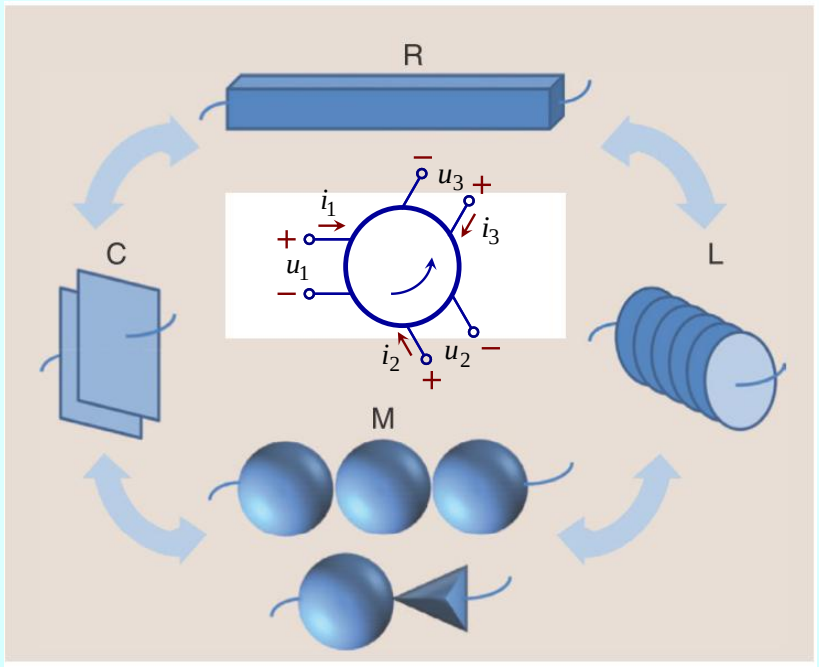
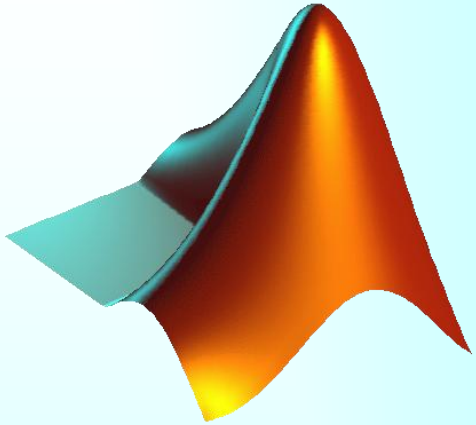
др Милка Потребић, ванредни професор, *Практикум из рачунарске анализе кола*, Универзитет у Београду – Електротехнички факултет, 2017.

Рачунарска анализа електричних кола





Милка Потребић

Рачунарски (софтверски) алати

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

Free/Libre Open Source Software (FLOSS)

Одзив на побуду

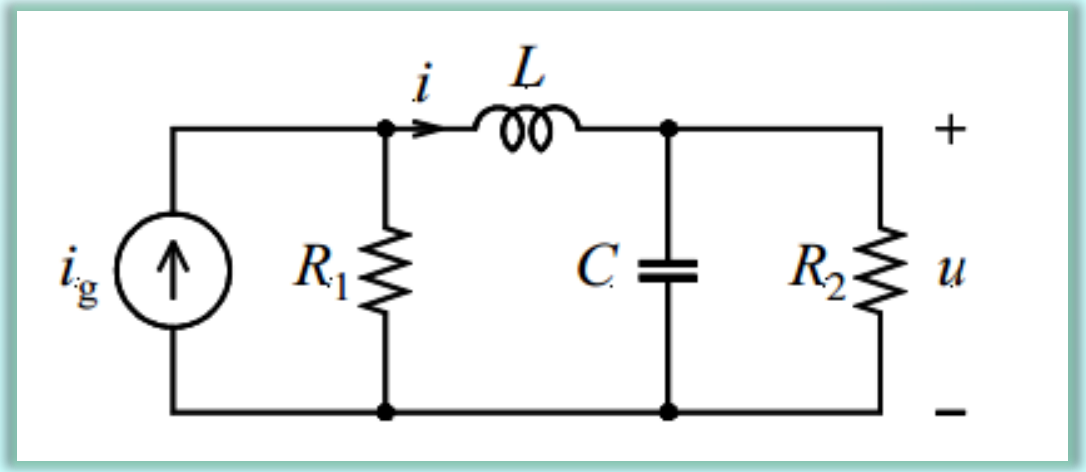
Вредности елемената електричног кола са слике су познате.

(а) Одредити једначине стања у скаларном и матричном облику. Који је ред кола?

(б) Одредити импулсни одзив (Гринову функцију) за напон u ако је

$R_1 = R_2 = R$,

$L = CR^2$.



MATLAB: MuPAD

Једначине стања

OdzivNaPobudu - MuPAD

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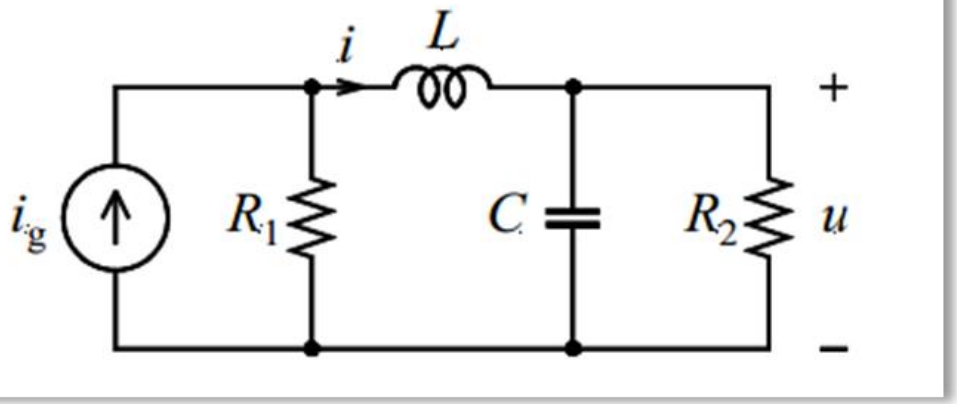
Generic Serif 20




```
jednacine:={ig = i1 + iL,
iL = iC + i2,
u1 = uL + uC,
uC = u2,
u1 = R1 * i1,
u2 = R2 * i2,
uL = L * DiL,
iC = C*DuC}
```

{u1 = uC + uL, uC = u2, iC = *C* DuC, uL = DiL *L*, u1 = R1 i1, u2 = R2 i2, iL = i2 + iC, ig = i1 + iL}

MATLAB: MuPAD

```
jednacine:={ig = i1 + iL,
iL = iC + i2,
u1 = uL + uC,
uC = u2,
u1 = R1 * i1,
u2 = R2 * i2,
uL = L * DiL,
iC = C*DuC}
```

$$\{u1 = uC + uL,\ uC = u2,\ iC = C\,DuC,\ uL = DiL\,L,\ u1 = R1\,i1,\ u2 = R2\,i2,\ iL = i2 + iC,\ ig = i1 + iL\}$$

```
jednacineIzvoda:=groebner::eliminate(jednacine,{i1, i2, iC, u1, u2, uL})
```

$$[uC + R1\,iL - R1\,ig + DiL\,L,\ R2\,iL - uC - C\,DuC\,R2,\ R1\,R2\,ig - R2\,uC - DiL\,L\,R2 - R1\,uC - C\,DuC\,R1\,R2]$$

```
assume({R1, R2, C, L, R, t} in R_)
assumeAlso( R1>0 and R2>0 and C>0 and L>0 and R>0 )
jednacineStanje := solve(jednacineIzvoda, {DiL, DuC})
```

$$\left\{\left[DiL = -\frac{uC + R1\,iL - R1\,ig}{L},\ DuC = -\frac{uC - R2\,iL}{C\,R2}\right]\right\}$$

```
PromenljiveStanjaIzvodi:={uC=uC(t), iL=iL(t), DiL=D(iL)(t), DuC=D(uC)(t)}
```

$$\{iL = iL(t),\ uC = uC(t),\ DiL = iL'(t),\ DuC = uC'(t)\}$$

MATLAB: MuPAD

```
zamene := {R1=R, R2=R, L=C*R^2}
```

$$\{R1 = R,\ R2 = R,\ L = C\,R^2\}$$

```
JS:=jednacineStanje | PromenljiveStanjaIzvodi | zamene
```

$$\left\{\left[\mathrm{iL}'(t) = -\frac{\mathrm{uC}(t) - R\,\mathrm{ig} + R\,\mathrm{iL}(t)}{C\,R^2},\ \mathrm{uC}'(t) = -\frac{\mathrm{uC}(t) - R\,\mathrm{iL}(t)}{C\,R}\right]\right\}$$

```
JednacineDiffExpand := expand(JS)
```

$$\left\{\left[\mathrm{iL}'(t) = \frac{\mathrm{ig}}{C\,R} - \frac{\mathrm{iL}(t)}{C\,R} - \frac{\mathrm{uC}(t)}{C\,R^2},\ \mathrm{uC}'(t) = \frac{\mathrm{iL}(t)}{C} - \frac{\mathrm{uC}(t)}{C\,R}\right]\right\}$$

```
rhsJednacineDiff :=map(op(JednacineDiffExpand), rhs)
```

$$\left[\frac{\mathrm{ig}}{C\,R} - \frac{\mathrm{iL}(t)}{C\,R} - \frac{\mathrm{uC}(t)}{C\,R^2},\ \frac{\mathrm{iL}(t)}{C} - \frac{\mathrm{uC}(t)}{C\,R}\right]$$

```
Acol1 := coeff(rhsJednacineDiff[i], iL(t),1)$ i = 1..2
```

$$-\frac{1}{C\,R},\ \frac{1}{C}$$

```
Acol2 := coeff(rhsJednacineDiff[i], uC(t),1)$ i = 1..2
```

$$-\frac{1}{C\,R^2},\ -\frac{1}{C\,R}$$

MATLAB: MuPAD

```
Atr := matrix([[Acol1],[Acol2]])
```

$$\begin{pmatrix} -\frac{1}{C\,R} & \frac{1}{C} \\ -\frac{1}{C\,R^2} & -\frac{1}{C\,R} \end{pmatrix}$$

```
A := transpose(Atr)
```

$$\begin{pmatrix} -\frac{1}{C\,R} & -\frac{1}{C\,R^2} \\ \frac{1}{C} & -\frac{1}{C\,R} \end{pmatrix}$$

```
X := matrix([[iL(t)],[uC(t)]])
```

$$\begin{pmatrix} \mathrm{iL}(t) \\ \mathrm{uC}(t) \end{pmatrix}$$

```
Ftr :=  coeff(rhsJednacineDiff[i]| uC(t)=0, iL(t),0)$ i = 1..2
```

$$\frac{\mathrm{ig}}{C\,R},\ 0$$

```
F := (matrix([Ftr]))
```

$$\begin{pmatrix} \frac{\mathrm{ig}}{C\,R} \\ 0 \end{pmatrix}$$

```
print([D(X)])
```

$$\left[\begin{pmatrix} \mathrm{iL}(t) \\ \mathrm{uC}(t) \end{pmatrix}'\right]$$

```
print( (D(X)), "=", A, ".", X ,"+", F)
```

$$\begin{pmatrix} \mathrm{iL}(t) \\ \mathrm{uC}(t) \end{pmatrix}', \text{"="}, \begin{pmatrix} -\frac{1}{C\,R} & -\frac{1}{C\,R^2} \\ \frac{1}{C} & -\frac{1}{C\,R} \end{pmatrix}, \text{"."}, \begin{pmatrix} \mathrm{iL}(t) \\ \mathrm{uC}(t) \end{pmatrix}, \text{"+"}, \begin{pmatrix} \frac{\mathrm{ig}}{C\,R} \\ 0 \end{pmatrix}$$

```
Jednako := newDomain("Jednako"):  e1 := new(Jednako, 1):
Jednako::print := x -> "=":
print(e1):
```

=

```
Puta := newDomain("Puta"):  e2 := new(Puta, 1):
Puta::print := x -> ".":
print(e2):
```

.

```
Plus := newDomain("Plus"):  e3 := new(Plus, 1):
Plus::print := x -> "+":
print(e3):
```

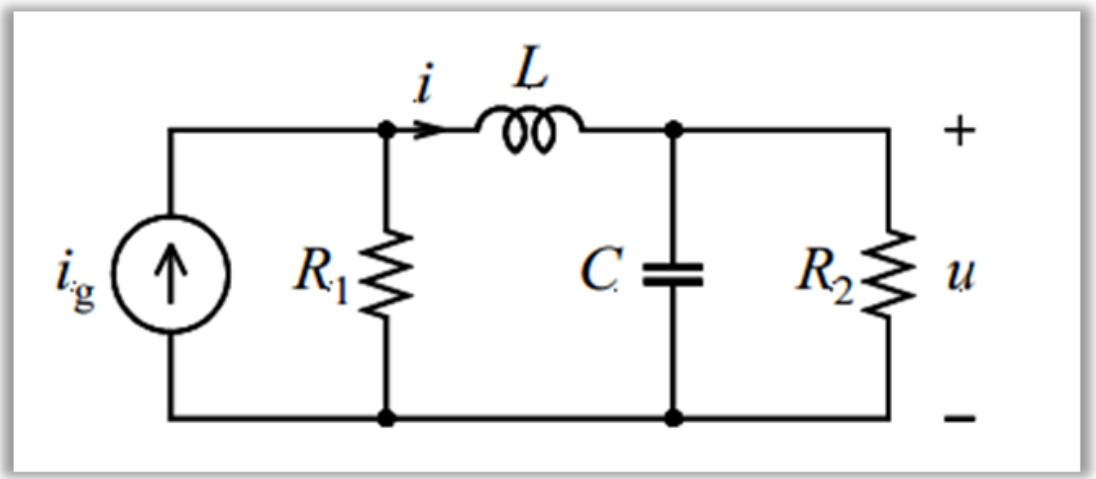
+

```
myexprseq := funcenv(myexprseq, builtin(1100, 20, "", "myexprseq")):
print(myexprseq((D(X)), e1, A, e2, X ,e3, F)):
```

$$\begin{pmatrix} \mathrm{iL}(t) \\ \mathrm{uC}(t) \end{pmatrix}' = \begin{pmatrix} -\frac{1}{C\,R} & -\frac{1}{C\,R^2} \\ \frac{1}{C} & -\frac{1}{C\,R} \end{pmatrix} \cdot \begin{pmatrix} \mathrm{iL}(t) \\ \mathrm{uC}(t) \end{pmatrix} + \begin{pmatrix} \frac{\mathrm{ig}}{C\,R} \\ 0 \end{pmatrix}$$

