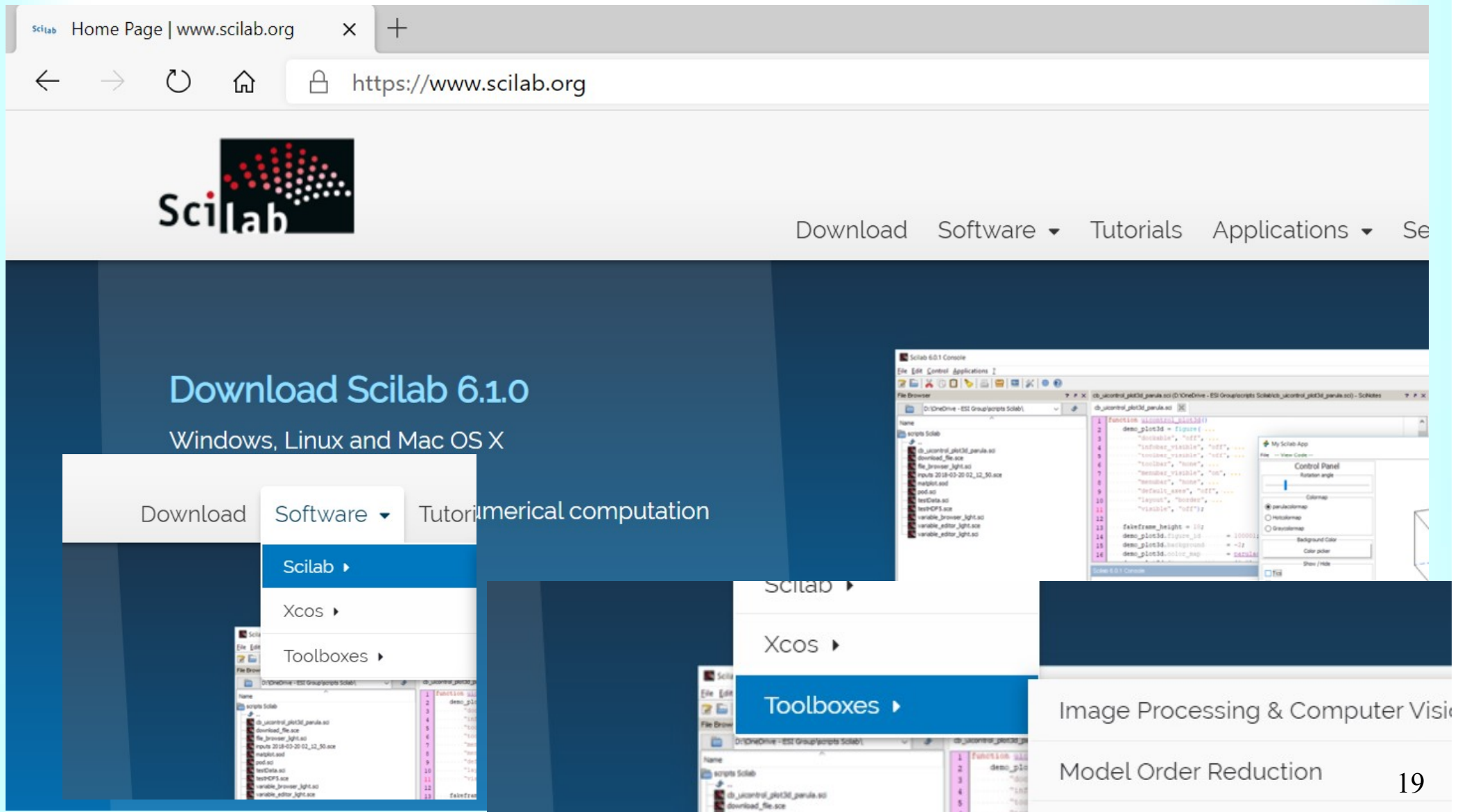
Plotting: $x \sin(x)$ assuming $T = 2\pi$

View Larger

Your To Top

SciLab

<https://www.scilab.org/>



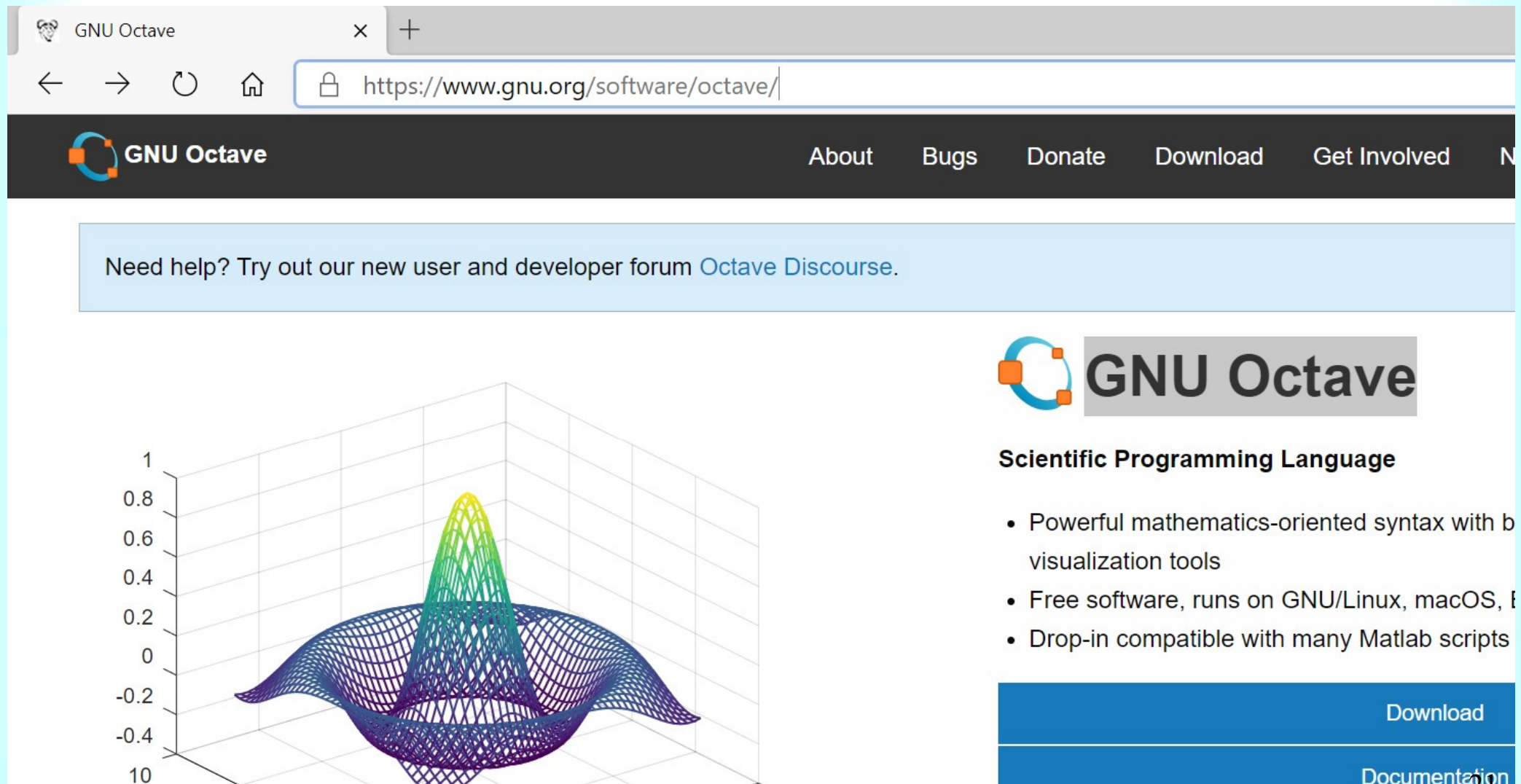
Xcos

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

The screenshot displays the Xcos website interface. At the top, the Scilab logo is visible on the left, and navigation links for 'Download', 'Software', 'Tutorials', 'Applications', and 'Services' are on the right. A blue banner below the navigation bar contains the text 'Home > Software' and a large 'Xcos' title. Below the banner, three preview images of the Xcos software interface are shown. The first image on the left shows a block diagram with three 'Signal Builder' blocks connected to a scope. The middle image shows a 'Watertank' control system diagram with a feedback loop. The third image on the right shows a more complex block diagram with multiple interconnected blocks.

GNU Octave

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



The screenshot shows the GNU Octave website. At the top, there's a browser tab labeled 'GNU Octave' and a URL bar with 'https://www.gnu.org/software/octave/'. Below the navigation bar, a light blue banner contains the text 'Need help? Try out our new user and developer forum [Octave Discourse](#).' The main content area features a 3D wireframe plot of a mathematical surface on the left. On the right, the GNU Octave logo is displayed above the text 'GNU Octave' and 'Scientific Programming Language'. Below this, a list of features is provided: 'Powerful mathematics-oriented syntax with b visualization tools', 'Free software, runs on GNU/Linux, macOS, f', and 'Drop-in compatible with many Matlab scripts'. At the bottom right, there are two blue buttons labeled 'Download' and 'Documentation'.

GNU Octave

About Bugs Donate Download Get Involved N

Need help? Try out our new user and developer forum [Octave Discourse](#).

 **GNU Octave**

Scientific Programming Language

- Powerful mathematics-oriented syntax with b visualization tools
- Free software, runs on GNU/Linux, macOS, f
- Drop-in compatible with many Matlab scripts

[Download](#)

[Documentation](#)

Micro-Cap

<http://www.spectrum-soft.com/index.shtml>

← → ↻ 🏠 ⚠ Not secure | www.spectrum-soft.com/index.shtml



Home Products Download Newsletters Support Contact Us

Industrial Strength Simulation

Select :

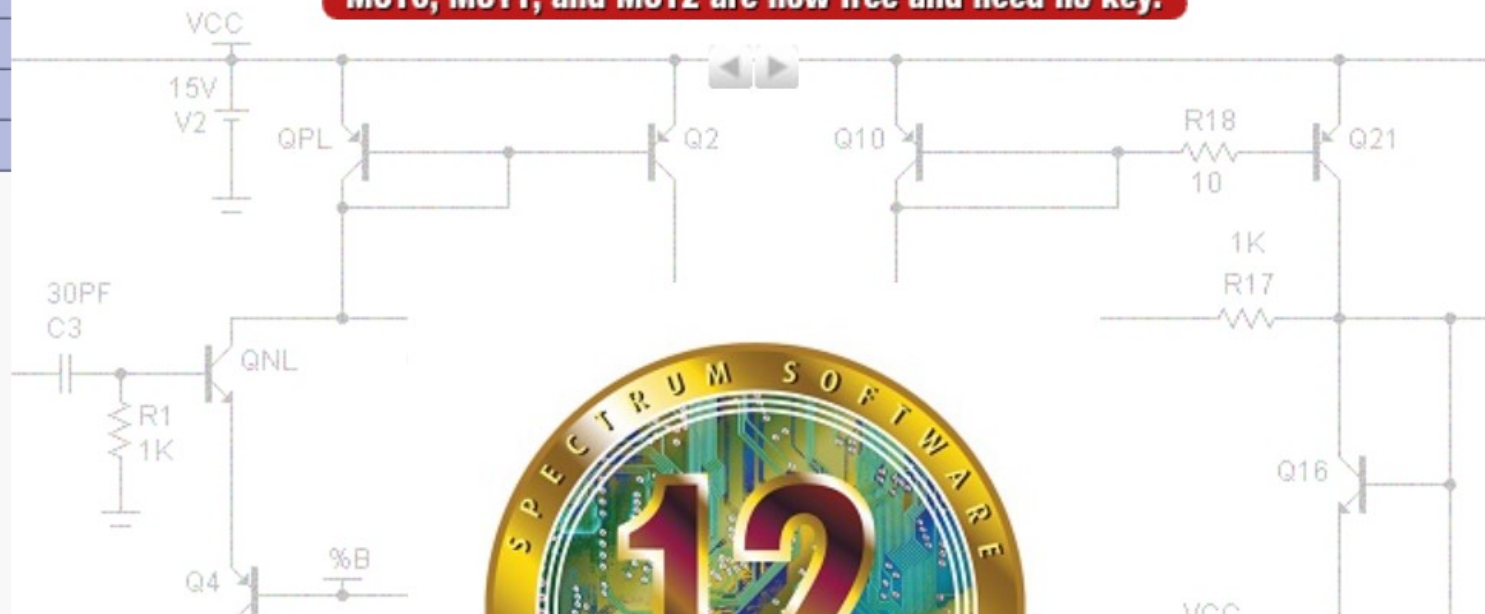
- MC12 Revision History
- Product Information
- Features Tour
- New MC12 Features

News:
Effective 7/4/2019,
Spectrum Software is
closed. Micro-Cap is now
free.

Technical support will be
available for at least 90
days via email at
[Support](mailto:support@spectrum-soft.com).

You can download the

MC10, MC11, and MC12 are now free and need no key.



About Spectrum

Spectrum Software
to provide softwa
Initially, the com
software for App

One of the earlie
Simulator. Releas
the first integrat
simulation systerm
More...

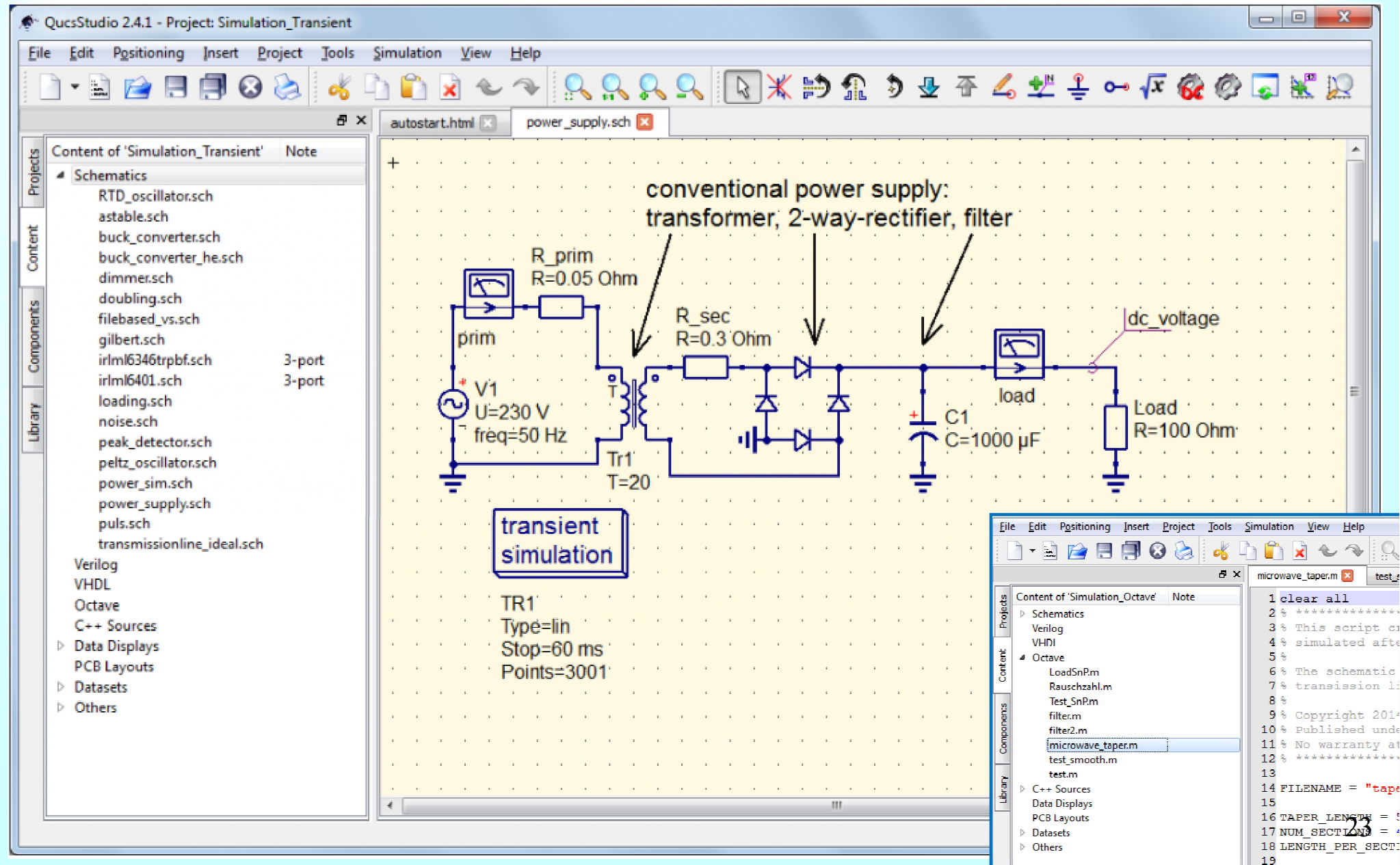
Help

Search our news
application notes

QucsStudio

<http://qucsstudio.de>

*Octave engine
inside!*



CircuitLab

<https://www.circuitlab.com/>

The screenshot shows the CircuitLab website homepage. At the top, there's a navigation bar with the CircuitLab logo, a search bar, and links for 'My Workbench', 'Electronics Q&A', and 'Textbook'. On the right, a user profile for 'milka.potrebic' is shown with links for 'inbox (0)', 'settings', and 'log out'. The main heading reads 'Circuit simulation and schematics.' Below this, a sub-heading says 'Build and simulate circuits right in your browser.' A list of features is provided: 'Design with our easy-to-use schematic editor.', 'Analog & digital circuit simulations in seconds.', 'Professional schematic PDFs, wiring diagrams, and plots.', and 'No installation required! Launch it instantly with [one click](#).'

The screenshot shows the CircuitLab editor interface. On the left is a component library with categories like 'Essentials', 'DC Sources', 'Passive Elements', 'Voltage Signal Sources', 'Current Signal Sources', and 'Operational Amplifiers'. The main workspace displays a circuit schematic. It includes a voltage source 'V1' labeled 'square 1 kHz', a resistor 'R1' labeled '100 Ω ', and a capacitor 'C1' labeled '10 μ F'. The circuit has an input terminal 'in' and an output terminal 'out'. The background is a grid.

The screenshot shows a video player interface for a tutorial titled 'Getting Started with CircuitLab'. The video content displays a circuit schematic similar to the one in the previous block, but with a different configuration of components including resistors 'R1' and 'R2' (both 100 Ω), a capacitor 'C1' (1 μ F), and a voltage source 'V1' (sine 1 kHz). The video player has standard controls like play, pause, and volume, and a progress bar at the bottom.

1-minute Tutorial

1. Click and drag a wire from the right of R1 to the top of C1.

2. Click "Simulate."

3. Click "Run Time-domain" and look at the filter output.

4. Double-click R1, change "1k", and simulate again.

5. Run the Frequency-Domain simulation.

Interactive Electronics Textbook **NEW!**

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Get started with some sample circuits !

Colpitts Oscillator

This circuit generates a continuous sinusoidal signal. The tank circuit is made up of two capacitors and an inductor in parallel

Active Low Pass Filter

This circuit made up using op-amp and will allow signals lower than a particular cut off frequency to pass through and attenuates those above it.

Active High Pass Filter

This circuit uses an op-amp as the active element and allows only the input signals with frequency higher than the cut-off frequency and rejects those below it.

