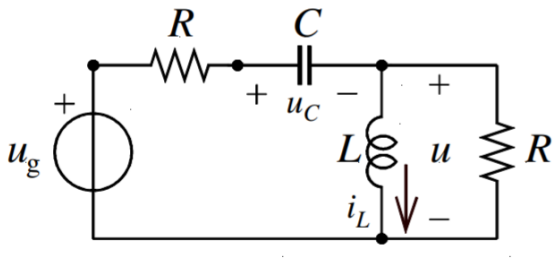
Задаци

LC-реализација филтра (Butterworth maximally flat highpass approximation) има познате параметре и

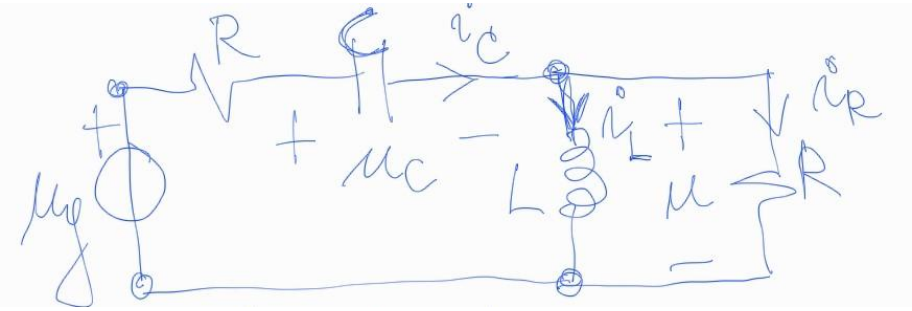
$L = \frac{R}{\sqrt{2}\,\Omega}$, $C = \frac{1}{\sqrt{2}\,R\Omega}$, и реални параметар $\Omega > 0$.



Решимо задатак са испита!

Практикум из рачунарске анализе трофазних кола,
ЕНЕРГЕТИКА, 4. семестар !!!

Поставимо систем једначина кола (СЈК)