Одређивање индиционе функције и импулсног одзива

MATLAB: MuPAD




```
jednacine:={ig = i1 + iL,
iL = iC + i2,
u1 = uL + uC,
uC = u2,
u1 = R1 * i1,
u2 = R2 * i2,
uL = L * DiL,
iC = C*DuC}
```

{u1 = uC + uL, uC = u2, iC = *C* DuC, uL = DiL *L*, u1 = R1 i1, u2 = R2 i2, iL = i2 + iC, ig = i1 + iL}

```
jednacineIzvoda:=groebner::eliminate(jednacine,{i1, i2, iC, u1, u2, uL})
```

[uC + R1 iL – R1 ig + DiL *L*, R2 iL – uC – *C* DuC R2, R1 R2 ig – R2 uC – DiL *L* R2 – R1 uC – *C* DuC R1 R2]

```
assume({R1, R2, C, L, R, t} in R_)
assumeAlso( R1>0 and R2>0 and C>0 and L>0 and R>0 )
```

MATLAB: MuPAD

```
jednacineStanje := solve(jednacineIzvoda, {DiL, DuC})
```

$$\left\{\left[\mathrm{DiL} = -\frac{\mathrm{uC} + \mathrm{R1\ iL} - \mathrm{R1\ ig}}{L},\ \mathrm{DuC} = -\frac{\mathrm{uC} - \mathrm{R2\ iL}}{C\ \mathrm{R2}}\right]\right\}$$

```
PromenljiveStanjaIzvodi:={uC=uC(t), iL=iL(t), DiL=D(iL)(t), DuC=D(uC)(t)}
```

$$\{\mathrm{iL} = \mathrm{iL}(t),\ \mathrm{uC} = \mathrm{uC}(t),\ \mathrm{DiL} = \mathrm{iL}'(t),\ \mathrm{DuC} = \mathrm{uC}'(t)\}$$

```
zamene := {R1=R, R2=R, L=C*R^2, ig=heaviside(t)}
```

$$\{\mathrm{R1} = R,\ \mathrm{R2} = R,\ \mathrm{ig} = \mathrm{heaviside}(t),\ L = C\ R^2\}$$

```
JS:=jednacineStanje | PromenljiveStanjaIzvodi | zamene
```

$$\left\{\left[\mathrm{iL}'(t) = -\frac{\mathrm{uC}(t) - R\ \mathrm{heaviside}(t) + R\ \mathrm{iL}(t)}{C\ R^2},\ \mathrm{uC}'(t) = -\frac{\mathrm{uC}(t) - R\ \mathrm{iL}(t)}{C\ R}\right]\right\}$$

```
op(op(JS))
```

$$\mathrm{iL}'(t) = -\frac{\mathrm{uC}(t) - R\ \mathrm{heaviside}(t) + R\ \mathrm{iL}(t)}{C\ R^2},\ \mathrm{uC}'(t) = -\frac{\mathrm{uC}(t) - R\ \mathrm{iL}(t)}{C\ R}$$

```
JSpocetveVrednosti:={op(op(JS)), uC(0)=0, iL(0)=0}
```

$$\left\{\mathrm{uC}'(t) = -\frac{\mathrm{uC}(t) - R\ \mathrm{iL}(t)}{C\ R},\ \mathrm{iL}'(t) = -\frac{\mathrm{uC}(t) - R\ \mathrm{heaviside}(t) + R\ \mathrm{iL}(t)}{C\ R^2},\ \mathrm{iL}(0) = 0,\ \mathrm{uC}(0) = 0\right\}$$

```
odziv := ode::solve(JSpocetveVrednosti, {uC(t), iL(t)})
```

$$\left\{\left[uC(t) = \frac{R\,\text{heaviside}(t)}{2} - \frac{R\,\sigma_1\,\sigma_3\,\text{heaviside}(t)}{2} - \frac{R\,\sigma_1\,\sigma_2\,\text{heaviside}(t)}{2},\ iL(t) = \frac{\text{heaviside}(t)}{2} - \frac{\sigma_1\,\sigma_3\,\text{heaviside}(t)}{2} + \frac{\sigma_1\,\sigma_2\,\text{heaviside}(t)}{2}\right]\right\}$$

where

$$\sigma_1 = e^{-\frac{t}{C\,R}}$$

$$\sigma_2 = \sin\left(\frac{t}{C\,R}\right)$$

$$\sigma_3 = \cos\left(\frac{t}{C\,R}\right)$$

```
f(t):=(uC(t) | (odziv))
```

Индициона функција

$$\frac{R\,\text{heaviside}(t)}{2} - \frac{R\,e^{-\frac{t}{C\,R}}\cos\left(\frac{t}{C\,R}\right)\text{heaviside}(t)}{2} - \frac{R\,e^{-\frac{t}{C\,R}}\sin\left(\frac{t}{C\,R}\right)\text{heaviside}(t)}{2}$$

```
g(t):=simplify(diff(f(t),t))
```

Импулсни одзив

$$\frac{e^{-\frac{t}{C\,R}}\sin\left(\frac{t}{C\,R}\right)\text{heaviside}(t)}{C}$$

f(t):=(uC(t) | (odziv))

$$\frac{R\,\mathrm{heaviside}(t)}{2} - \frac{R\,e^{-\frac{t}{C\,R}}\cos\left(\frac{t}{C\,R}\right)\mathrm{heaviside}(t)}{2} - \frac{R\,e^{-\frac{t}{C\,R}}\sin\left(\frac{t}{C\,R}\right)\mathrm{heaviside}(t)}{2}$$

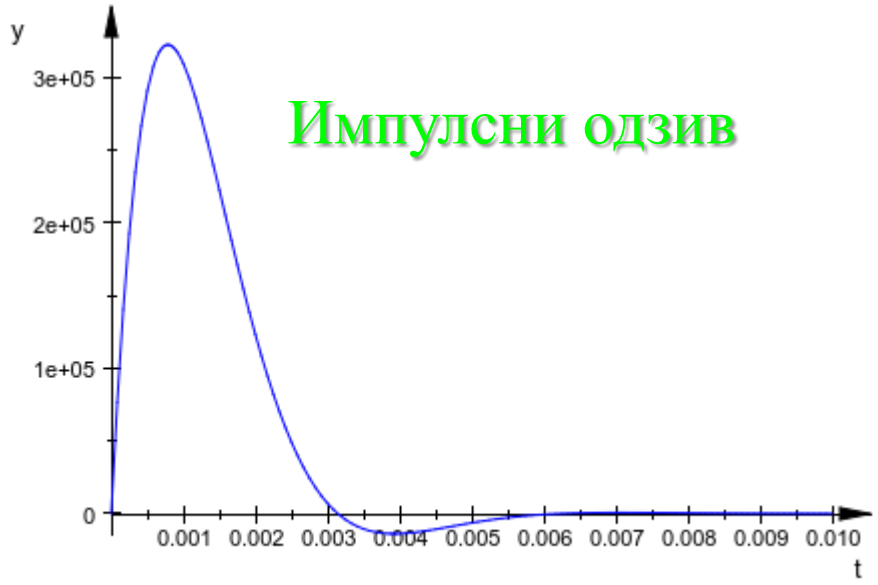
g(t):=simplify(diff(f(t),t))

$$\frac{e^{-\frac{t}{C\,R}}\sin\left(\frac{t}{C\,R}\right)\mathrm{heaviside}(t)}{C}$$

zamena:={R=1e3, C=1e-6}

$$\{R = 1000.0,\ C = 0.000001\}$$

plot(g(t)|zamena, t=0..0.01)