Clipper

This is a wave-shaping modify the shape of the "clipping" off a portion of a diode is forward-biased across it will be a cons

ngSpice

<http://ngspice.sourceforge.net/>

← → ↻ 🏠 ⚠ Not secure | ngspice.sourceforge.net



**MIXED MODE - MIXED LEVEL
CIRCUIT SIMULATOR
BASED ON BERKELEY'S SPICE3F5**

NGSPICE

[Home](#) [News](#) [Screenshots](#) [Download](#) [Documentation](#) [Tutorials](#) [Extras/Options](#) [Applications](#) [Development](#) [Simulation](#)

Ngspice Home

[Home](#)
[What is ngspice ?](#)
[Features, Extras & Options](#)
[F.A.Q.](#)
[Tutorials](#)
[Sourceforge Developer Pages](#)

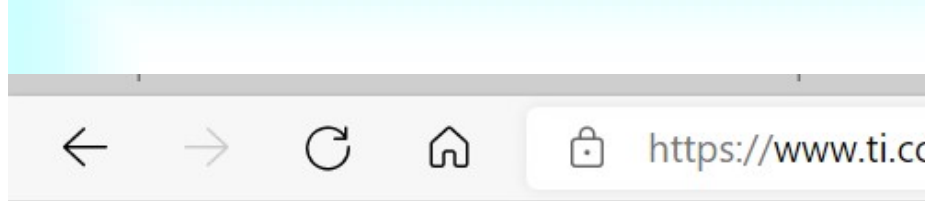
ngspice - open source spice simulator

ngspice is the open source spice simulator for electric and electronic circuits.

Such a circuit may comprise of JFETs, bipolar and MOS transistors, passive elements, transmission lines and other devices, all interconnected in a netlist. Digital circuits are driven and fast, from single gates to complex circuits. And you may enter the combination of digital as a mixed-signal circuit.

ngspice offers a wealth of device models for active, passive, analog, and digital elements. These are provided by our [collections](#), by the [semiconductor device manufacturers](#), or from the user. The user adds her circuits as a netlist, and the output is one or more graphs of electrical quantities or is saved in a data file.

ngspice does not provide schematic entry. Its input is command line or file based. [Party](#) interfaces available.



Products

Applications

Design resources

Home / Design resources

TINA-TI

SPICE-based analog simulation program

TINA-TI

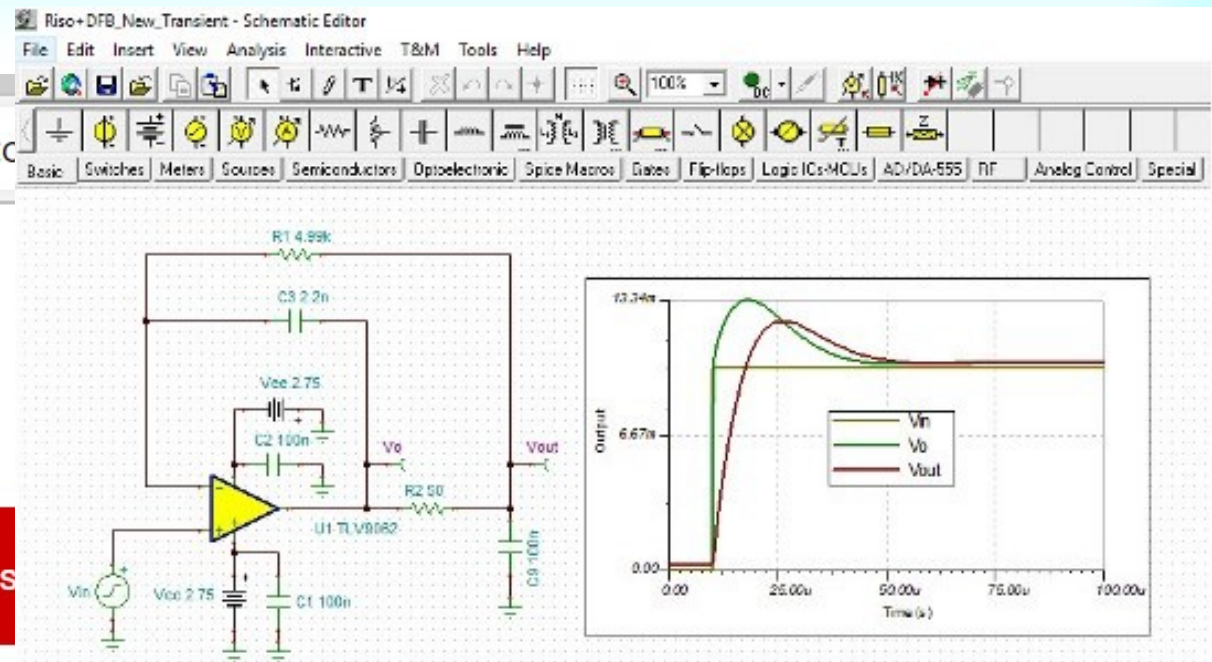
<https://www.ti.com/tool/TINA-TI>

Overview

Downloads

Technical documentation

Support & training



Electric Circuit Studio

The screenshot shows the Google Play Store interface. At the top, the browser address bar displays the URL: <https://play.google.com/store/apps/details?id=com.ecstudiosystems.electriccircuitstudio&hl=rs>. Below the address bar is the Google Play logo and a search bar. The main navigation bar includes 'Apps' (selected), 'Categories', 'Home', 'Top charts', and 'New releases'. A left sidebar menu lists 'My apps', 'Shop', 'Games', 'Kids', 'Editors' Choice', 'Account', 'Payment methods', 'Play Points' (with a 'New' badge), 'My subscriptions', and 'Redeem'. The app 'Electric Circuit Studio' by 'ECStudio Systems' is featured. Its icon is a blue square with a white circuit diagram. The app is categorized under 'Education' and is rated 'Everyone'. It is marked as 'Contains Ads' with a warning that 'You don't have any devices'. An 'Add to Wishlist' button is visible. At the bottom, a toolbar contains various icons for editing and navigation, and the page number '28' is shown in the bottom right corner.

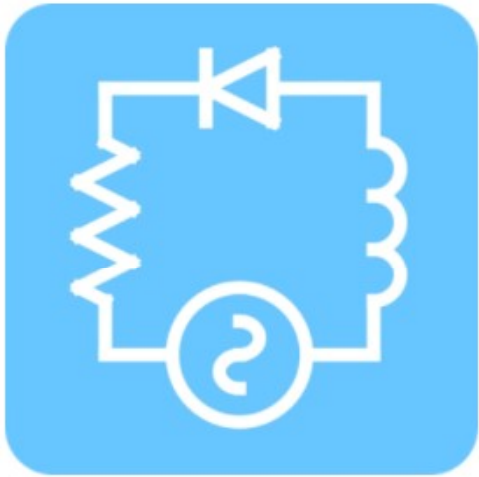
← → ↻ 🏠 🔒 <https://play.google.com/store/apps/details?id=com.ecstudiosystems.electriccircuitstudio&hl=rs>

Google Play Search

🗖 Apps Categories ▾ Home Top charts New releases

My apps
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Account
Payment methods
Play Points **New**
My subscriptions
Redeem

 **Electric Circuit Studio**
ECStudio Systems Education
Everyone
Contains Ads
⚠ You don't have any devices
🔖 Add to Wishlist

🔧 ▶ 🗑 © 📄 ↶ ↷ 📁 📄 ✂ 📄 📄 📄 🔍 28

CircuitSafari SPICE Simulator

The screenshot shows the Google Play Store interface. At the top, the URL is https://play.google.com/store/apps/details?id=com.logipipe.circuitsafari&hl=en_US&gl=L. The Google Play logo is on the left, with a search bar. Below the logo, the 'Apps' tab is selected. The left sidebar shows 'My apps', 'Shop', 'Games', 'Kids', 'Editors' Choice', 'Account', 'Payment methods', 'Play Points' (with a 'New' badge), 'My subscriptions', and 'Redeem'. The main content area displays the app 'CircuitSafari SPICE Simulator (Early Access)' by Logipipe, LLC, categorized under 'Productivity'. The app is rated 'E Everyone'. A warning states: 'Offers in-app purchases. This app is in development. It may be unstable. You don't have any devices'. There is an 'Add to Wishlist' button. The app icon features a yellow circuit diagram on a red grid background.

← → ↺ 🏠 https://play.google.com/store/apps/details?id=com.logipipe.circuitsafari&hl=en_US&gl=L

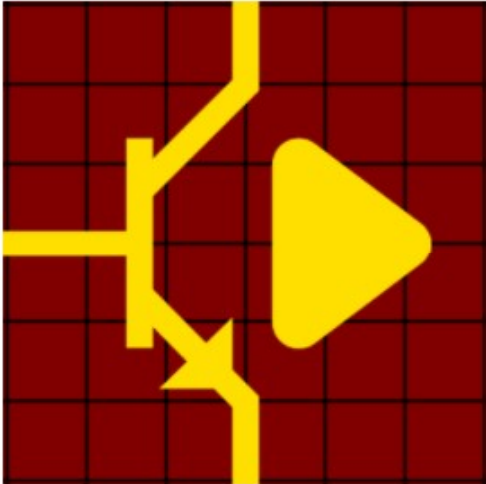
Google Play Search

Apps Categories ▾ Home Top charts New releases

My apps
Shop

< Games
Kids
Editors' Choice

Account
Payment methods
Play Points **New**
My subscriptions
Redeem



CircuitSafari SPICE Simulator
(Early Access)

Logipipe, LLC Productivity

E Everyone

Offers in-app purchases

This app is in development. It may be unstable.
 You don't have any devices

Add to Wishlist



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MATLAB Parallel Server

Math and Optimization

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Optimization Toolbox
Global Optimization Toolbox
Symbolic Math Toolbox
Mapping Toolbox

SIMULINK®
PRODUCT FAMILY

Simulink

System Composer

Event-Based Modeling

Stateflow
SimEvents

Physical Modeling

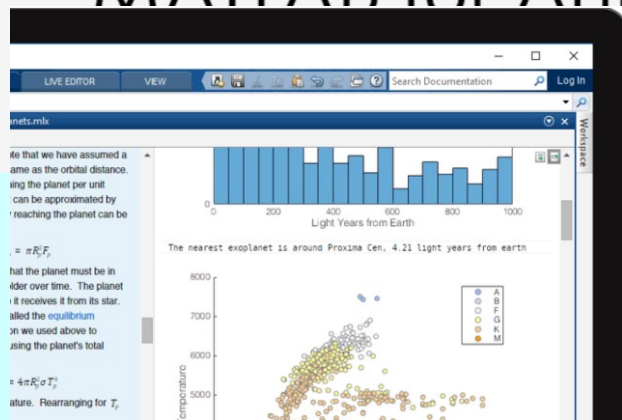
Simscape
Simscape Driveline
Simscape Electrical
Simscape Fluids

SERVICES

Software Maintenance
Training
Consulting

LICENSE TYPES

Industry Use
Student Use
University Use
Startup Use
Primary and Secondary School Use
Home Use





MATLAB

 <http://www.mathworks.com/>

MATLAB R2019a

HOME PLOTS APPS

FILE VARIABLE CODE ENVIRONMENT SIMULINK RESOURCES

Current Folder: C:\Program Files\Polyspace\R2019a\bin

Command Window: New to MATLAB? See resources for [Getting Started](#).

Workspace: Name Value

System target file browser: Simulink2DSHplus

System target file: Description:

System target file	Description
asap2.tlc	ASAM-ASAP2 Data Definition Target
dsh.tlc	Borland C++ DSHplus Real-Time Target with
dsh.tlc	Visual C/C++ DSHplus Real-Time Target with
ert.tlc	RTW Embedded Coder (no auto configuration)
ert.tlc	RTW Embedded Coder (auto configures for C)
ert.tlc	C++ Project Makefile only for the
ert.tlc	Real-Time Target
ert.tlc	C++ Project Makefile only for the

Full name: Template makefile Make compiler

Cancel Help Apply

Simulink2DSHplus

MathWorks

Toolboxes...

MATLAB®

Professional License

R2019a (9.6.0.1072779)
64-bit (win64)
March 8, 2019
License Number: 968398

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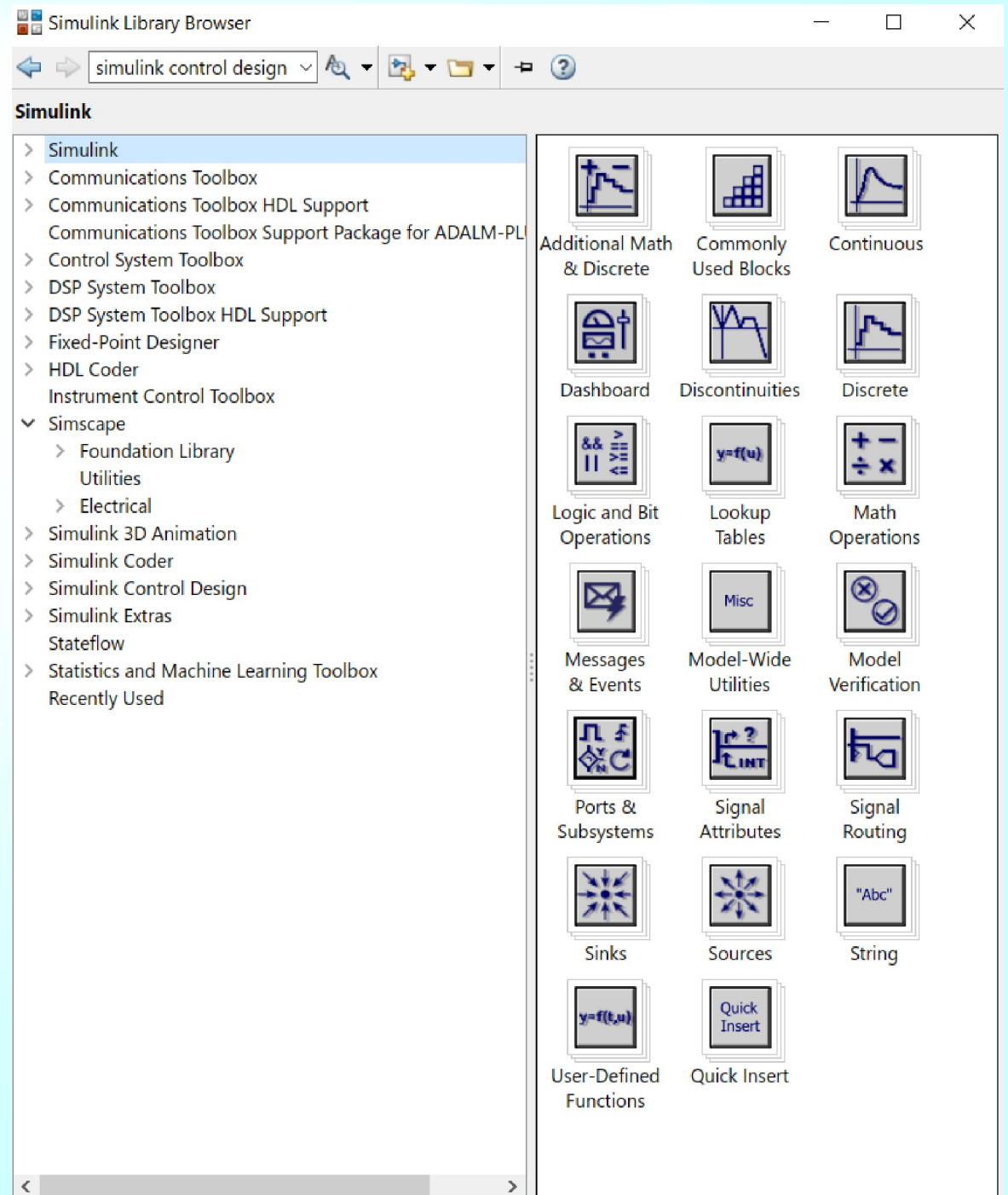
MathWorks® R2019a

Ready

MATLAB

Simulink

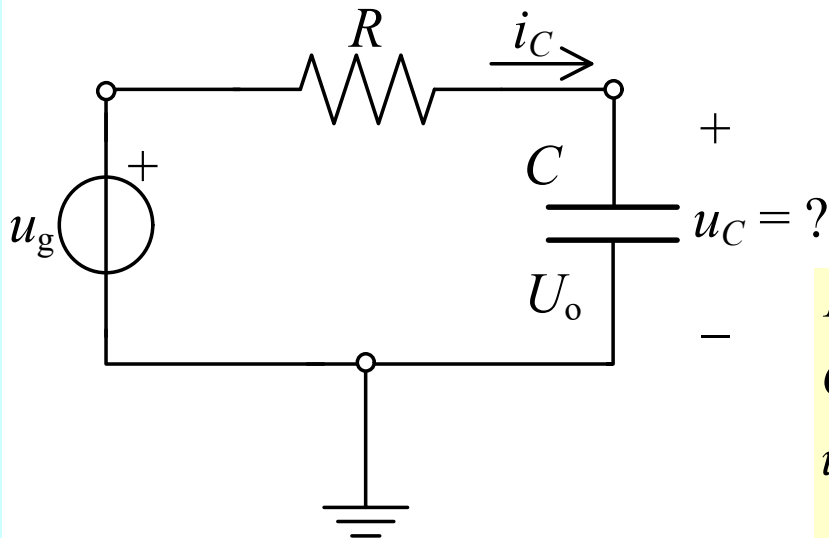
- Алатка за нумеричку анализу математичких модела
- Систем се дефинише графички, уметањем блокова и њиховим повезивањем у мрежу



Simulink > Simscape

- Библиотека за симулацију и нумеричку анализу мултидоменских проблема (механика, електродинамика, оптика)
- Пример једноставног електричног кола:

коло је образовано у тренутку $t_0 = 0$

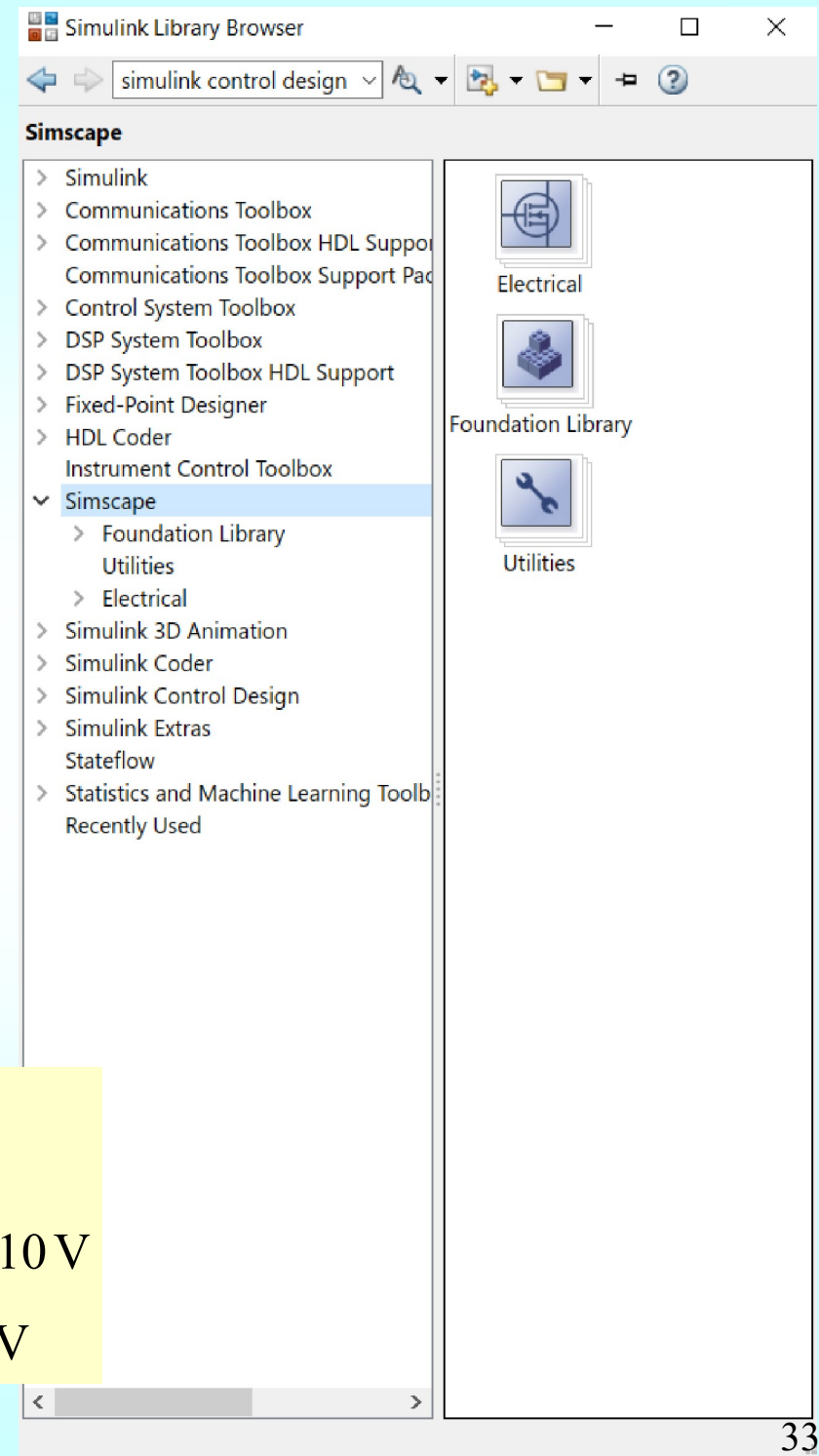


$$R = 1 \text{ k}\Omega$$

$$C = 1 \mu\text{F}$$

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

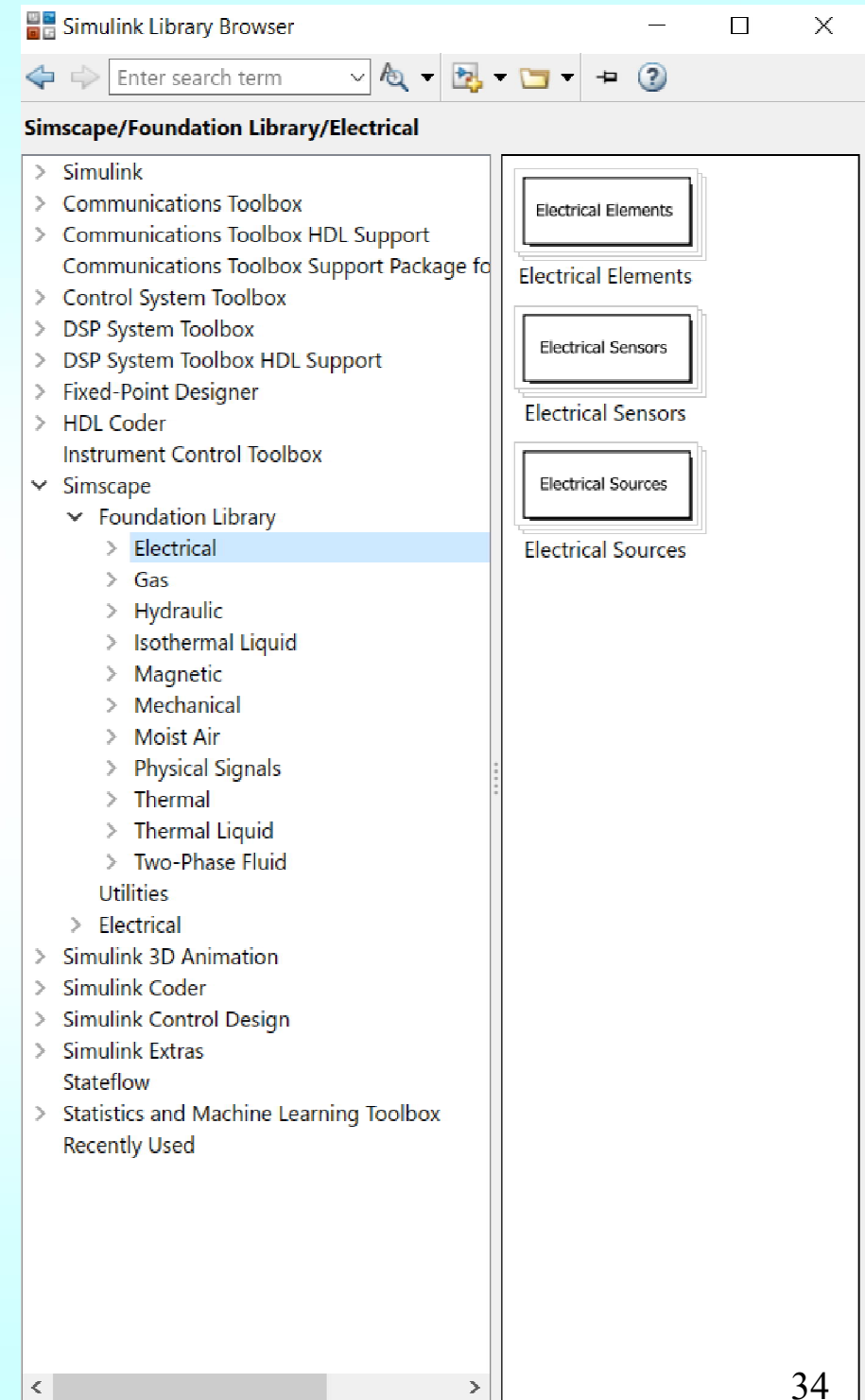
$$u_C(t_0^-) = U_0 = -10 \text{ V}$$



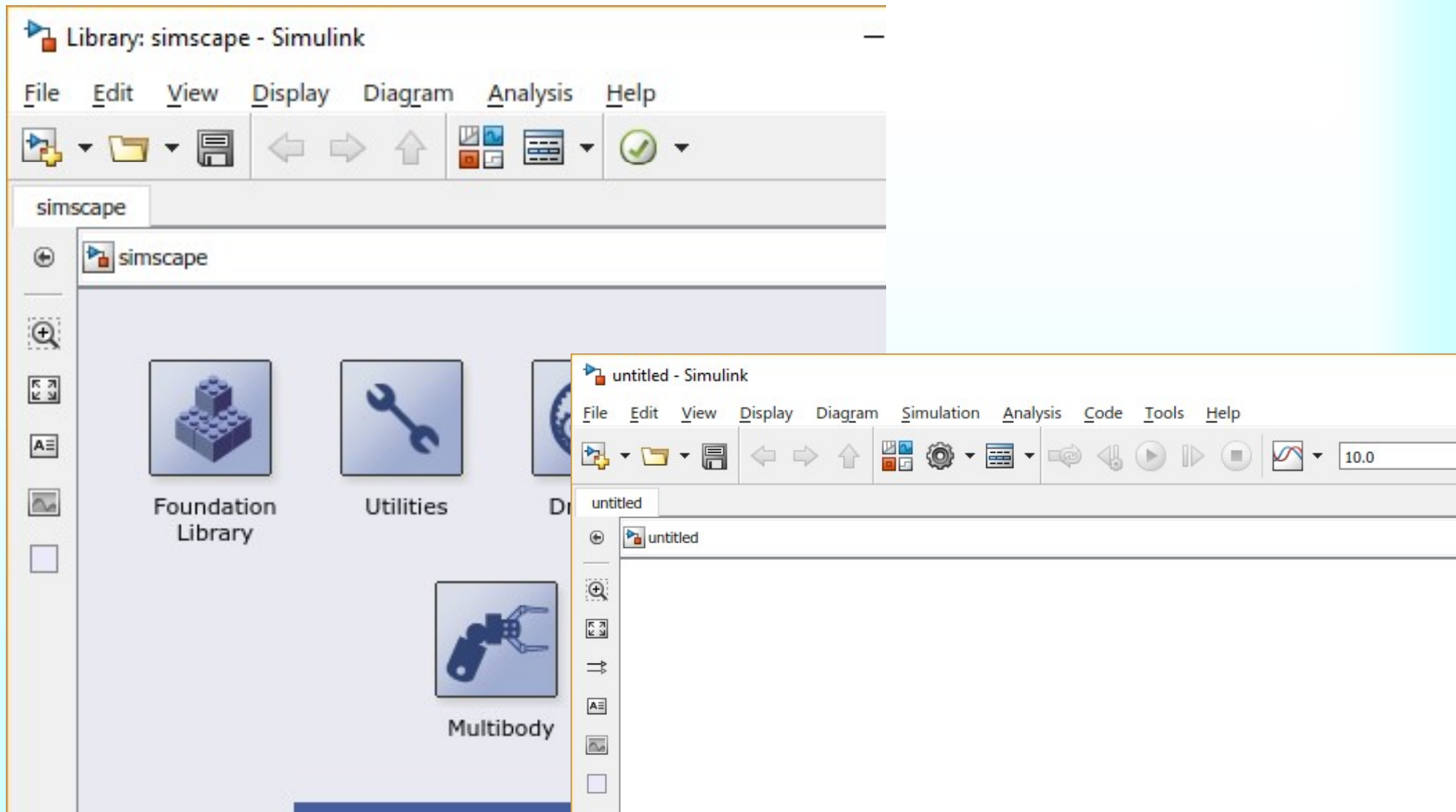
Simulink > Simscape > Foundation Library > Electrical

- Симулација линеарних и нелинеарних електричних кола

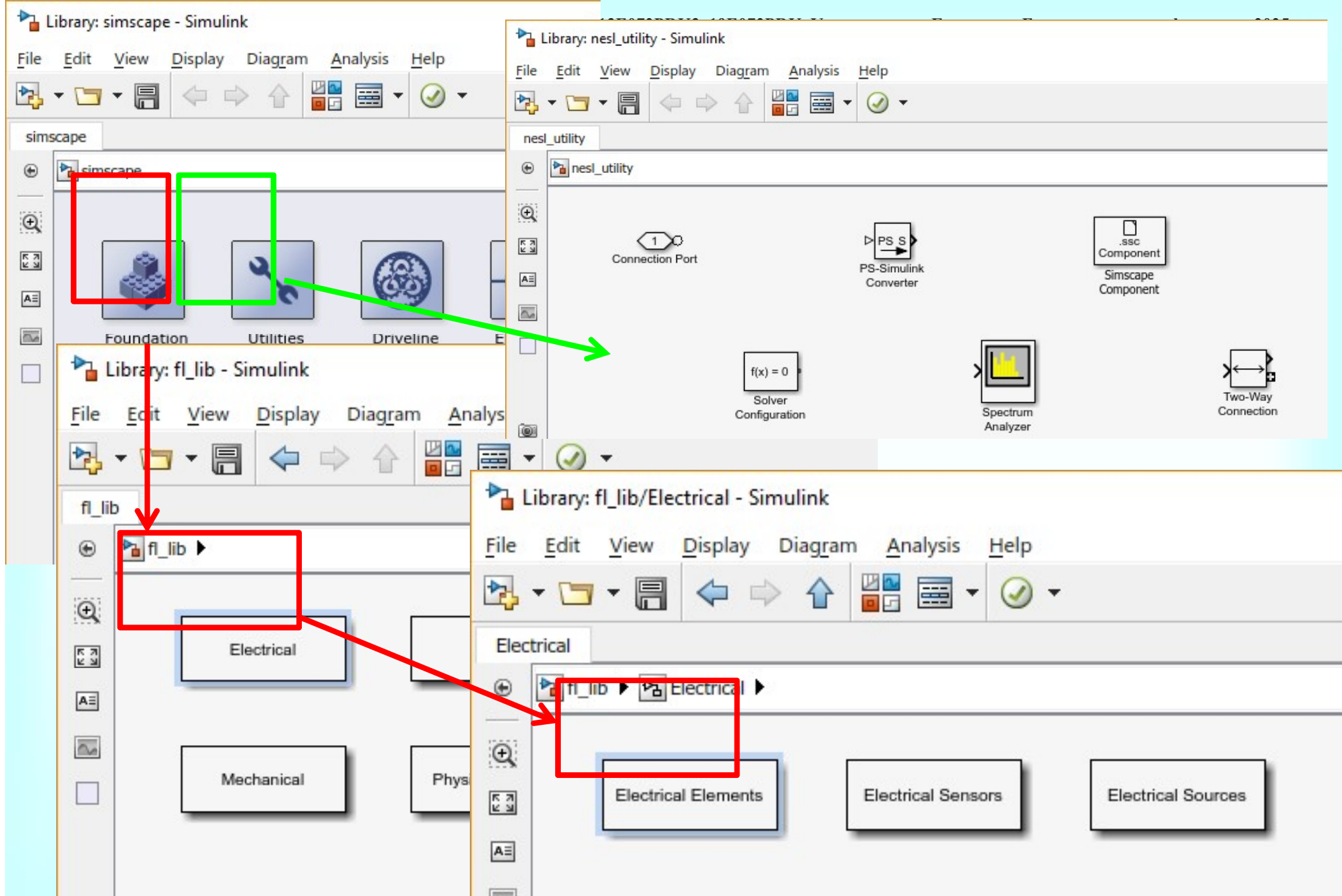
**MATLAB > Simscape >
Foundation Library, Utilities**



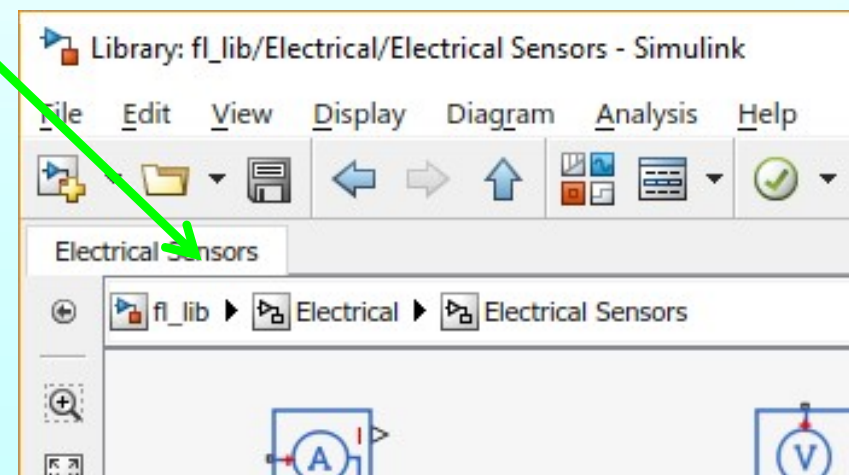
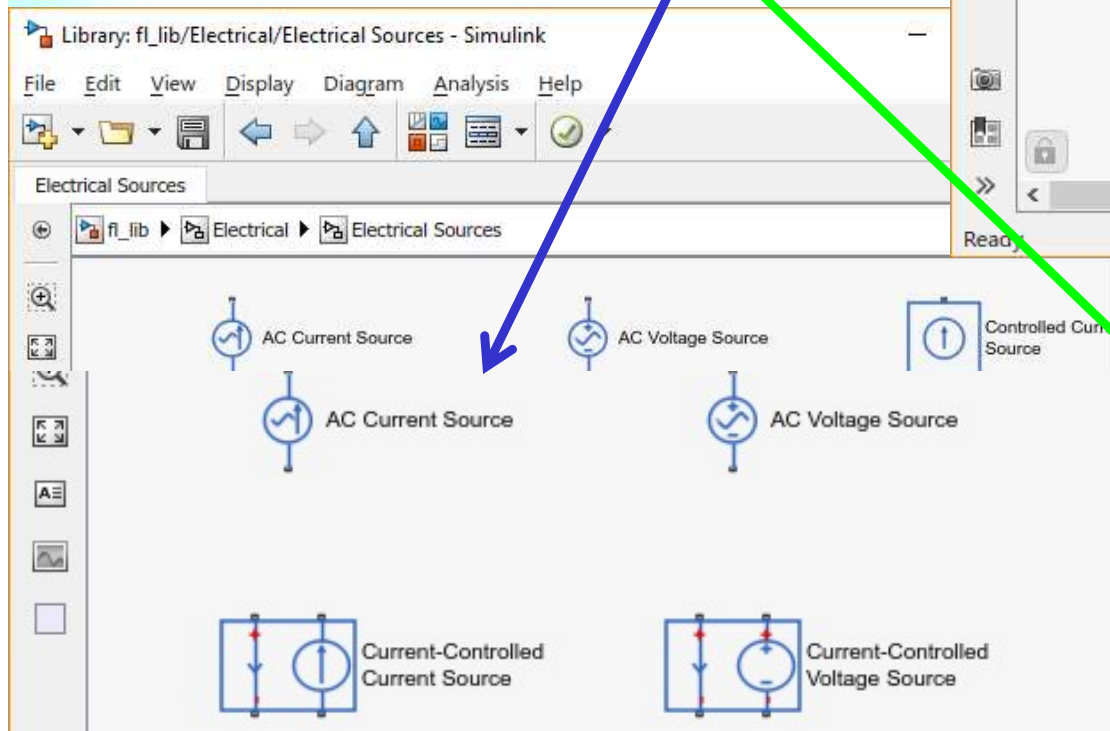
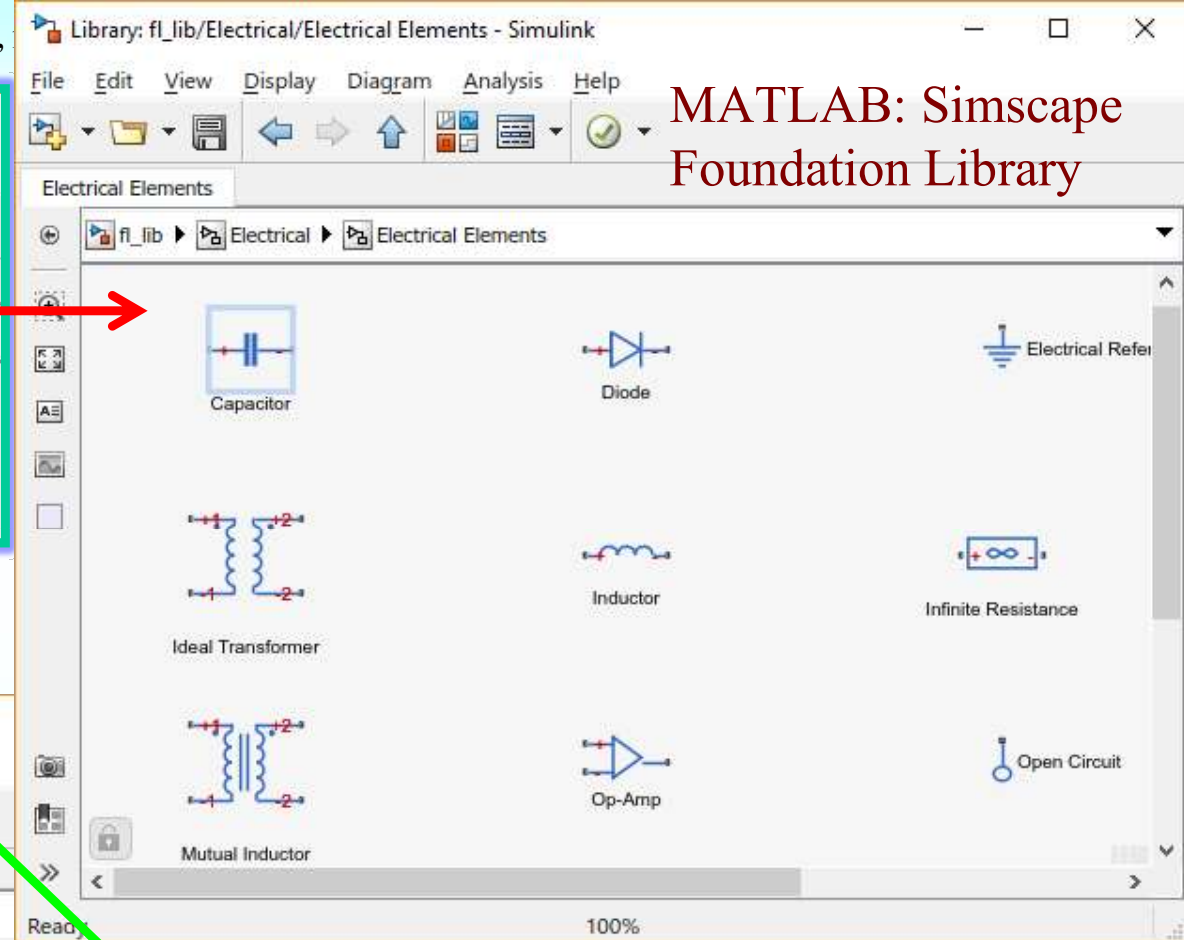
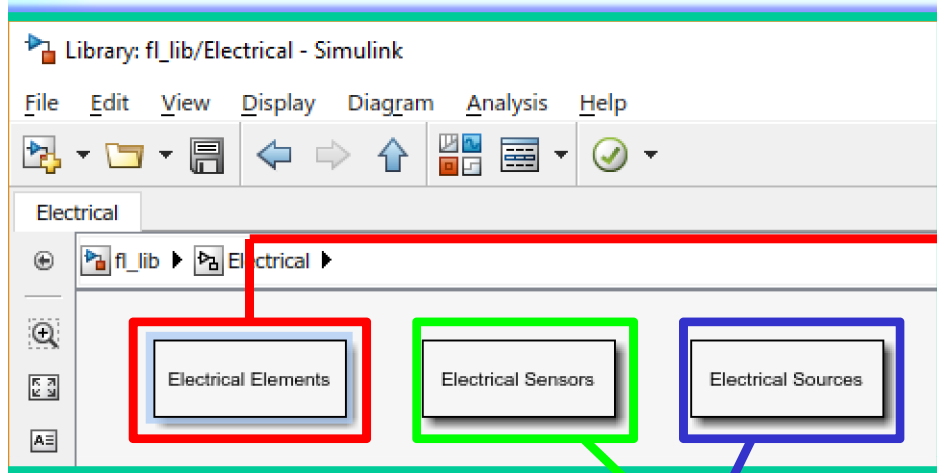
Симулација електричног кола коришћењем **Simscape > Foundation Library** библиотеке