1) $i_C = i_L + i_R$

2) $u_g = R \cdot i_C + u_C + u$

3) $i_C = C \cdot \frac{du_C}{dt}$

4) $u_L = L \frac{di_L}{dt}$

5) $u = R \cdot i_R$

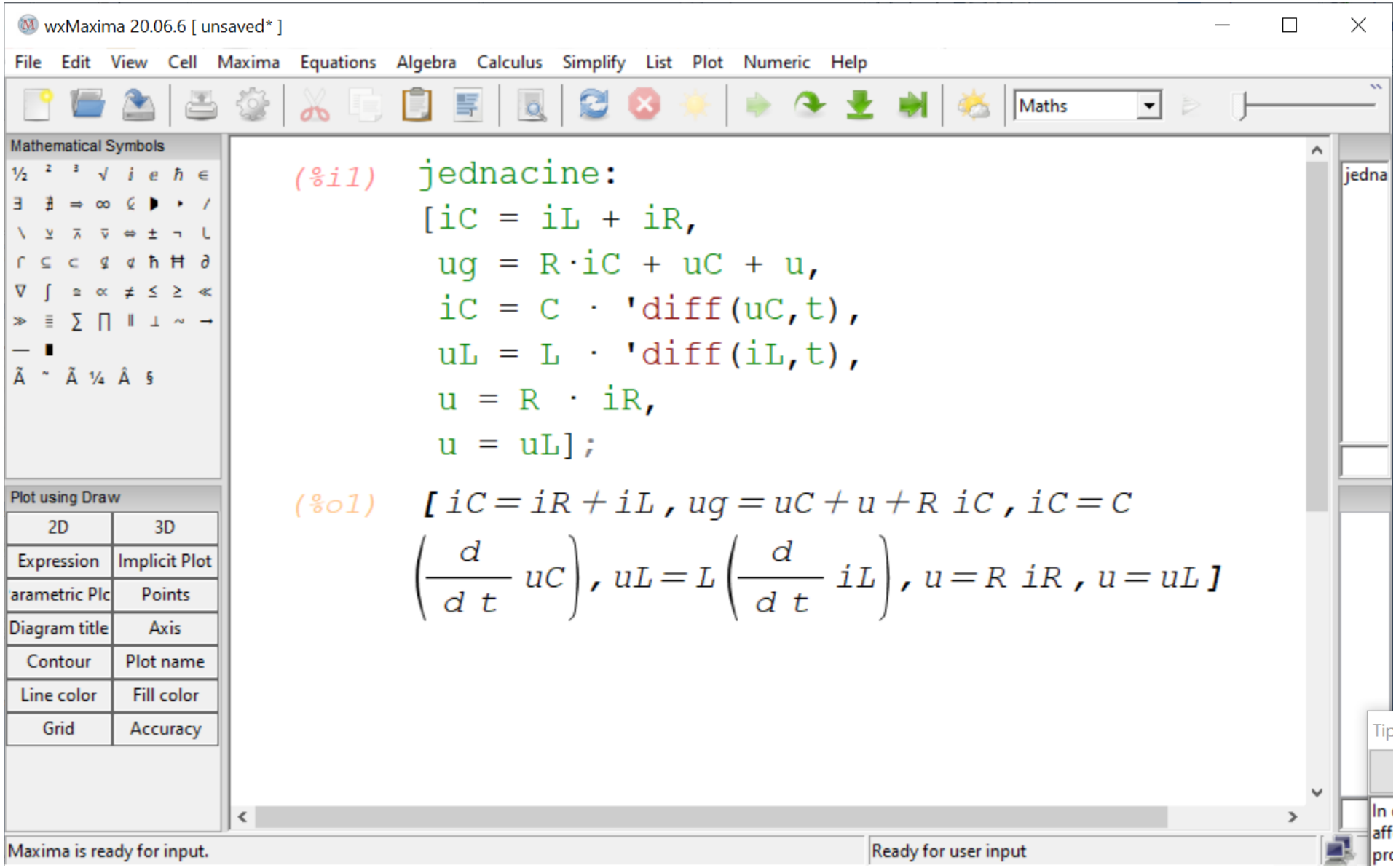
6) $u = u_L$

ПРОМЕНЉИВЕ:

i_C i_L u

u_C u_L i_R

http://wxmaxima-developers.github.io/wxmaxima/



Одредити једначине стања (ЈС)

(10) Једначине стања су (заокружити тачне једначине)

(а) $\mathrm{d}u_C/\mathrm{d}t = -(\Omega/\sqrt{2})u_C + (\Omega R/\sqrt{2})i_L + (\Omega/\sqrt{2})u_\mathrm{g}$,

(б) $\mathrm{d}u_C/\mathrm{d}t = (\Omega/\sqrt{2})u_C - (\Omega R/\sqrt{2})i_L + \left(\Omega/\sqrt{2}\right)u_\mathrm{g}$,

(в) $0 = u_C - Ri_L - u_\mathrm{g}$,

(г) $\mathrm{d}i_L/\mathrm{d}t = -\Omega/(\sqrt{2}R)u_C - \Omega/\sqrt{2}\,i_L + \Omega u_\mathrm{g}/(\sqrt{2}R)$,

(д) $0 = \sqrt{2}u_C + 2Ri_L - \sqrt{2}u_\mathrm{g}$,

(ђ) $\dfrac{\mathrm{d}u_C}{\mathrm{d}t} = \Omega u_C + \sqrt{2}R\Omega i_L$.

Нађимо JC користећи Maxima

```
jednacine:
[iC = iL + iR,
 ug = R·iC + uC + u,
 iC = C · 'diff(uC,t),
 uL = L · 'diff(iL,t),
 u = R · iR,
 u = uL];
```

Стања кола су: напон кондезатора u_C и струја калема i_L

$$[iC = iR + iL,\ ug = uC + u + R\ iC,\ iC = C\left(\frac{d}{d\,t}\ uC\right),\ uL = L\left(\frac{d}{d\,t}\ iL\right),\ u = R\ iR,\ u = uL]$$