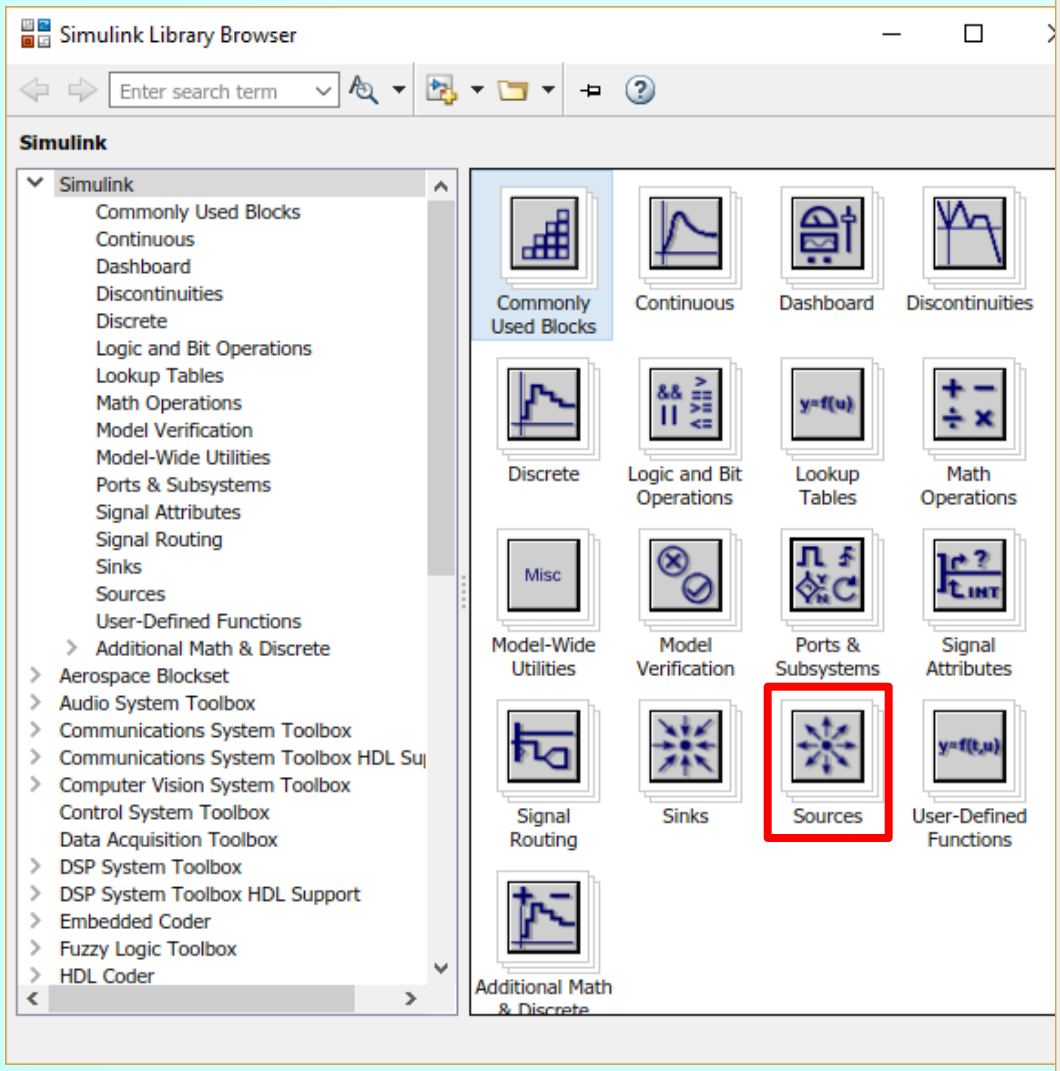


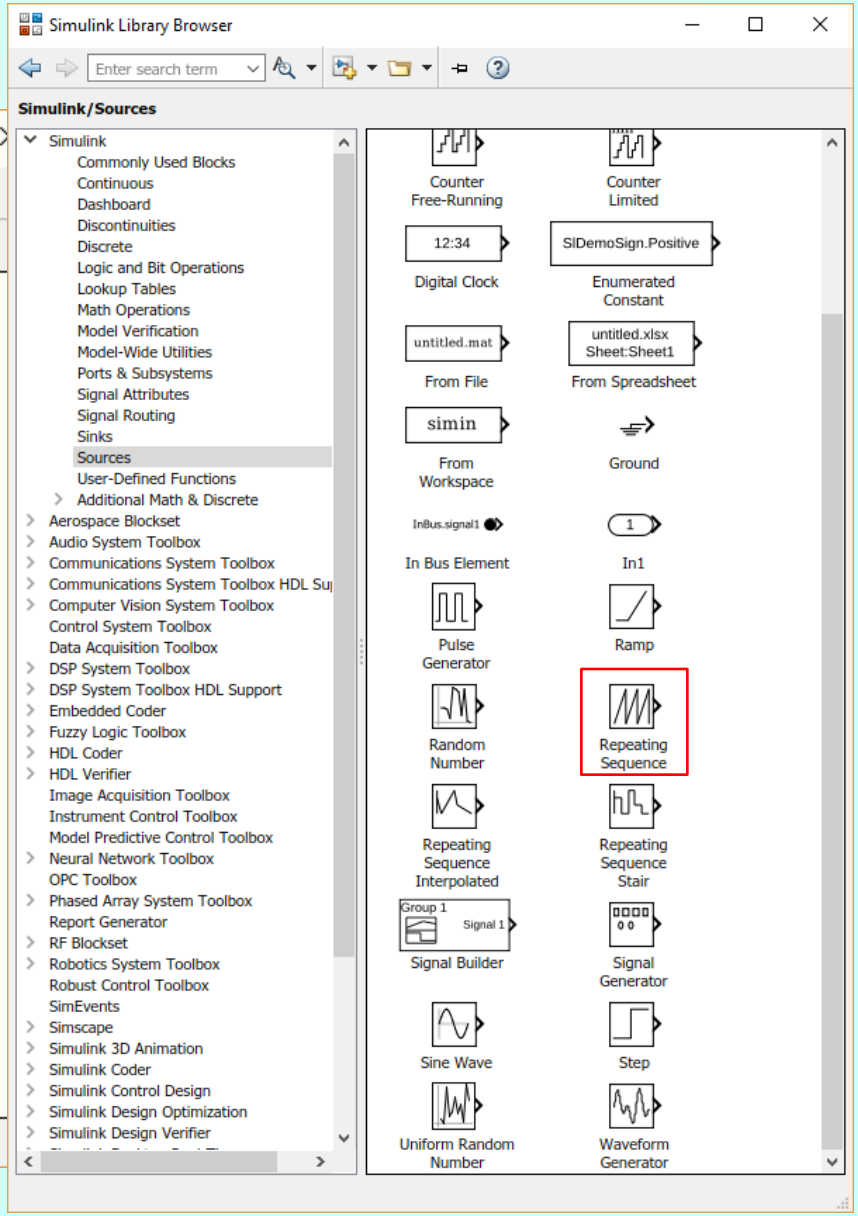
Импулсни одзив

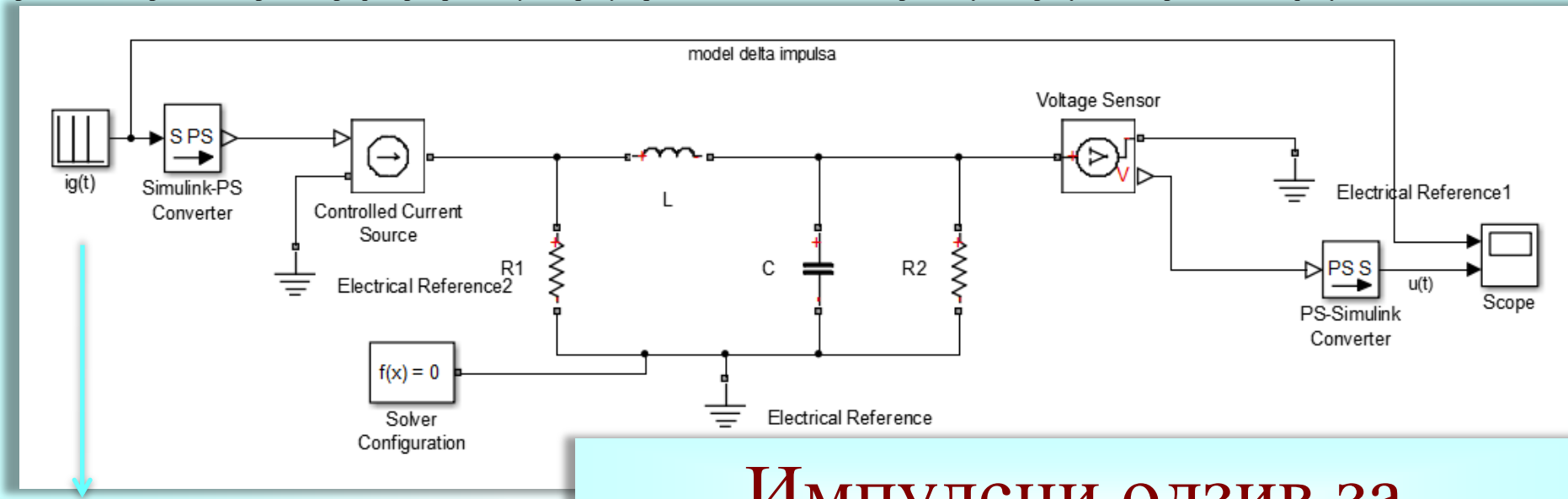
MATLAB: MuPAD

MATLAB: Simulink

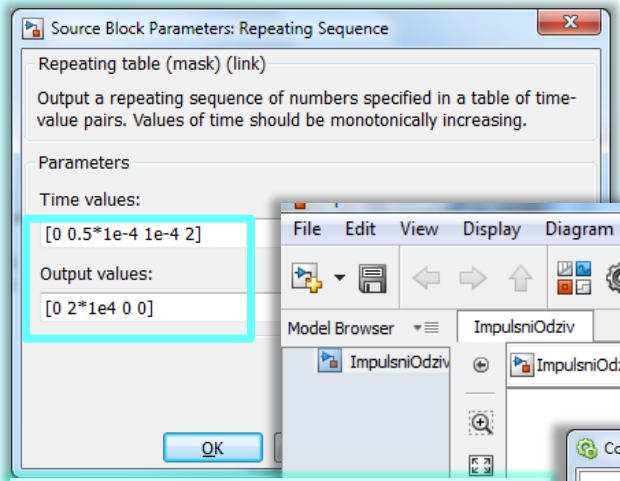
Sources

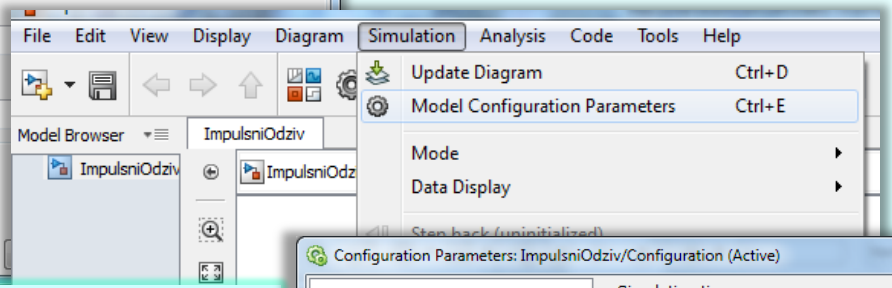






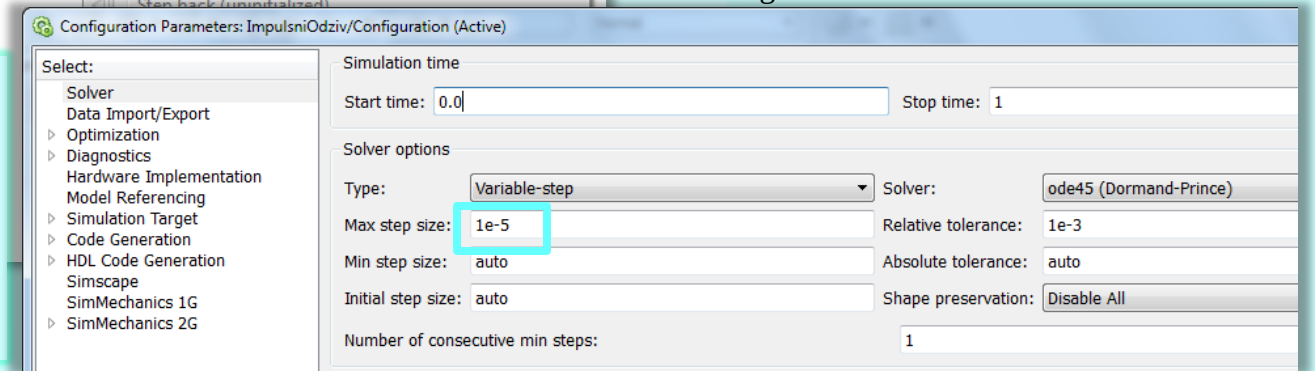
Импулсни одзив за напон кондензатора $u(t)$

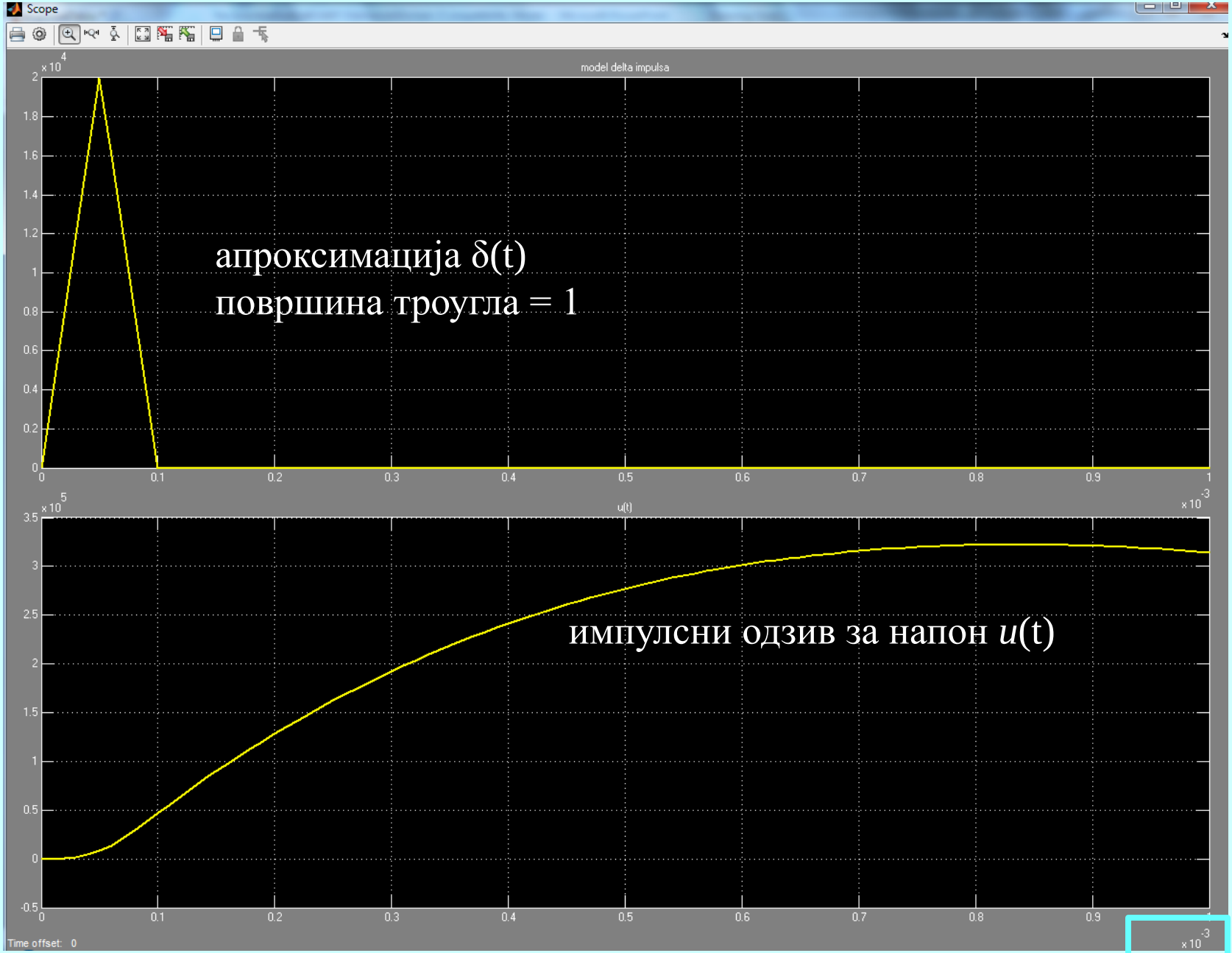


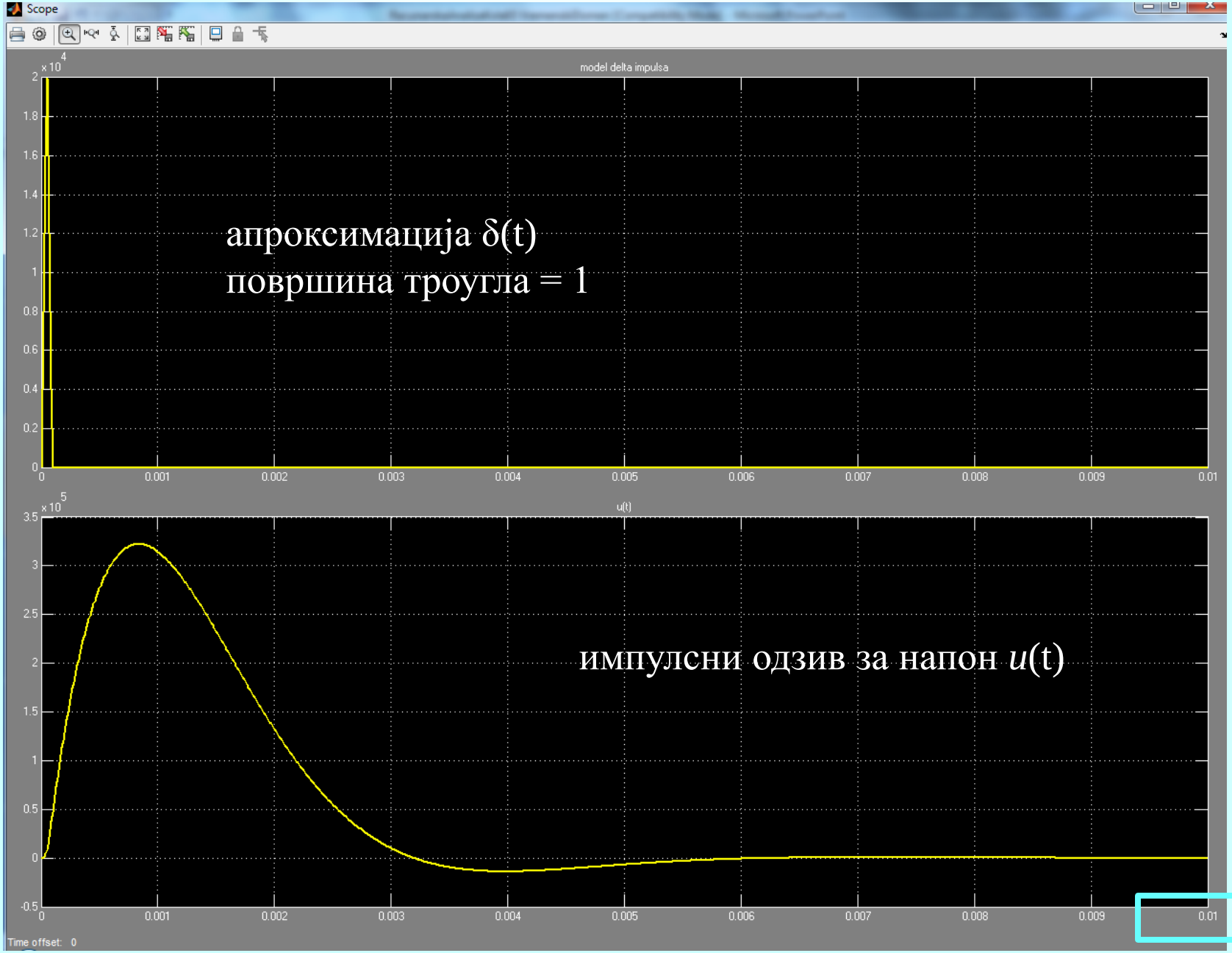


$R_1 = R_2 = R = 1\ \text{k}\Omega$
$L = 1\ \text{H}$
$C = 1\ \mu\text{F}$
$i_g(t) = \delta(t)$

