Symbolic analysis of linear electric circuits with Maxima CAS

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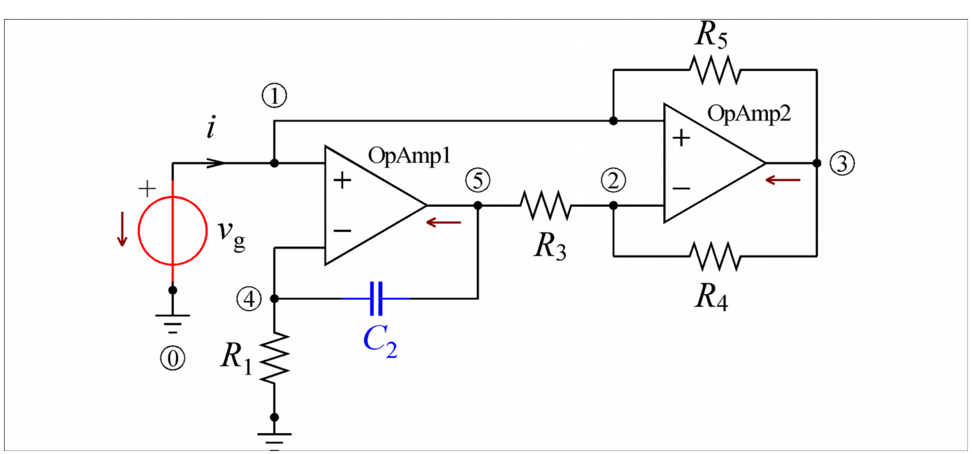



```
(%i3) Riordan_response: SALECx(Riordan_shema);
```

(Riordan_response) $[V_1 = Vg, V_2 = Vg, V_3 = -\frac{R4\ Vg - C2\ R1\ R3\ Vg\ s}{C2\ R1\ R3\ s}, V_4 = Vg, V_5 = \frac{C2\ R1\ Vg\ s + Vg}{C2\ R1\ s}, I_{OpAmp2} = \frac{R5\ Vg + R4\ Vg}{C2\ R1\ R3\ R5\ s}, I_{OpAmp1} = -\frac{C2\ R3\ Vg\ s + Vg}{C2\ R1\ R3\ s}, I_{Vg} = -\frac{R4\ Vg}{C2\ R1\ R3\ R5\ s}]$

```
(%i4) Zin: Vg/(-I["Vg"]), Riordan_response;
```

(Zin) $\frac{C2\ R1\ R3\ R5\ s}{R4}$

```
(%i5) Lsynthetic: Zin/s;
```

(Lsynthetic) $\frac{C2\ R1\ R3\ R5}{R4}$

What is symbolic simulation

- ***Symbolic simulation or analysis*** is a formal technique to calculate the behavior or a characteristic of a system (e.g. digital system, electronic circuit, or continuous-time system) with an independent variable (sample index, time, or frequency), the dependent variables (sample values, signals, voltages, and currents), and (some or all) the element values represented by **symbols**.
- A ***symbolic simulator*** is a computer program that receives the system description as input and can automatically carry out the symbolic analysis and thus generate the **symbolic** expression for the desired system characteristic.

- P. Lin, ***Symbolic Network Analysis***. Amsterdam, The Netherlands: Elsevier, 1991.
- G. Gielen and W. Sansen, ***Symbolic Analysis for Automated Design of Analog Integrated Circuits***. Norwell, MA: Kluwer, 1991.
- L. Huelsman and G. Gielen (Eds.), ***Symbolic Analysis of Analog Circuits: Techniques and Applications***. Norwell, MA: Kluwer, 1993.
- G. Gielen, P. Wambacq, and W. Sansen, "**Symbolic Analysis Methods and Applications for Analog Circuits: A Tutorial Overview**," *Proceedings of the IEEE*, vol. 82, no. 2, pp. 286–304, Feb. 1994.
- F. Fernández, A. Rodríguez-Vázquez, J. Huertas, and G. Gielen, ***Symbolic analysis techniques: Applications to analog design automation***. New York, NY: Wiley-IEEE Press, 1997.
- G. Shi, S. X.-D. Tan, E. T. Cuautle, ***Advanced Symbolic Analysis for VLSI Systems***. New York, NY: Springer, 2014.

What is SALECx

- **SALECx** is a symbolic simulator for symbolic analysis of linear time-invariant finite circuits.
- SALECx is an acronym for **S**ymbolic **A**nalysis of **L**inear **E**lectric **C**ircuits with Ma**x**ima.
- SALECx is distributed as **free/libre open-source** software under the Creative Commons license.
- SALECx is developed and maintained by Dr. *Dejan Tošić*, Full Professor, University of Belgrade – School of Electrical Engineering.

What is Maxima?

- *Computer Algebra System* (CAS) is software designed primarily for symbolic manipulation. CAS performs symbolic calculation one might do "by hand", i.e. works with closed-form, analytic, expressions and manipulates them.
- ***Maxima*** is a free/libre open-source CAS for technical and mathematical computing.
- *wxMaxima* is a free/libre open-source user interface for the computer algebra system Maxima.