Извршимо смену

$$\frac{du_C}{dt} \to Du_c$$

$$\frac{di_L}{dt} \to Di_L$$

```
(%i2) jednacineDiLDuC: jednacine, 'diff(iL,t)=DiL, 'diff(uC,t)=DuC;
```

$$(\%o2)\quad [iC = iR + iL,\ ug = uC + u + R\ iC,\ iC = C\ DuC,\ uL = DiL\ L,\ u = R\ iR,\ u = uL]$$

```
(%i3) JednacineIzvoda: eliminate(jednacineDiLDuC,
      [iC, uL, u, iR]);
```

$$(\%o3)\quad [ug - uC + R\ iL - 2\ C\ DuC\ R,\ R\ (ug - uC - R\ iL - 2\ DiL\ L)]$$

```
(%i4) jednacineStanja: linsolve(JednacineIzvoda, [DiL, DuC]);
```

$$(\%o4)\quad [DiL = \frac{ug - uC - R\ iL}{2\ L},\ DuC = \frac{ug - uC + R\ iL}{2\ C\ R}]$$

```
(%i4) jednacineStanja: linsolve(JednacineIzvoda, [DiL, DuC]);
```

$$(\%o4)\quad \left[DiL=\frac{ug-uC-R\,iL}{2\,L},\ DuC=\frac{ug-uC+R\,iL}{2\,C\,R}\right]$$

```
(%i5) jednacineDiff: jednacineStanja,
      DiL='diff(iL, t),
      DuC='diff(uC, t);
```

$$(\%o5)\quad \left[\frac{d}{d\,t}\,iL=\frac{ug-uC-R\,iL}{2\,L},\ \frac{d}{d\,t}\,uC=\frac{ug-uC+R\,iL}{2\,C\,R}\right]$$

```
(%i6) zamena:[L = R/(Omega·sqrt(2)), C = 1/(Omega·R·sqrt(2))];
```

$$(\%o6)\quad \left[L=\frac{R}{\sqrt{2}\,Omega},\ C=\frac{1}{\sqrt{2}\,Omega\,R}\right]$$

```
(%i7) jednacineDiff, zamena;
```

$$(\%o7)\quad \left[\frac{d}{d\,t}\,iL=\frac{Omega\,(ug-uC-R\,iL)}{\sqrt{2}\,R},\ \frac{d}{d\,t}\,uC=\frac{Omega\,(ug-uC+R\,iL)}{\sqrt{2}}\right]$$

г) $\mathrm{d}i_L/\mathrm{d}t=-\Omega/(\sqrt{2}R)\,u_C-\Omega/\sqrt{2}\,i_L+\Omega u_g/(\sqrt{2}R)$,

а) $\mathrm{d}u_C/\mathrm{d}t=-(\Omega/\sqrt{2})\,u_C+(\Omega R/\sqrt{2})\,i_L+(\Omega/\sqrt{2})\,u_g$,

Филтар нема почетну енергију и $u_{\mathrm{g}} = U\vartheta(t)$.

(7) Излазни напон $u(t)$ је

(а) $\dfrac{U}{\sqrt{2}}\mathrm{e}^{-\frac{\Omega t}{\sqrt{2}}}\sin\left(\dfrac{\pi}{4}-\dfrac{\Omega t}{\sqrt{2}}\right)\vartheta(t)$,

(б) $\dfrac{U}{\sqrt{2}}\mathrm{e}^{-\frac{\Omega t}{\sqrt{2}}}\sin\left(\dfrac{\pi}{2}-\dfrac{\Omega t}{\sqrt{2}}\right)\vartheta(t)$,

(в) $\dfrac{U}{\sqrt{2}}\mathrm{e}^{-\frac{\Omega t}{\sqrt{2}}}\cos\left(\dfrac{\pi}{4}-\dfrac{\Omega t}{\sqrt{2}}\right)$,

(г) $-\dfrac{U}{\sqrt{2}}\mathrm{e}^{-\frac{\Omega t}{\sqrt{2}}}\sin\left(\dfrac{\Omega t}{\sqrt{2}}\right)$, (д) $\dfrac{U}{\sqrt{2}}\sin\left(\dfrac{\pi}{4}-\dfrac{\Omega t}{\sqrt{2}}\right)\vartheta(t)$,

```
(%i8) jednacineLT: jednacine, 'diff(iL,t)=s·iL, 'diff(uC,t)=s·uC, zamena;
```

$$(\%o8)\quad [iC=iR+iL,\ ug=uC+u+R\,iC,\ iC=\frac{s\,uC}{\sqrt{2}\,Omega\,R},\ uL=\frac{R\,iL\,s}{\sqrt{2}\,Omega},\ u=R\,iR,\ u=uL]$$

```
(%i9) promenljive: [iC, uC, iL, uL, u, iR];
```

