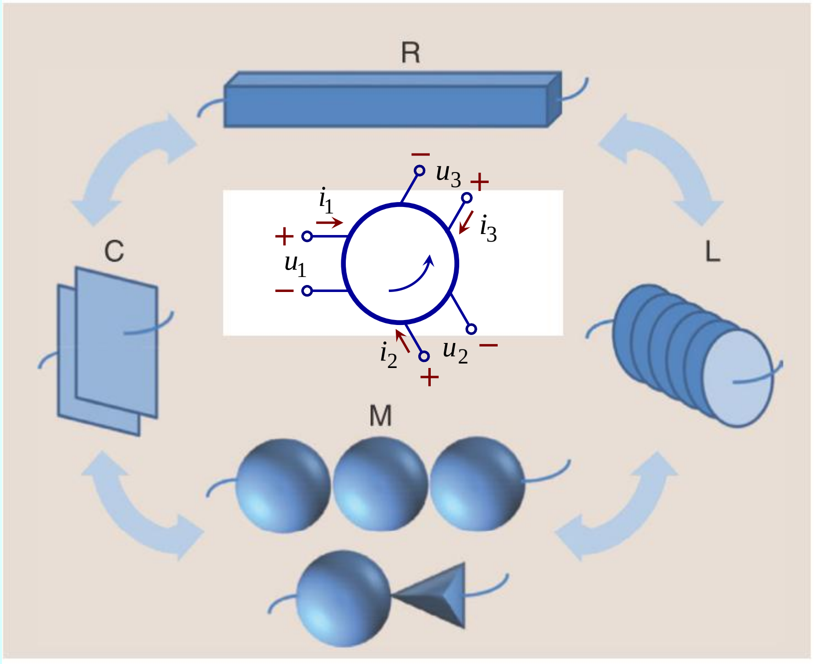
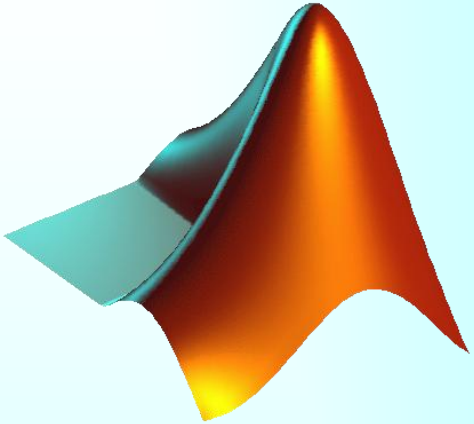
Računarska analiza električnih kola





Milka Potrebić

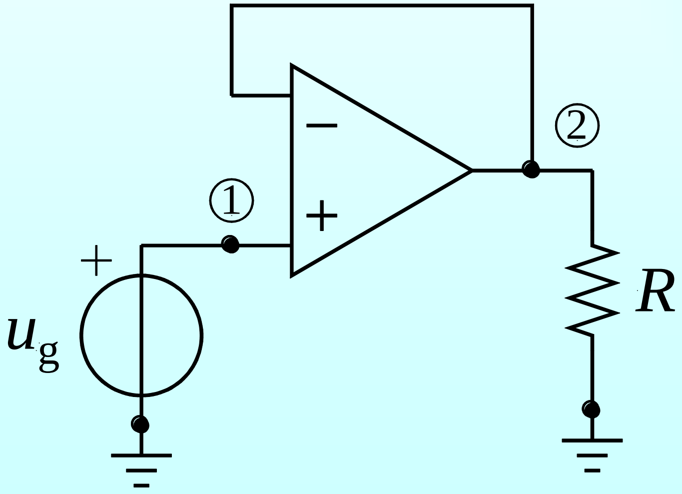
Računarski (softverski) alati

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

Free/Libre Open Source Software (FLOSS)

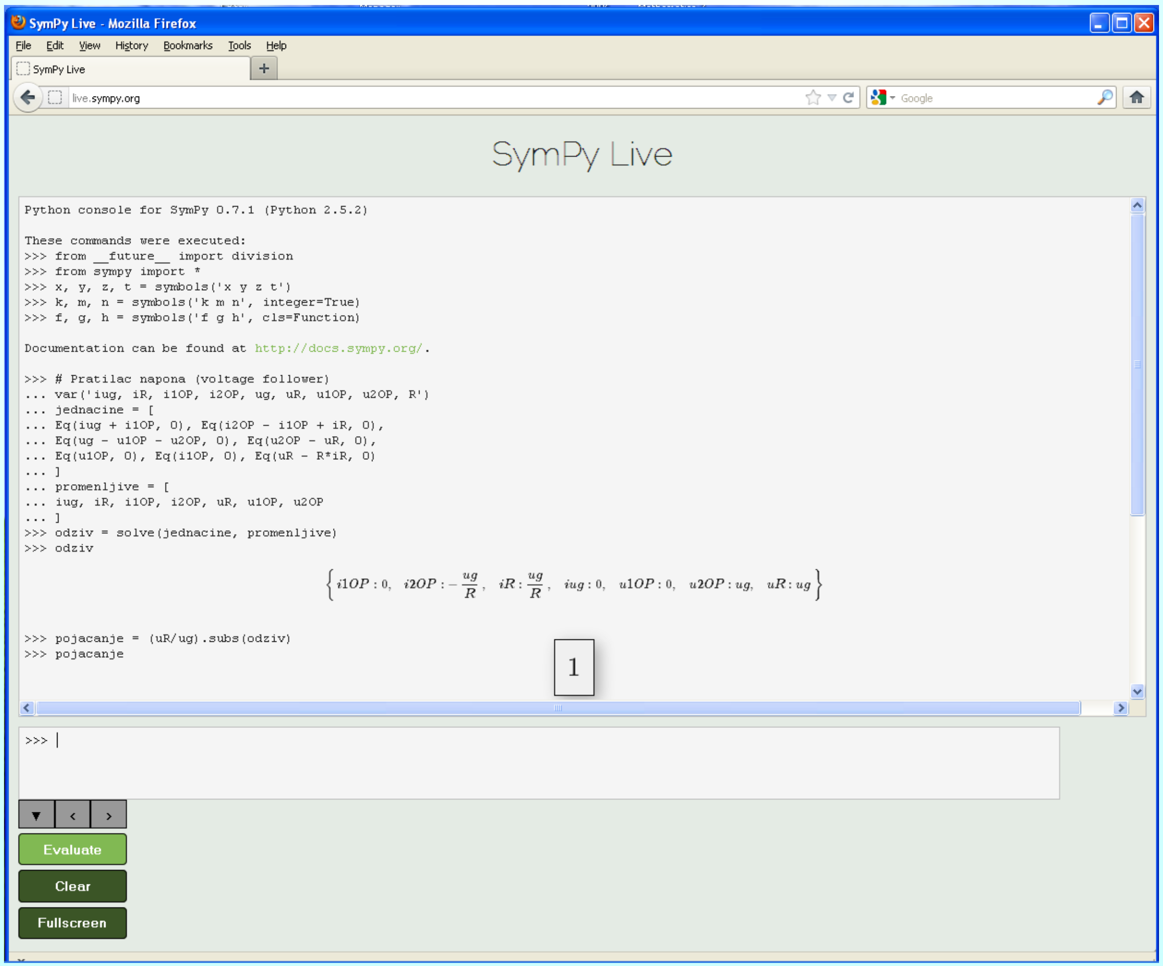
Pratilac napona

Odrediti naponsko pojačanje kola sa slike, koje se naziva pratilac napona (voltage follower).



SymPy Live

Symbolic Python Live, http://live.sympy.org/



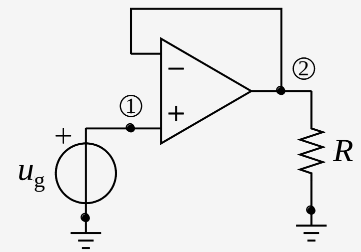
SymPy Live

```
Python console for SymPy 0.7.1 (Python 2.5.2)

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/.

>>> # Pratilac napona (voltage follower)
... var('iug, iR, i1OP, i2OP, ug, uR, u1OP, u2OP, R')
... jednacine = [
... Eq(iug + i1OP, 0), Eq(i2OP - i1OP + iR, 0),
... Eq(ug - u1OP - u2OP, 0), Eq(u2OP - uR, 0),
... Eq(u1OP, 0), Eq(i1OP, 0), Eq(uR - R*iR, 0)
... ]
... promenljive = [
... iug, iR, i1OP, i2OP, uR, u1OP, u2OP
... ]
>>> od
>>> od
```



$$\left\{ i1OP: 0,\quad i2OP: -\frac{ug}{R},\quad iR: \frac{ug}{R},\quad iug: 0,\quad u1OP: 0,\quad u2OP: ug,\quad uR: ug \right\}$$

```
>>> pojacanje = (uR/ug).subs(odziv)
>>> pojacanje
```

1

D:\eKola\Zbirka\Alati\a3 Pratilac\PratilacNapona.py - Notepad++

File Edit Search View Encoding Language Settings Macro Run Plugins Window ?

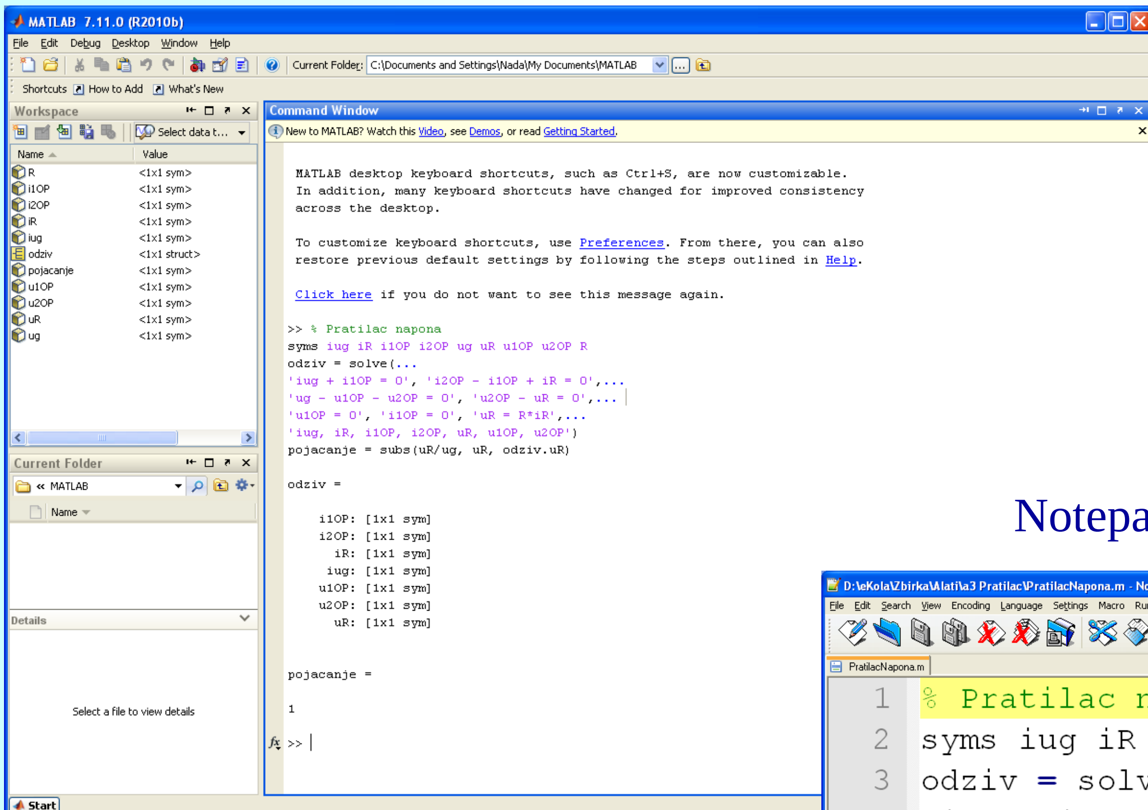
PratilacNapona.py

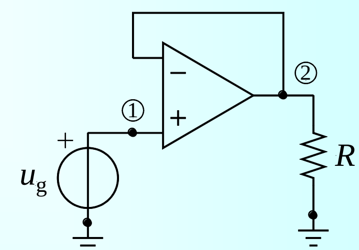
```python
# Pratilac napona (voltage follower)
var('iug, iR, i1OP, i2OP, ug, uR, u1OP, u2OP, R')
jednacine = [
Eq(iug + i1OP, 0), Eq(i2OP - i1OP + iR, 0),
Eq(ug - u1OP - u2OP, 0), Eq(u2OP - uR, 0),
Eq(u1OP, 0), Eq(i1OP, 0), Eq(uR - R*iR, 0)
]
promenljive = [
iug, iR, i1OP, i2OP, uR, u1OP, u2OP
]
odziv = solve(jednacine, promenljive)
pojacanje = (uR/ug).subs(odziv)
```

Python file | length : 369 lines : 12 | Ln : 1 Col : 1 Sel : 0 | Dos\Windows | ANSI | INS

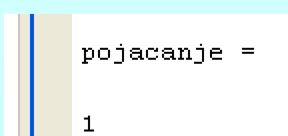
Notepad++, http://notepad-plus-plus.org/