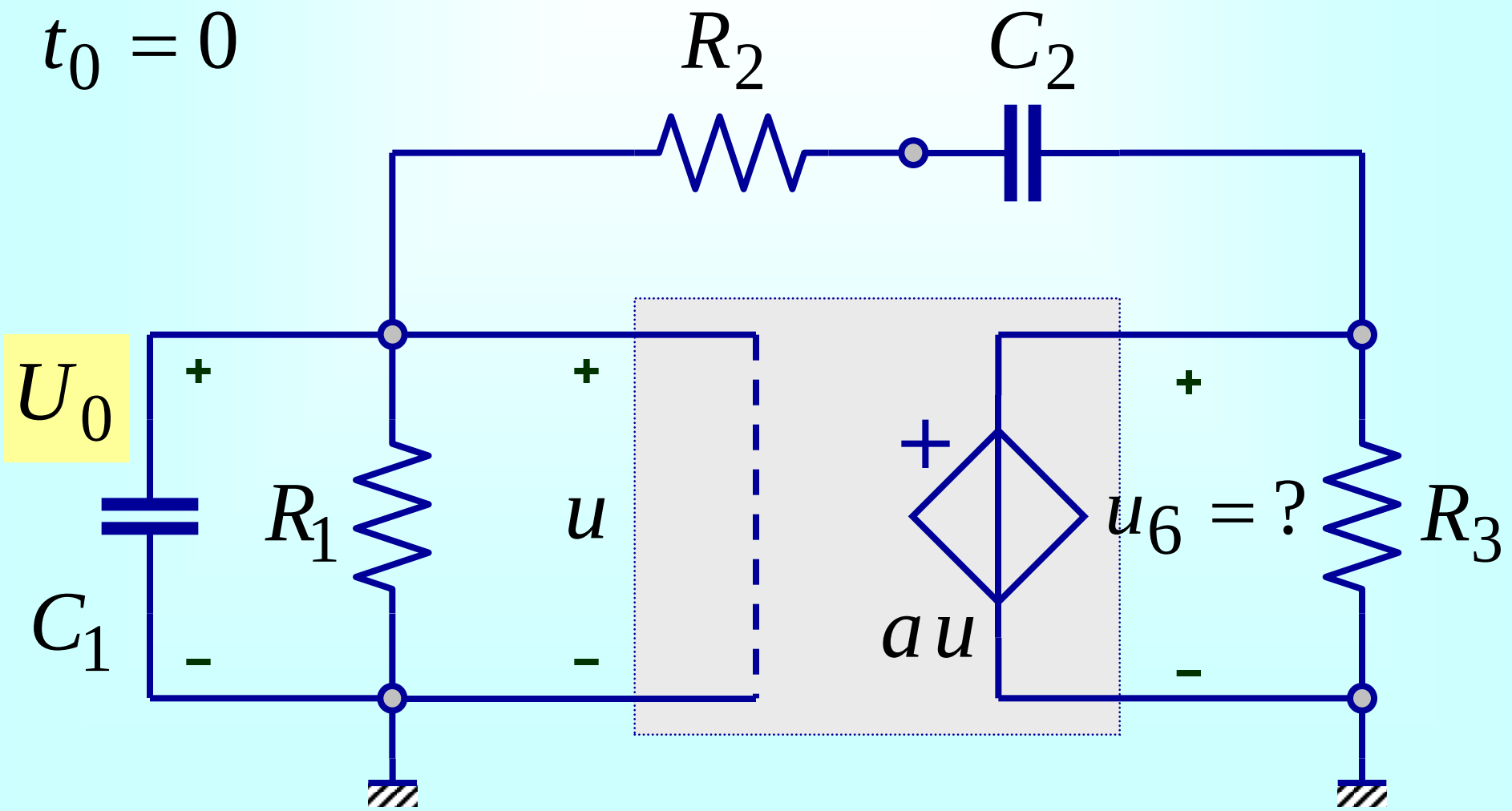
MATLAB: Simscape
Foundation Library
Utilities
Simulink




Scope
model delta impulsa
x 10^4
апроксимација δ(t)
површина троугла = 1
x 10^5
u(t)
x 10^-3
импулсни одзив за напон u(t)
Time offset: 0
x 10^-3

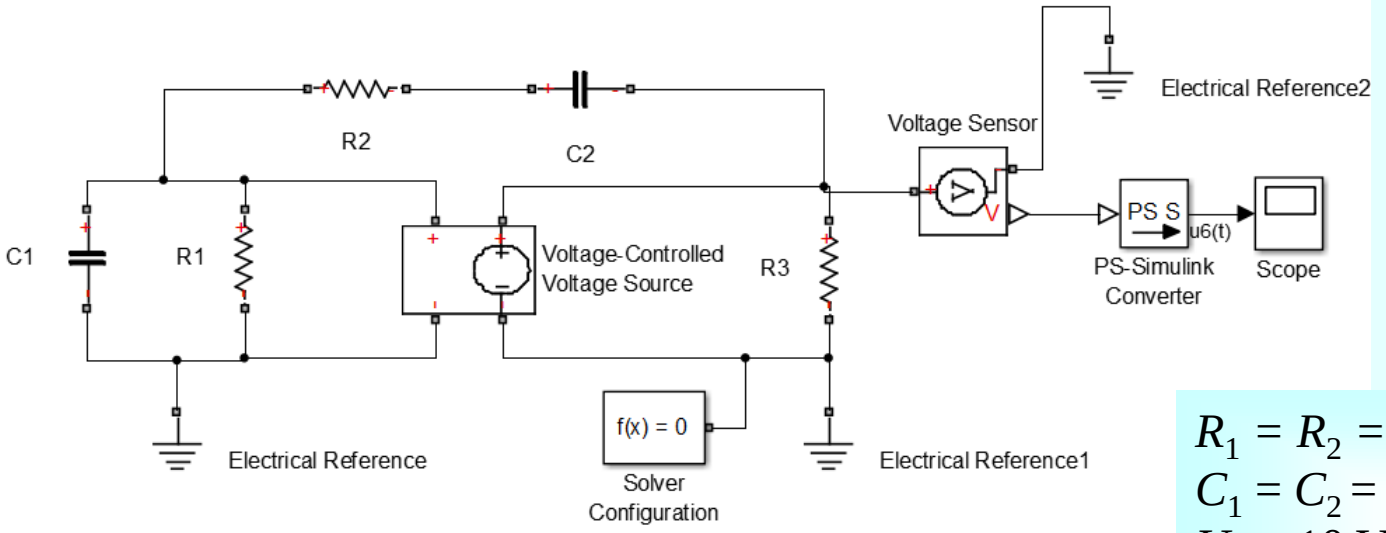

Scope
model delta impulsa
x 10^4
апроксимација δ(t)
површина троугла = 1
u(t)
x 10^5
импулсни одзив за напон u(t)
Time offset: 0