$$(\%o9)\quad [iC,uC,iL,uL,u,iR]$$

```
(%i10) assume(R>0, Omega>0);
```

$$(\%o10)\quad [R>0,Omega>0]$$

Применимо Лапласову трансформацију на СЈК

```
(%i11) odziv: solve(jednacineLT, promenljive);
```

$$(\%o11)\quad [[iC=\frac{(s^2+\sqrt{2}\,Omega\,s)\,ug}{R\,(2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2)},\ uC=\frac{(\sqrt{2}\,Omega\,s+2\,Omega^2)\,ug}{2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2},$$

$$iL=\frac{\sqrt{2}\,Omega\,s\,ug}{R\,(2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2)},\ uL=\frac{s^2\,ug}{2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2},\ u=$$

$$\frac{s^2\,ug}{2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2},\ iR=\frac{s^2\,ug}{R\,(2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2)}]]$$

```
(%i12) Us: u, odziv;
```

$$(\%o12)\quad \frac{s^2\,ug}{2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2}$$

```
(%i12) Us: u, odziv;
```

$$(\%o12)\quad \frac{s^2\, ug}{2\,s^2+2^{3/2}\,Omega\,s+2\,Omega^2}$$

```
(%i13) u_t: ilt(ev(Us, ug=U/s), s, t), factor;
```

$$(\%o13)\quad -\frac{U\ \%e^{-\frac{Omega\ t}{\sqrt{2}}}\left(\sin\left(\frac{Omega\ t}{\sqrt{2}}\right)-\cos\left(\frac{Omega\ t}{\sqrt{2}}\right)\right)}{2}$$

Филтар нема почетну енергију и $u_g = U\vartheta(t)$.

(7) Излазни напон $u(t)$ је

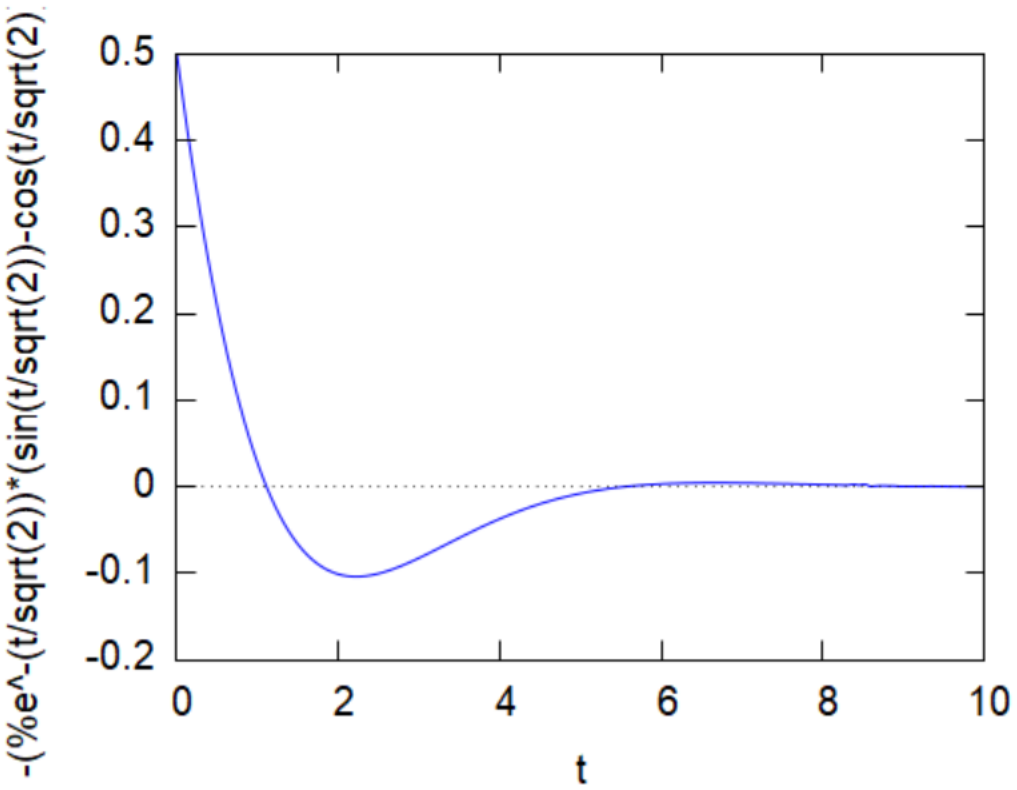
(a) $$\frac{U}{\sqrt{2}}\,\mathrm{e}^{-\frac{\Omega t}{\sqrt{2}}}\sin\left(\frac{\pi}{4}-\frac{\Omega t}{\sqrt{2}}\right)\vartheta(t),$$

```
ratsimp((U/sqrt(2))·%e^(-Omega·t/sqrt(2))·trigrat(sin(%pi/4-Omega·t/sqrt(2))))
```