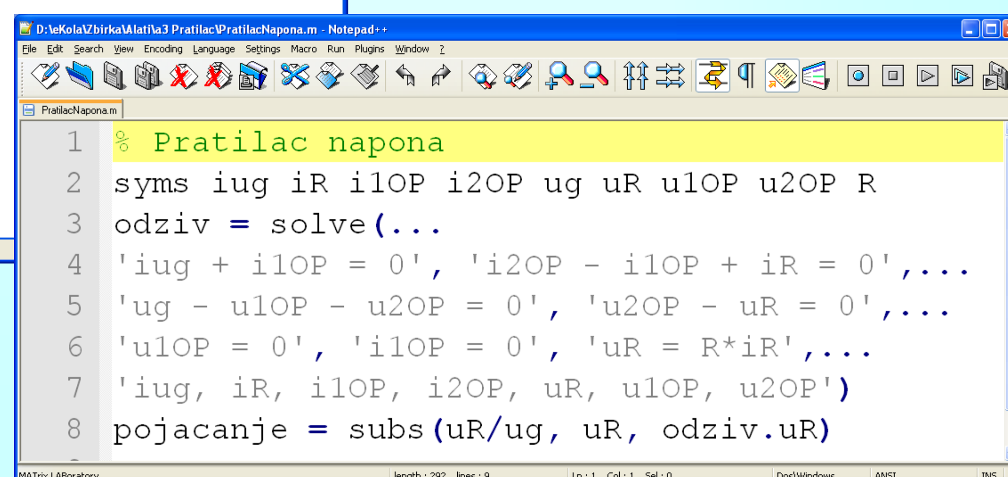
MATLAB: Symbolic Math Toolbox



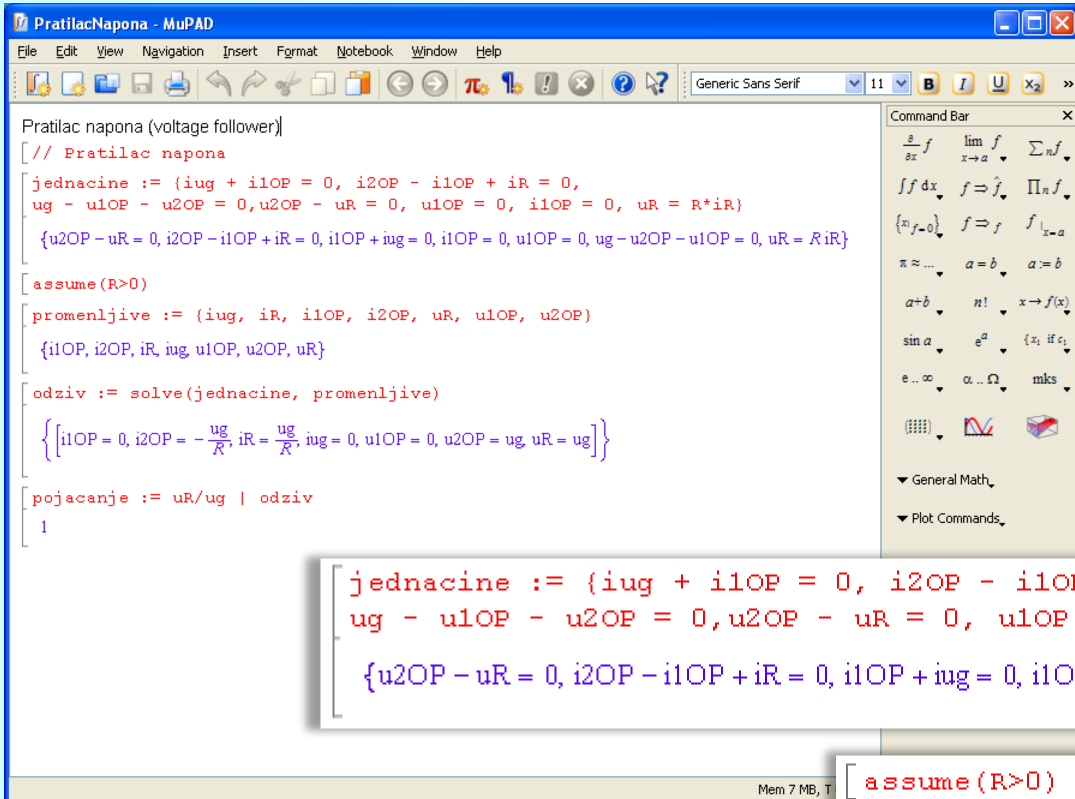


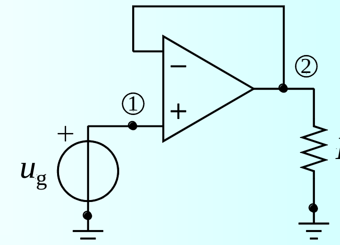
Notepad++, http://notepad-plus-plus.org/





MATLAB: MuPAD






```
jednacine := {iug + i1OP = 0, i2OP - i1OP + iR = 0,
ug - u1OP - u2OP = 0,u2OP - uR = 0, u1OP = 0, i1OP = 0, uR = R*iR}
```

$\{u2OP - uR = 0, i2OP - i1OP + iR = 0, i1OP + iug = 0, i1OP = 0, u1OP = 0, ug - u2OP - u1OP = 0, uR = R\,iR\}$

```
assume(R>0)
```

```
promenljive := {iug, iR, i1OP, i2OP, uR, u1OP, u2OP}
```

$\{i1OP, i2OP, iR, iug, u1OP, u2OP, uR\}$

```
odziv := solve(jednacine, promenljive)
```

$\left\{\left[i1OP = 0, i2OP = -\frac{ug}{R}, iR = \frac{ug}{R}, iug = 0, u1OP = 0, u2OP = ug, uR = ug\right]\right\}$

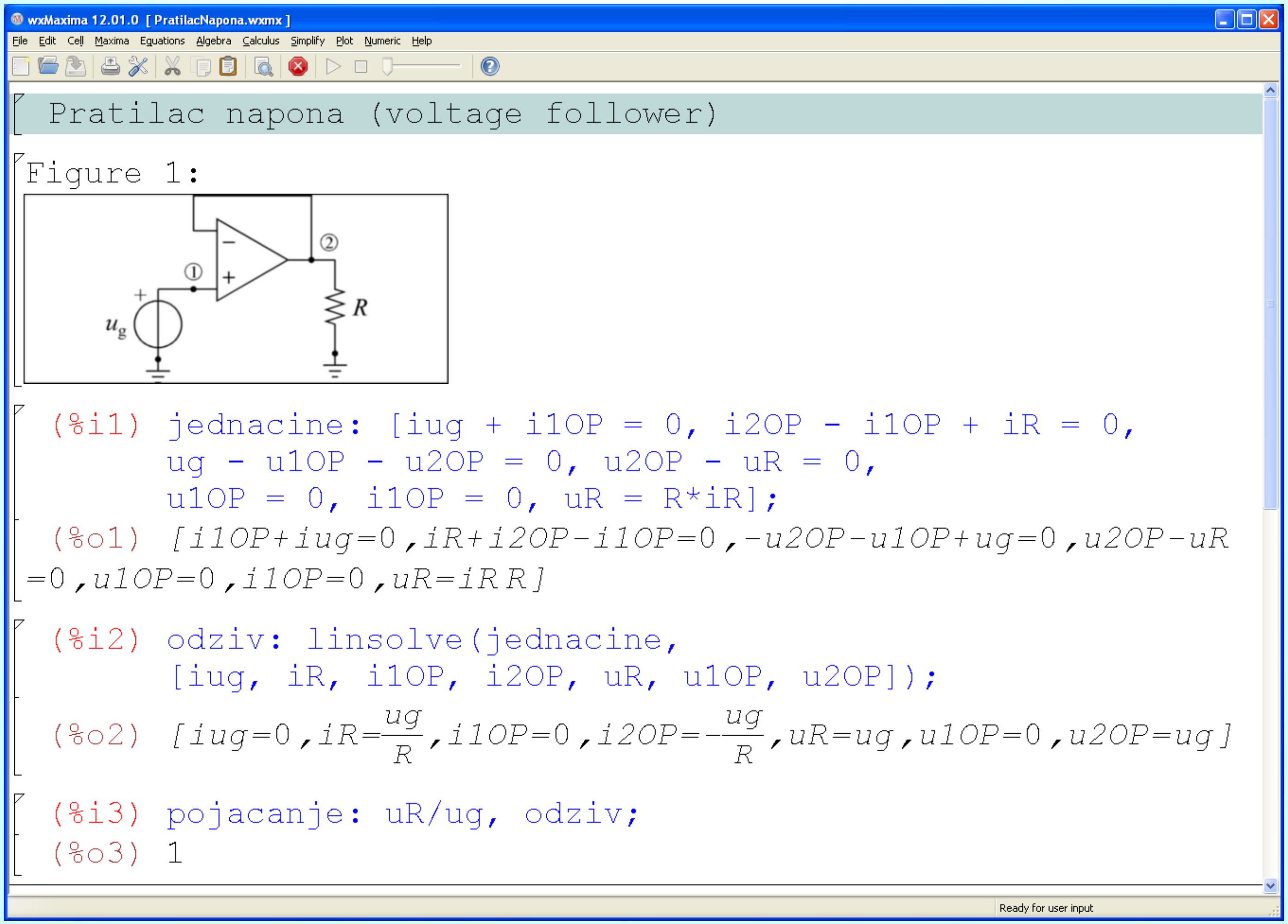
```
pojacanje := uR/ug | odziv
```

1

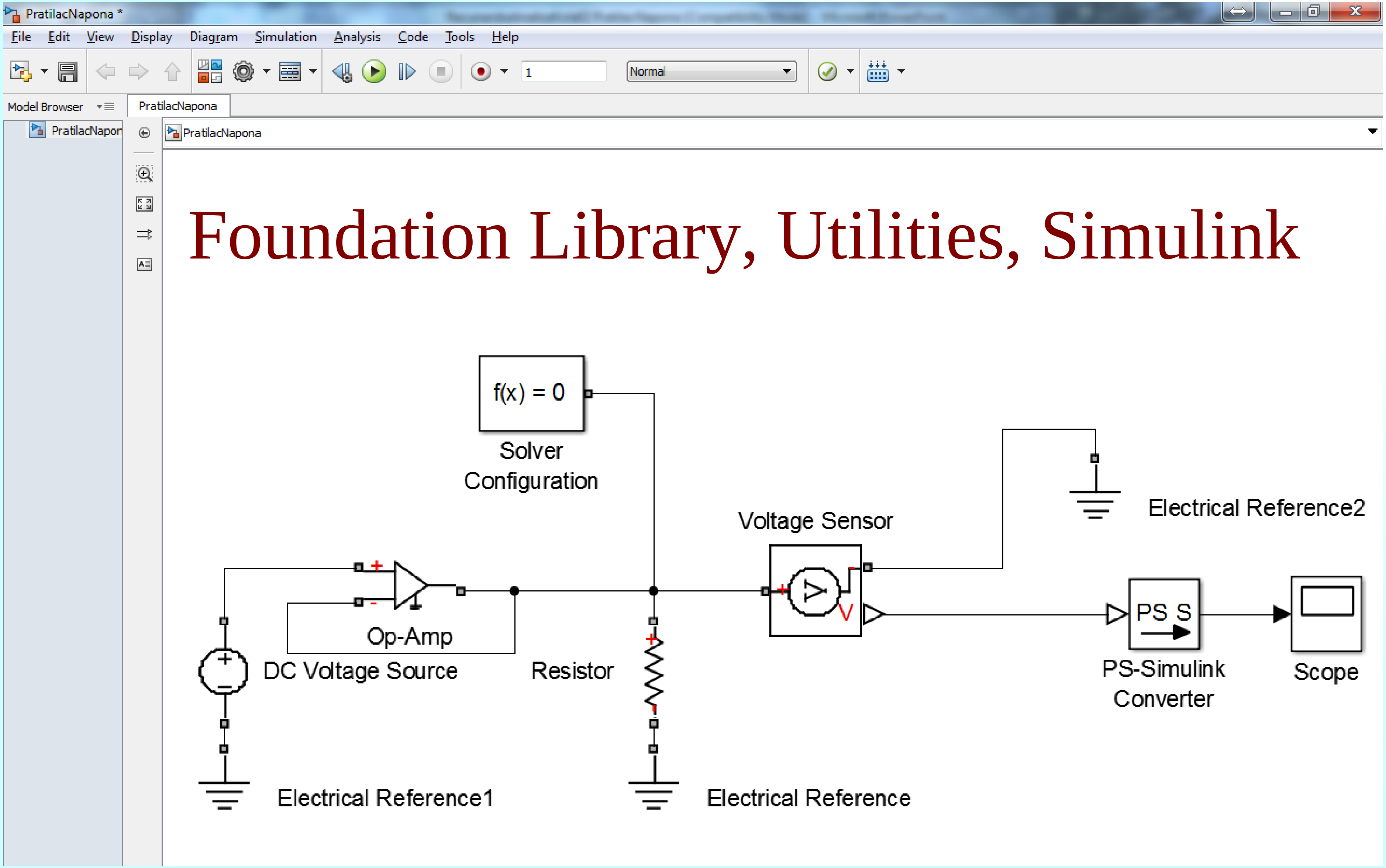
Maxima

Maxima, http://maxima.sourceforge.net/

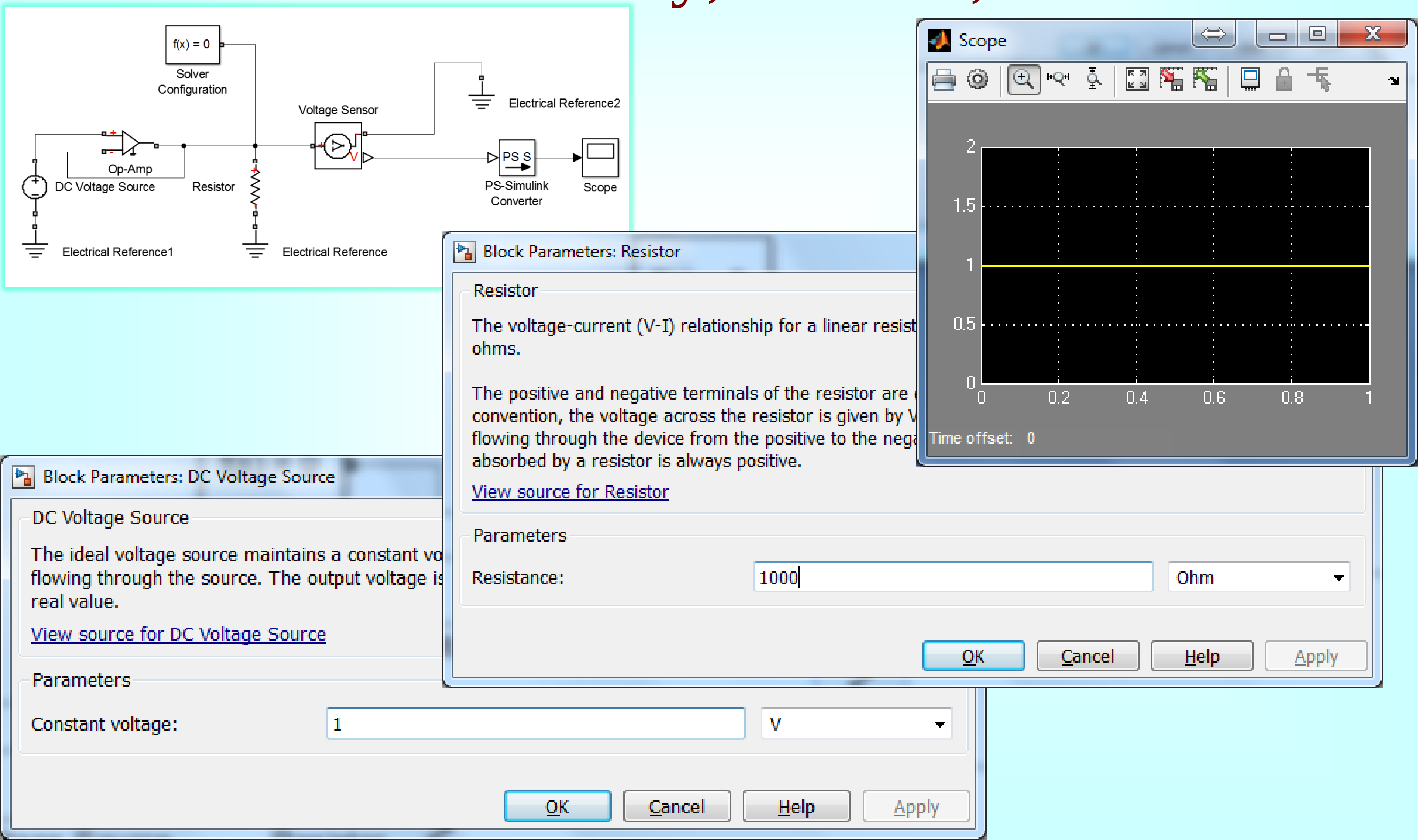
wxMaxima, http://andrejv.github.com/wxmaxima/index.html