Одзив на сакупљену енергију

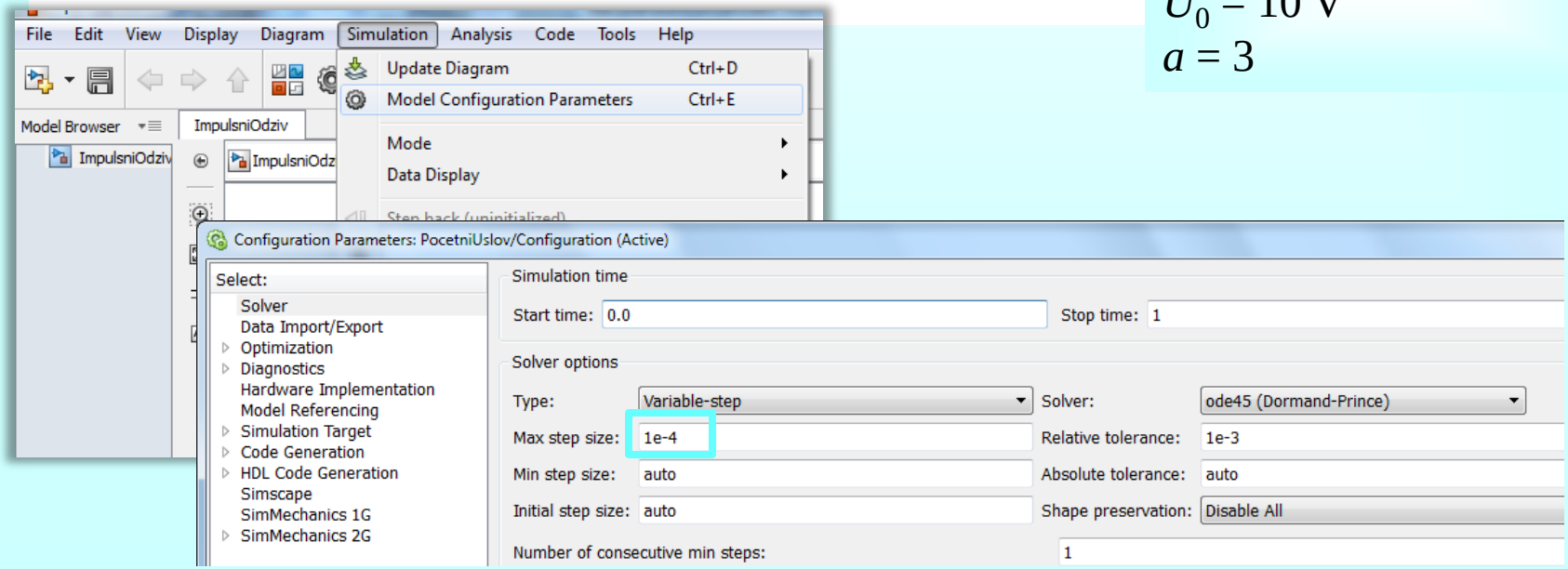


MATLAB: Simscape
Foundation Library, Utilities, Simulink

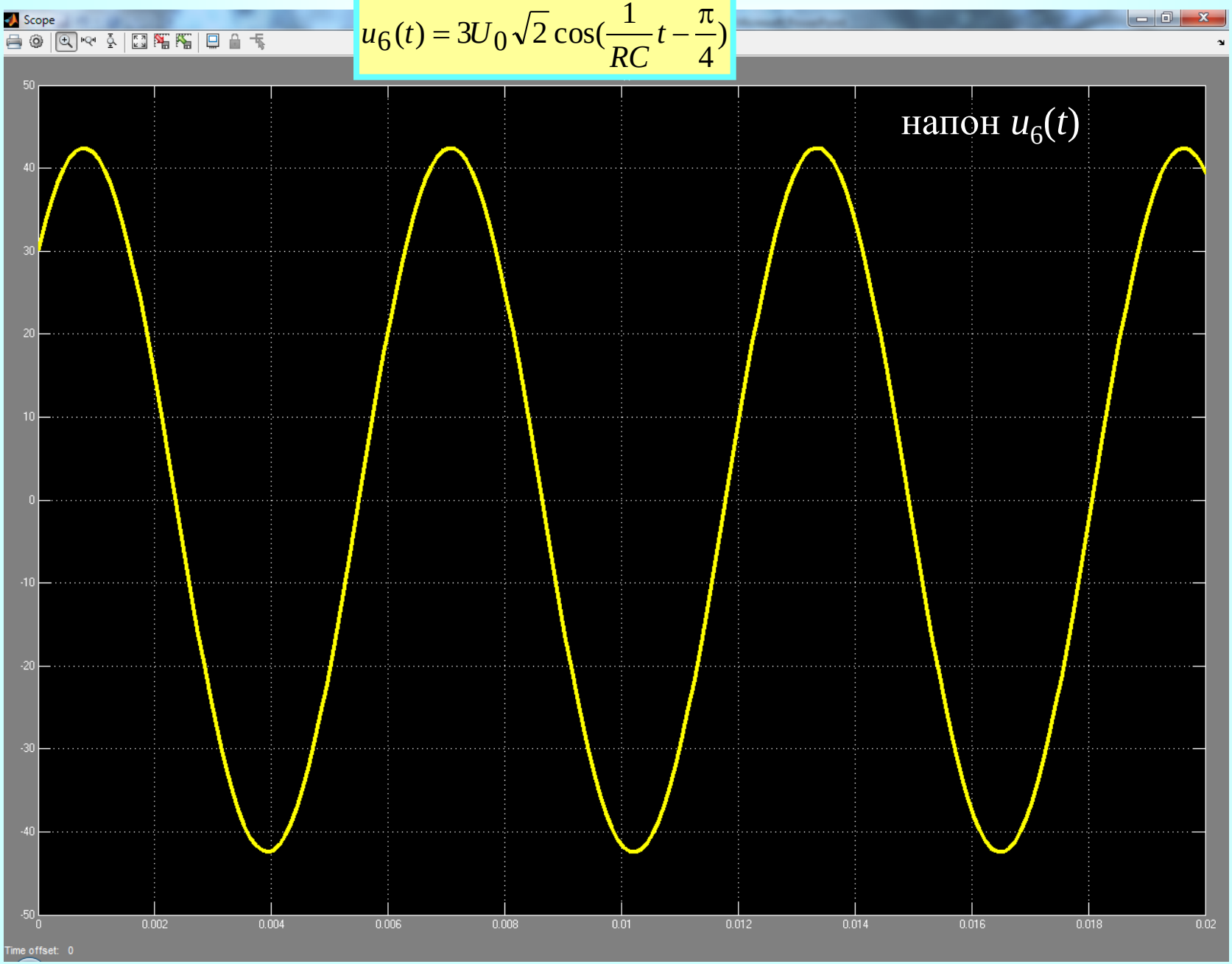
$t > t_0$



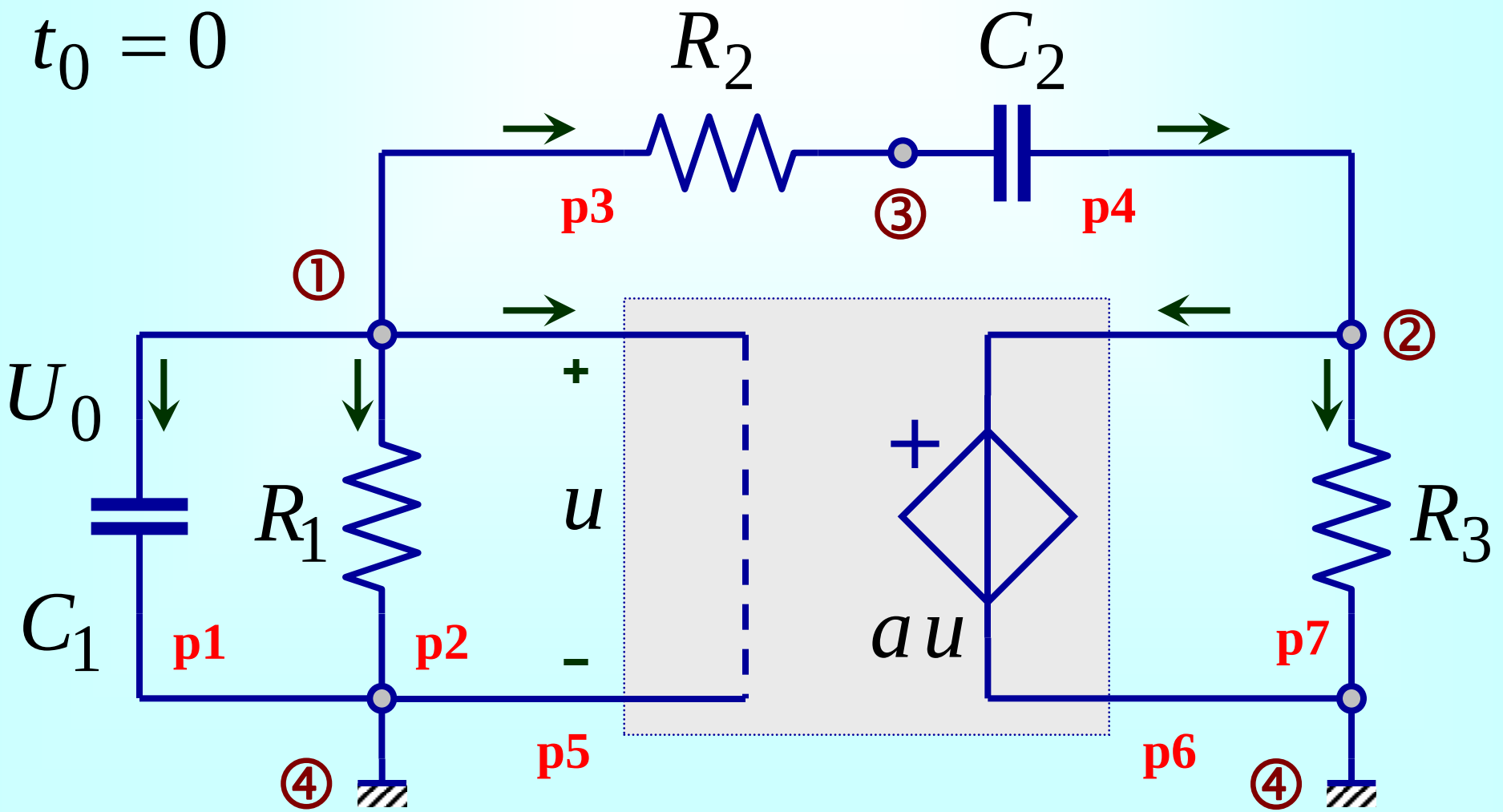
$R_1 = R_2 = R = 1\ \text{k}\Omega$
$C_1 = C_2 = 1\ \mu\text{F}$
$U_0 = 10\ \text{V}$
$a = 3$



$$u_6(t) = 3U_0\sqrt{2}\cos\left(\frac{1}{RC}t - \frac{\pi}{4}\right)$$



Ознаке чворова и приступа



MATLAB: MuPAD

Систем једначина кола

JednacineStanja_VinovOscilator* - MuPAD

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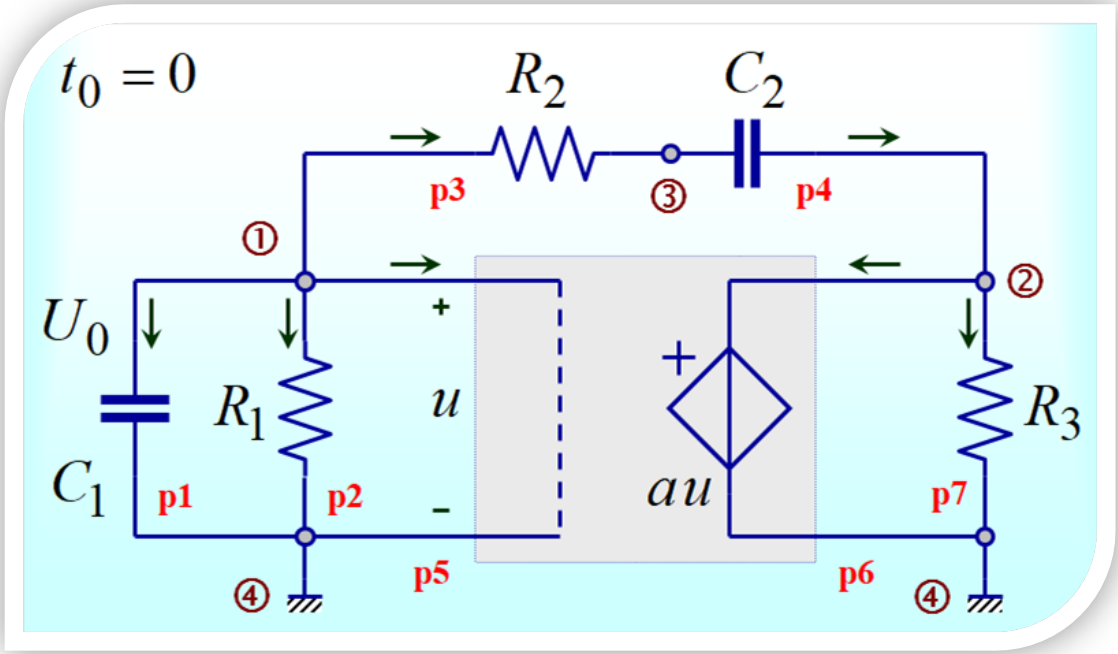
Generic Serif 18

```
jednacine:={i1 + i2 + i3 + i5 = 0,
-i4 + i6 + i7 = 0,
-i3 + i4 = 0,
u1 - u2 = 0,
u2 - u5 = 0,
u5 - u6 - u4 - u3 = 0,
u6 - u7 = 0,
i1 = C1 *Du1,
u2 = R1 * i2,
u3 = R2 * i3,
i4 = C2 * Du4,
i5 = 0,
u6 = a*u5,
u7 = R3*i7}
```



$$\{u1 - u2 = 0,\ u2 - u5 = 0,\ u6 - u7 = 0,\ u6 = a\ u5,\ i6 - i4 + i7 = 0,\ i1 + i2 + i3 + i5 = 0,$$
$$i1 = C1\ Du1,\ i4 = C2\ Du4,\ u5 - u4 - u3 - u6 = 0,\ i5 = 0,\ u2 = R1\ i2,\ u3 = R2\ i3,$$
$$u7 = R3\ i7,\ i4 - i3 = 0\}$$

MATLAB: MuPAD

Једначине стања

```
jednacineIzvoda:=groebner::eliminate(jednacine,{i1, i2, i3, i4, i5, i6, i7, u2, u3, u5, u6, u7})
```

$$[u1 + C1\ Du1\ R1 + C2\ Du4\ R1,\ u4 - u1 + a\ u1 + C2\ Du4\ R2]$$

```
assume({R1, R2, R3, C1, C2, a, t} in R_)
assumeAlso( R1>0 and R2>0 and R3>0 and C1>0 and C2>0 and a>0)
jednacineStanje := solve(jednacineIzvoda, {Du1, Du4})
```

$$\left\{\left[Du1 = -\frac{R1\ u1 + R2\ u1 - R1\ u4 - R1\ a\ u1}{C1\ R1\ R2},\ Du4 = -\frac{u4 - u1 + a\ u1}{C2\ R2}\right]\right\}$$

PromenljiveStanjaIzvodi:={u1=u1(t), u4=u4(t), Du1=D(u1)(t), Du4=D(u4)(t)}

$$\{u1 = u1(t),\ u4 = u4(t),\ Du1 = u1'(t),\ Du4 = u4'(t)\}$$

zamene := {R1=R, R2=R, R3=R, C1=C, C2=C, a=3}

$$\{R1 = R,\ R2 = R,\ R3 = R,\ a = 3,\ C1 = C,\ C2 = C\}$$

JS:=jednacineStanje | PromenljiveStanjaIzvodi | zamene

$$\left\{\left[u1'(t) = \frac{R\,u1(t) + R\,u4(t)}{C\,R^2},\ u4'(t) = -\frac{2\,u1(t) + u4(t)}{C\,R}\right]\right\}$$

op(JS)

$$\left[u1'(t) = \frac{R\,u1(t) + R\,u4(t)}{C\,R^2},\ u4'(t) = -\frac{2\,u1(t) + u4(t)}{C\,R}\right]$$

op(op(JS))

$$u1'(t) = \frac{R\,u1(t) + R\,u4(t)}{C\,R^2},\ u4'(t) = -\frac{2\,u1(t) + u4(t)}{C\,R}$$

JSpocetveVrednosti:={op(op(JS)), u1(0)=10, u4(0)=0}

$$\left\{u4'(t) = -\frac{2\,u1(t) + u4(t)}{C\,R},\ u1'(t) = \frac{R\,u1(t) + R\,u4(t)}{C\,R^2},\ u4(0) = 0,\ u1(0) = 10\right\}$$

MATLAB: MuPAD

Одзив – напон $u_6(t)$

```
odziv := ode::solve(JSpocetveVrednosti, {u1(t), u4(t)})
```

$$\left\{\left[u4(t) = -10\,e^{-\frac{t\,i}{C\,R}}\,i + 10\,e^{\frac{t\,i}{C\,R}}\,i,\ u1(t) = e^{-\frac{t\,i}{C\,R}}\,(5+5\,i) + e^{\frac{t\,i}{C\,R}}\,(5-5\,i)\right]\right\}$$

```
Simplify(u1(t)|odziv)
```

$$10\sqrt{2}\,\sin\left(\frac{\pi}{4} + \frac{t}{C\,R}\right)$$

```
u6(t):=Simplify(3*u1(t)|odziv)
```

$$30\sqrt{2}\,\sin\left(\frac{\pi}{4} + \frac{t}{C\,R}\right)$$

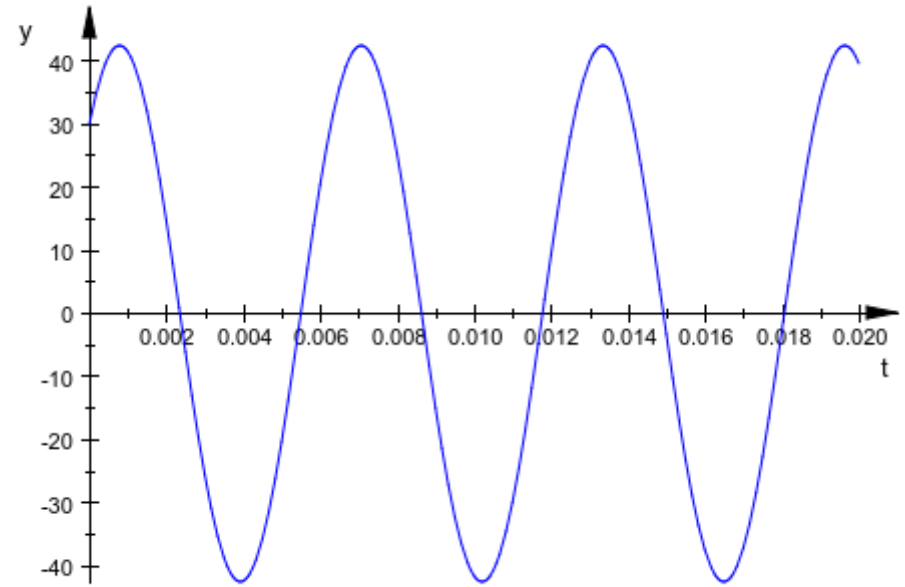
```
zamena:={R=1000, C=1e-6}
```

$$\{R = 1000,\ C = 0.000001\}$$

```
u6_zam(t):=Simplify(u6(t) | odziv |zamena)
```

$$42.42640687\,\cos(1000.0\,t - 0.7853981634)$$

```
plot(u6_zam(t), t=0..0.02)
```