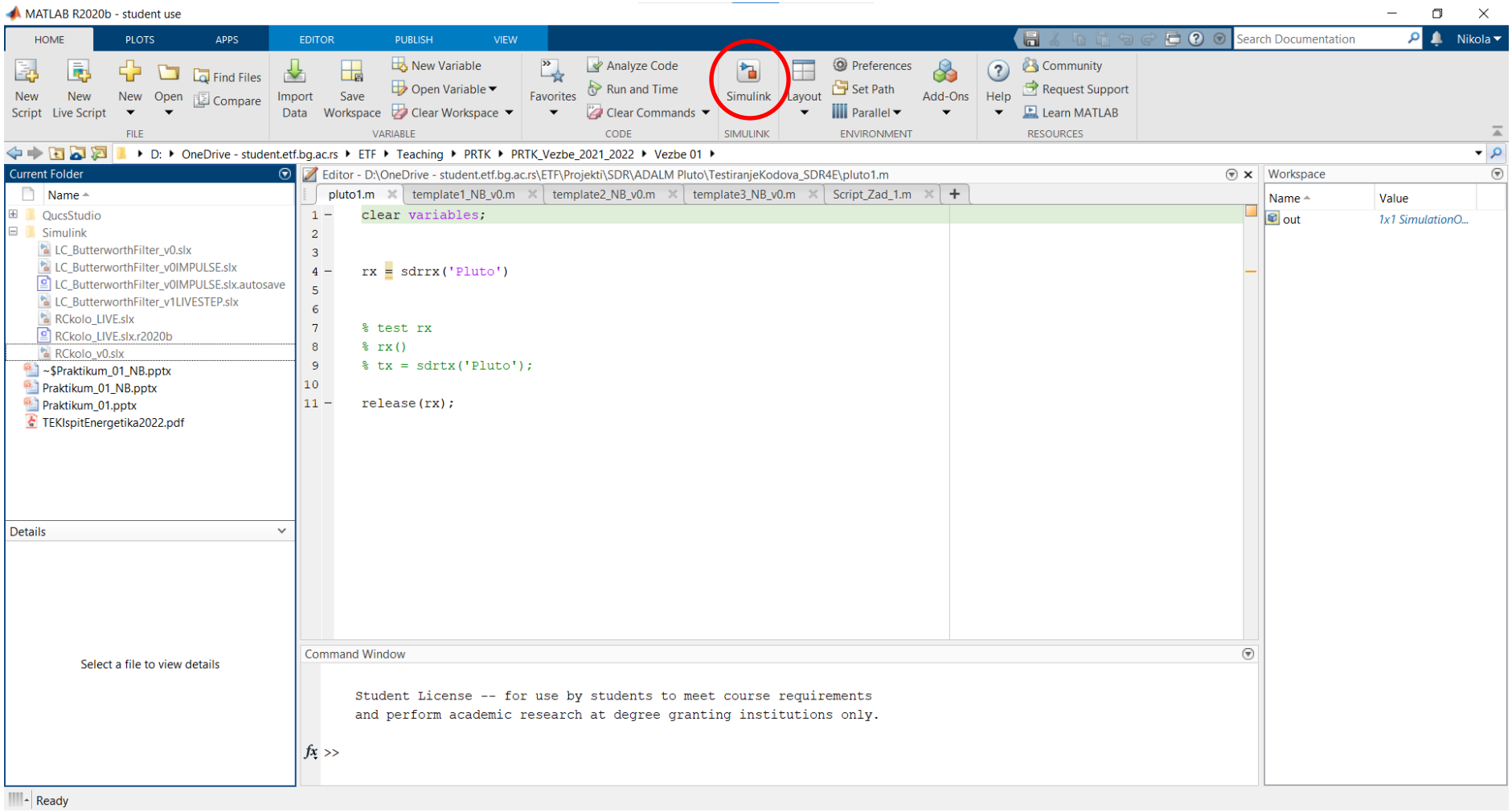
$$-\frac{\%e^{-\frac{Omega\ t}{\sqrt{2}}}\left(U\sin\left(\frac{Omega\ t}{\sqrt{2}}\right)-U\cos\left(\frac{Omega\ t}{\sqrt{2}}\right)\right)}{2}$$