MATLAB: Simscape

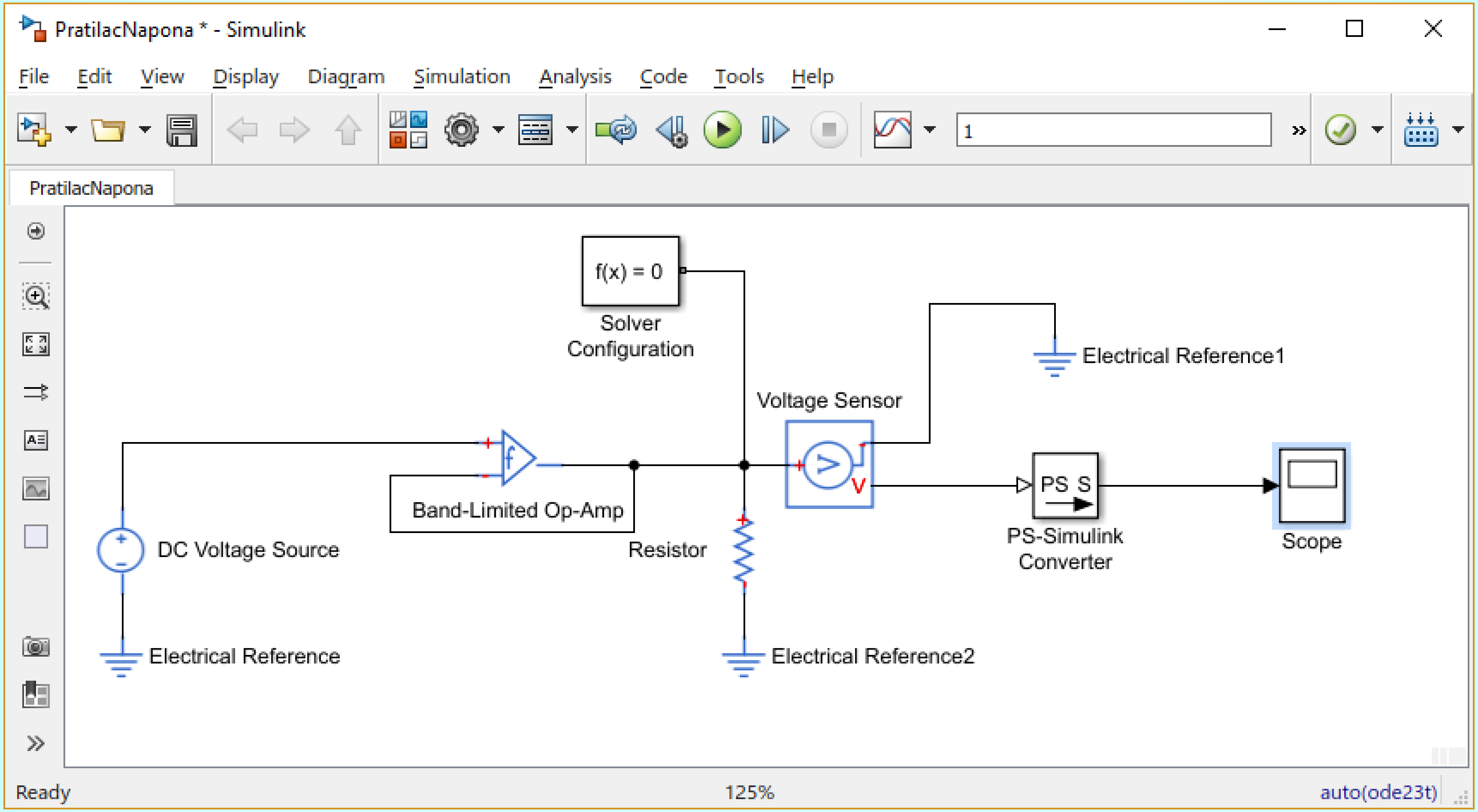


MATLAB: Simscape
Foundation Library, Utilities, Simulink

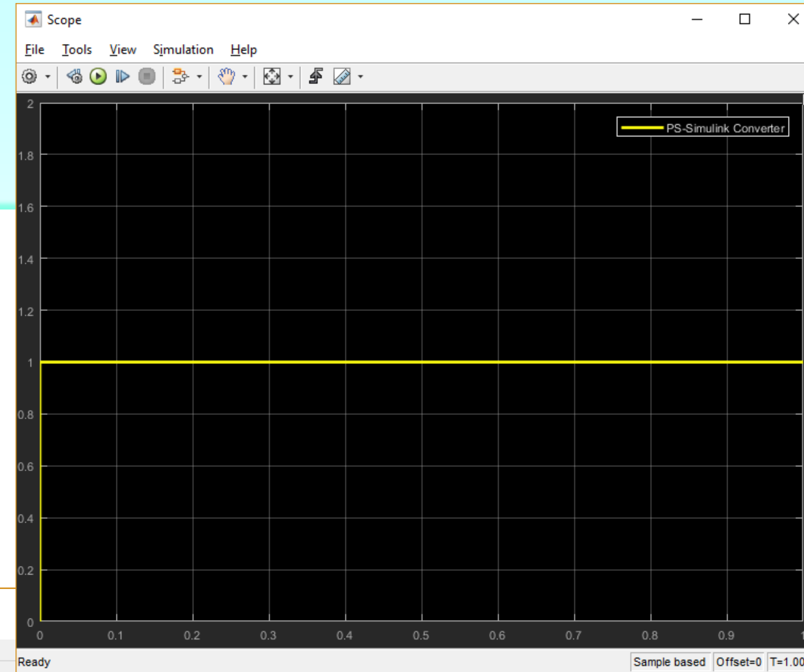


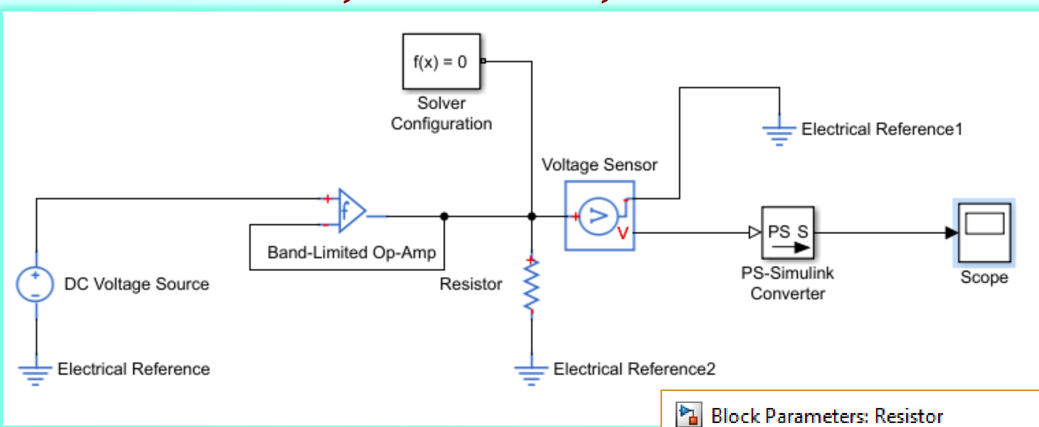
MATLAB: Simscape

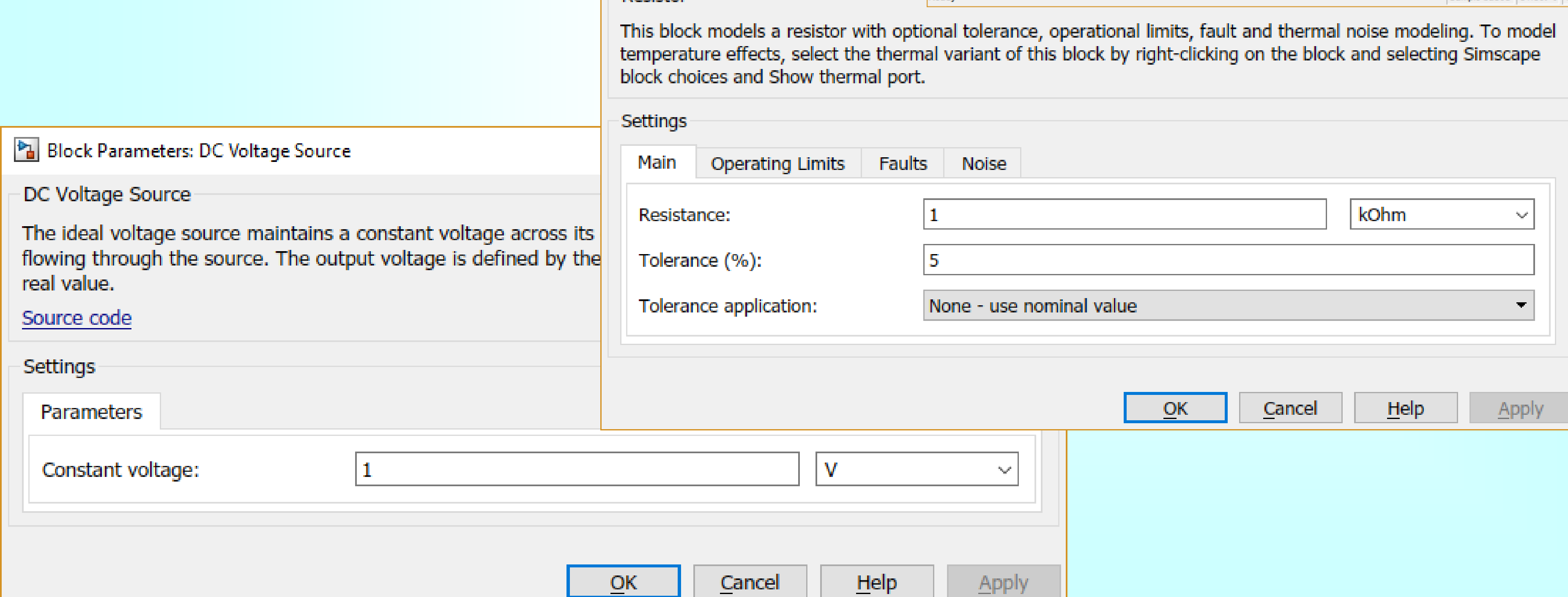
Electronics, Utilities, Simulink



MATLAB: Simscape
Electronics, Utilities, Simulink







Operational Amplifier **LM7301**

TEXAS INSTRUMENTS

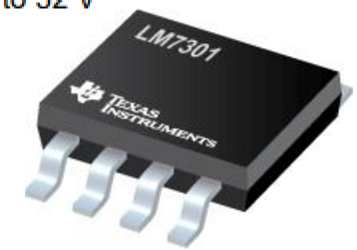
LM7301

SNOS879I – AUGUST 1999 – REVISED MAY 2016

LM7301 Low Power, 4-MHz GBW, Rail-to-Rail Input-Output Operational Amplifier in SOT-23 Package

1 Features

- At V_S = 5 V (Typical Unless Otherwise Noted)
- Tiny, Space-Saving, 5-Pin SOT-23 Package
- Greater than Rail-to-Rail Input CMVR: −0.25 V to 5.2 V
- Rail-to-Rail Output Swing: 007 V to 4.93 V
- Wide Gain-Bandwidth: 4 MHz
- Low Supply Current: 0.6 mA
- Wide Supply Range: 1.8 V to 32 V
- High PSRR: 104 dB
- High CMRR: 93 dB
- Excellent Gain: 97 dB



2 Applications

- Portable Instrumentation
- Signal Conditioning Amplifiers/ADC Buffers
- Active Filters
- Modems
- PCMCIA Cards

3 Description

The LM7301 provides high performance in a wide range of applications. The LM7301 offers greater than rail-to-rail input range, full rail-to-rail output swing, large capacitive load driving ability, and low distortion.

With only 0.6-mA supply current, the 4-MHz gain-bandwidth of this device supports new portable applications where higher power devices unacceptably drain battery life.

The LM7301 can be driven by voltages that exceed both power supply rails, thus eliminating concerns over exceeding the common-mode voltage range. The rail-to-rail output swing capability provides the maximum possible dynamic range at the output. This is particularly important when operating on low supply voltages.

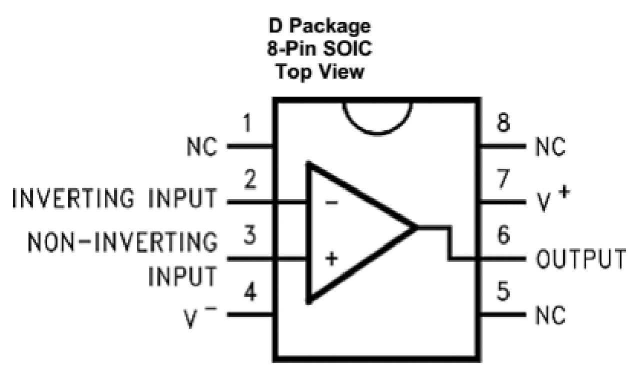
Operating on supplies of 1.8 V to 32 V, the LM7301 is excellent for a very wide range of applications in low power systems.

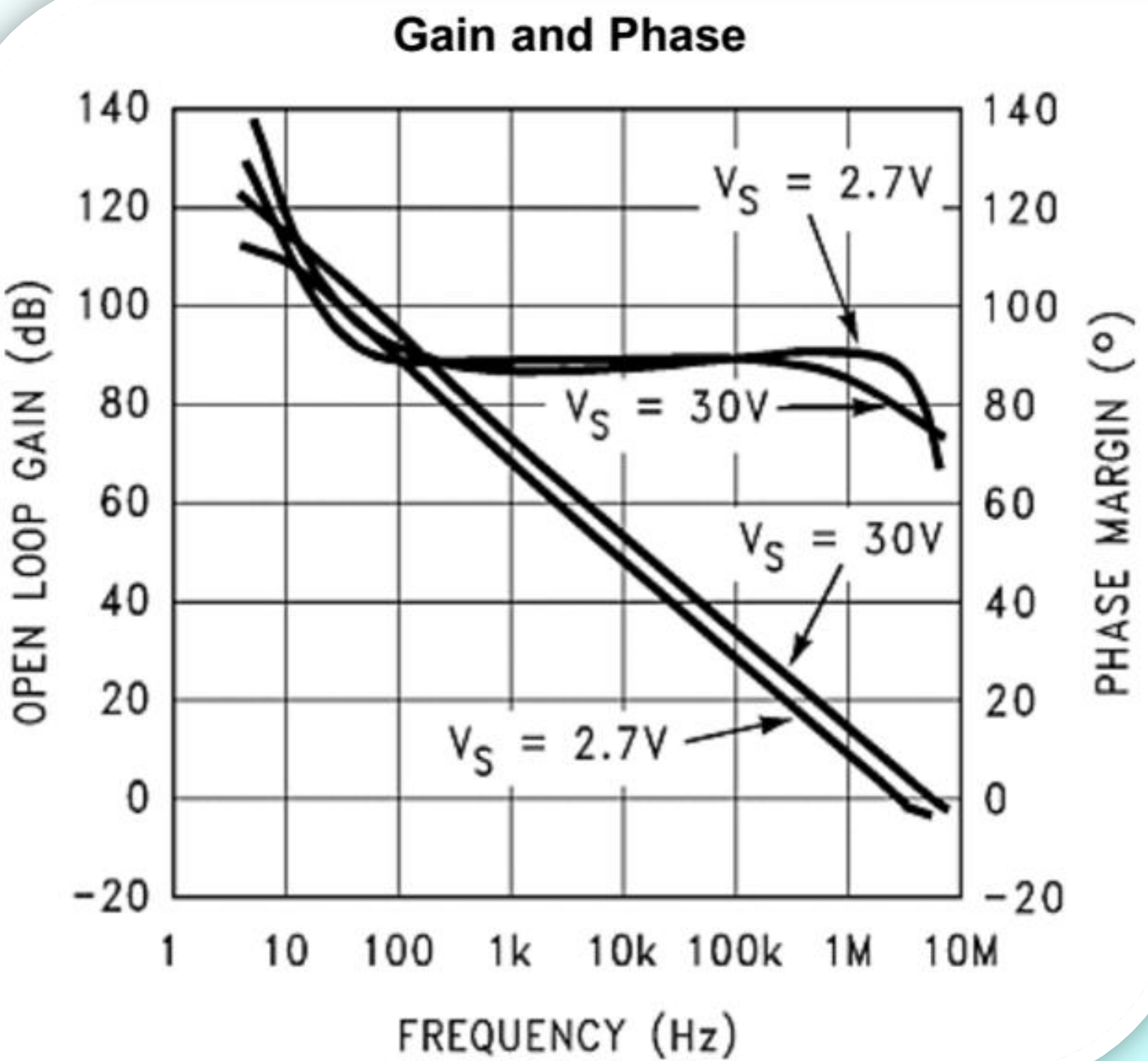
Placing the amplifier right at the signal source reduces board size and simplifies signal routing. The LM7301 fits easily on low profile PCMCIA cards.