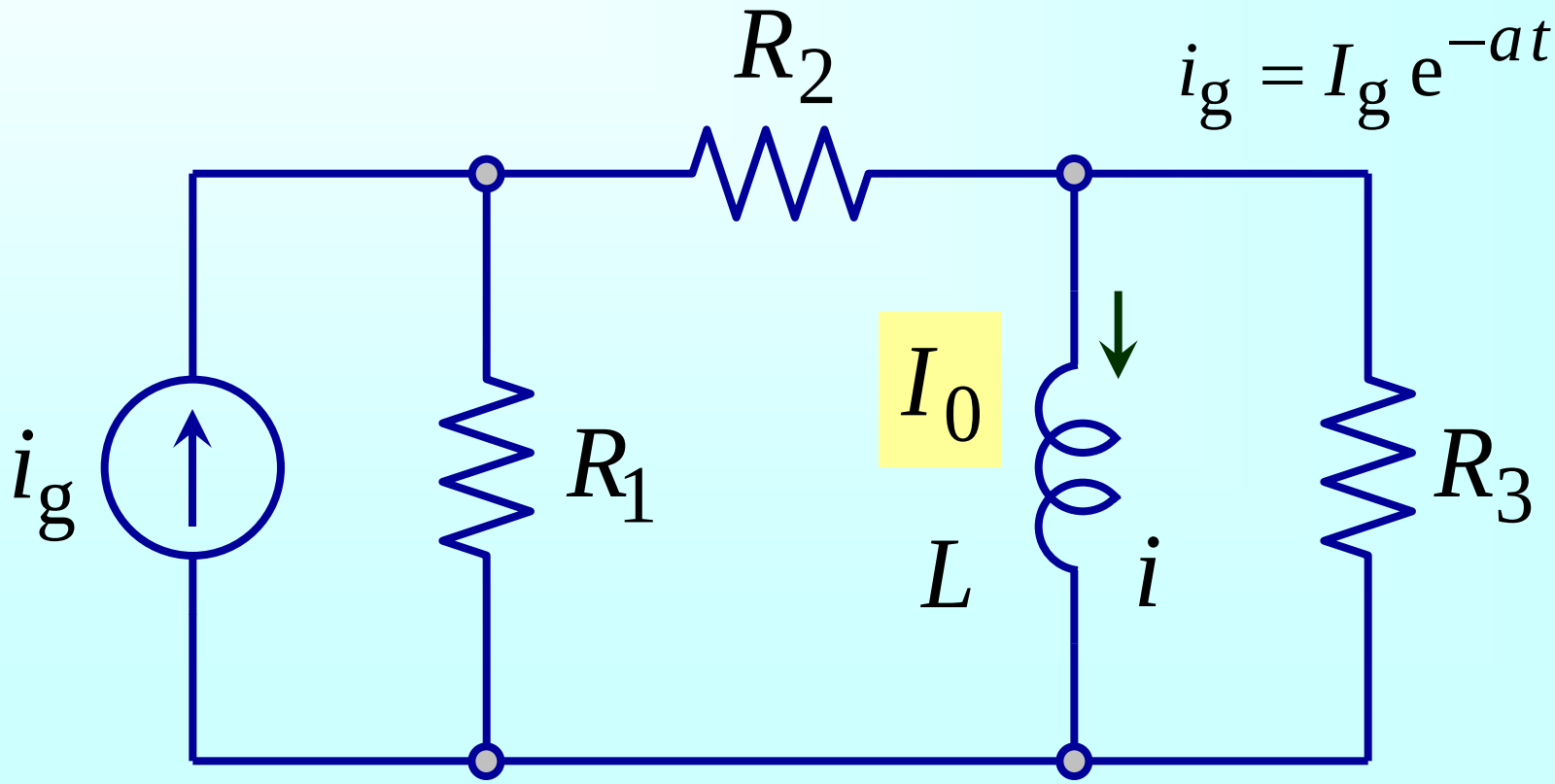
Одзив на побуду и сакупљену енергију

$t_0 = 0$

$R_1 = R_2 = R$

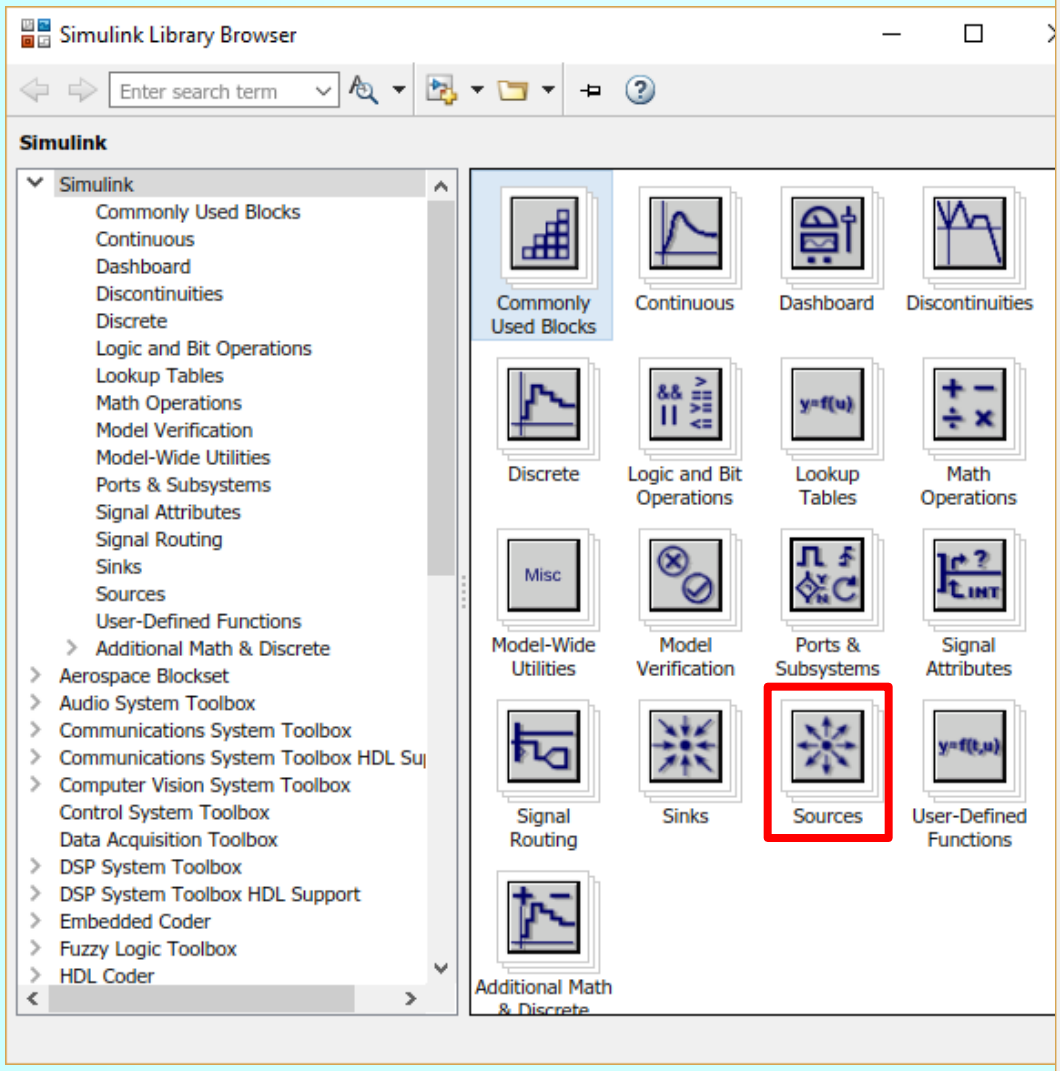
$R_3 = 2R$

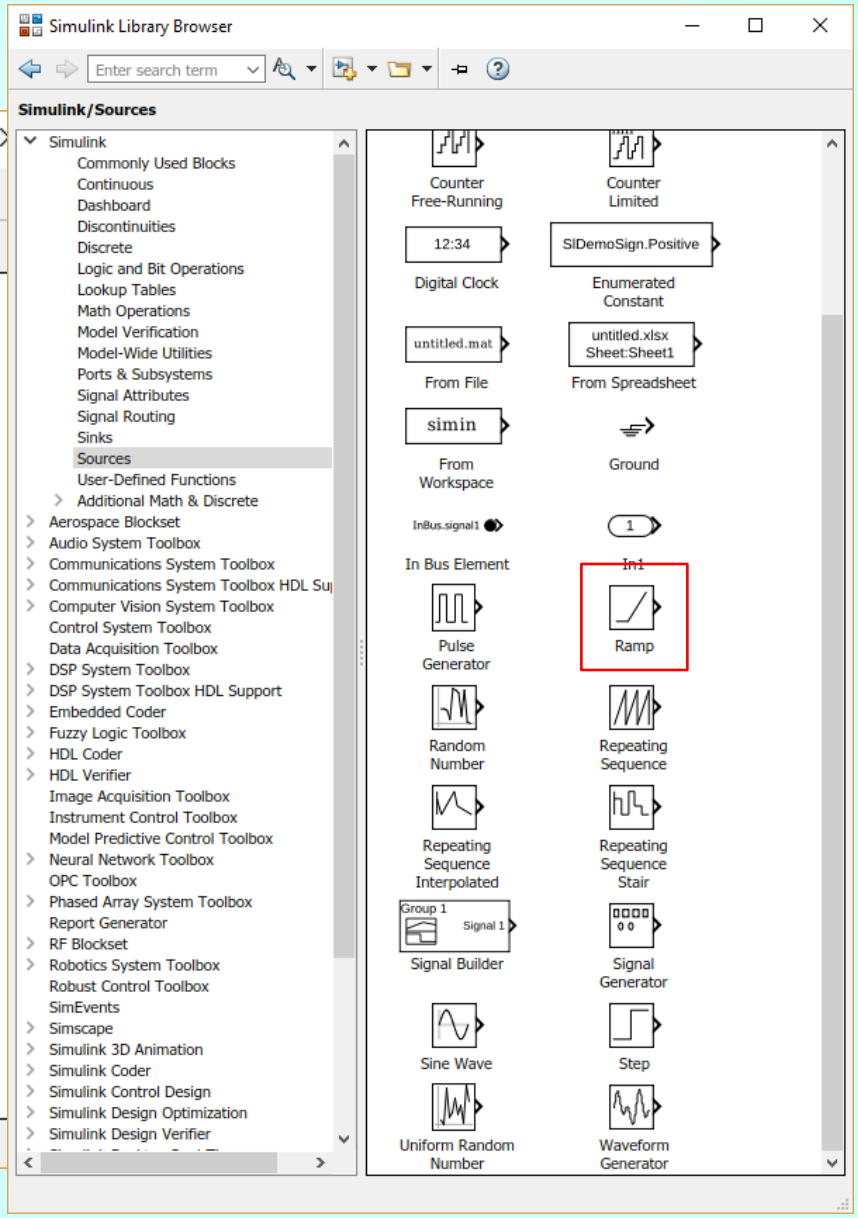
$i_g = I_g \, e^{-at} \, h(t)$



MATLAB: Simulink

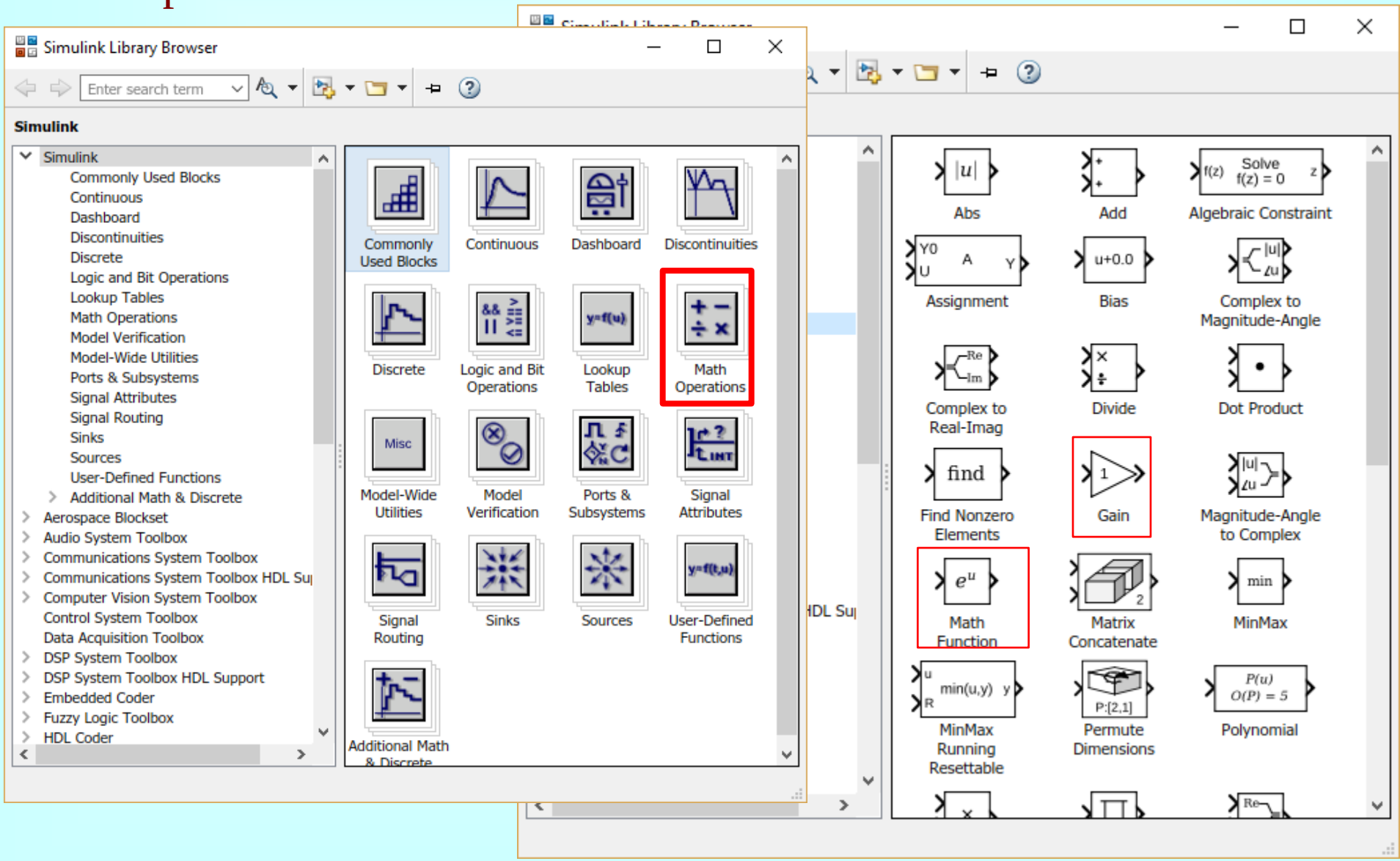
Sources



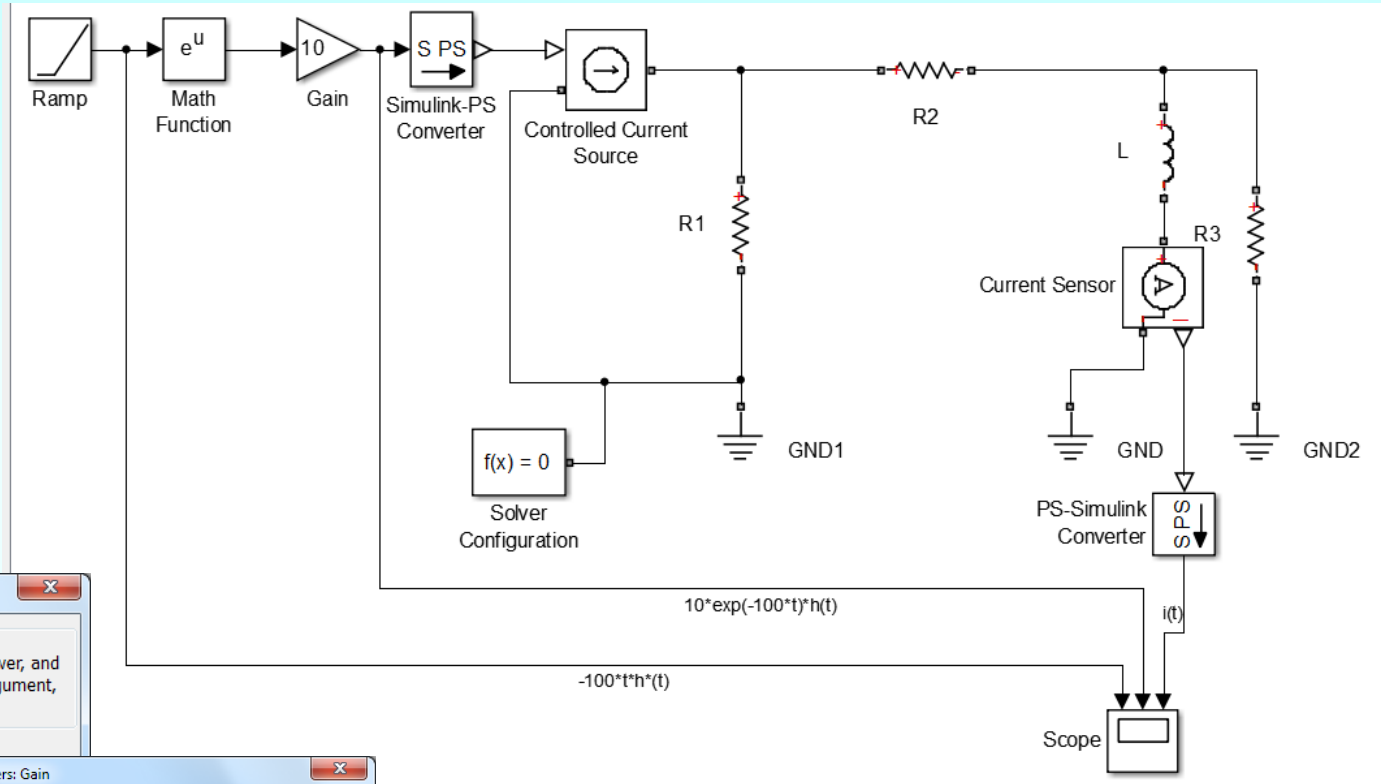


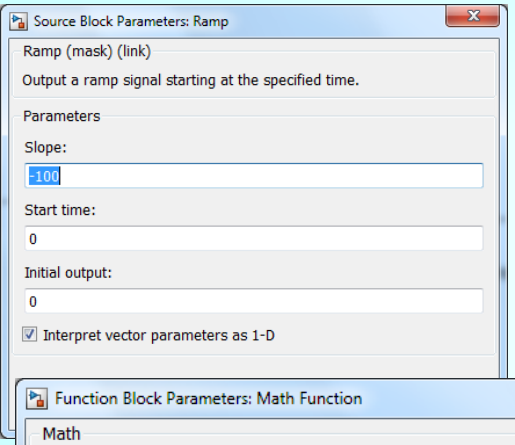
MATLAB: Simulink

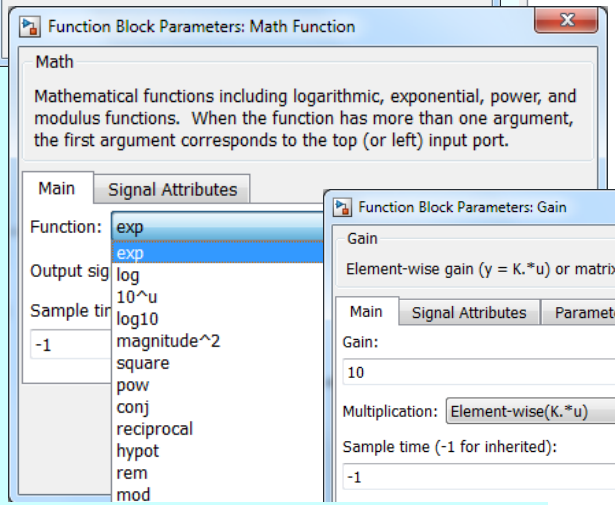
Math Operations

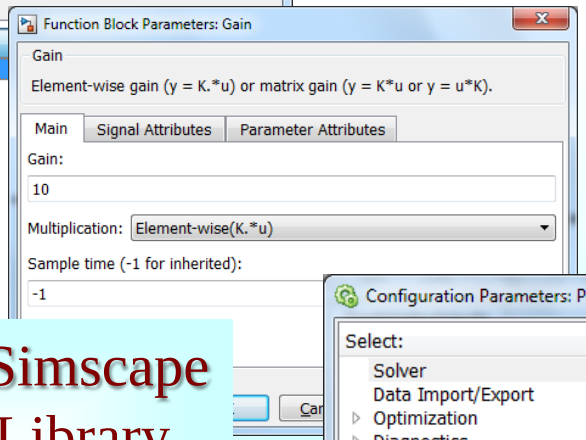


$$t > t_0, \quad t_0 = 0$$





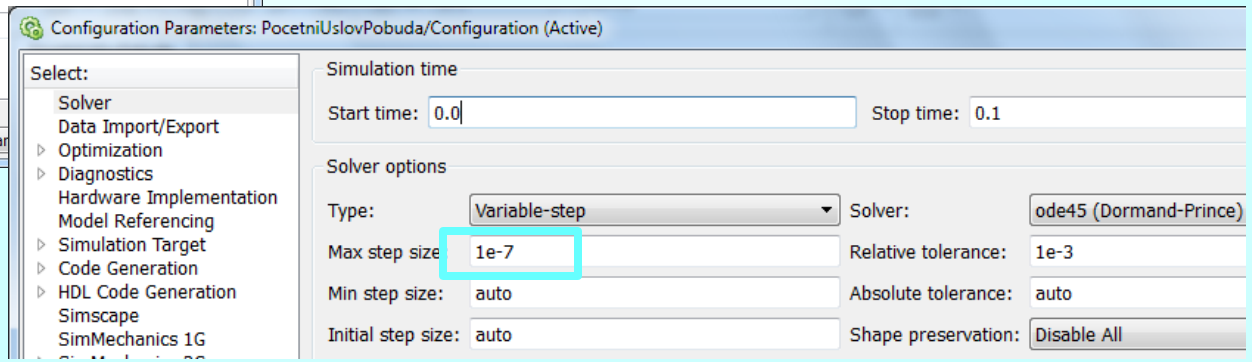