**MATLAB > Simscape >
Foundation Library, Utilities**

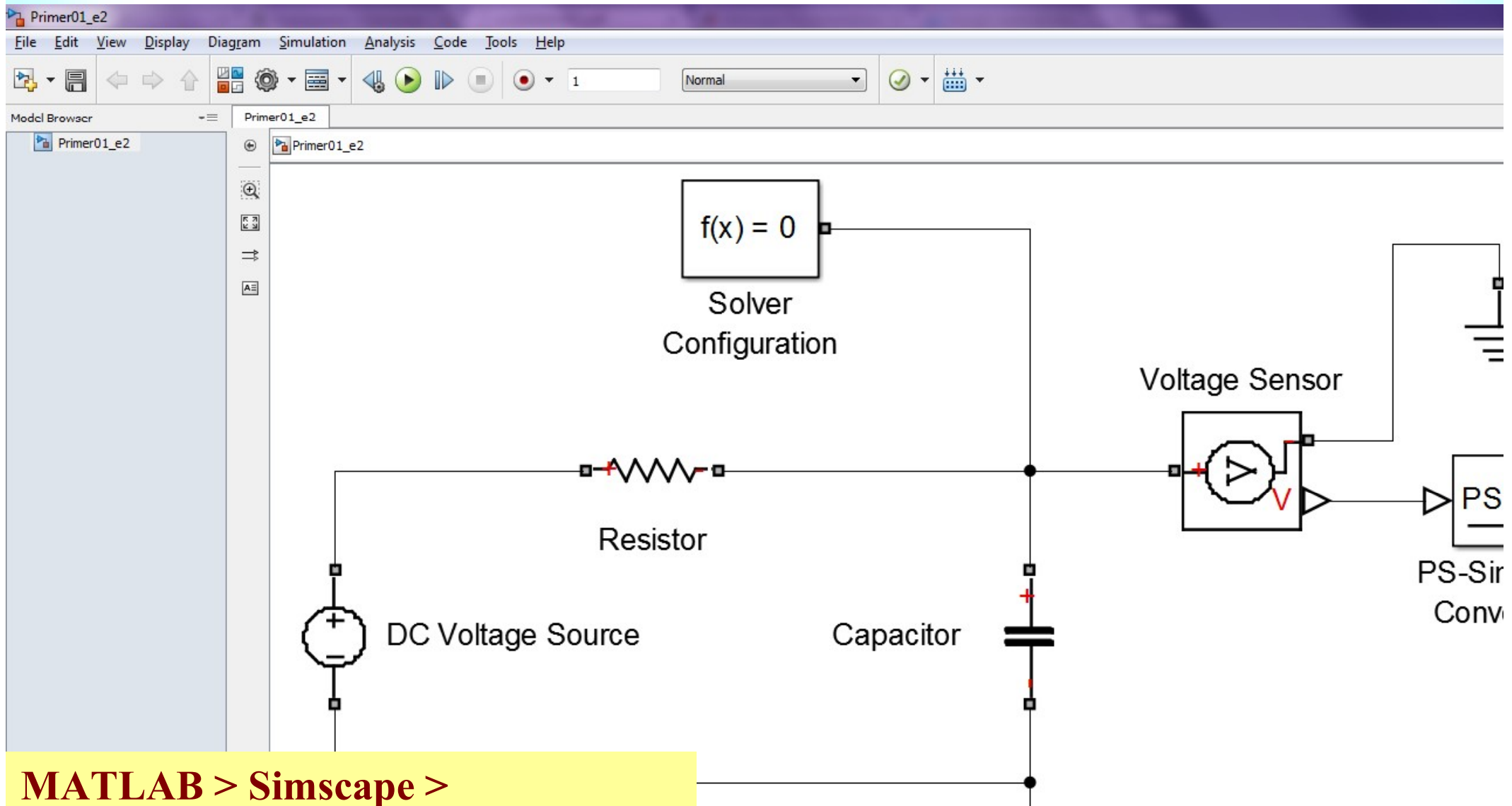


**MATLAB > Simscape >
Foundation Library, Utilities**

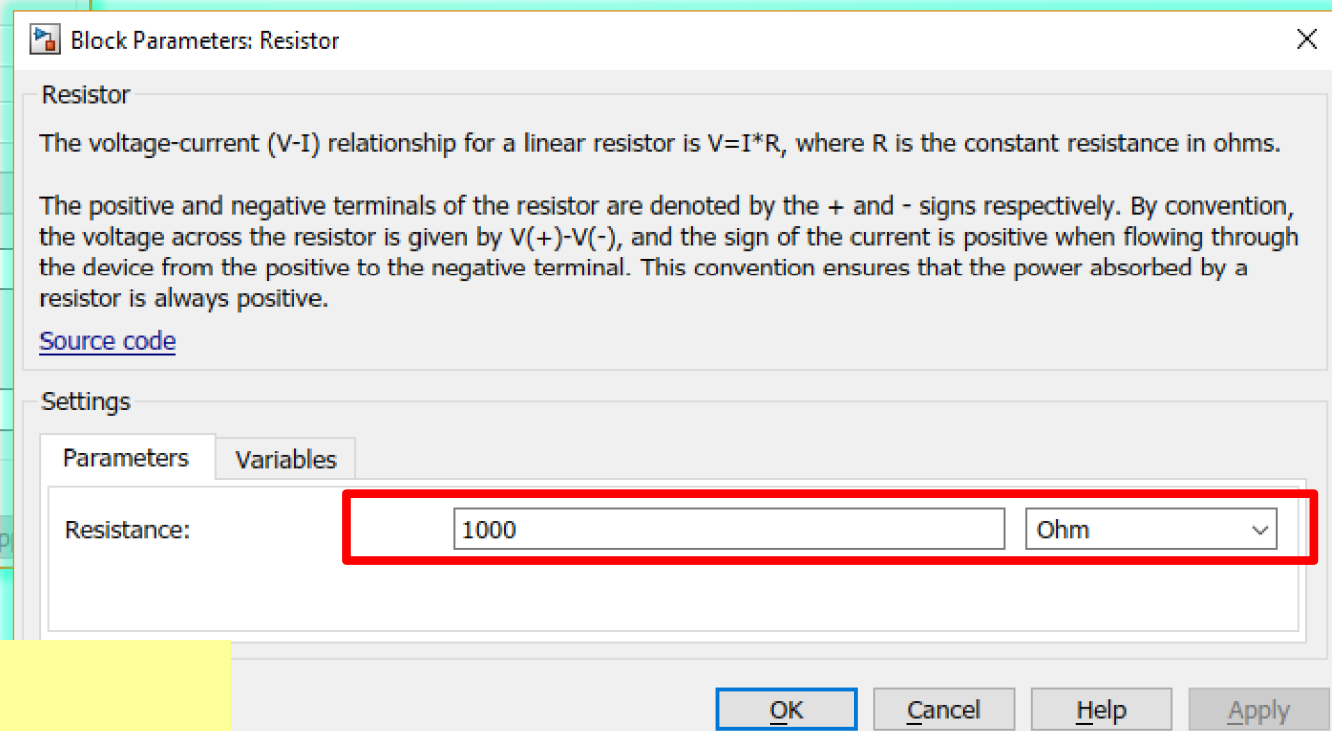
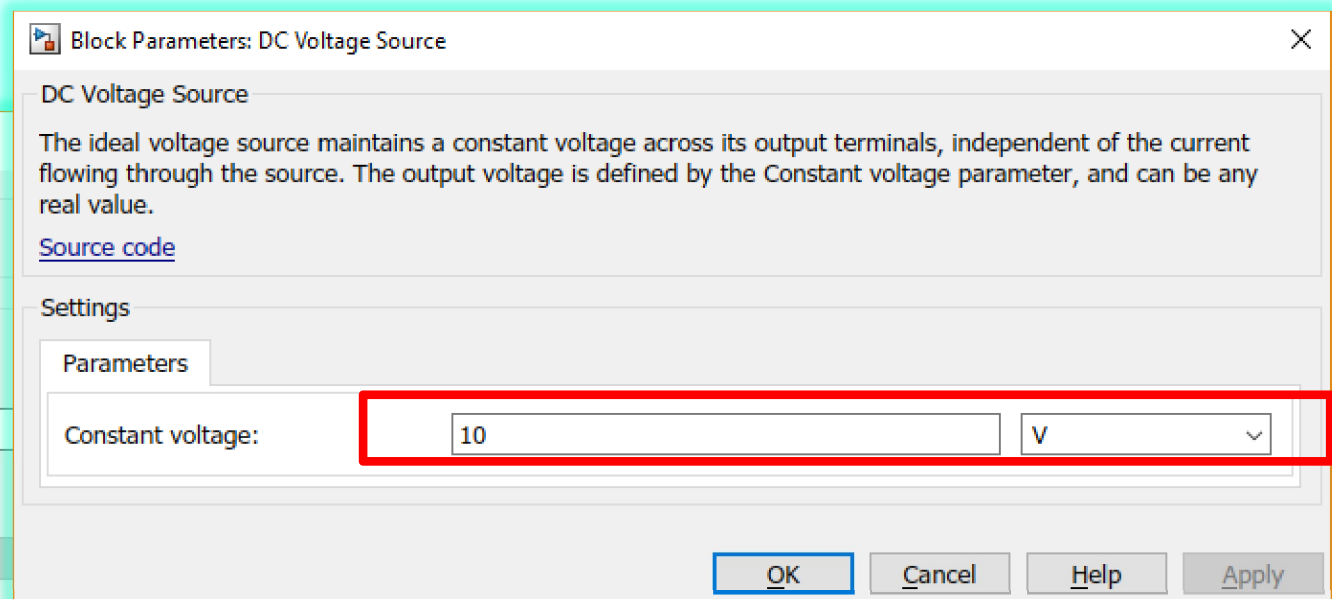


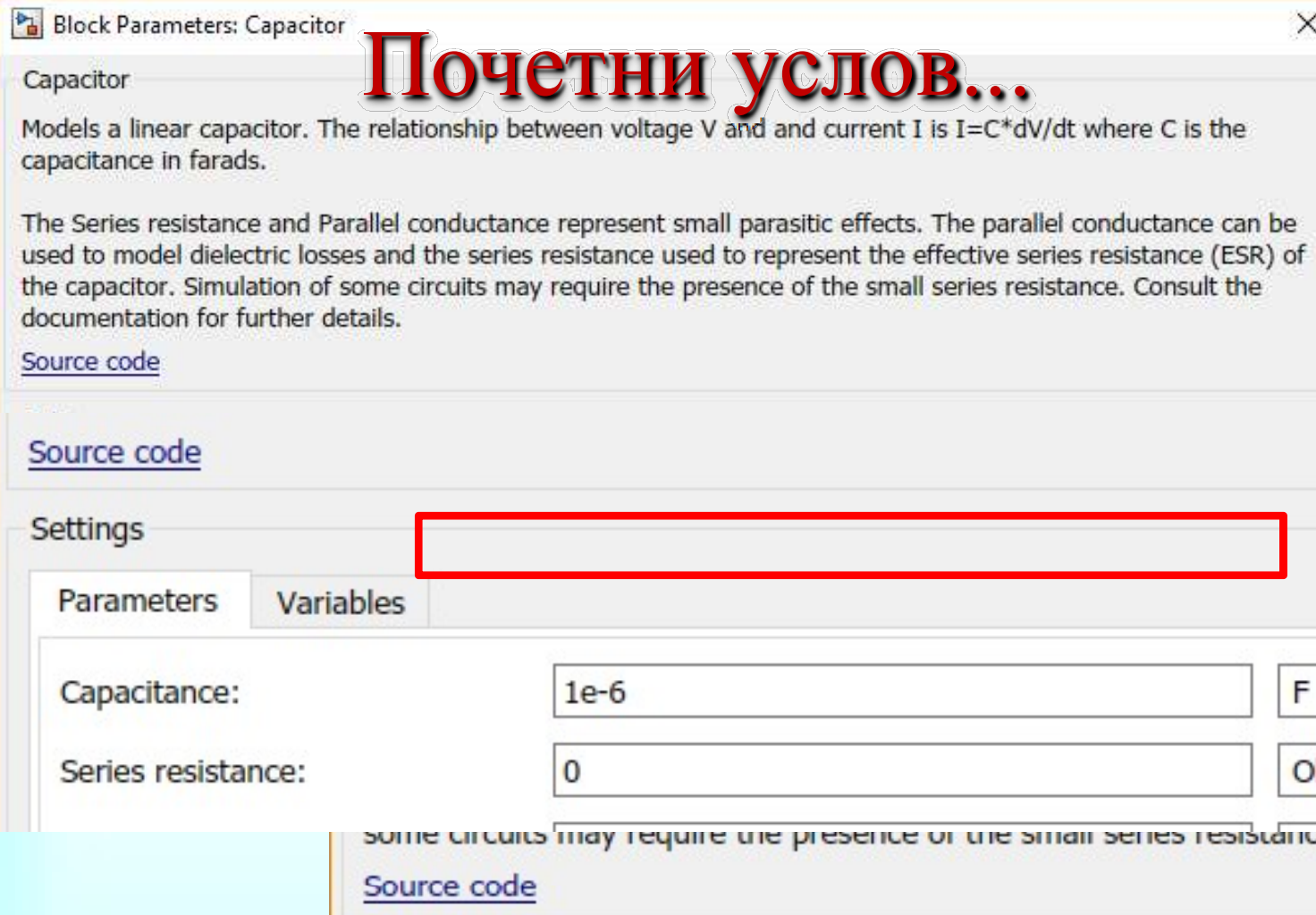
**MATLAB > Simscape >
Foundation Library, Utilities**

Симулација електричног кола коришћењем **Simscape > Foundation Library** библиотеке



**MATLAB > Simscape >
Foundation Library, Utilities**



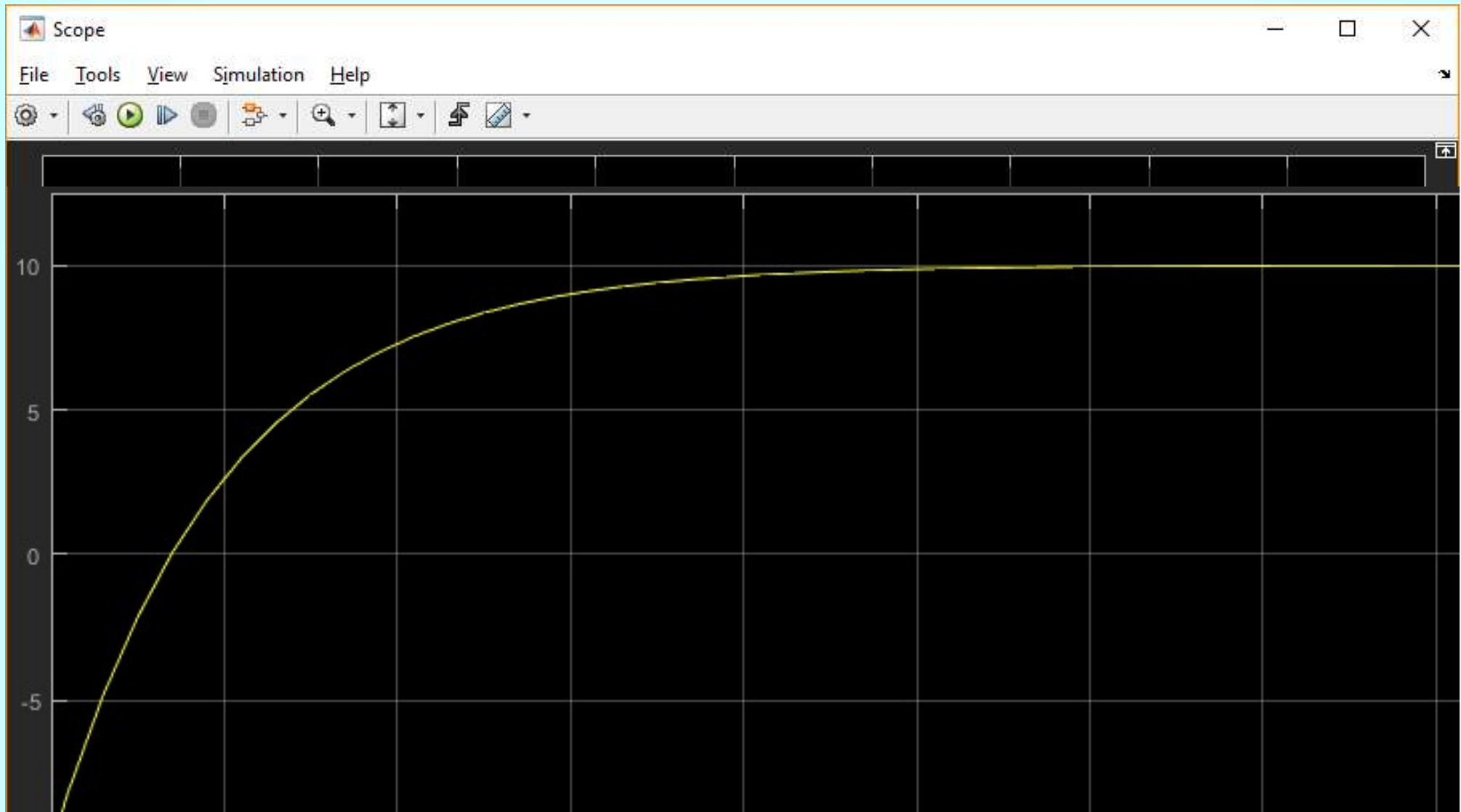


Settings

Parameters Variables

Override	Variable	Priority	Beginning Value
☐	Current	None ▼ 0	A
		None ▼ 0	V
		High ▼ -10	V 40

Налажење одзива...