9 Power Supply Recommendations

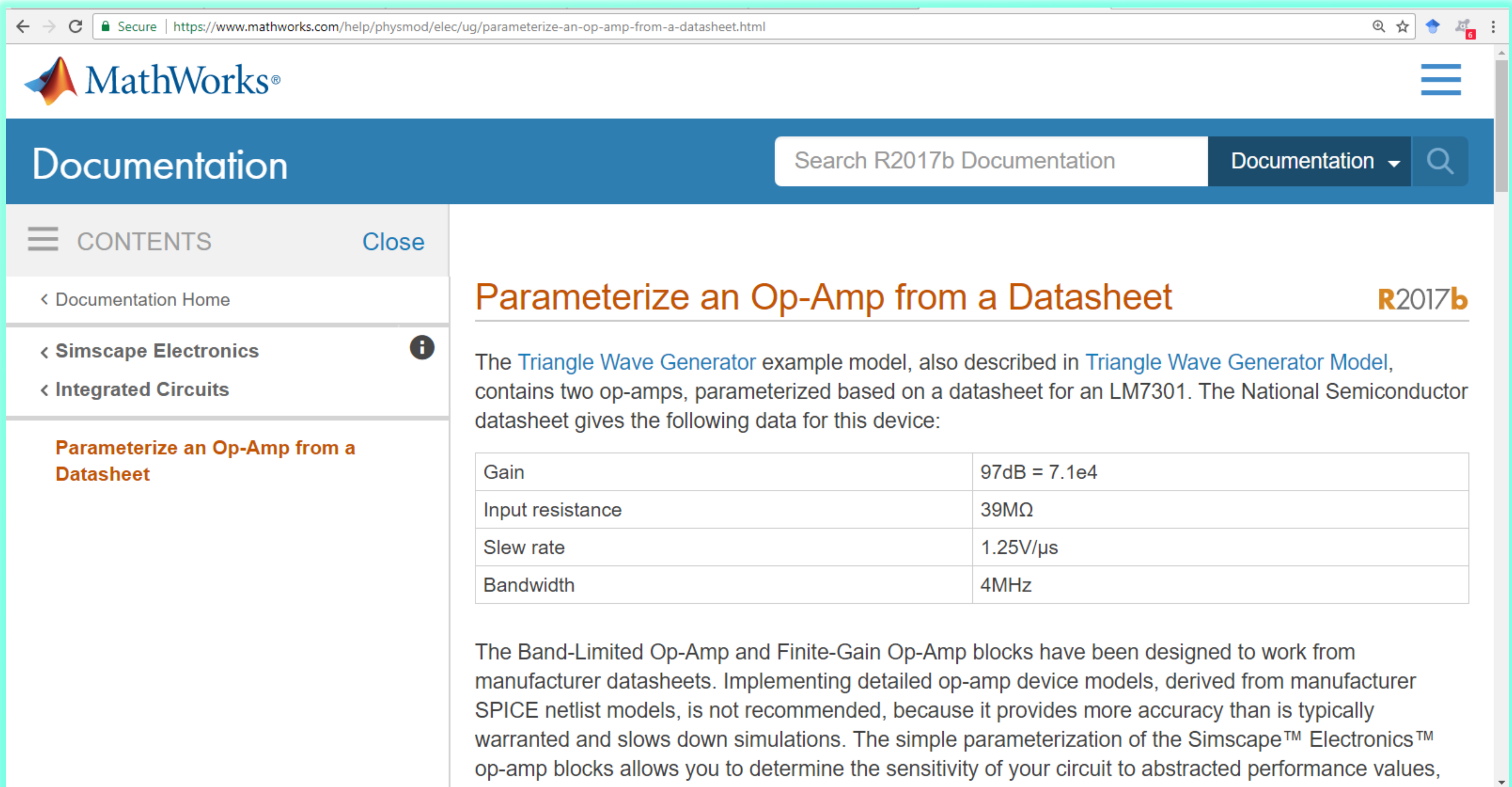
The LM7301 is specified for operation from 1.8 V to 32 V (±0.9 V to ±16 V). Being a rail-to-rail input and output device, any operating voltage conditions within the supply voltage range can be accommodated.

Op-Amp LM7301





Parametrizacija realnog operacionog pojačavača na osnovu dokumentacije proizvođača


Secure | https://www.mathworks.com/help/physmod/elec/ug/parameterize-an-op-amp-from-a-datasheet.html

MathWorks®

Documentation

Search R2017b Documentation

Documentation

CONTENTS Close

‹ Documentation Home

‹ Simscape Electronics

‹ Integrated Circuits

Parameterize an Op-Amp from a Datasheet

Parameterize an Op-Amp from a Datasheet R2017b

The Triangle Wave Generator example model, also described in Triangle Wave Generator Model, contains two op-amps, parameterized based on a datasheet for an LM7301. The National Semiconductor datasheet gives the following data for this device:

Gain	97dB = 7.1e4
Input resistance	39MΩ
Slew rate	1.25V/μs
Bandwidth	4MHz

The Band-Limited Op-Amp and Finite-Gain Op-Amp blocks have been designed to work from manufacturer datasheets. Implementing detailed op-amp device models, derived from manufacturer SPICE netlist models, is not recommended, because it provides more accuracy than is typically warranted and slows down simulations. The simple parameterization of the Simscape™ Electronics™ op-amp blocks allows you to determine the sensitivity of your circuit to abstracted performance values, Block Parameters: Band-Limited Op-Amp

Band-Limited Op-Amp

This block models a band-limited op-amp. If the voltages at the positive and negative pins are denoted Vp and Vm, then the output voltage is given by

Vout = A*(Vp-Vm)*1/(s/(2*pi*f)+1)-Iout*Rout

where A is the gain, Rout is the output resistance, Iout is the output current, s is the Laplace operator, and f is the 3dB bandwidth. The input current is given by (Vp-Vm)/Rin where Rin is the input resistance. The no-load output voltage is limited the range Vmin to Vmax, and the slew rate is limited to +-Vdot.

The Initial output voltage, V0, sets the initial op-amp output voltage. Note that this does not take account of any voltage drop across Rout. The initial condition is not used if you select the Start simulation from steady state option in the Solver Configuration block.

Settings

Parameters

Gain, A:	7.1e4	
Input resistance, Rin:	39	MOhm
Output resistance, Rout:	0	Ohm
Minimum output, Vmin:	-20	V
Maximum output, Vmax:	20	V
Maximum slew rate, Vdot:	1.25/1e-6	V/s
Bandwidth, f:	4e6	Hz
Initial output voltage, V0:	0	V

OK Cancel Help Apply

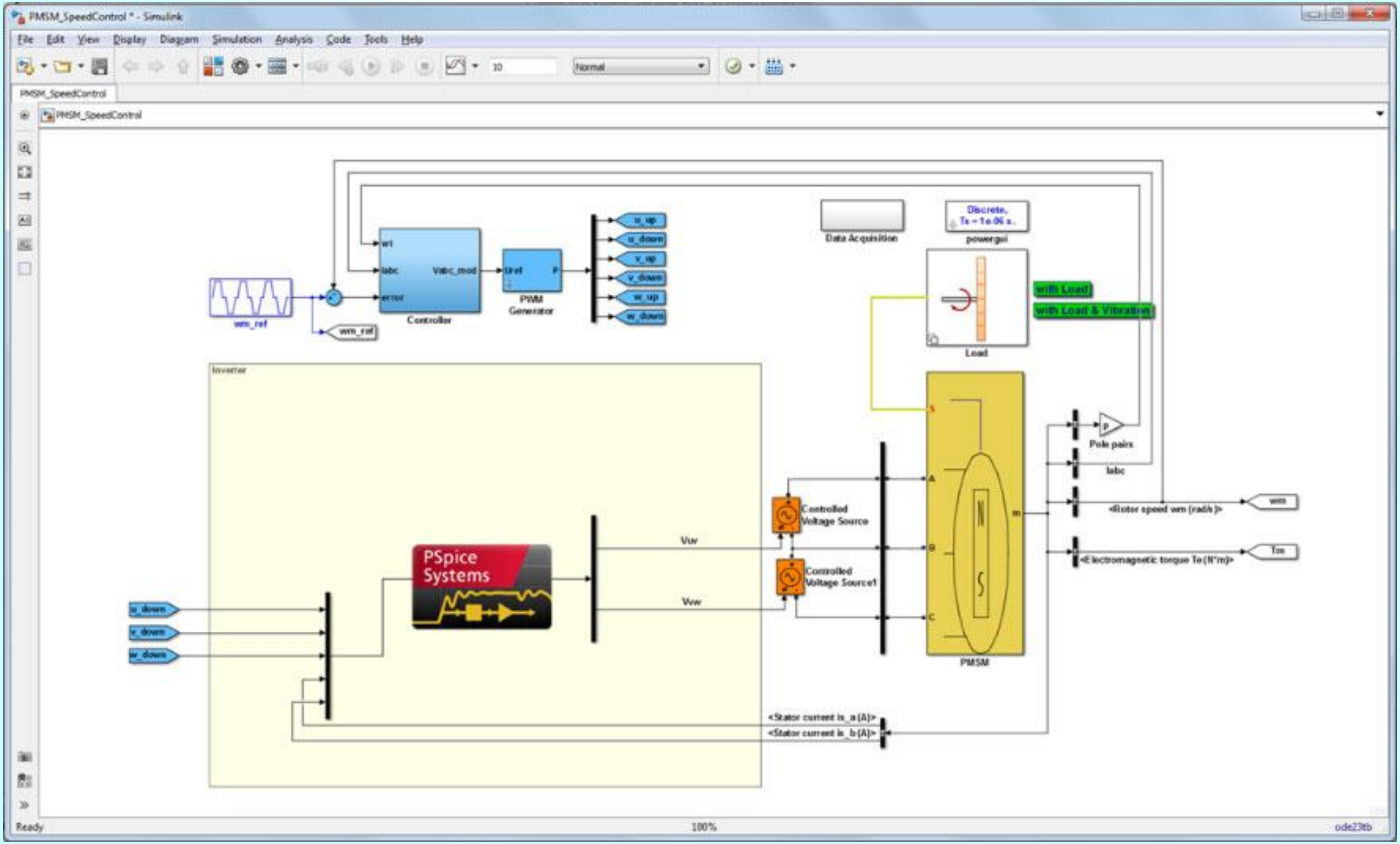
Cadence PSpice Systems Option

Cadence® PSpice® integrated with MATLAB and Simulink to provide a complete system-level simulation solution for PCB design and implementation

Highlights

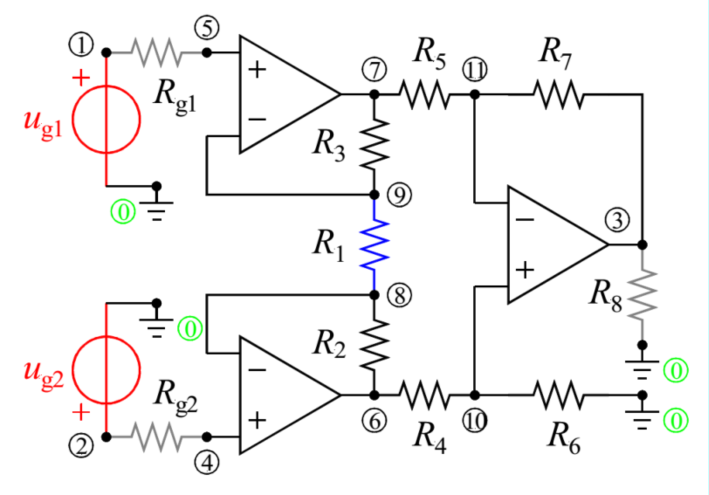
- Co-simulate Simulink and PSpice together for complete system simulation
- View PSpice simulation results in MATLAB
- Use MATLAB functions directly in measurement expressions within PSpice
- Export behavioral models from Simulink to PSpice using Cadence's Device

Integracija PSpice & Simulink



Instrumentacioni pojačavač

- Odrediti napon v_3 otpornika R_8?
- Nacrtati grafik napona v_3 otpornika R_8 u funkciji vremena?
- Kolika je snaga izvora?



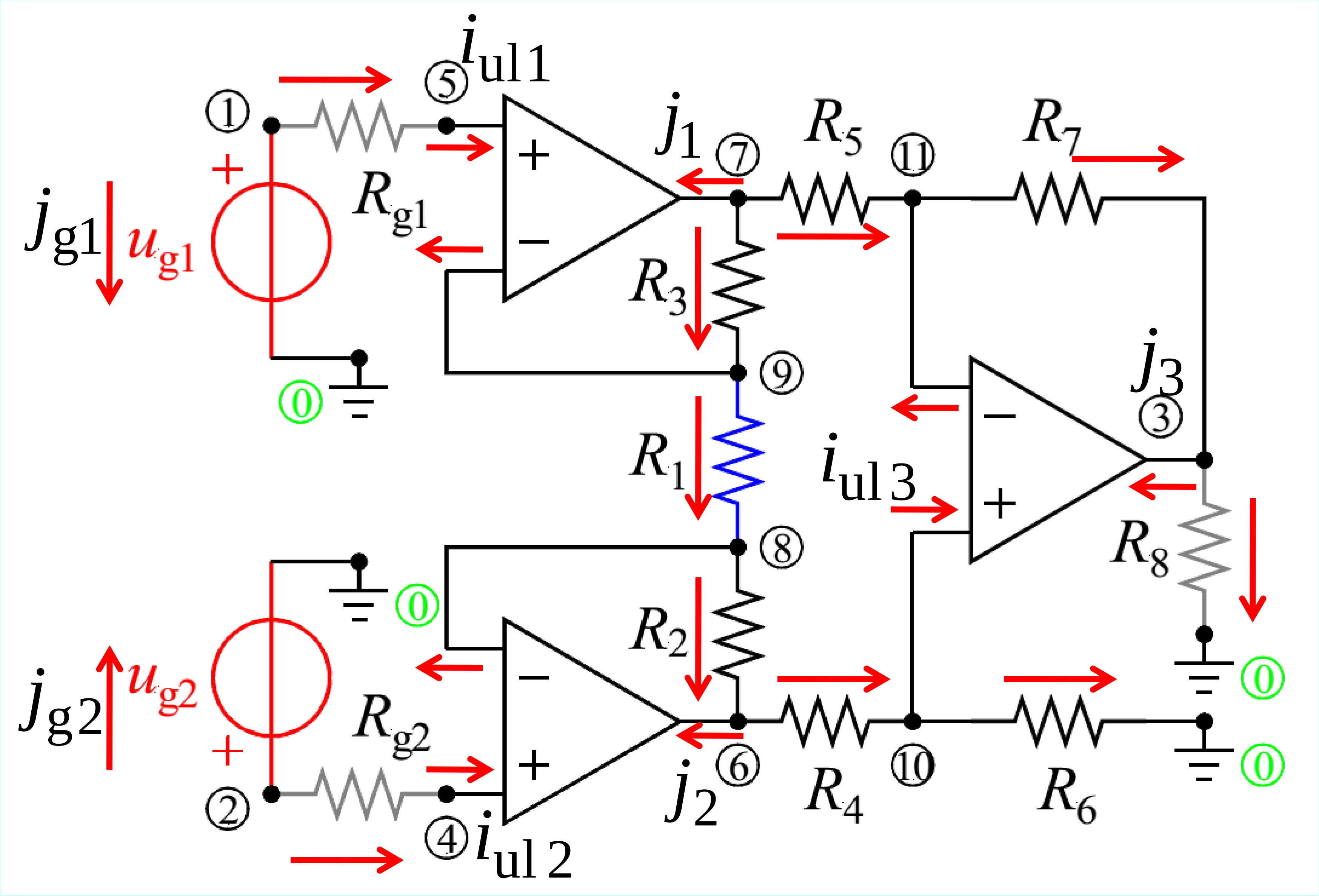
Vrednosti elemenata su poznate.