Приказ одзива – излазног напона

```
wxplot2d(ev(u_t, [Omega=1, R=1, U=1]), [t, 0, 10]);
```



MATLAB - Основни прозор



MATLAB Simulink - елементи

Задаци

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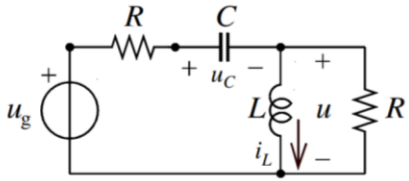

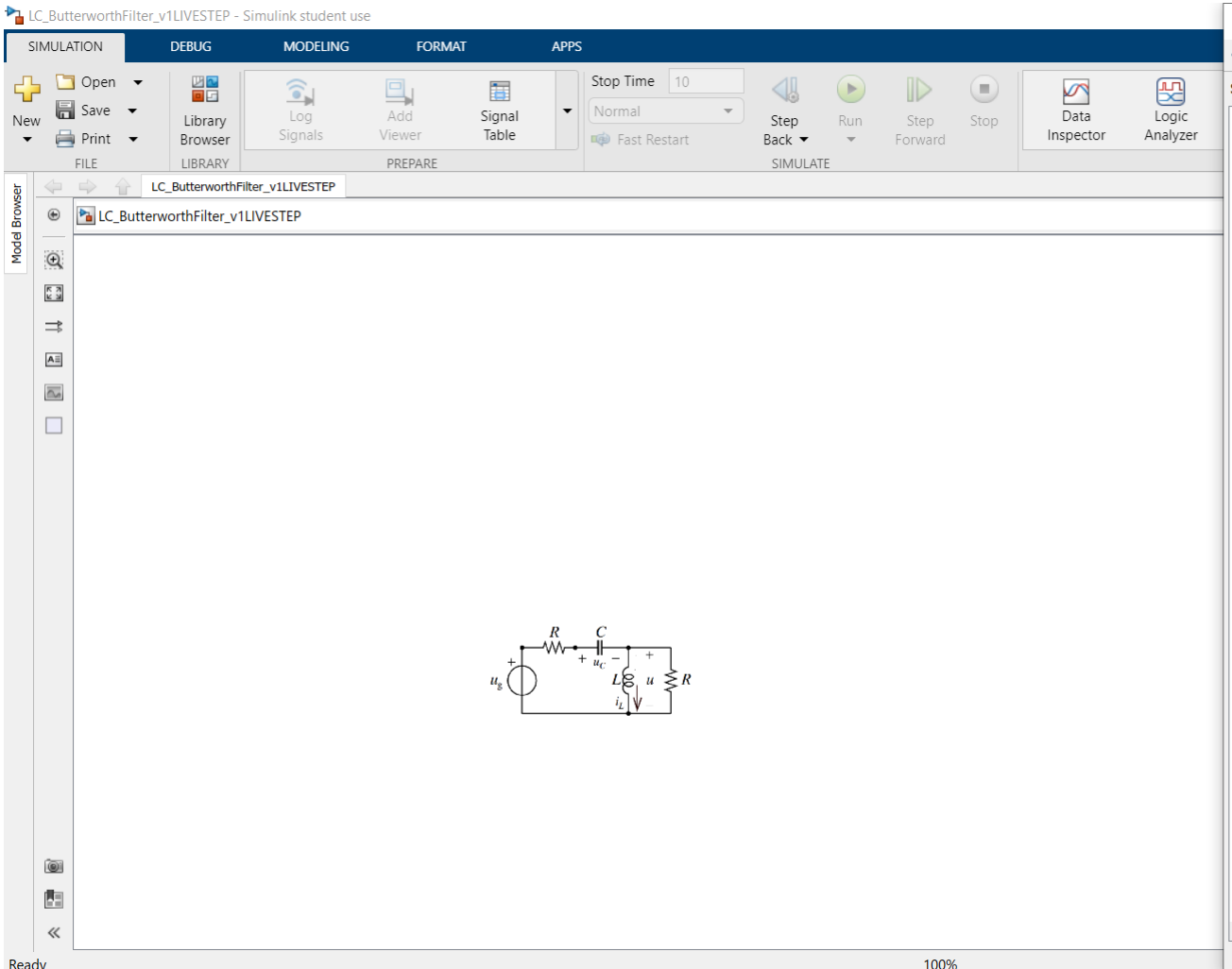

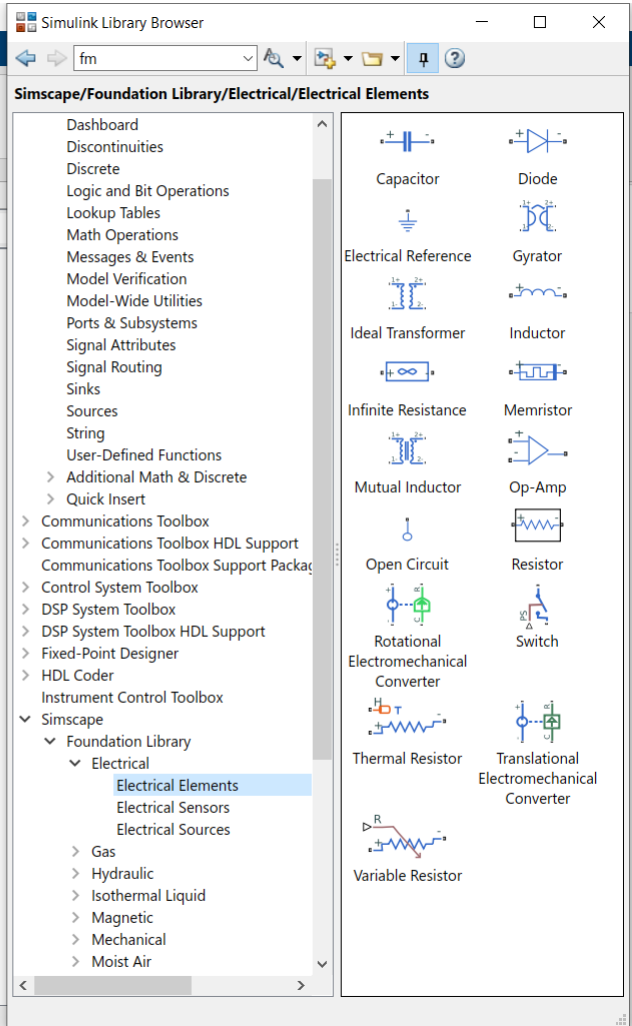

MATLAB Simulink - коло

Задаци

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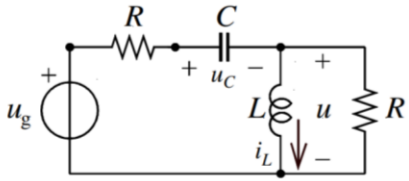

LC_ButterworthFilter_v0IMPULSE * - Simulink student use

SIMULATION | DEBUG | MODELING | FORMAT | APPS | SCOPE

New | Open | Save | Print | Library Browser | Log Signals | Add Viewer | Signal Table | Stop Time 10 | Normal | Fast Restart | Step Back | Run | Step Forward | Stop | Data Inspector | Logic Analyzer

FILE | LIBRARY | PREPARE | SIMULATE | REVIEW RESULTS

LC_ButterworthFilter_v0IMPULSE

u_g

FIZICKE (ELEKTRICNE) VELICINE

Voltage Sensor
Simscape/Foundation Library/Electrical/Electrical Sensors

R1 C L R2 f(x) = 0

Solver Configuration
Simscape/Foundation Library/Utilities

V_L

NUMERICKI SIGNALI

PS to Simulink Converter
Simscape/Foundation Library/Utilities

Scope

Simulink/Sinks/Scope

Ready 100% auto(ode45)

MATLAB Simulink - одзив

Задаци

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