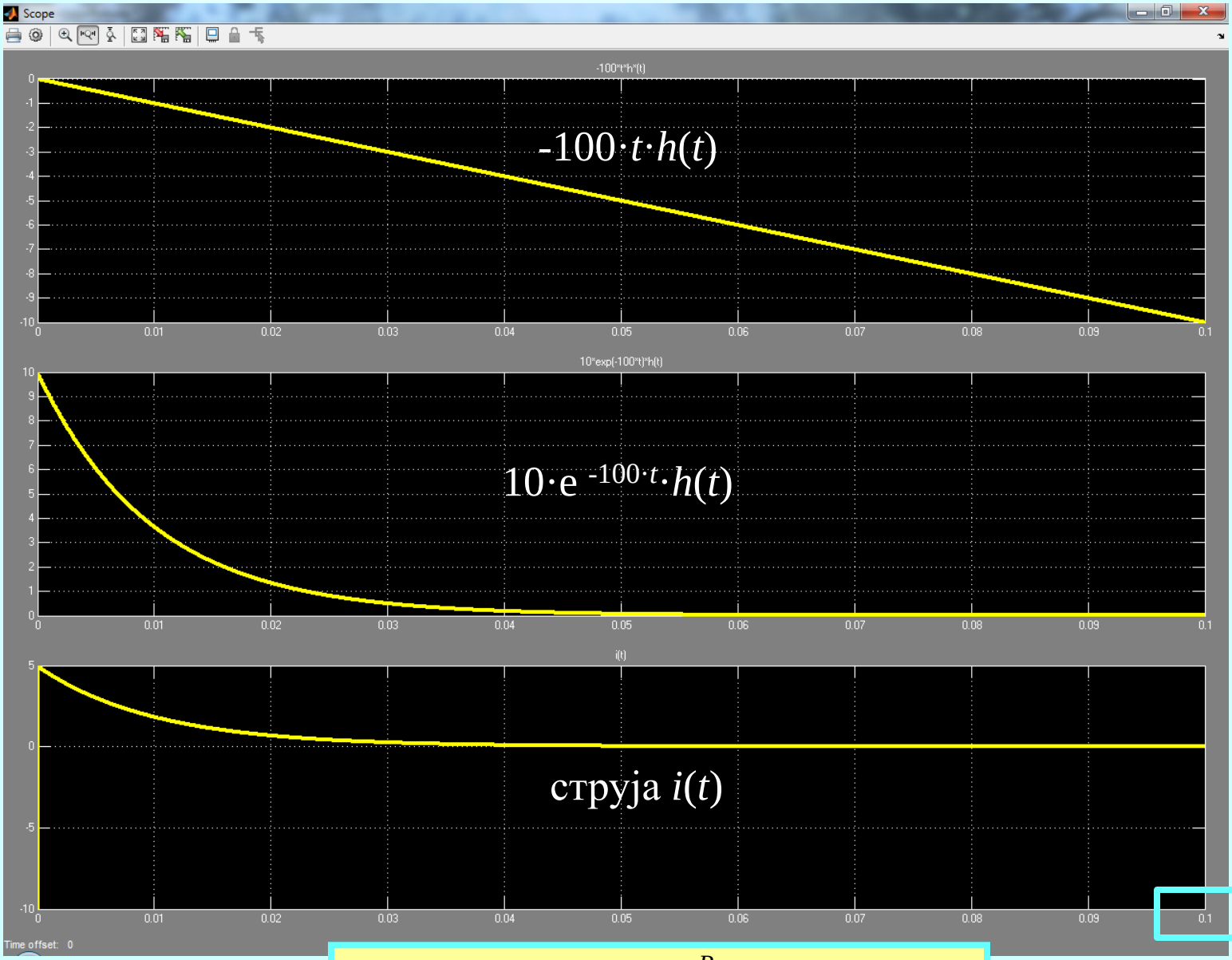
$$R_1 = R_2 = R = 1\text{k}\Omega, R_3 = 2R, L = 1\text{mH}$$

$$i_g(t) = I_g e^{-at} h(t), I_g = 10\,\text{A}, a = 100$$

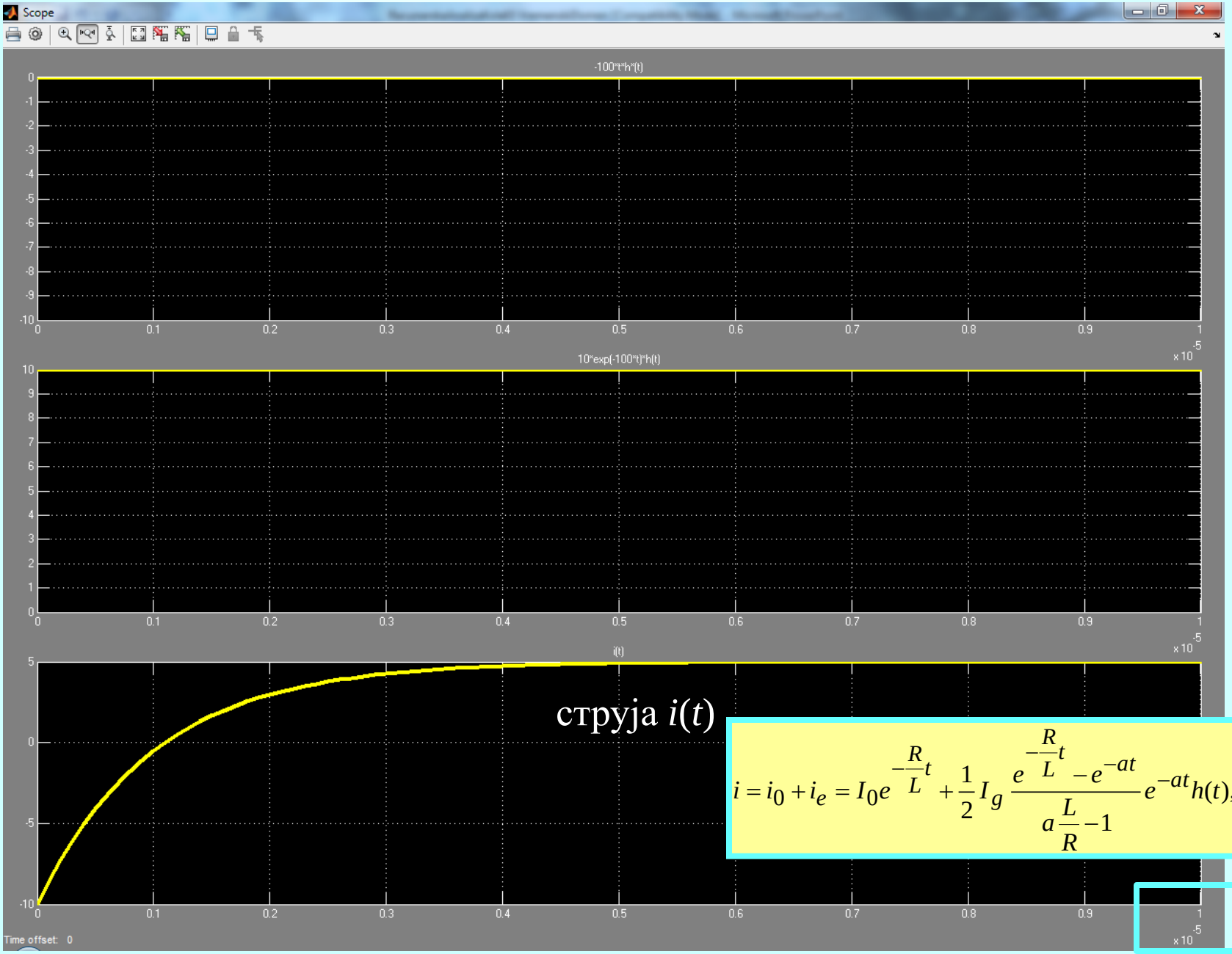
$$i(0^-) = I_0 = -10\,\text{A}$$



MATLAB: Simscape
Foundation Library
Utilities
Simulink



$$i(t) = i_0 + i_e = I_0 e^{-\frac{R}{L}t} + \frac{1}{2} I_g \frac{e^{-\frac{R}{L}t} - e^{-at}}{a\frac{L}{R} - 1} e^{-at} h(t), a \neq \frac{R}{L}$$



струја $i(t)$

$$i = i_0 + i_e = I_0 e^{-\frac{R}{L}t} + \frac{1}{2} I_g \frac{e^{-\frac{R}{L}t} - e^{-at}}{a\frac{L}{R} - 1} e^{-at} h(t), a \neq \frac{R}{L}$$