$R_2 = R_3 = R_4 = R_5 = R_6 = R_7 = R_8 = R$

$R = 1\ \text{k}\Omega$, $R_1 = 2\ \text{k}\Omega$, $R_{g1} = R_{g2} = 1\ \text{k}\Omega$

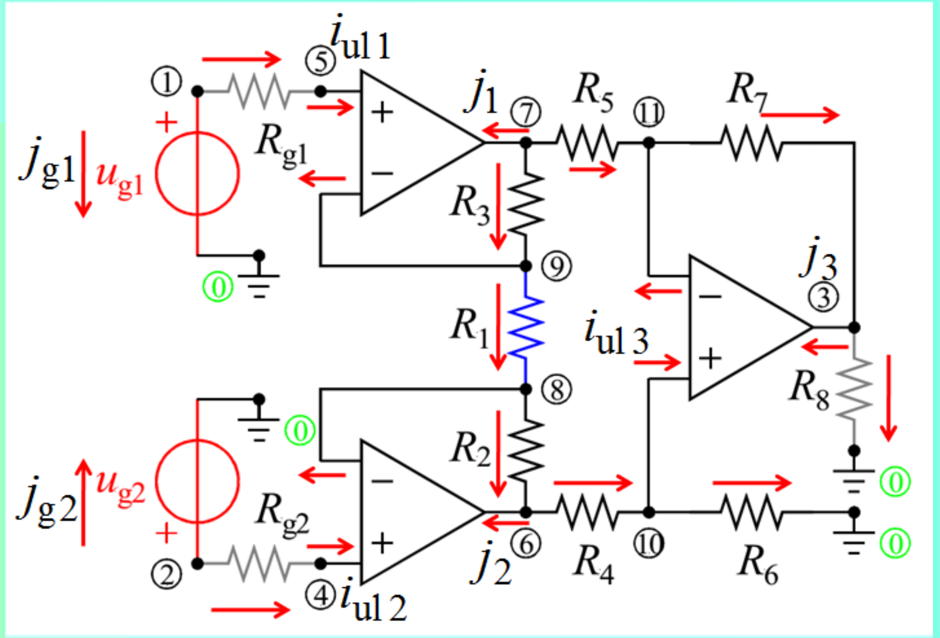
$u_{g1}(t) = U\,h(t)$, $u_{g2}(t) = U\,h(t-T)$

$U = 10$ V, $T = 1$ s



i_{ul1}
j_1
j_2
j_3
i_{ul2}
i_{ul3}
j_{g1}
u_{g1}
j_{g2}
u_{g2}
R_{g1}
R_{g2}
R_1
R_2
R_3
R_4
R_5
R_6
R_7
R_8
1
2
3
4
5
6
7
8
9
10
11
0
+
–

Modifikovana metoda potencijala čvorova



$$(1)\ j_{g1}+\left(V_1-V_5\right)/R_{\text{g}1}=0$$

$$(2)\ j_{g2}+\left(V_2-V_4\right)/R_{\text{g}2}=0$$

$$(3)\ j_3-\left(V_{11}-V_3\right)/R_7+V_3/R_8=0$$

$$(4)-\left(V_2-V_4\right)/R_{\text{g}2}+i_{\text{ul}2}=0$$

$$(5)-\left(V_1-V_5\right)/R_{\text{g}1}+i_{\text{ul}1}=0$$

$$(6)\ j_2+\left(V_6-V_{10}\right)/R_4-\left(V_8-V_6\right)/R_2=0$$

$$(7)\ j_1+\left(V_7-V_9\right)/R_3+\left(V_7-V_{11}\right)/R_5=0$$

$$(8)-i_{\text{ul}2}-\left(V_9-V_8\right)/R_1+\left(V_8-V_6\right)/R_2=0$$

$$(9)-i_{\text{ul}1}-\left(V_7-V_9\right)/R_3+\left(V_9-V_8\right)/R_1=0$$

$$(10)-\left(V_6-V_{10}\right)/R_4+i_{\text{ul}3}+V_{10}/R_6=0$$

$$(11)-\left(V_7-V_{11}\right)/R_5-i_{\text{ul}3}+\left(V_{11}-V_3\right)/R_7=0$$

$$i_{\text{ul}1}=0$$

$$i_{\text{ul}2}=0$$

$$i_{\text{ul}3}=0$$

$$V_5=V_9$$

$$V_4=V_8$$

$$V_{10}=V_{11}$$

$$V_1=u_{\text{g}1}$$

$$V_2=u_{\text{g}2}$$

MATLAB: MuPAD

Jednačine

InstrumentacioniPojacavac - MuPAD

```
jednacine:= {jg1 + (v1-v5)/Rg1 = 0,
v1 = ug1,
jg2 + (v2-v4)/Rg2 = 0,
v2 = ug2,
j3 + v3/R8 -(v11-v3)/R7 = 0,
-(v2-v4)/Rg2 + iul2 = 0, -(v1-v5)/Rg1 + iul1 = 0,
j2 + (v6-v10)/R4 - (v8-v6)/R2 = 0,
j1 + (v7-v11)/R5 + (v7-v9)/R3 = 0,
-iul2 - (v9-v8)/R1 + (v8-v6)/R2 = 0,
-iul1 - (v7-v9)/R3 + (v9-v8)/R1 = 0,
-(v6-v10)/R4 + v10/R6 + iul3 = 0,
-(v7-v11)/R5 + (v11-v3)/R7 -iul3 = 0,
iul1 = 0, iul2 = 0, iul3 = 0, v5=v9, v4=v8,  v10 = v11}
```

$$\left\{v1 = ug1,\ v2 = ug2,\ v4 = v8,\ v5 = v9,\ v10 = v11,\ iul3 + \frac{v10}{R6} - \frac{v6 - v10}{R4} = 0,\ j3 + \frac{v3}{R8} + \frac{v3 - v11}{R7} = 0,\ j2 + \frac{v6 - v8}{R2} + \frac{v6 - v10}{R4} = 0,\ j1 + \frac{v7 - v9}{R3} + \frac{v7 - v11}{R5} = 0,\ iul1 = 0,\ iul2 = 0,\ iul3 = 0,\ iul1 - \frac{v1 - v5}{Rg1} = 0,\ iul2 - \frac{v2 - v4}{Rg2} = 0,\ jg1 + \frac{v1 - v5}{Rg1} = 0,\ jg2 + \frac{v2 - v4}{Rg2} = 0,\ \frac{v8 - v9}{R1} - \frac{v6 - v8}{R2} - iul2 = 0,\ -iul1 - \frac{v8 - v9}{R1} - \frac{v7 - v9}{R3} = 0,\ -iul3 - \frac{v3 - v11}{R7} - \frac{v7 - v11}{R5} = 0\right\}$$

MATLAB: MuPAD

assume, Promenljive, solve…

```
assume(Rg1>0 and Rg2>0 and R1>0 and R2>0 and R3>0 and R4>0 and R5>0 and R6>0 and R7>0 and R8>0 and R>0)
promenljive:={v1, v2, v3, v4, v5, v6, v7, v8, v9, v10, v11, j1, j2, j3, iul1, iul2, iul3, jg1, jg2}
```

$\{iul1, iul2, iul3, j1, j2, j3, jg1, jg2, v1, v2, v3, v4, v5, v6, v7, v8, v9, v10, v11\}$

```
odziv:=solve(jednacine, promenljive)
```


```
assume(Rg1>0 and Rg2>0 and R1>0 and R2>0 and R3>0 and R4>0 and R5>0 and R6>0 and R7>0 and R8>0 and R>0)
promenljive:={v1, v2, v3, v4, v5, v6, v7, v8, v9, v10, v11, j1, j2, j3, iul1, iul2, iul3, jg1, jg2}
```

$\{iul1, iul2, iul3, j1, j2, j3, jg1, jg2, v1, v2, v3, v4, v5, v6, v7, v8, v9, v10, v11\}$

```
odziv:=solve(jednacine, promenljive)
```


$$\Big\{\Big[iul1 = 0,\ iul2 = 0,\ iul3 = 0,\ j1 = -\frac{R1\,R4\,ug1 + R1\,R6\,ug1 + R3\,R4\,ug1 - R1\,R6\,ug2 + R2\,R6\,ug1 - R3\,R4\,ug2 - R2\,R6\,ug2 + R3\,R6\,ug1 + R4\,R5\,ug1 - R3\,R6\,ug2 - R4\,R5\,ug2 + R5\,R6\,ug1 - R5\,R6\,ug2}{\sigma_1},$$

$$j2 = -\frac{R1\,ug2 - R2\,ug1 + R2\,ug2 - R4\,ug1 + R4\,ug2 - R6\,ug1 + R6\,ug2}{R1\,(R4+R6)},\ j3 = (R1\,R4\,R7\,ug1 + R1\,R4\,R8\,ug1 - R1\,R5\,R6\,ug2 + R2\,R5\,R6\,ug1 + R1\,R6\,R7\,ug1 - R2\,R5\,R6\,ug2 + R3\,R4\,R7\,ug1 - R1\,R6\,R7\,ug2$$

$$+ R1\,R6\,R8\,ug1 + R2\,R6\,R7\,ug1 - R3\,R4\,R7\,ug2 + R3\,R4\,R8\,ug1 - R1\,R6\,R8\,ug2 - R2\,R6\,R7\,ug2 + R2\,R6\,R8\,ug1 - R3\,R4\,R8\,ug2 + R3\,R6\,R7\,ug1 - R2\,R6\,R8\,ug2 - R3\,R6\,R7\,ug2 + R3\,R6\,R8\,ug1$$

$$- R3\,R6\,R8\,ug2)/(R1\,R5\,R8\,(R4+R6)),\ jg1 = 0,\ jg2 = 0,\ v1 = ug1,\ v2 = ug2,$$

$$v3 = -\frac{R1\,R4\,R7\,ug1 - R1\,R5\,R6\,ug2 + R2\,R5\,R6\,ug1 + R1\,R6\,R7\,ug1 - R2\,R5\,R6\,ug2 + R3\,R4\,R7\,ug1 - R1\,R6\,R7\,ug2 + R2\,R6\,R7\,ug1 - R3\,R4\,R7\,ug2 - R2\,R6\,R7\,ug2 + R3\,R6\,R7\,ug1 - R3\,R6\,R7\,ug2}{\sigma_1},\ v4 = ug2,\ v5 = ug1,\ v6 = \frac{\sigma_3}{R1},$$

$$v7 = \frac{R1\,ug1 + R3\,ug1 - R3\,ug2}{R1},\ v8 = ug2,\ v9 = ug1,\ v10 = \sigma_2,\ v11 = \sigma_2\Big]\Big\}$$

where

$$\sigma_1 = R1\,R5\,(R4+R6)$$

$$\sigma_2 = \frac{R6\,\sigma_3}{R1\,(R4+R6)}$$

$$\sigma_3 = R1\,ug2 - R2\,ug1 + R2\,ug2$$

MATLAB: MuPAD

Zamena…, simplify, heaviside, plot…

```
zamena:={R2=R, R3=R, R4=R, R5=R, R6=R, R7=R}
```

$\{R2 = R, R3 = R, R4 = R, R5 = R, R6 = R, R7 = R\}$

```
v3|odziv
```

$$-\frac{R1\,R4\,R7\,ug1 - R1\,R5\,R6\,ug2 + R2\,R5\,R6\,ug1 + R1\,R6\,R7\,ug1 - R2\,R5\,R6\,ug2 + R3\,R4\,R7\,ug1 - R1\,R6\,R7\,ug2 + R2\,R6\,R7\,ug1 - R3\,R4\,R7\,ug2 - R2\,R6\,R7\,ug2 + R3\,R6\,R7\,ug1 - R3\,R6\,R7\,ug2}{R1\,R5\,(R4 + R6)}$$

```
v3|odziv|zamena
```

$$-\frac{4\,R^3\,ug1 - 4\,R^3\,ug2 + 2\,R^2\,R1\,ug1 - 2\,R^2\,R1\,ug2}{2\,R^2\,R1}$$

```
simplify(v3|odziv|zamena)
```

$$-\frac{(2\,R + R1)\,(ug1 - ug2)}{R1}$$

```
assume(U>0 and T>0 and t>0): pobude:={ug1=U*heaviside(t),ug2=U*heaviside(t-T)}
```

$\{ug1 = U, ug2 = U\,\mathrm{heaviside}(t - T)\}$

```
simplify(v3|odziv|zamena)|pobude
```

$$-\frac{(U - U\,\mathrm{heaviside}(t - T))\,(2\,R + R1)}{R1}$$

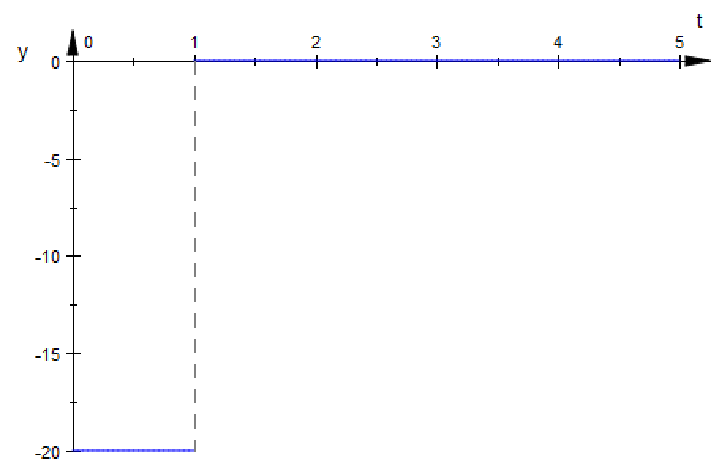
```
vrednosti:={U=10, T=1, R=1000, R1=2000}
```