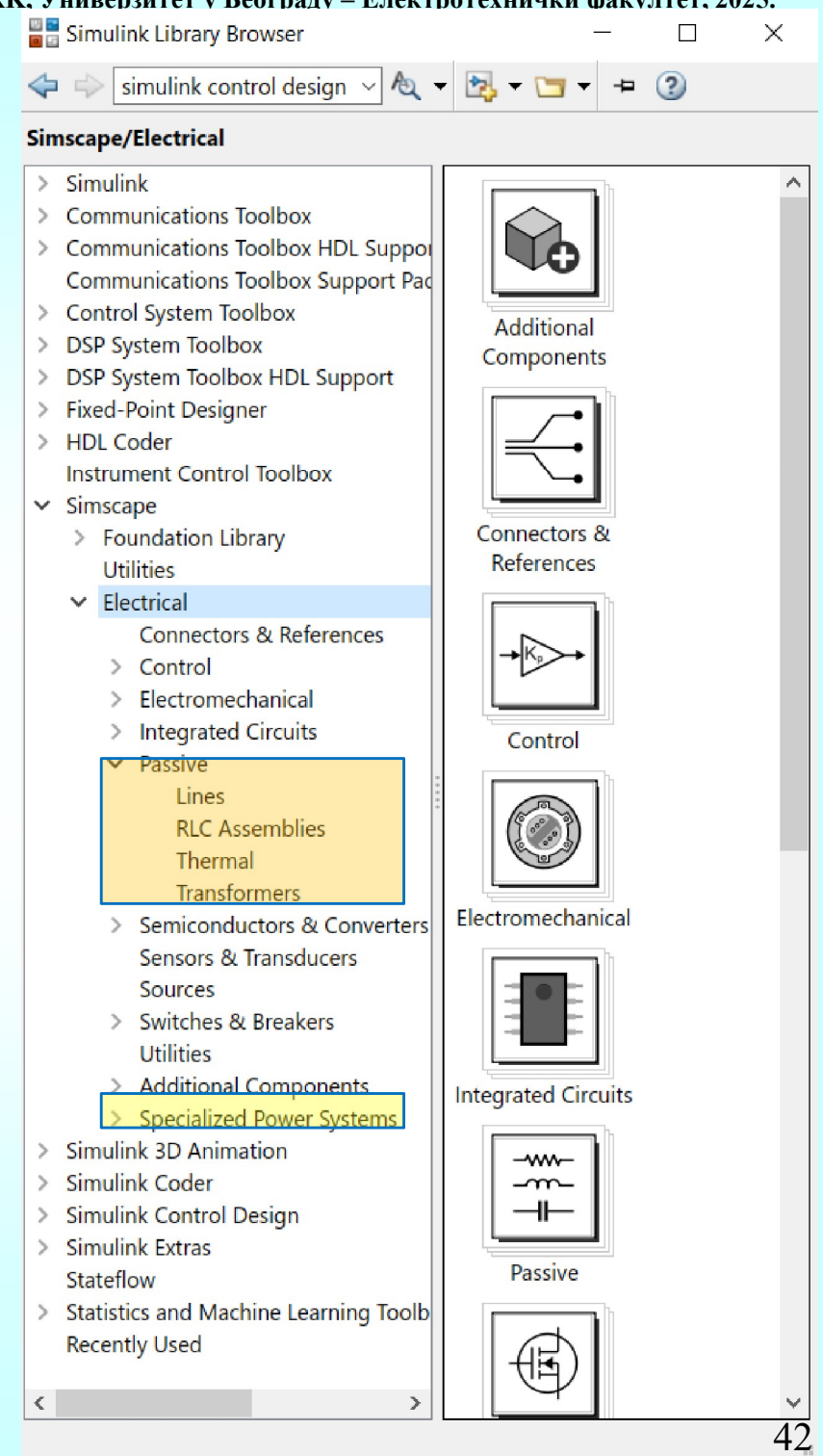


**MATLAB > Simscape >
Foundation Library, Utilities**

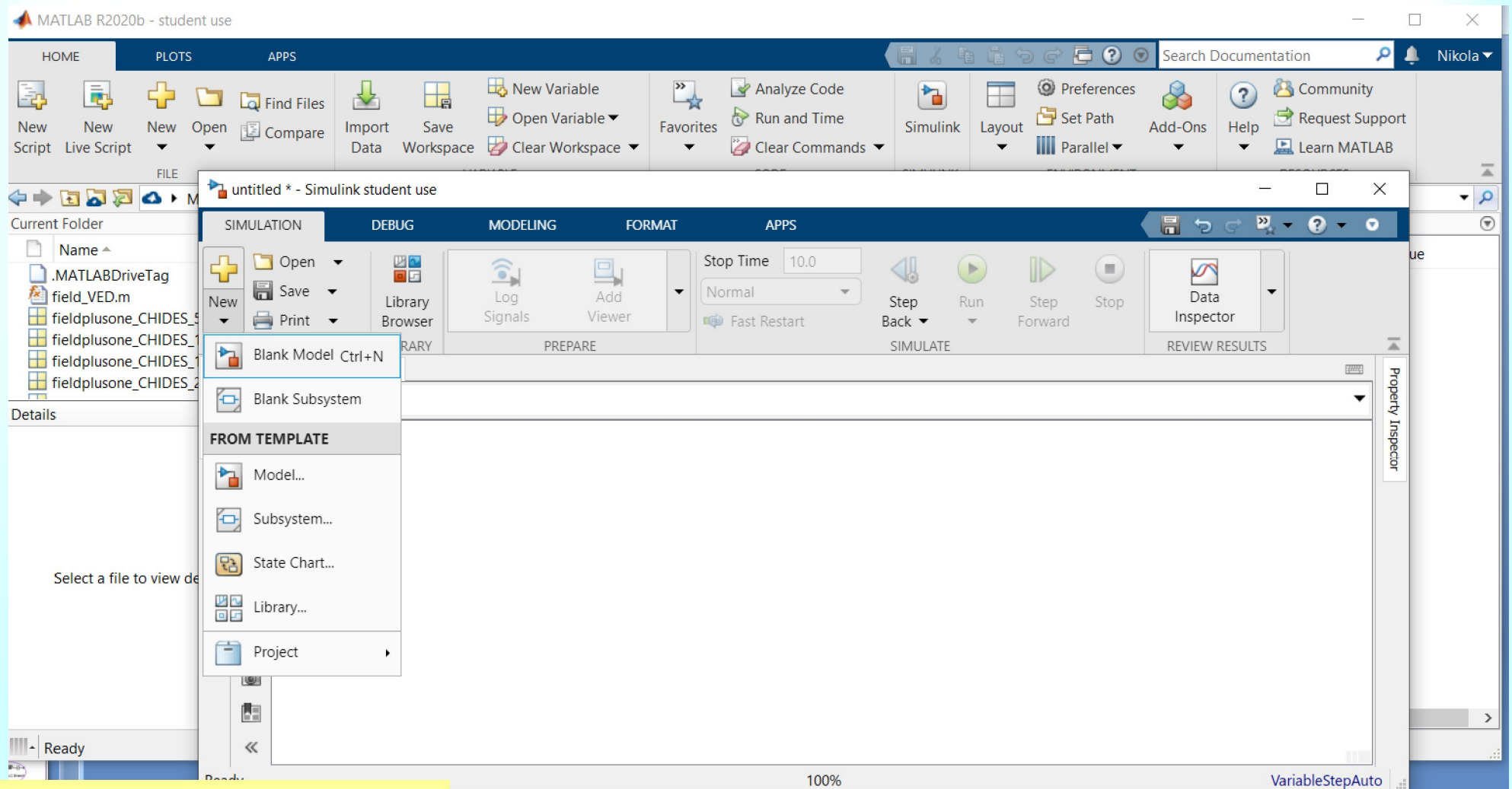
Simulink > Simscape > Electrical

- Библиотека за симулацију и нумеричку анализу електроенергетских система
- Трофазни извори, водови, трансформатори, потрошачи
- Термална анализа

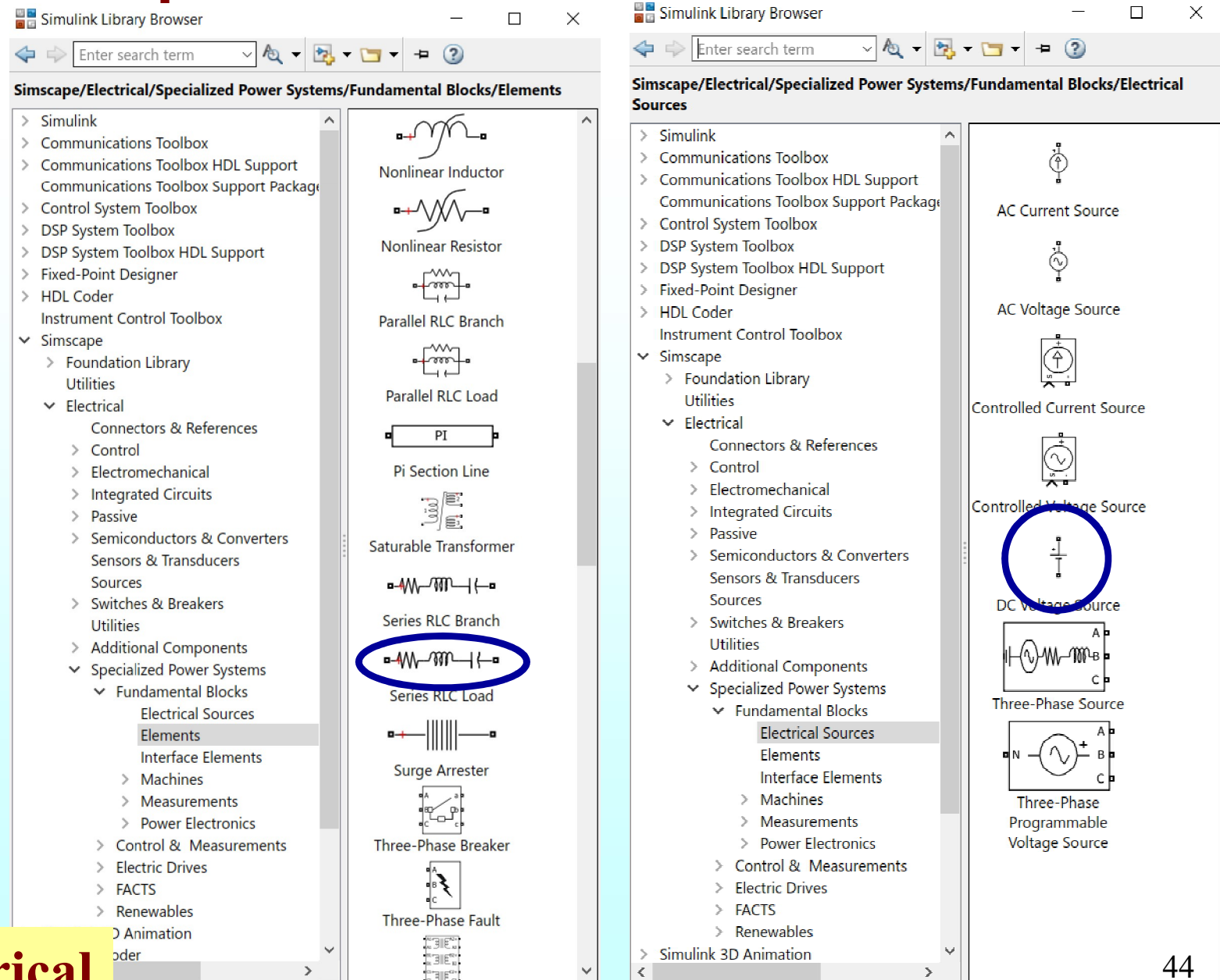
Simscape > Electrical



Симулација електричног кола коришћењем **Simscape>Electrical** библиотеке

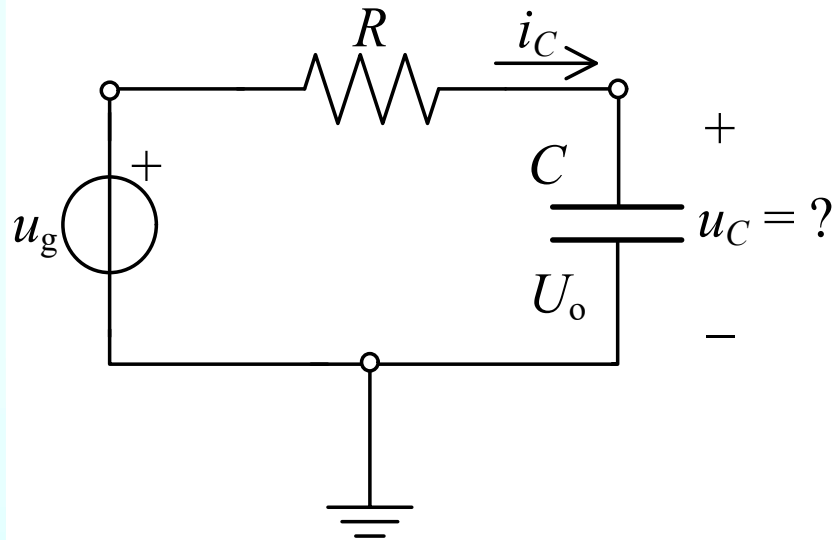


Симулација електричног кола коришћењем Simscape>Electrical библиотеке



Симулација електричног кола коришћењем **Simscape>Electrical** библиотеке

коло је образовано у тренутку $t_0 = 0$

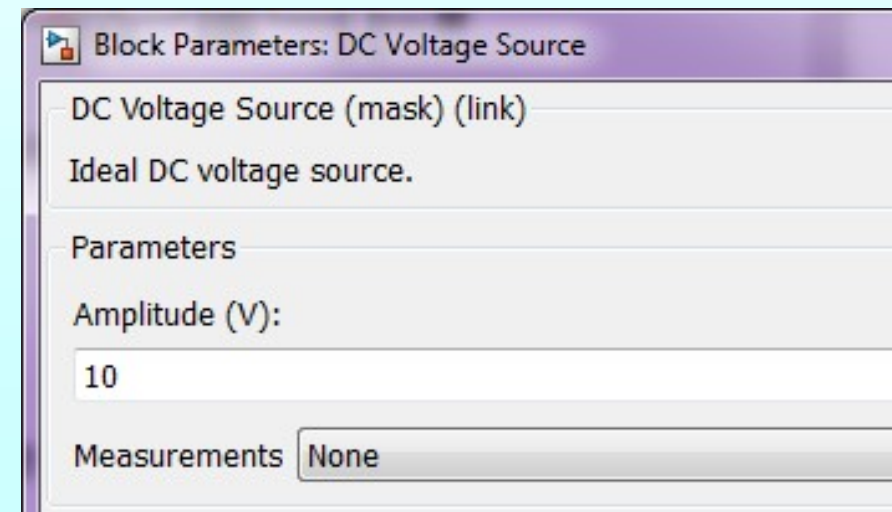
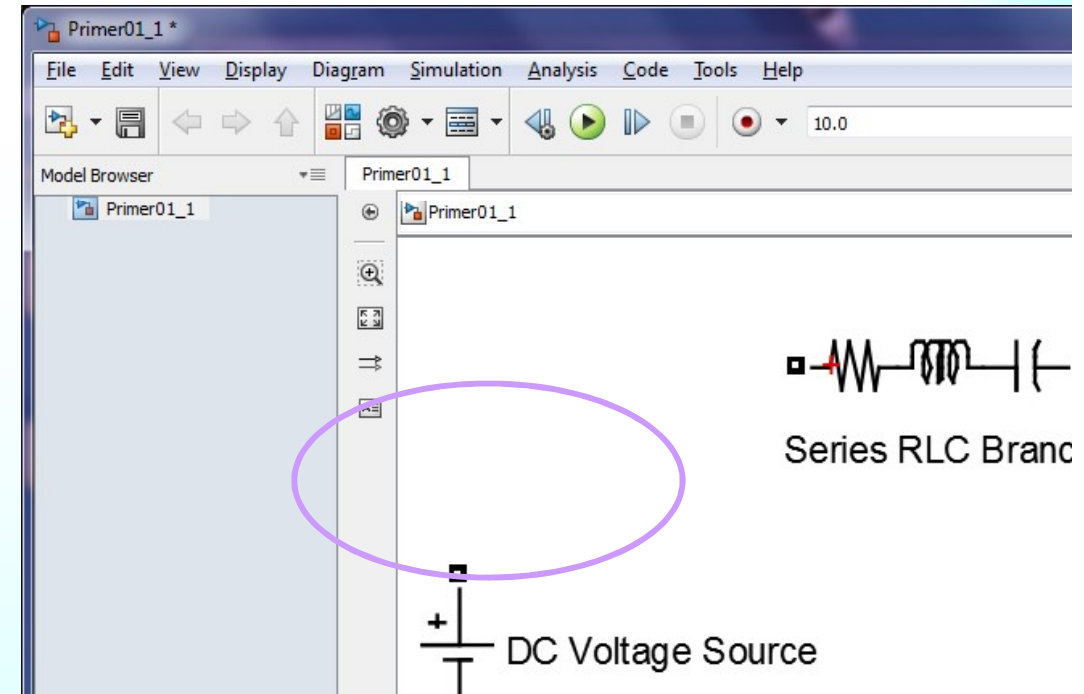