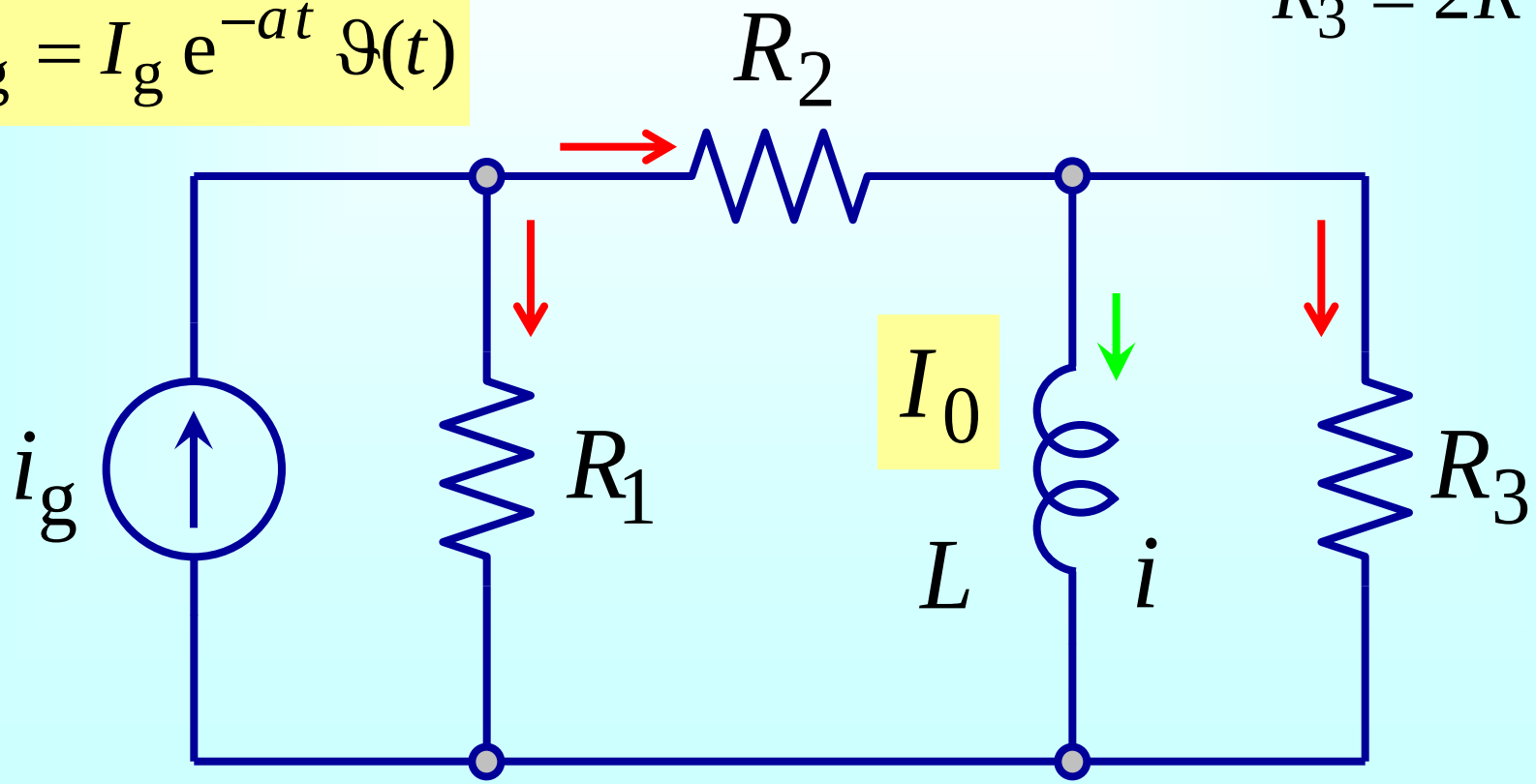
Коло са побудом и почет. енер.

$t_0 = 0$

$R_1 = R_2 = R$

$R_3 = 2R$

$i_g = I_g \, e^{-at} \, \vartheta(t)$



PotpunOdziv* - MuPAD

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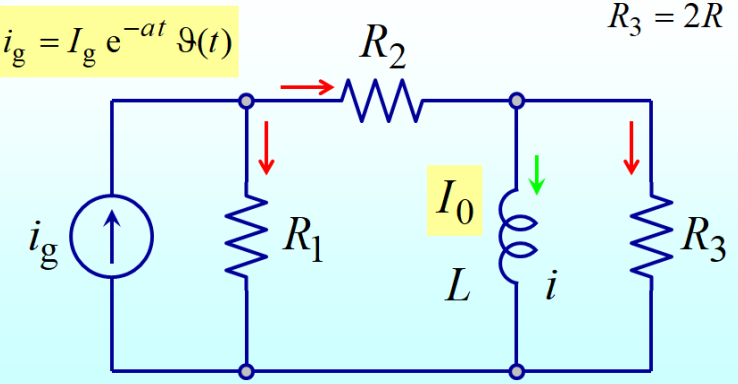
Систем једначина кола

$t_0 = 0$

$R_1 = R_2 = R$

$R_3 = 2R$

$i_g = I_g\, e^{-at}\, \vartheta(t)$




```
jednacine:={iR1 + iR2 - ig = 0,
-iR2 + i + iR3 = 0,
uR1 - uL - uR2= 0,
uL - uR3 = 0,
uL = L *Di,
uR1 = R1 * iR1,
uR2 = R2 * iR2,
uR3 = R3 * iR3}
```

$\{uL - uR3 = 0,\ i - iR2 + iR3 = 0,\ iR1 + iR2 - ig = 0,\ uL = Di\ L,\ uR1 - uL - uR2 = 0,$
$uR1 = R1\ iR1,\ uR2 = R2\ iR2,\ uR3 = R3\ iR3\}$

```
jednacineIzvoda:=groebner::eliminate(jednacine,{iR1, iR2, iR3, uR1, uR2, uR3, uL})
```

$[R1\ R3\ ig - Di\ L\ R2 - Di\ L\ R3 - R1\ R3\ i - R2\ R3\ i - Di\ L\ R1]$

```
assume({R1, R2, R3, L, t} in R_)
assumeAlso( R1>0 and R2>0 and R3>0 and L>0)
jednacineStanje := solve(jednacineIzvoda, {Di})
```

$$\left\{\left[Di = -\frac{R1\ R3\ i + R2\ R3\ i - R1\ R3\ ig}{L\ R1 + L\ R2 + L\ R3}\right]\right\}$$

MATLAB: MuPAD

PromenljiveStanjaIzvodi:={i=i(t), Di=D(i)(t)}

$$\{i = i(t),\ \mathrm{Di} = i'(t)\}$$

zamene := {R1=R, R2=R, R3=2*R, ig=Ig*exp(-a*t)*heaviside(t)}

$$\{\mathrm{R1} = R,\ \mathrm{R2} = R,\ \mathrm{R3} = 2\,R,\ \mathrm{ig} = \mathrm{Ig}\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)\}$$

JS:=jednacineStanje | PromenljiveStanjaIzvodi | zamene

$$\left\{\left[i'(t) = -\frac{4\,R^2\,i(t) - 2\,\mathrm{Ig}\,R^2\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)}{4\,L\,R}\right]\right\}$$

op(JS)

$$\left[i'(t) = -\frac{4\,R^2\,i(t) - 2\,\mathrm{Ig}\,R^2\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)}{4\,L\,R}\right]$$

op(op(JS))

$$i'(t) = -\frac{4\,R^2\,i(t) - 2\,\mathrm{Ig}\,R^2\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)}{4\,L\,R}$$

JSpocetveVrednosti:={op(op(JS)), i(0)=I0}

$$\left\{i(0) = \mathrm{I0},\ i'(t) = -\frac{4\,R^2\,i(t) - 2\,\mathrm{Ig}\,R^2\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)}{4\,L\,R}\right\}$$

Одзив – струја $i(t)$

JSpocetveVrednosti:={op(op(JS)), i(0)=I0}

$$\left\{ i(0) = \mathrm{I0},\ i'(t) = -\frac{4\,R^2\,i(t) - 2\,\mathrm{Ig}\,R^2\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)}{4\,L\,R} \right\}$$

odziv := ode::solve(JSpocetveVrednosti, {i(t)})

$$\left\{ \mathrm{I0}\,\mathrm{e}^{-\frac{R\,t}{L}} - \mathrm{e}^{-\frac{R\,t}{L}} \left(\frac{\mathrm{Ig}\,R\,\mathrm{heaviside}(t)}{2\,(R - L\,a)} - \frac{\mathrm{Ig}\,R\,\mathrm{e}^{\frac{R\,t}{L}}\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)}{2\,(R - L\,a)} \right) \right\}$$

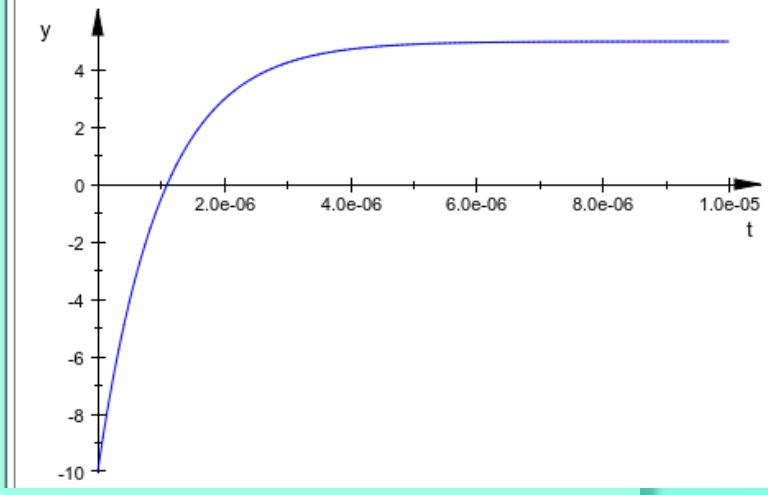
iL(t):=Simplify(op(odziv))

$$\mathrm{I0}\,\mathrm{e}^{-\frac{R\,t}{L}} - \frac{\frac{\mathrm{Ig}\,R\,\mathrm{e}^{-\frac{R\,t}{L}}\,\mathrm{heaviside}(t)}{2} - \frac{\mathrm{Ig}\,R\,\mathrm{e}^{-a\,t}\,\mathrm{heaviside}(t)}{2}}{R - L\,a}$$

zamena:={R=1000, L=1e-3, a=100, Ig=10, I0=-10}

$$\{\mathrm{I0} = -10,\ \mathrm{Ig} = 10,\ R = 1000,\ a = 100,\ L = 0.001\}$$

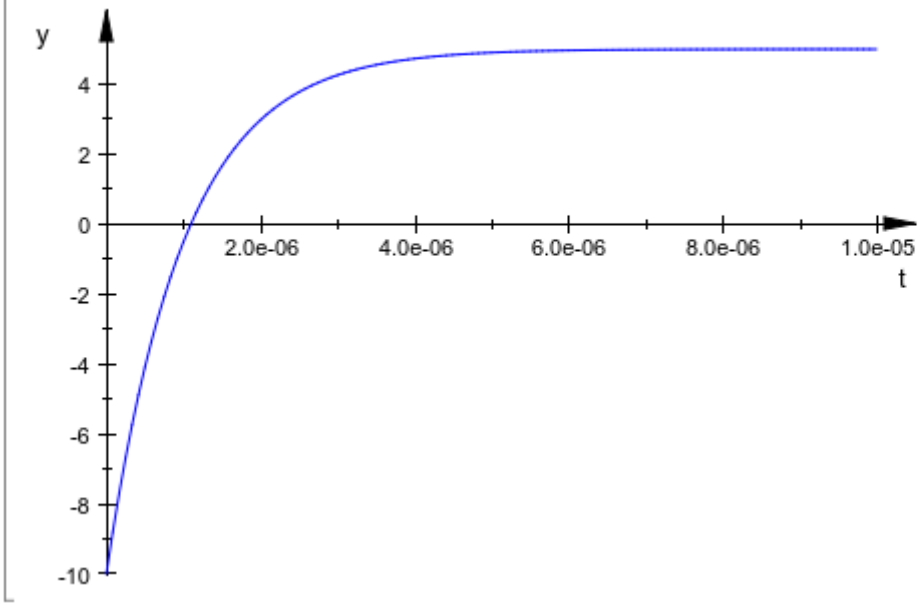
plot(uL_zam(t), t=0..1e-5)



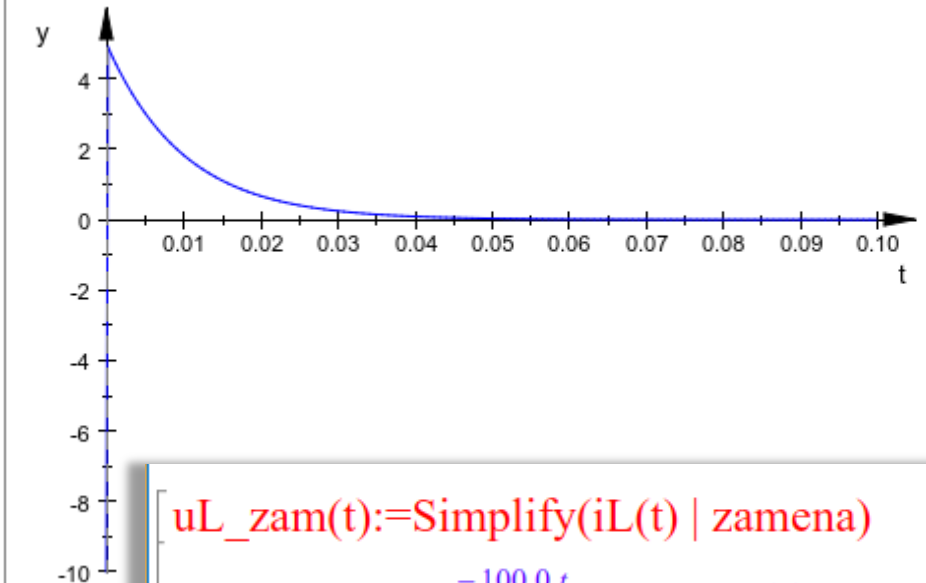
uL_zam(t):=Simplify(iL(t) | zamena)

$$5.00050005\,\mathrm{e}^{-100.0\,t}\,\mathrm{heaviside}(t) - 10\,\mathrm{e}^{-1000000.0\,t} - 5.00050005\,\mathrm{e}^{-1000000.0\,t}\,\mathrm{heaviside}(t)$$

plot(uL_zam(t), t=0..1e-5)



plot(uL_zam(t), t=0..0.1)

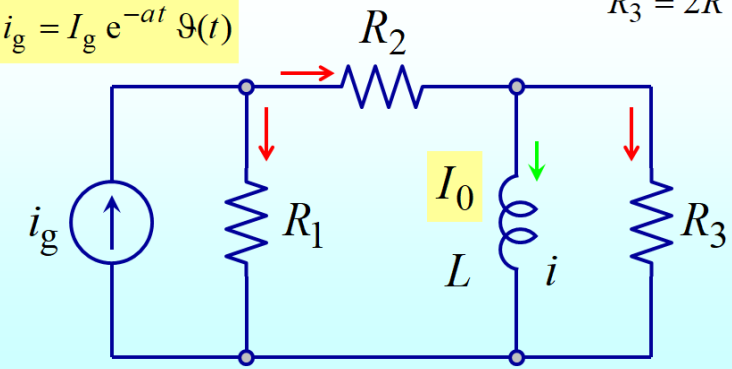


$t_0 = 0$

$R_1 = R_2 = R$

$R_3 = 2R$

$i_g = I_g \, e^{-at} \, \vartheta(t)$



uL_zam(t):=Simplify(iL(t) | zamena)

$$5.00050005\, e^{-100.0\, t}\, \text{heaviside}(t) - 10\, e^{-1000000.0\, t} - 5.00050005\, e^{-1000000.0\, t}\, \text{heaviside}(t)$$