$\{R = 1000, R1 = 2000, T = 1, U = 10\}$

```
uR8(t):=simplify(v3|odziv|zamena)|pobude|vrednosti
```

$20\,\mathrm{heaviside}(t - 1) - 20$

```
plot(uR8(t), t=0..5)
```

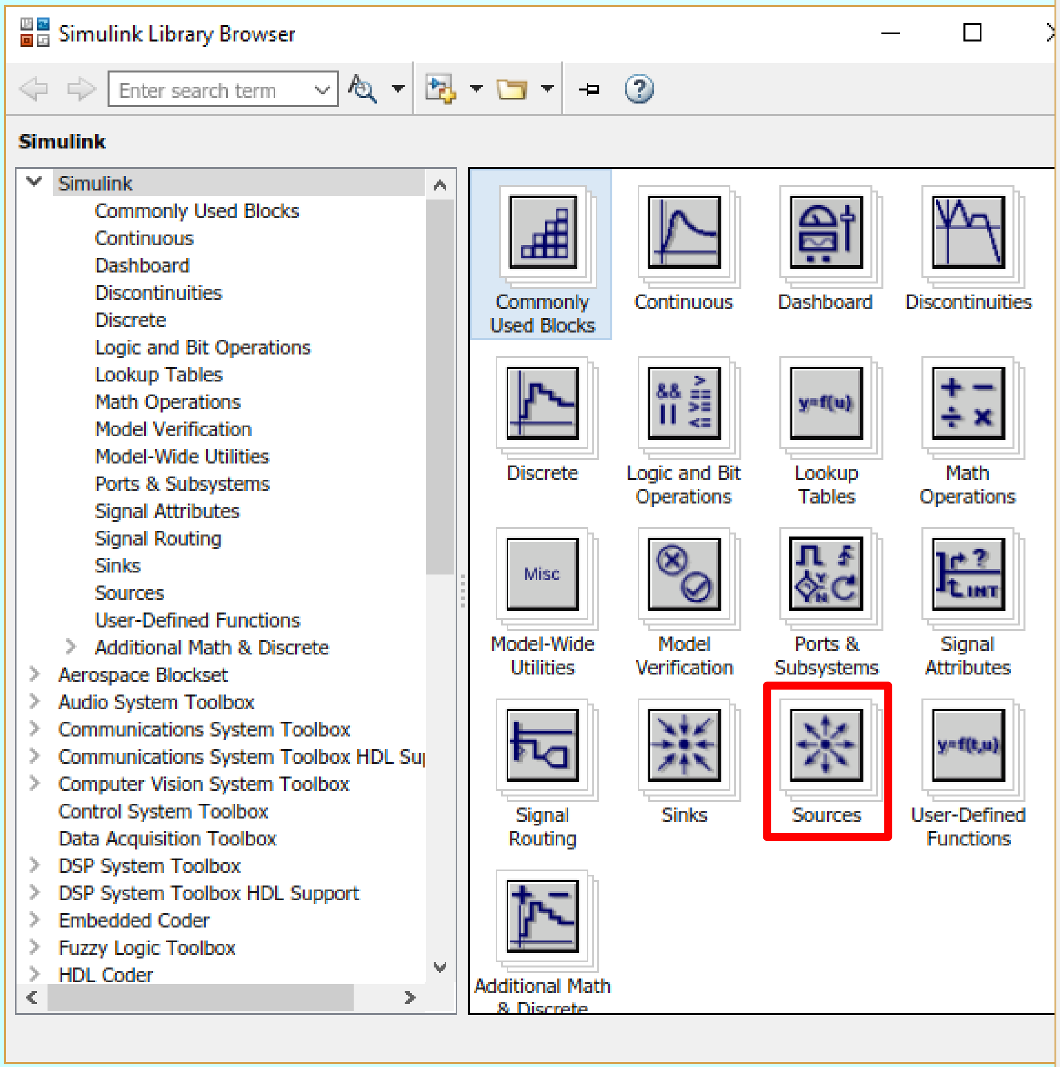


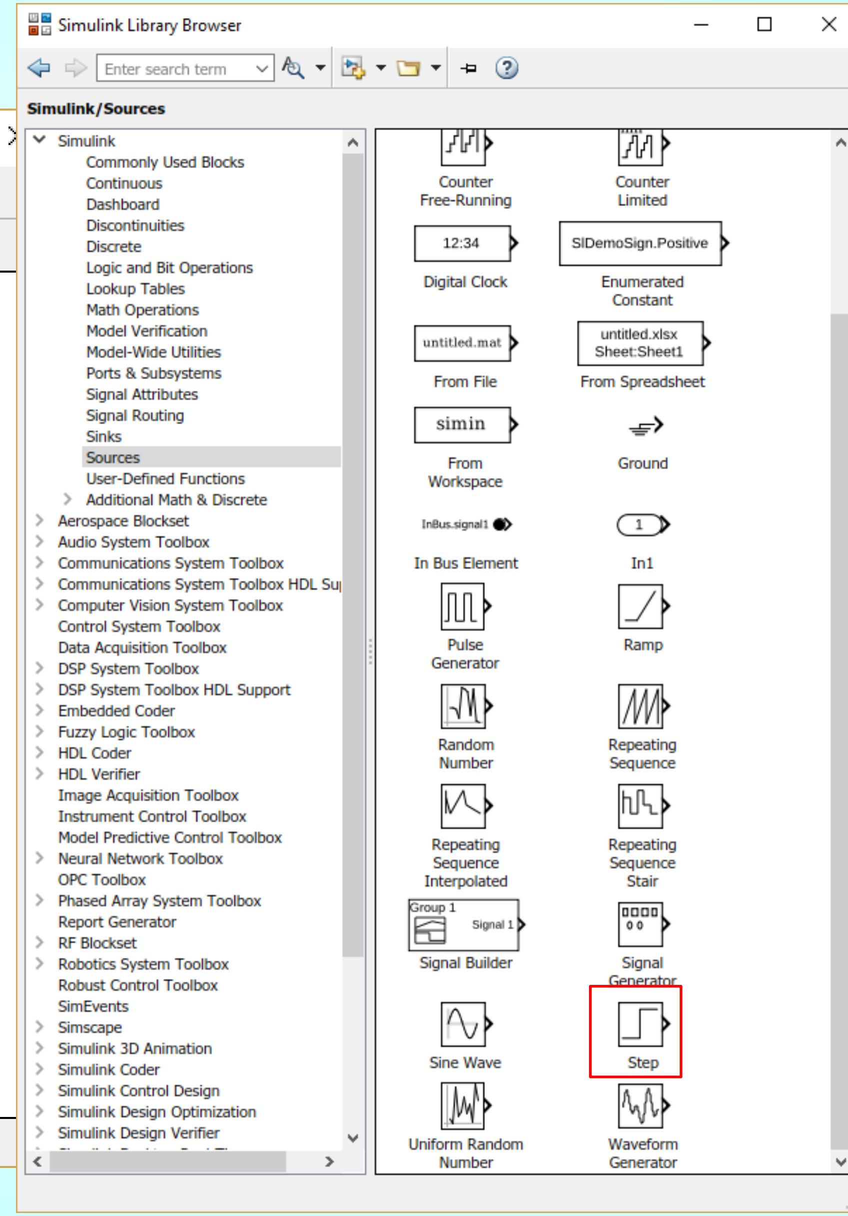

```
pg:=jg1*ug1+jg2*ug2|odziv
```

0

MATLAB: Simulink

Sources

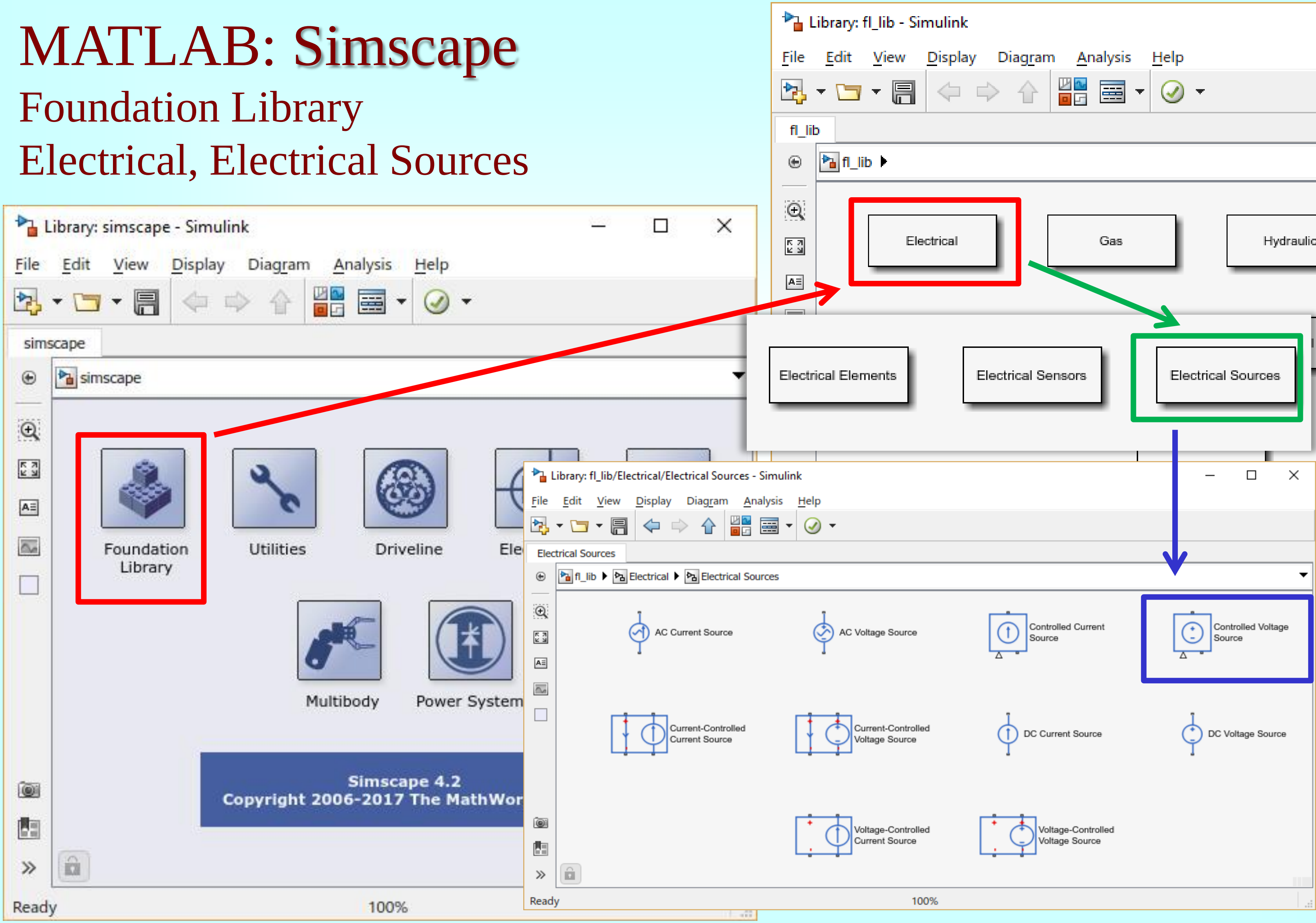




MATLAB: Simscape

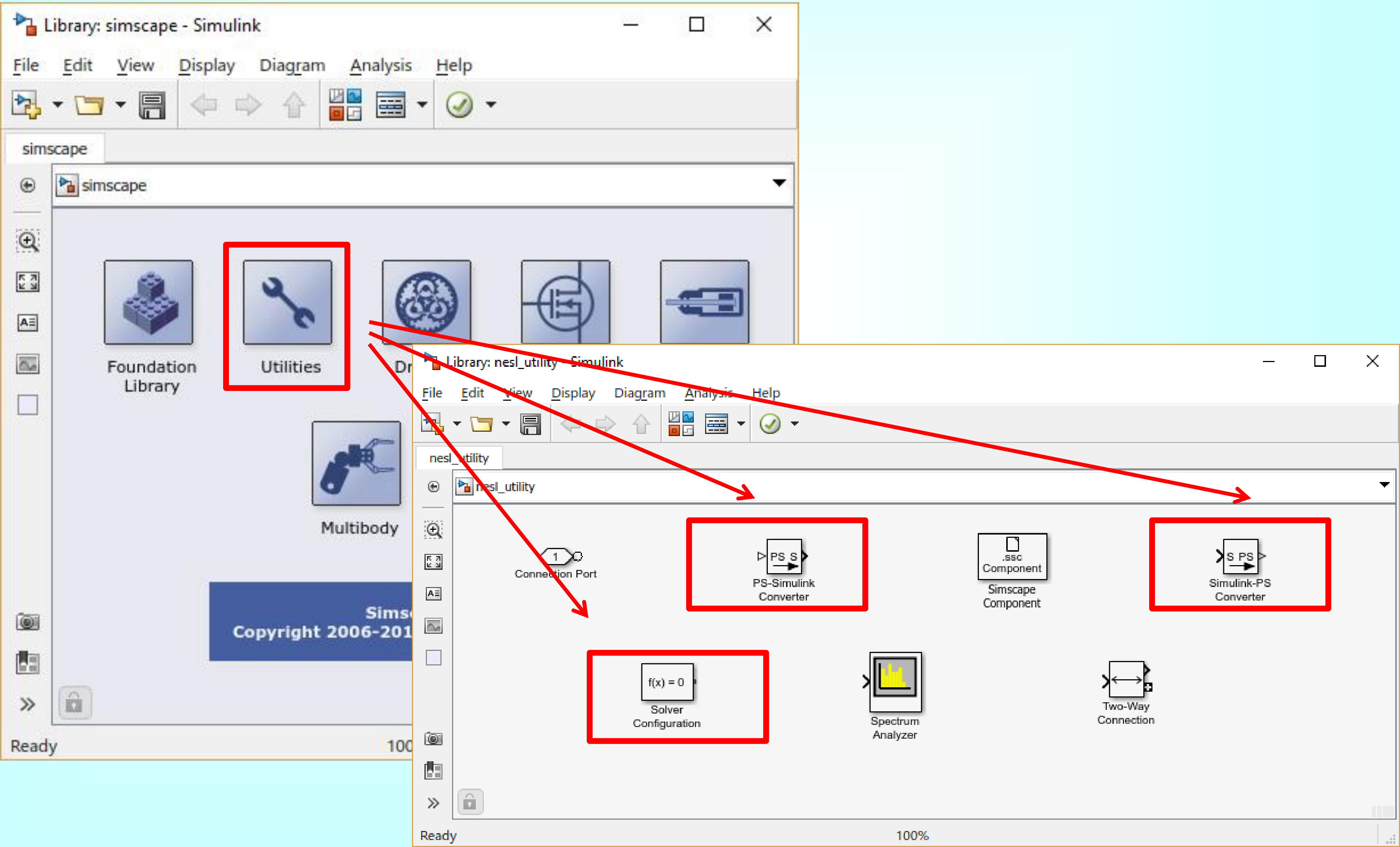
Foundation Library

Electrical, Electrical Sources



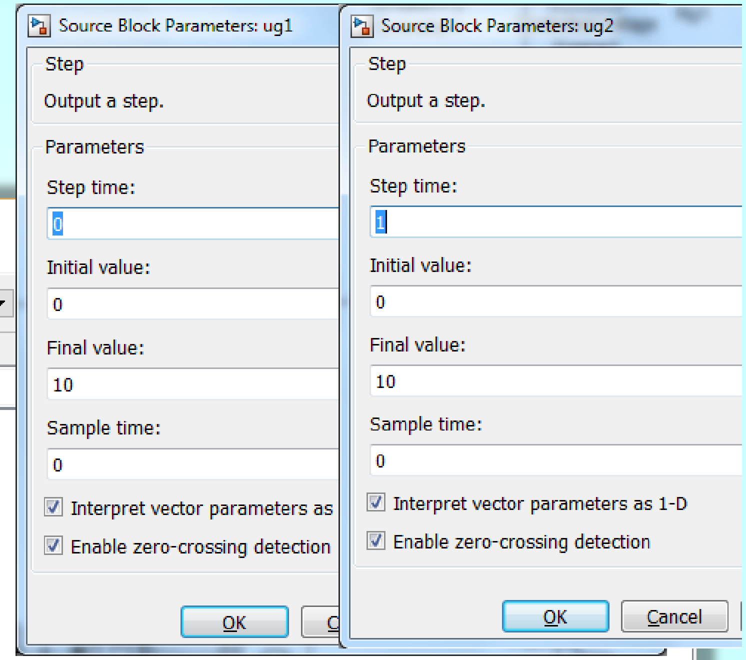
MATLAB: Simscape

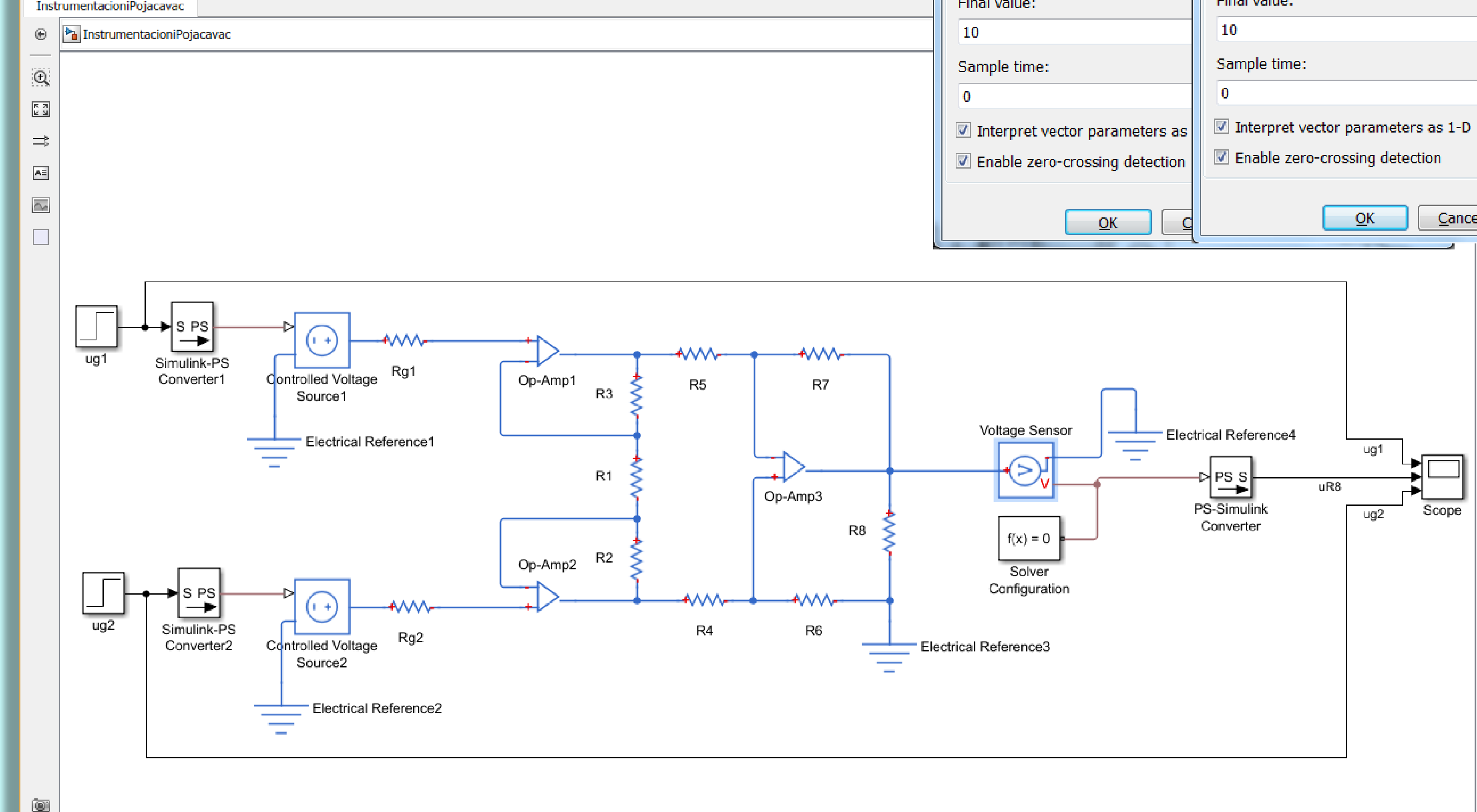
Utilities

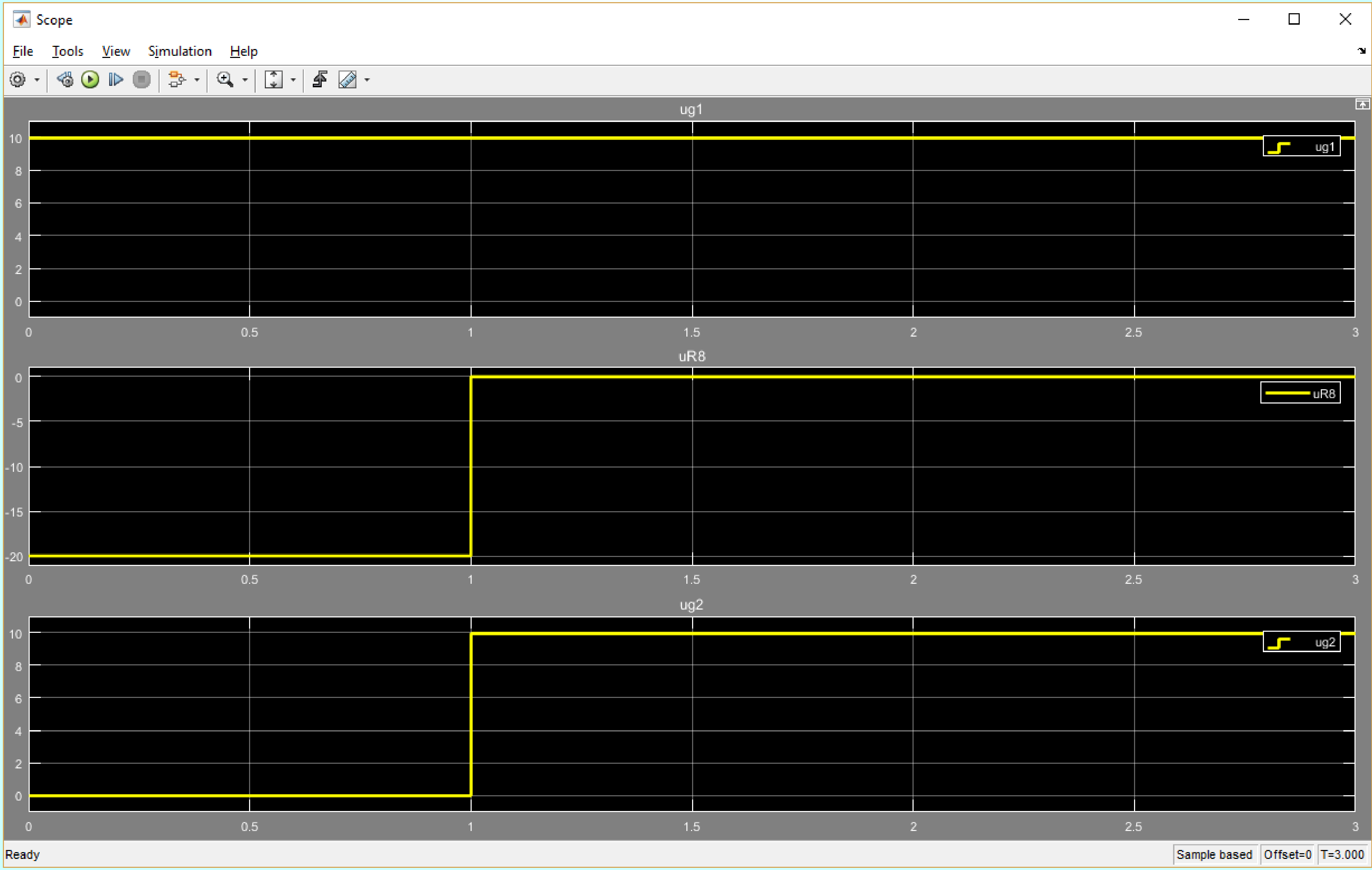


MATLAB: Simscape

Foundation Library, Utilities, Simulink