$$R = 1\text{ k}\Omega$$

$$C = 1\text{ }\mu\text{F}$$

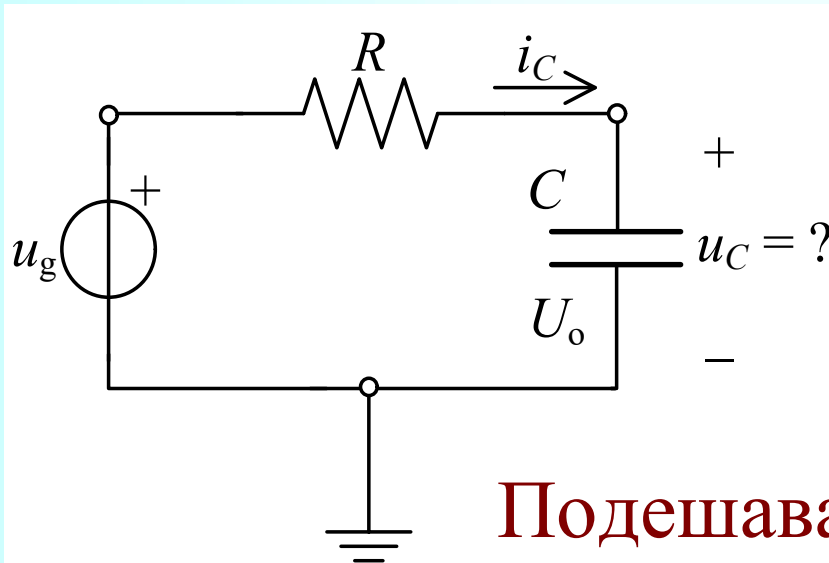
$$u_g(t) = U h(t), U = 10\text{ V}$$

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



Симулација електричног кола коришћењем Simscape>Electrical библиотеке

коло је образовано у тренутку $t_0 = 0$



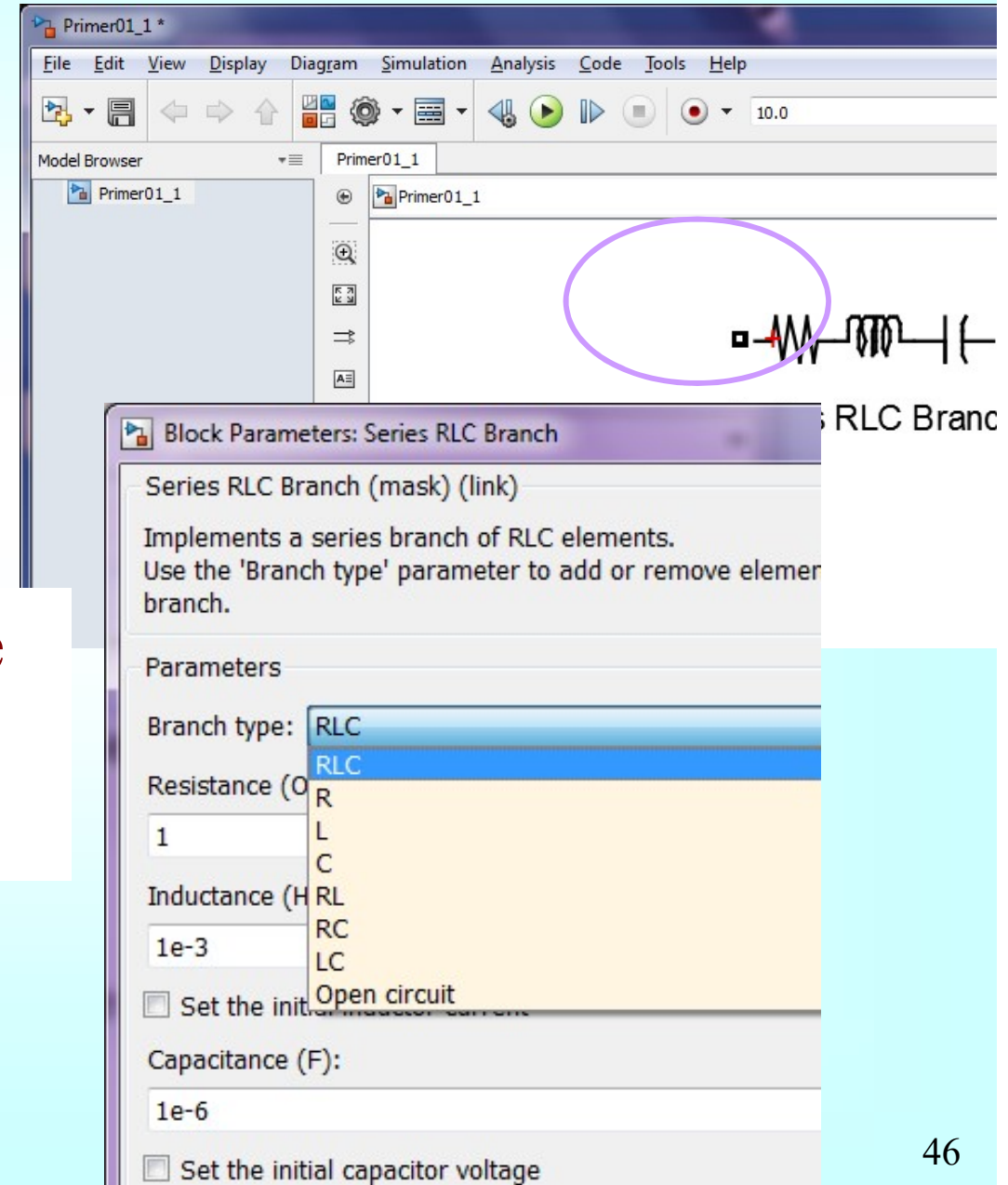
$$R = 1 \text{ k}\Omega$$

$$C = 1 \mu\text{F}$$

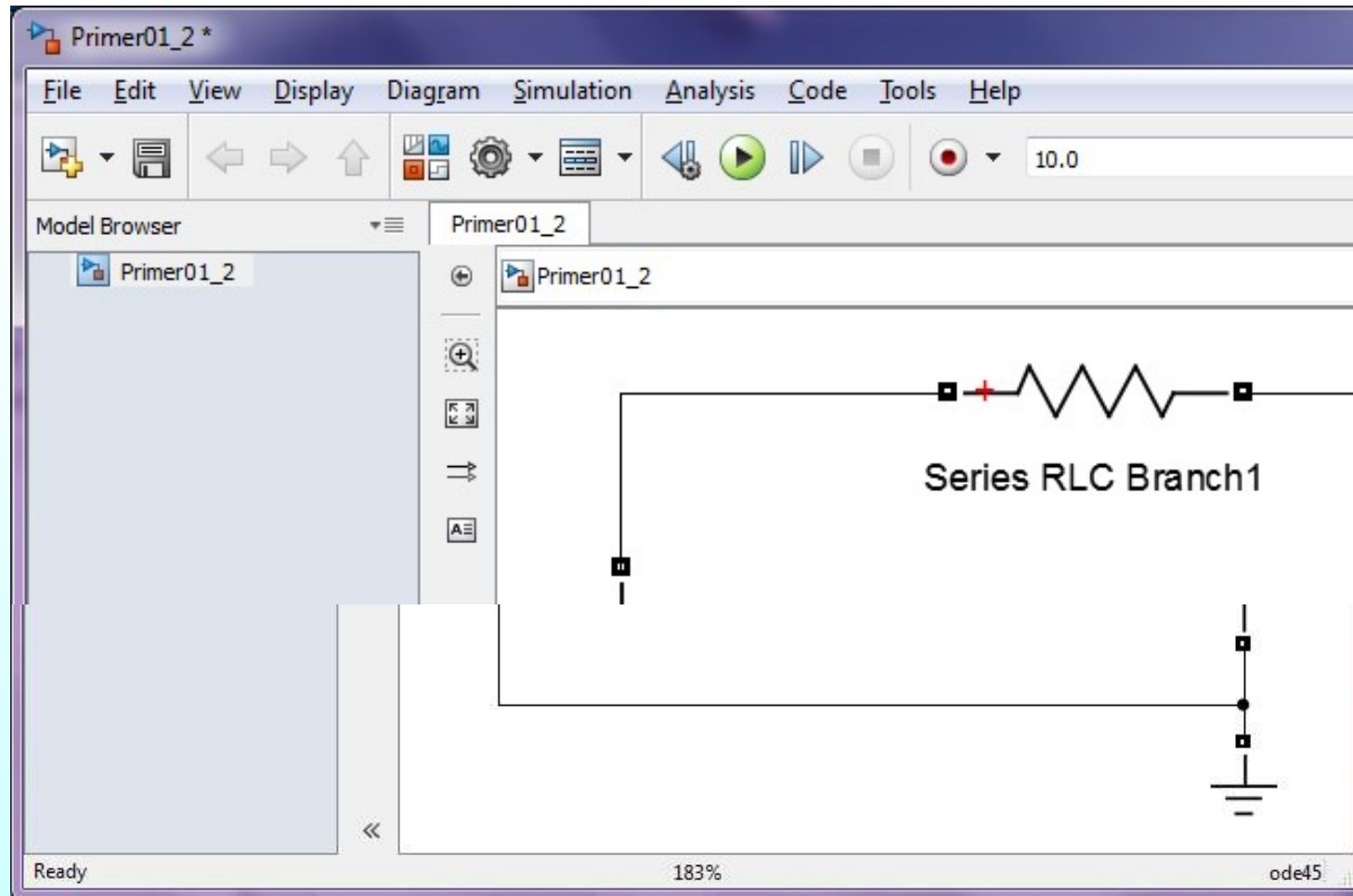
$$u_g(t) = U h(t), U = 10 \text{ V}$$

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

Подешавање
параметара
симулације



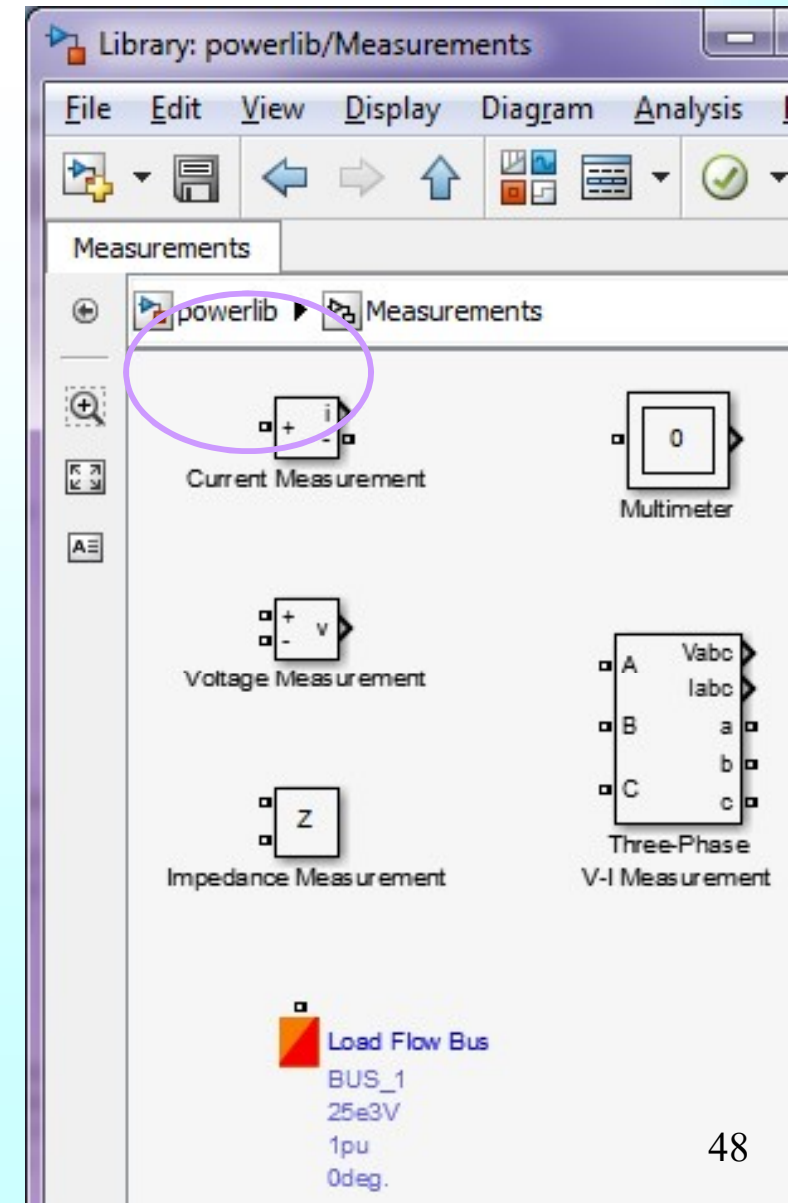
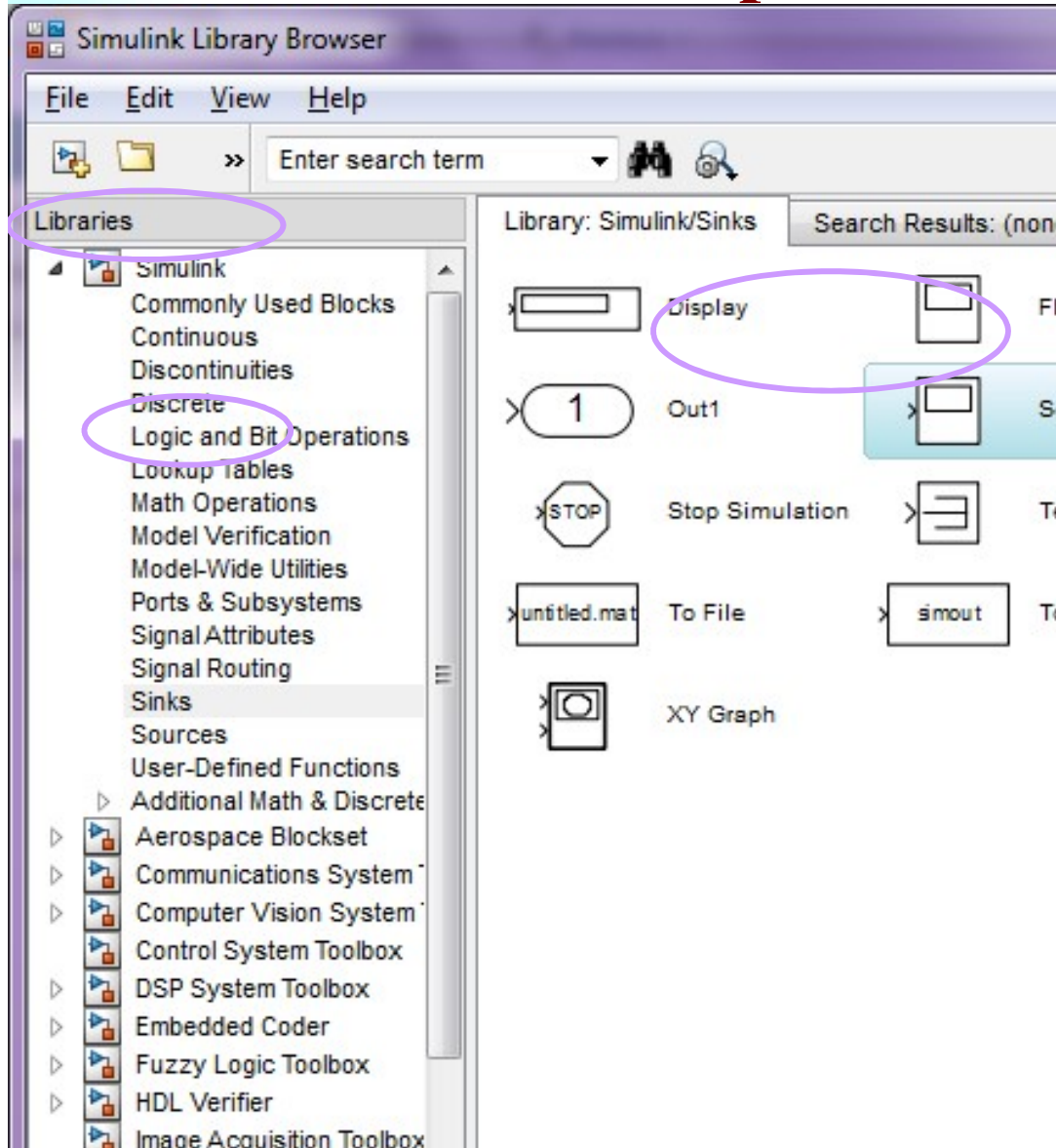
Симулација електричног кола коришћењем **Simscape>Electrical** библиотеке



Како се мери напон?

Simscape> Electrical

Симулација електричног кола коришћењем **Simscape>Electrical** библиотеке



Simscape> Electrical

 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: Stop time:

Solver options

Type: Solver:

▶ Additional options

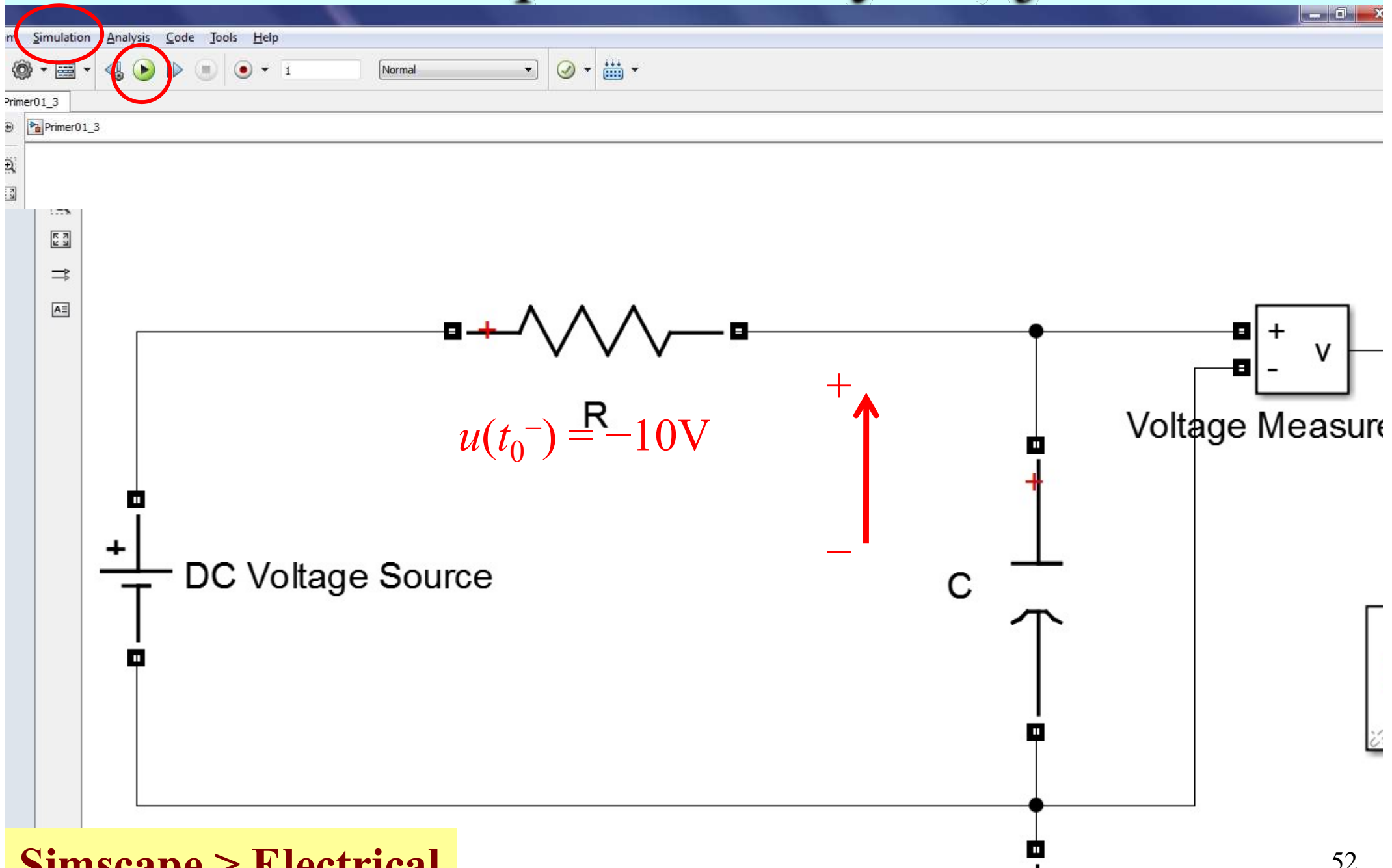
 Configuration Parameters: untitled/Configuration (Active)