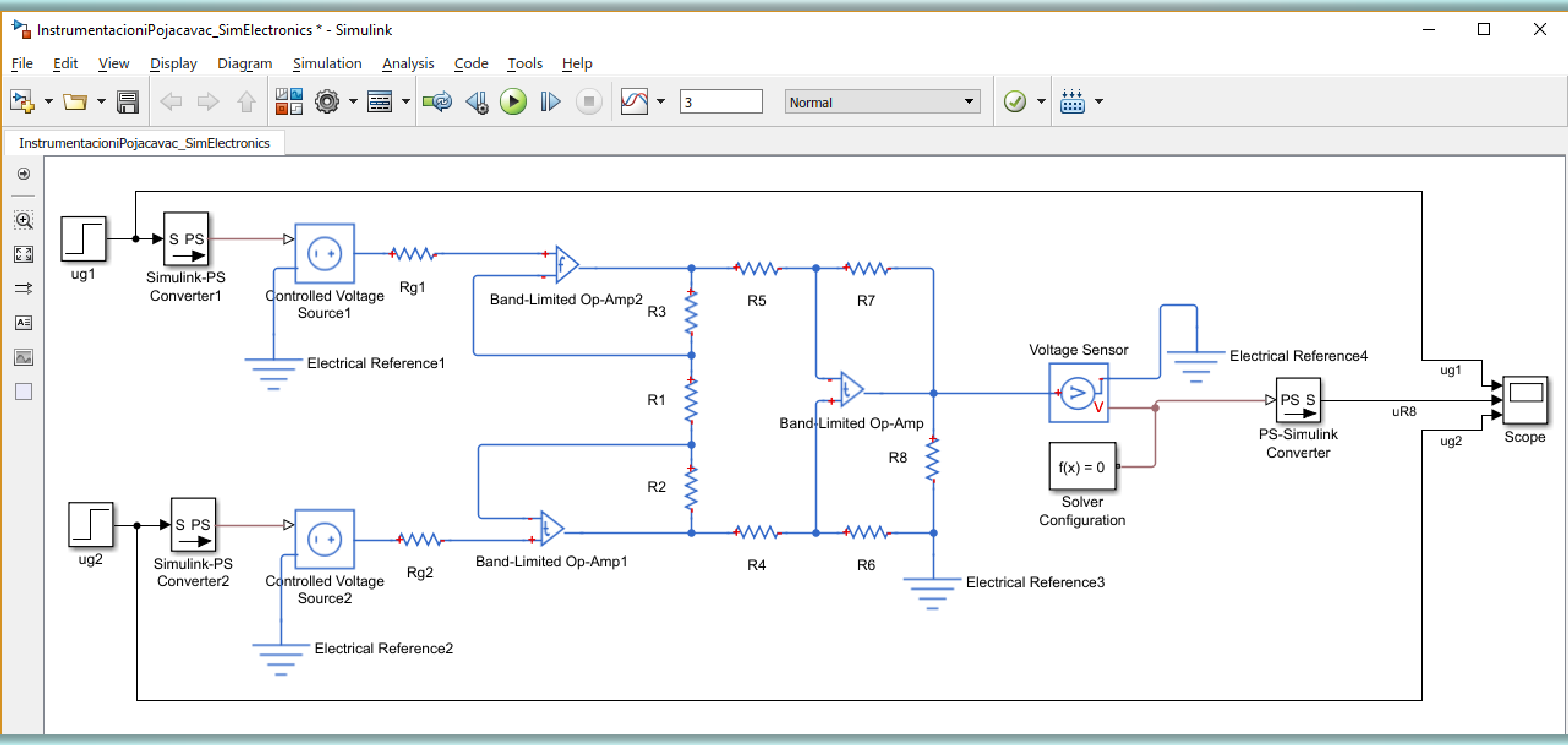




Scope
File Tools View Simulation Help
ug1
10
8
6
4
2
0
0 0.5 1 1.5 2 2.5 3
ug1
uR8
0
-5
-10
-15
-20
0 0.5 1 1.5 2 2.5 3
uR8
ug2
10
8
6
4
2
0
0 0.5 1 1.5 2 2.5 3
ug2
Ready
Sample based
Offset=0
T=3.000

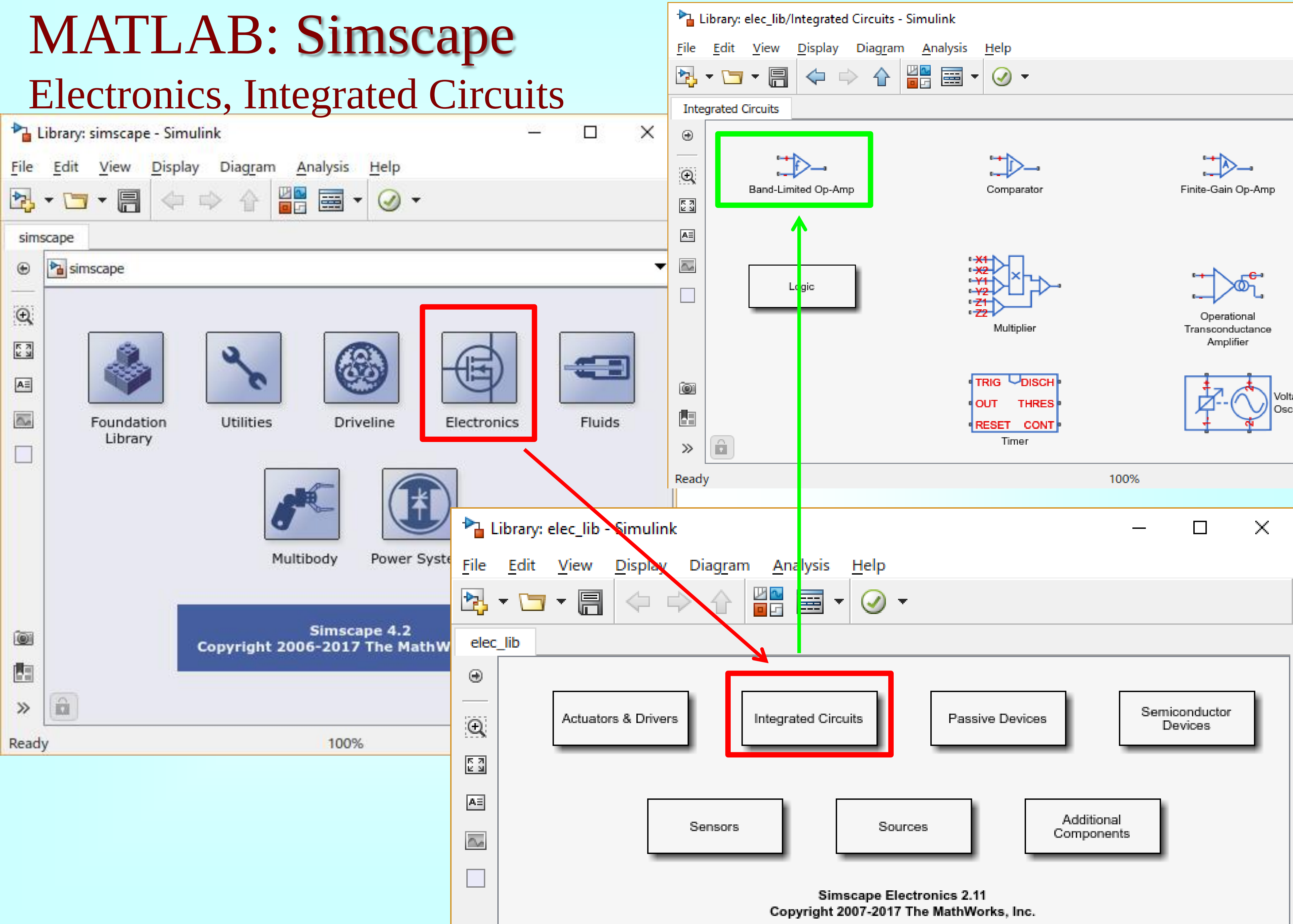
MATLAB: Simscape

Foundation Library, Electronics, Utilities, Simulink



MATLAB: Simscape

Electronics, Integrated Circuits



Band-Limited Op-Amp: LM7301

Block Parameters: Band-Limited Op-Amp

Band-Limited Op-Amp

This block models a band-limited op-amp. If the voltages at the positive and negative pins are denoted Vp and Vm, then the output voltage is given by

Vout = A*(Vp-Vm)*1/(s/(2*pi*f)+1)-Iout*Rout

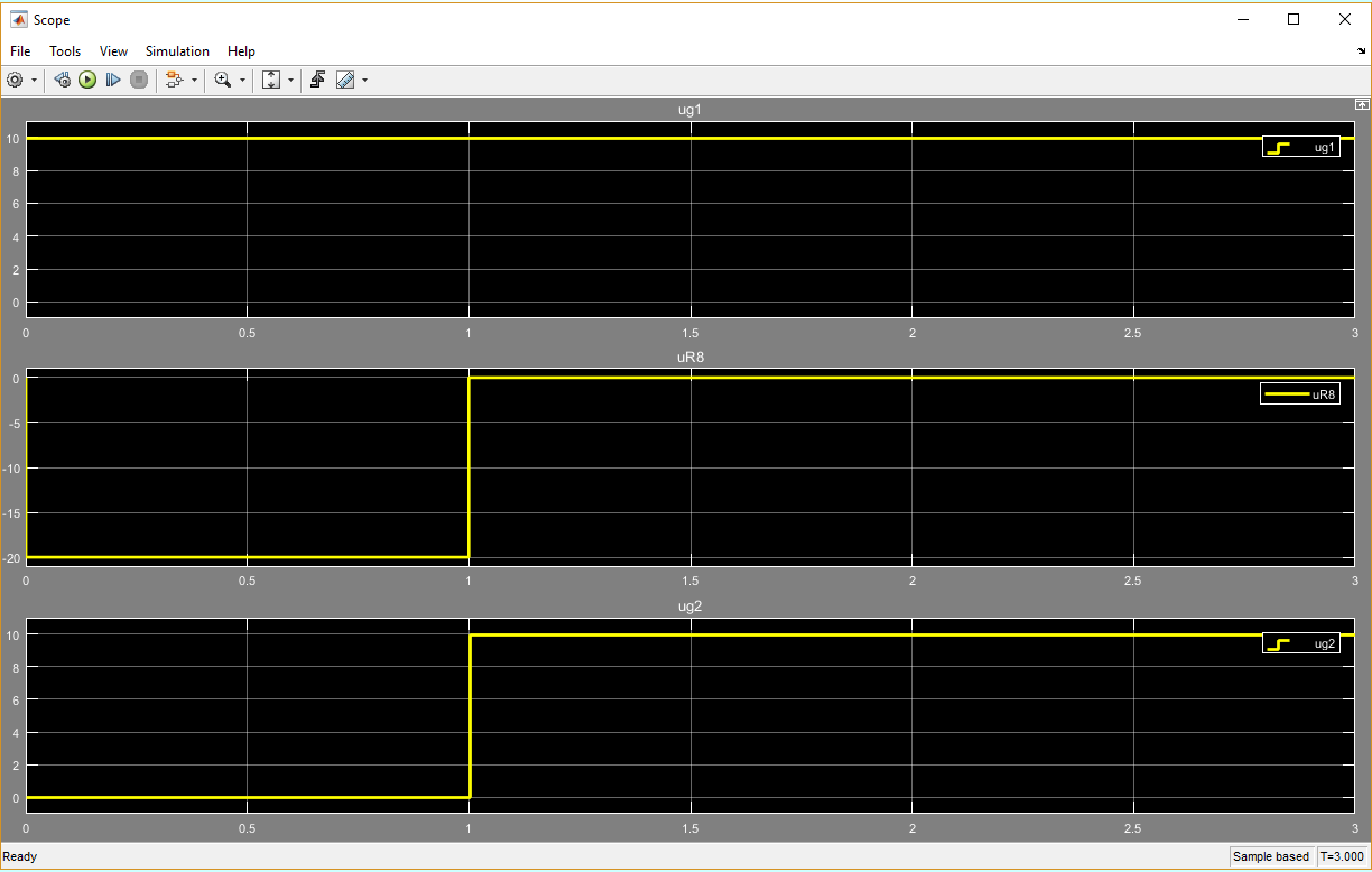
where A is the gain, Rout is the output resistance, Iout is the output current, s is the Laplace operator, and f is the 3dB bandwidth. The input current is given by (Vp-Vm)/Rin where Rin is the input resistance. The no-load output voltage is limited the range Vmin to Vmax, and the slew rate is limited to +-Vdot.

The Initial output voltage, V0, sets the initial op-amp output voltage. Note that this does not take account of any voltage drop across Rout. The initial condition is not used if you select the Start simulation from steady state option in the Solver Configuration block.

Settings

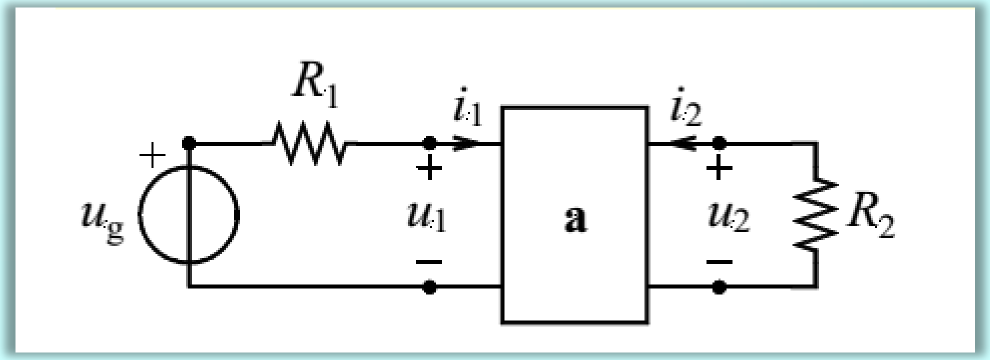
Parameters

Gain, A:	7.1e4	
Input resistance, Rin:	39	MOhm
Output resistance, Rout:	0	Ohm
Minimum output, Vmin:	-20	V
Maximum output, Vmax:	20	V
Maximum slew rate, Vdot:	1.25/1e-6	V/s
Bandwidth, f:	4e6	Hz
Initial output voltage, V0:	0	V


Scope
File Tools View Simulation Help
ug1
10
8
6
4
2
0
0 0.5 1 1.5 2 2.5 3
uR8
0
-5
-10
-15
-20
0 0.5 1 1.5 2 2.5 3
ug2
10
8
6
4
2
0
0 0.5 1 1.5 2 2.5 3
Ready
Sample based
T=3.000

ABCD parametri mreže

- Otpornosti otpornika i *a*-parametri (*ABCD*-parametri) mreže sa dva pristupa su poznati.
- Odrediti:
  - Količnik napona $A = u_2 / u_g$
  - Ulaznu otpornost mreže $R_u = u_1/i_1$
  - Struju i_1
- Smatrati da su *a*-parametri mreže realni i različiti od nule



ABCD-parametri* - MuPAD

File Edit View Navigation Insert Format Notebook Window Help

Generic Monospace 11

MATLAB: MuPAD

```
jednacine:= {ug = R1*i1 + u1,
u2 + R2*i2 = 0,
u1 = a11*u2 + a12*(-i2),
i1 = a21*u2 + a22*(-i2)}
```

$$\{u2 + R2\ i2 = 0,\ i1 = a21\ u2 - a22\ i2,\ u1 = a11\ u2 - a12\ i2,\ ug = u1 + R1\ i1\}$$

```
promenljive:={u1, u2, i1, i2}
```

$$\{i1, i2, u1, u2\}$$

```
odziv:=solve(jednacine, promenljive)
```

$$\begin{cases} \{[i1 = 0,\ i2 = z,\ u1 = 0,\ u2 = 0]\} & \text{if } R2 = 0 \wedge a12 = 0 \wedge a22 = 0 \wedge ug = 0 \\ \left\{\left[i1 = \frac{ug}{R1},\ i2 = -\frac{ug}{R1\ a22},\ u1 = 0,\ u2 = 0\right]\right\} & \text{if } R2 = 0 \wedge R1 \neq 0 \wedge a12 = 0 \wedge a22 \neq 0 \\ \{[i1 = -a22\ z,\ i2 = z,\ u1 = 0,\ u2 = 0]\} & \text{if } R2 = 0 \wedge a12 = 0 \wedge (R1 = 0 \vee a22 = 0) \wedge ug = 0 \\ \left\{\left[i1 = \frac{a22\ ug}{a12 + R1\ a22},\ i2 = -\frac{ug}{a12 + R1\ a22},\ u1 = \frac{a12\ ug}{a12 + R1\ a22},\ u2 = 0\right]\right\} & \text{if } a12 + R1\ a22 \neq 0 \wedge R2 = 0 \wedge a12 \neq 0 \\ \left\{\left[i1 = \frac{a22\ z}{a12},\ i2 = -\frac{z}{a12},\ u1 = z,\ u2 = 0\right]\right\} & \text{if } a12 + R1\ a22 = 0 \wedge R2 = 0 \wedge a12 \neq 0 \wedge ug = 0 \\ \left\{\left[i1 = \frac{a22\ ug + R2\ a21\ ug}{\sigma_1},\ i2 = -\frac{ug}{\sigma_1},\ u1 = \frac{ug\ (a12 + R2\ a11)}{\sigma_1},\ u2 = \frac{R2\ ug}{\sigma_1}\right]\right\} & \text{if } \sigma_1 \neq 0 \wedge R2 \neq 0 \\ \left\{\left[i1 = \frac{z\ (a22 + R2\ a21)}{R2},\ i2 = -\frac{z}{R2},\ u1 = \frac{z\ (a12 + R2\ a11)}{R2},\ u2 = z\right]\right\} & \text{if } \sigma_1 = 0 \wedge R2 \neq 0 \wedge ug = 0 \\ \emptyset & \text{if } (\sigma_1 = 0 \wedge (R2 = 0 \vee ug \neq 0)) \vee ((a12 + R1\ a22 = 0 \vee (a12 = 0 \wedge (R1 = 0 \vee a22 = 0))) \wedge R2 = 0 \wedge ug \neq 0) \end{cases}$$

where

$$\sigma_1 = a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21$$

```
odziv[6]
```

$$\left\{\left[i1 = \frac{a22\ ug + R2\ a21\ ug}{\sigma_1},\ i2 = -\frac{ug}{\sigma_1},\ u1 = \frac{ug\ (a12 + R2\ a11)}{\sigma_1},\ u2 = \frac{R2\ ug}{\sigma_1}\right]\right\}$$

where

$$\sigma_1 = a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21$$


```
odziv[6]
```

$$\left\{\left[i1 = \frac{a22\ ug + R2\ a21\ ug}{\sigma_1},\ i2 = -\frac{ug}{\sigma_1},\ u1 = \frac{ug\ (a12 + R2\ a11)}{\sigma_1},\ u2 = \frac{R2\ ug}{\sigma_1}\right]\right\}$$

where

$$\sigma_1 = a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21$$


```
A:=(u2|odziv[6])/ug
```

$$\frac{R2}{a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21}$$

```
Ru:=simplify((u1/i1)|odziv[6])
```

$$\frac{a12 + R2\ a11}{a22 + R2\ a21}$$

```
simplify(i1|odziv[6])
```

$$\frac{ug\ (a22 + R2\ a21)}{a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21}$$

ABCD-parametri_assumtion* - MuPAD

File Edit View Navigation Insert Format Notebook Window Help

MATLAB: MuPAD

```
jednacine:= {ug = R1*i1 + u1,
u2 + R2*i2 = 0,
u1 = a11*u2 + a12*(-i2),
i1 = a21*u2 + a22*(-i2)}
```

$$\{u2 + R2\ i2 = 0,\ i1 = a21\ u2 - a22\ i2,\ u1 = a11\ u2 - a12\ i2,\ ug = u1 + R1\ i1\}$$

```
promenljive:={u1, u2, i1, i2}
```

$$\{i1,\ i2,\ u1,\ u2\}$$

```
assume(a11*a22-a12*a21<>0 and R1>0 and R2>0 and ug<>0):
```

assume…

```
odziv:=solve(jednacine, promenljive)
```

$$\begin{cases} \emptyset & \text{if } \sigma_1 = 0 \\ \left\{\left[i1 = \frac{a22\ ug + R2\ a21\ ug}{\sigma_1},\ i2 = -\frac{ug}{\sigma_1},\ u1 = \frac{ug\ (a12 + R2\ a11)}{\sigma_1},\ u2 = \frac{R2\ ug}{\sigma_1}\right]\right\} & \text{if } \sigma_1 \neq 0 \end{cases}$$

where

$$\sigma_1 = a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21$$

```
odziv[2]
```

$$\left\{\left[i1 = \frac{a22\ ug + R2\ a21\ ug}{\sigma_1},\ i2 = -\frac{ug}{\sigma_1},\ u1 = \frac{ug\ (a12 + R2\ a11)}{\sigma_1},\ u2 = \frac{R2\ ug}{\sigma_1}\right]\right\}$$

where

$$\sigma_1 = a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21$$

```
A:=(u2|odziv[2])/ug
```

$$\frac{R2}{a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21}$$

```
Ru:=simplify((u1/i1)|odziv[2])
```

$$\frac{a12 + R2\ a11}{a22 + R2\ a21}$$

```
simplify(i1|odziv[2])
```

$$\frac{ug\ (a22 + R2\ a21)}{a12 + R2\ a11 + R1\ a22 + R1\ R2\ a21}$$