★ Commonly Used Parameters ≡ All Parameters

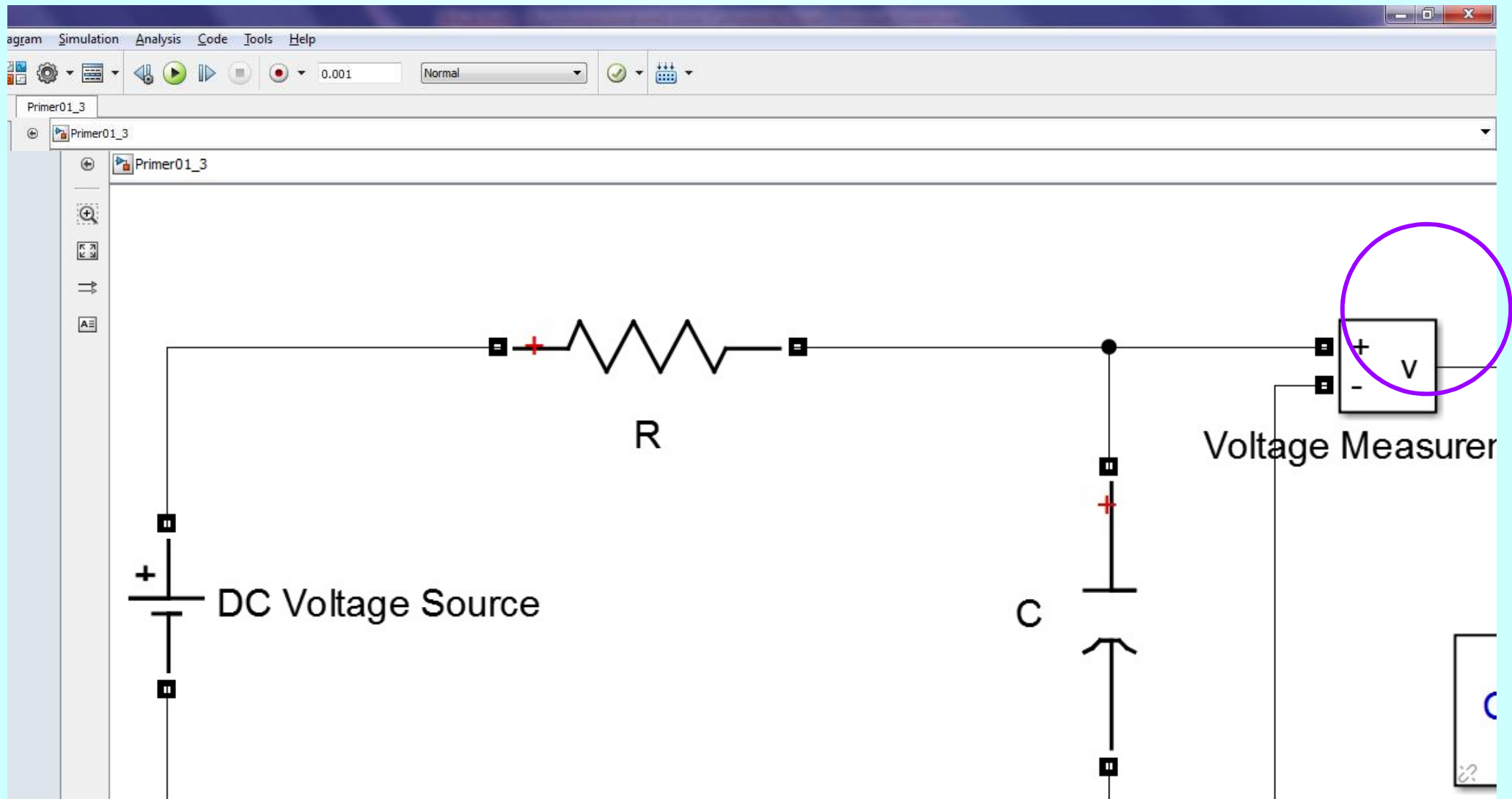
Category: 

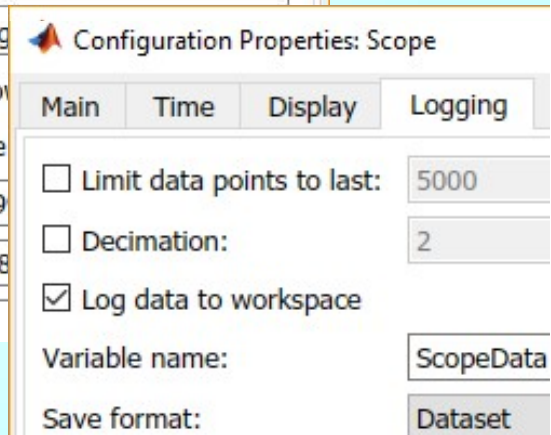
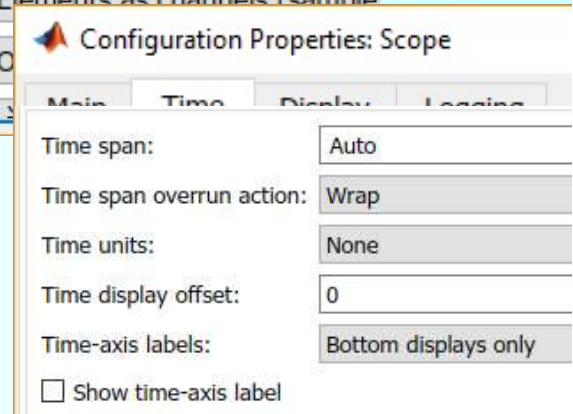
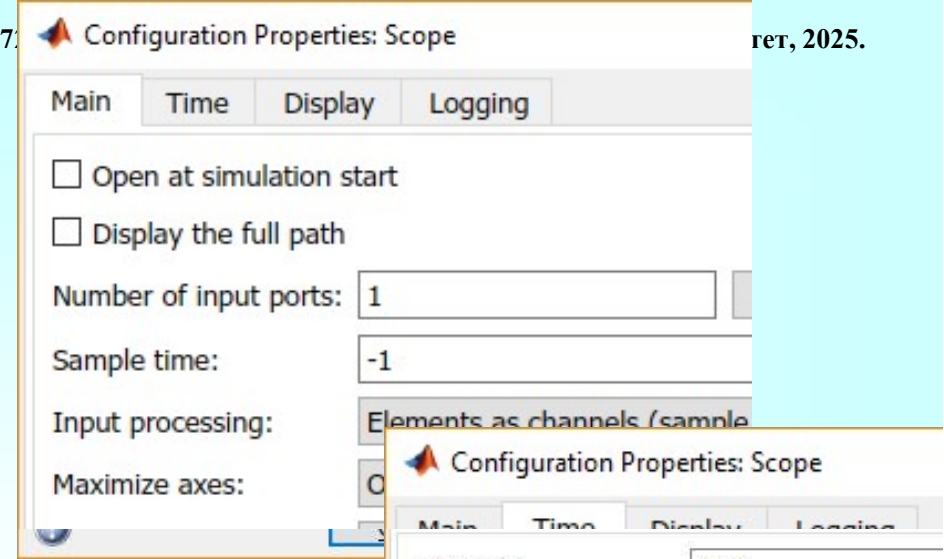
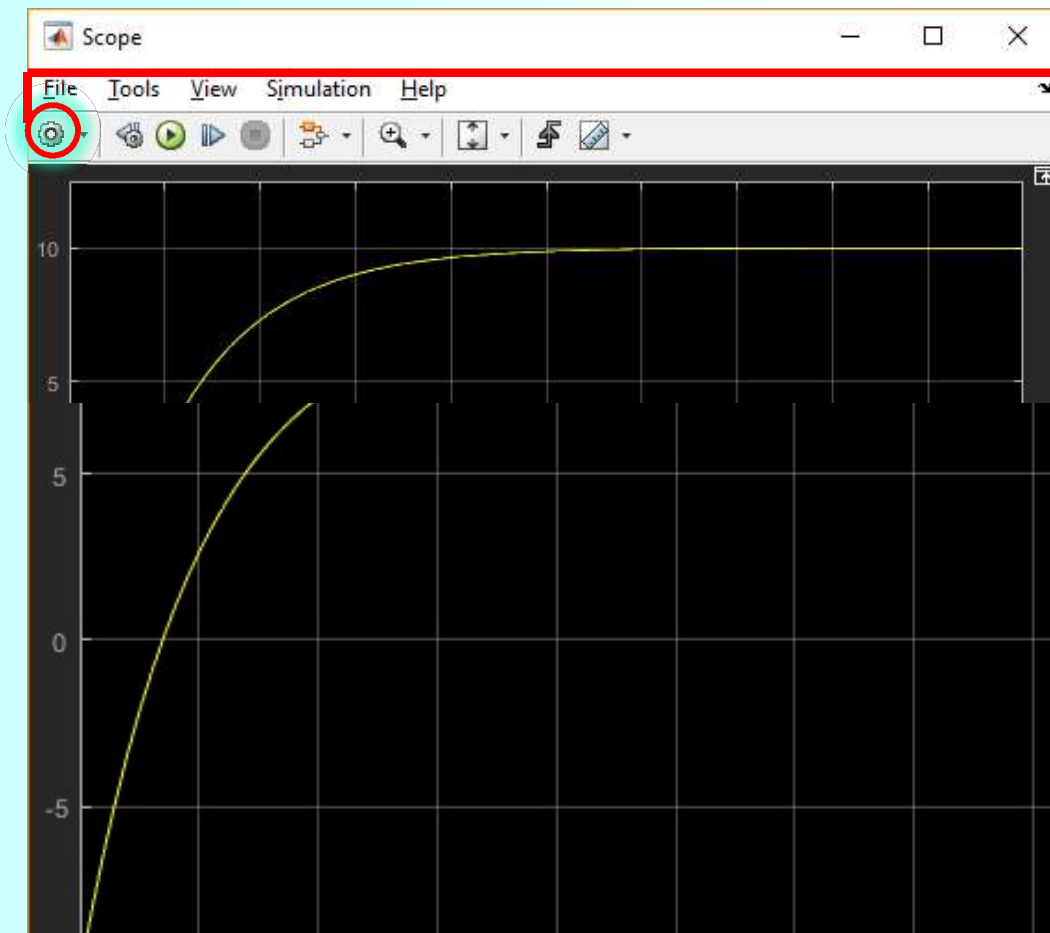
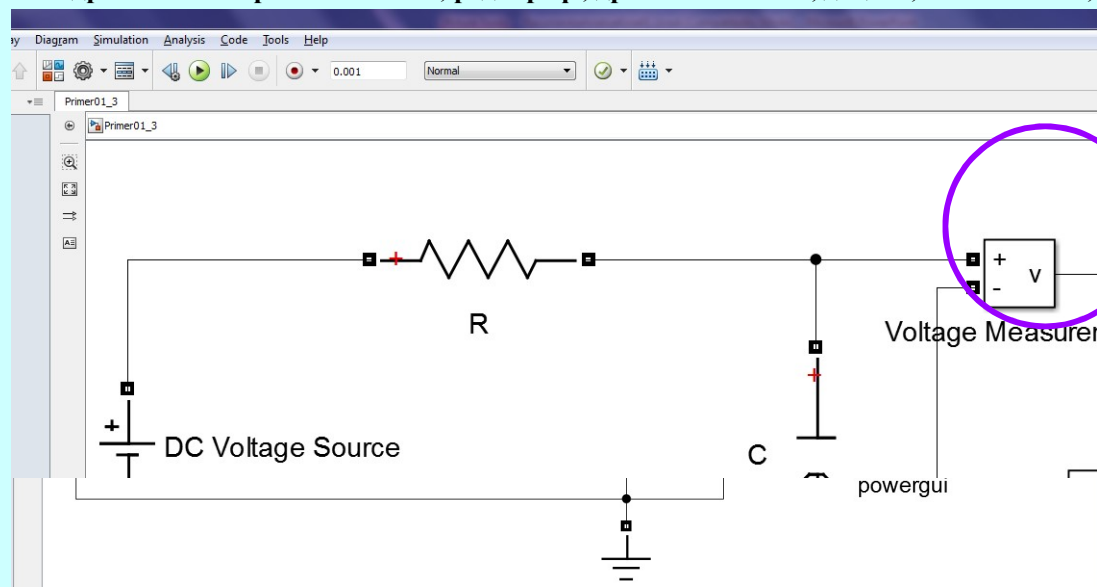
Parameter	Value	Co
Solver ▶ Simulation time		
> Start time Simulation start time. Note that the values that you specify as block i...	0.0	S
> Stop time Simulation stop time.	0.01	S
Solver ▶ Solver options		
> Type Choose a variable or fixed-step solver.	Variable-step 	S
> Solver Choose a solver. If disabled, enable in "Additional options" by changi...	auto (Automatic solver selection) 	S
Solver ▶ Additional options		
> Max step size Maximum step size for a variable-step solver.	1e-4	M
> Relative tolerance Specify the largest acceptable solver error, relative to the size of eac...	1e-3	R
> Min step size Minimum step size for a variable-step solver.	auto	M
> Absolute tolerance Specify the largest acceptable solver error, as the value of the meas...	auto	A

Покретање симулације...



Налажење одзива... Осцилоскоп







Configuration Parameters: untitled/Configuration (Active)

★ Commonly Used Parameters

≡ All Parameters

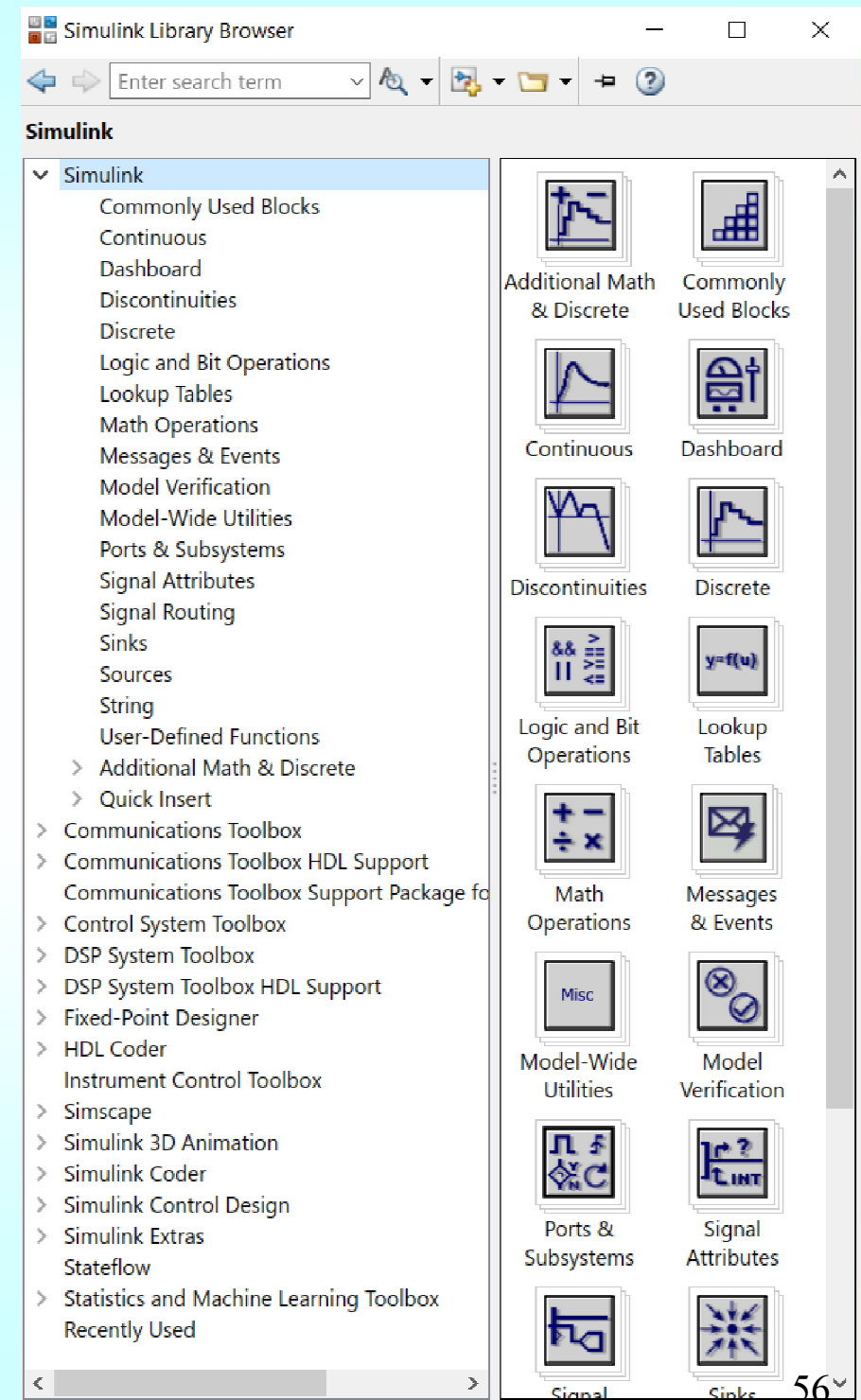
Category: All

Search selected category

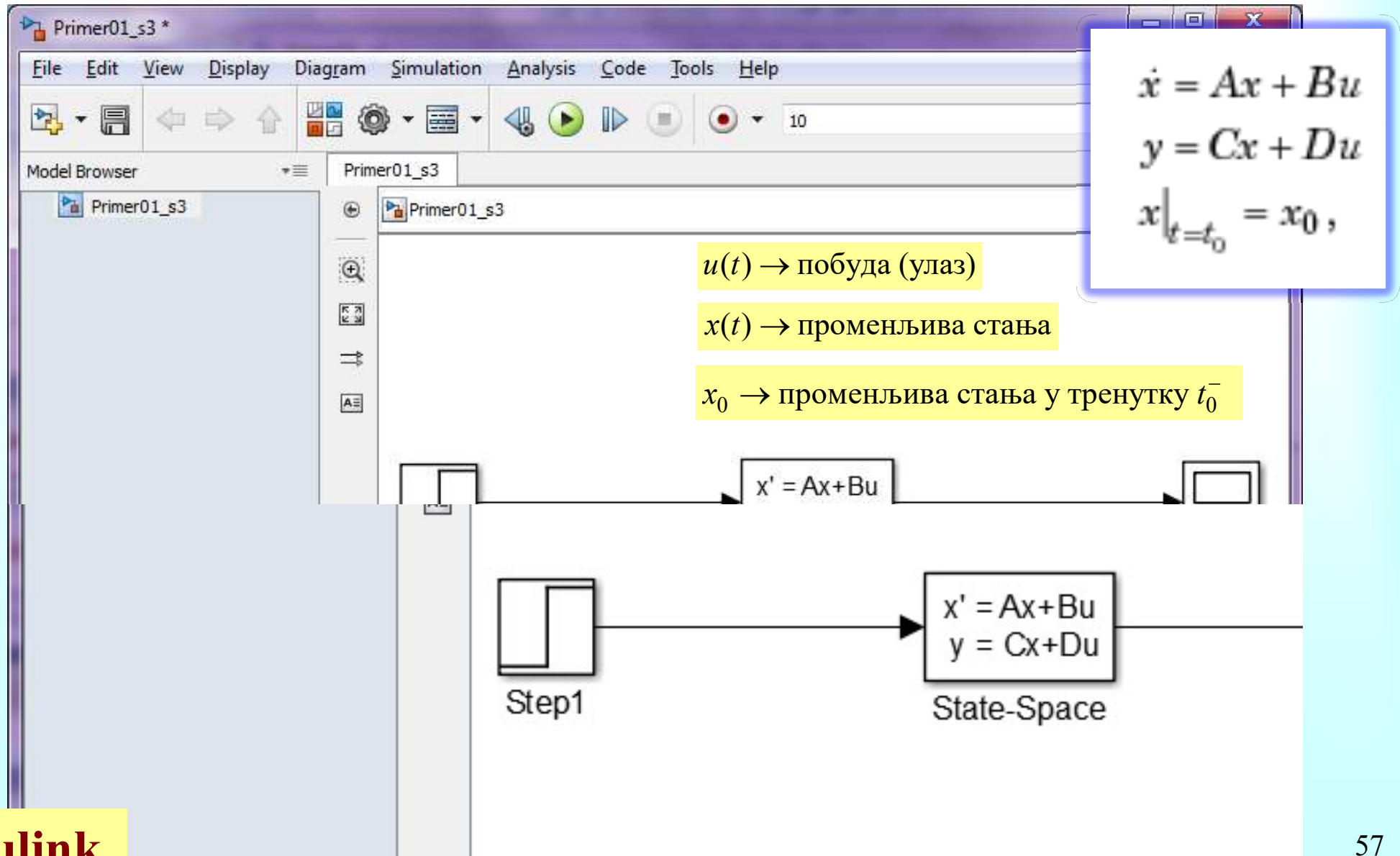
Parameter	Value	Co
Solver ► Simulation time		
Start time	0.0	S
Simulation start time. Note that the values that you specify as block i...		
Stop time	0.01	S
Simulation stop time.		
Solver ► Solver options		
Type	Variable-step	S
Choose a variable or fixed-step solver.		
Solver	auto (Automatic solver selection)	S
Choose a solver. If disabled, enable in "Additional options" by changi...		
Solver ► Additional options		
Max step size	1e-4	M
Maximum step size for a variable-step solver.		
Relative tolerance	1e-3	R
Specify the largest acceptable solver error, relative to the size of eac...		
Min step size	auto	M
Minimum step size for a variable-step solver.		
Absolute tolerance	auto	A
Specify the largest acceptable absolute error, relative to the value of the meas...		

Simulink

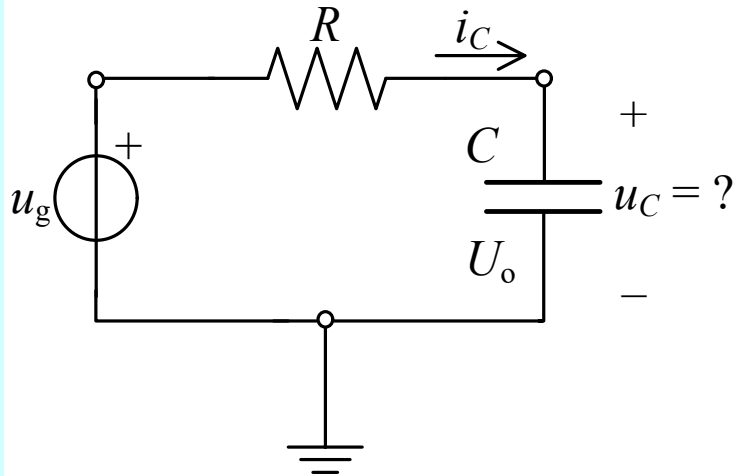
- Решавање кола може се извршити његовим свођењем на систем линеарних диференцијалних једначина
- Дати систем може се представити једноставним блоком са више улаза и излаза



Симулација електричног кола као уопштеног система коришћењем Simulink-а



Симулација електричног кола као уопштеног система коришћењем Simulink-а



коло је образовано у тренутку $t_0 = 0$

$$R = 1 \text{ k}\Omega$$

$$C = 1 \mu\text{F}$$

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

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

$u = u_g(t) \rightarrow$ 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^-

$$u_g(t) = Ri_C + u_C(t)$$

$$i_C = C \frac{du_C}{dt}$$

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

$$\begin{aligned} \dot{x} &= Ax + Bu \\ y &= Cx + Du \\ x|_{t=t_0} &= x_0, \end{aligned}$$

$$\frac{du_C(t)}{dt} = \frac{i_C}{C} = \frac{u_g(t) - u_C(t)}{RC} = -\frac{u_C(t)}{RC} + \frac{u_g(t)}{RC}$$

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

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

$$u_C(t) = Cu_C(t) \Rightarrow C = 1, D = 0$$

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

Симулација електричног кола као уопштеног система коришћењем Simulink-a

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

Function Block Parameters: State-Space

State Space

State-space model:

$$\frac{dx}{dt} = Ax + Bu$$

$$y = Cx + Du$$

Parameters

A:

-1000

B:

1000

C:

1

D:

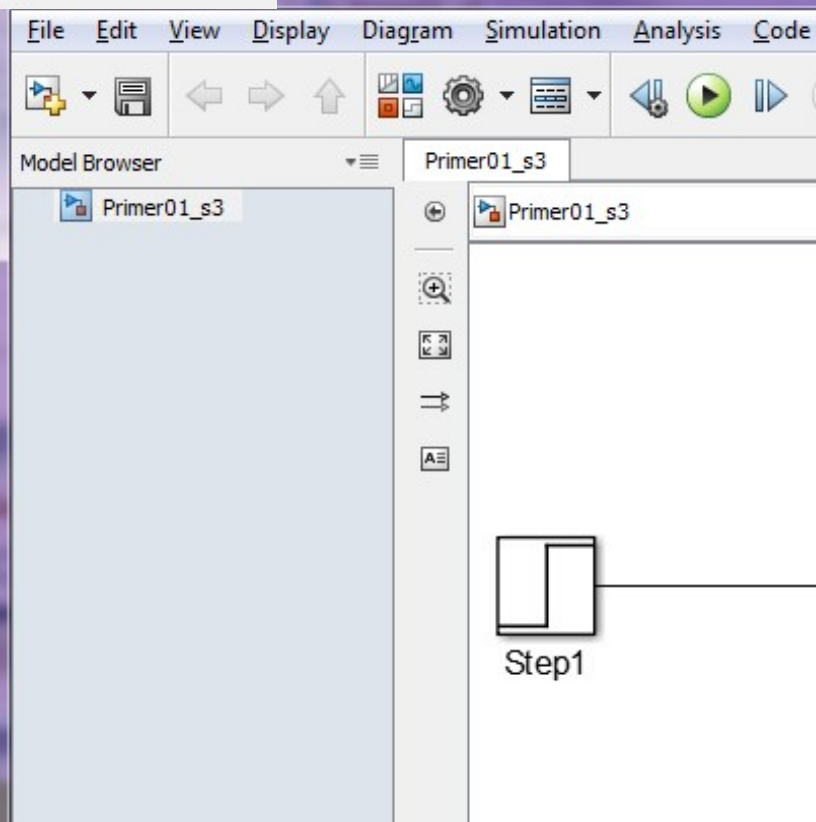
0

Initial conditions:

-10

Absolute tolerance:

auto



Симулација електричног кола као уопштеног система коришћењем Simulink-а

Function Block Parameters: State-Space

State Space

State-space model:

$$\frac{dx}{dt} = Ax + Bu$$

$$y = Cx + Du$$

Parameters

A:

-1000

B:

1000

C:

1

D:

0

Initial conditions:

-10

Absolute tolerance:

auto

Source Block Parameters: Step1

Step

Output a step.

Parameters

Step time:

0

Initial value:

0

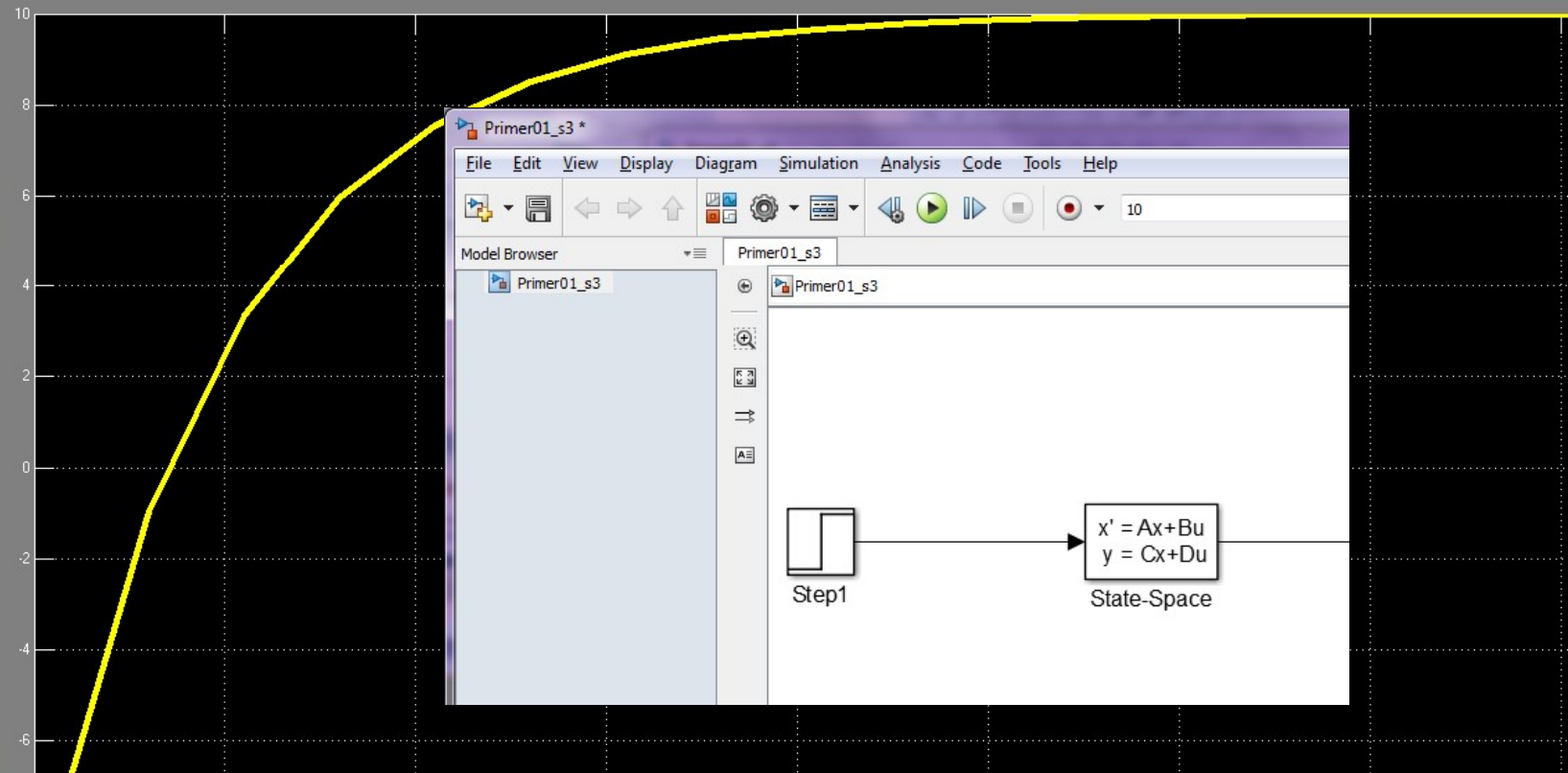
Final value:

10

Sample time:

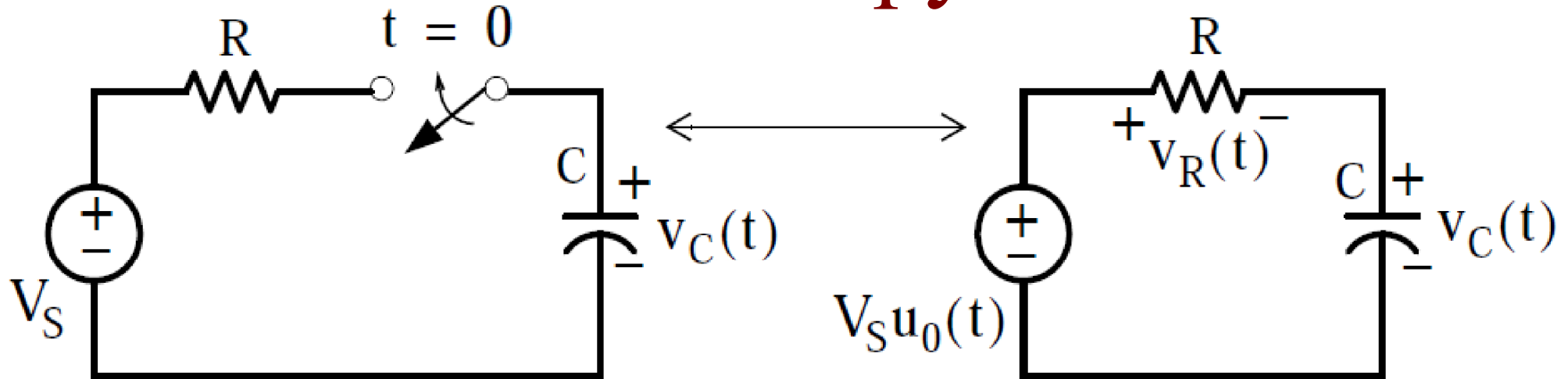
0

Scope1



Simulink

Решимо “ручно”



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

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

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

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

$$t > 0$$

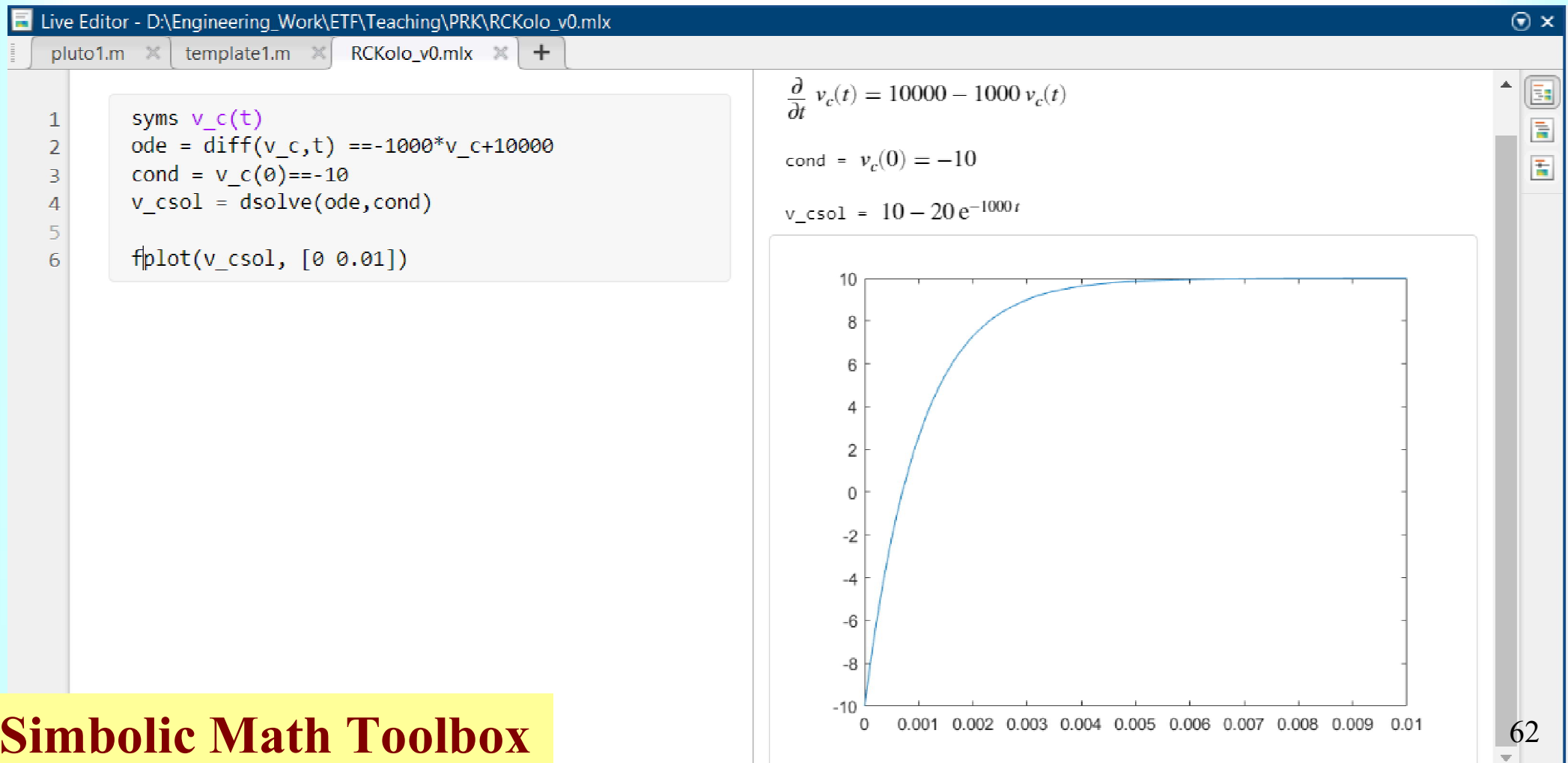
$$RC \frac{dv_C}{dt} + v_C = V_S$$

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

MATLAB

Symbolic Math Toolbox (Live Script)

- Библиотека за симболички рачун (алгебарске и диференцијалне једначине)
- Омогућава нумеричку анализу резултата прорачуна



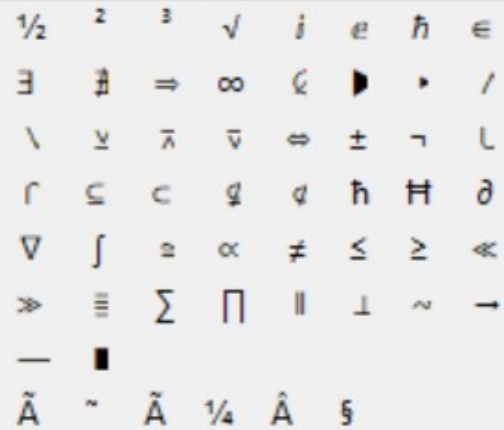
wxMaxima

wxMaxima 20.06.6 [unsaved*]

File Edit View Cell Maxima Equations Algebra Calculus Simplify List Plot Numeric Help



Mathematical Symbols



Plot using Draw

2D	3D
Expression	Implicit Plot
Parametric Plot	Points
Diagram title	Axis

```
(%i1) jednachine: [ug=R*iC+uC, iC=C*'diff(u
```

```
(%o1) [ug=uC+R iC, iC=C (d/dt uC)]
```

```
(%i2) jednachineDuC: jednachine, 'diff(uC,t)
```

```
(%o2) [ug=uC+R iC, iC=C DuC]
```

```
(%i3) JednachineIzvoda: eliminate(jednachine
[iC]);
```

```
(%o3) [-ug+uC+C DuC R]
```

```
(%i4) jednachineStanja: linsolve(JednachineI
```

```
(%o4) [DuC = (ug - uC) / (C R)]
```

```
(%i6) zamene: [ug=U];
(%o6) [ug=U]

(%i7) vrednosti: [R=1000, C=10^(-6), U=10, U0=-10];
(%o7) [R=1000, C=1/1000000, U=10, U0=-10]
```

```
(%i9) ode2(JednacineDiffZamena, uC, t);
```

```
(%o9) uC = %e- $\frac{t}{CR}$   $\left( U \%e^{\frac{t}{CR}} + \%C \right)$ 
```

```
(%i10) ic1(%, t=0, uC=U0);
```

```
(%o10) uC = %e- $\frac{t}{CR}$   $\left( U \%e^{\frac{t}{CR}} + U0 - U \right)$ 
```

```
(%i11) uCt: ev(%, vrednosti);
```

```
(%o11) uC = %e-1000 t  $\left( 10 \%e^{1000 t} - 20 \right)$ 
```

```
(%i17) wxplot2d(rhs(uCt), [t, 0, 0.01],
  [xlabel, " t [s] "],
  [ylabel, " uC [V] "],
  [xtics, 0, 0.002, 0.01],
  [legend, "Napon kondenzatora"], grid2d)$
```