Seifedine Kadry, Pauly Awad, *Mathematics for Engineers and Science Labs Using Maxima*, Apple Academic Press, 2019.
Zachary Hannan, *wxMaxima for Calculus I and II*. Fairfield, CA: Solano Community College, 2015.

Why is it important?

- SALECx can be included in **Electric Circuit Theory** teaching and learning, at initial learning stages, to motivate and encourage students
- (1) to **solve** their homework and numerous circuit problems by automated computer-aided symbolic analysis, and
- (2) to **verify** their designs and confirm circuit analyses obtained traditionally by hand, i.e. by paper and pencil.
- SALECx free open-source code reveals the underlining algorithm in full detail, promotes a **better understanding** of the corresponding circuit analysis method, and might prompt some students to edit the code and **add** their on extensions and contributions.

From passive to active learner

- SALECx can help students to solve much **more** real-life circuit example problems compared to the relatively smaller number of problems they are willing to solve by hand.
- The example-problem-based learning paradigm can be supported.
- Allows novice students to grasp concepts and phenomena from circuit theory with **higher learning performance** and lower mental effort, until they reach expert levels.
- The role of a student might change from passive to **active learner** under the new learning paradigm.

Overcome the difficult barriers of mathematics

- Mastering circuit analysis requires some degree of practice and one must be adept in algebraic manipulation.
- The burden of algebraic manipulation causes the student to lose sight of the wood from the trees.
- In the classic method of study a student must overcome the difficult barriers of mathematics, which makes the subject very unattractive.

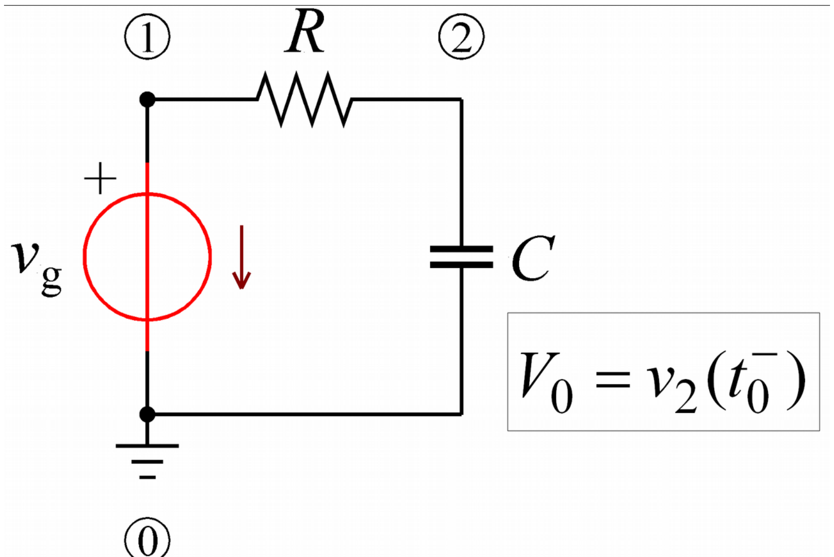
Ernst Mach, 1883

- When doing mathematics, instead of burdening the brain with the repetitive job of redoing numerical operations which have already been done before, it's possible to save that brainpower for more important situations by using symbols, instead, to represent those numerical calculations.
- Today, with computer algebra systems, such as Maxima/ Macsyma, it is possible to calculate in minutes or hours the results that would (and did) years to accomplish by paper and pencil.
- SALECx can help students acquire a "functional understanding" of Electric Circuit Theory and foster mastery of the MNA (Modified Nodal Analysis) equation formulation.

Better insight

- Symbolic circuit response generated by SALECx, i.e. closed-form **analytic** expressions for circuit voltages and currents, can provide **better insight** than numerical solutions, e.g. obtained by SPICE.
- By inspection of the symbolic response, it might be immediately clear **how** a parameter (or an element value) **contributes** to the performance and **behavior** of the electric circuit.

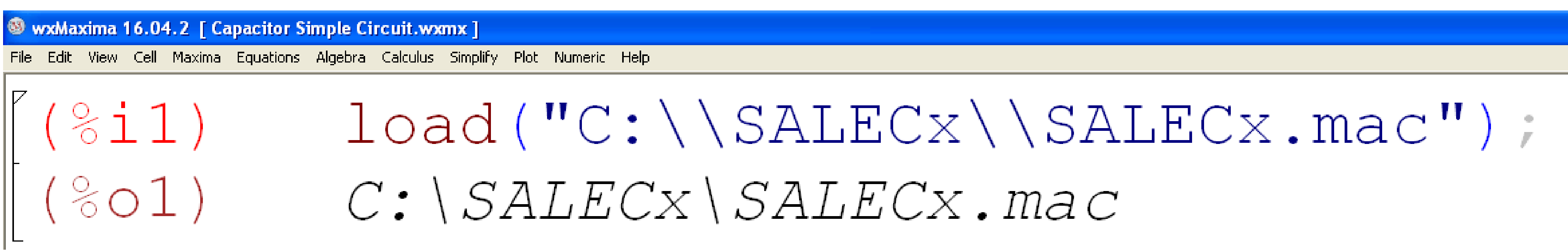
In Medias Res



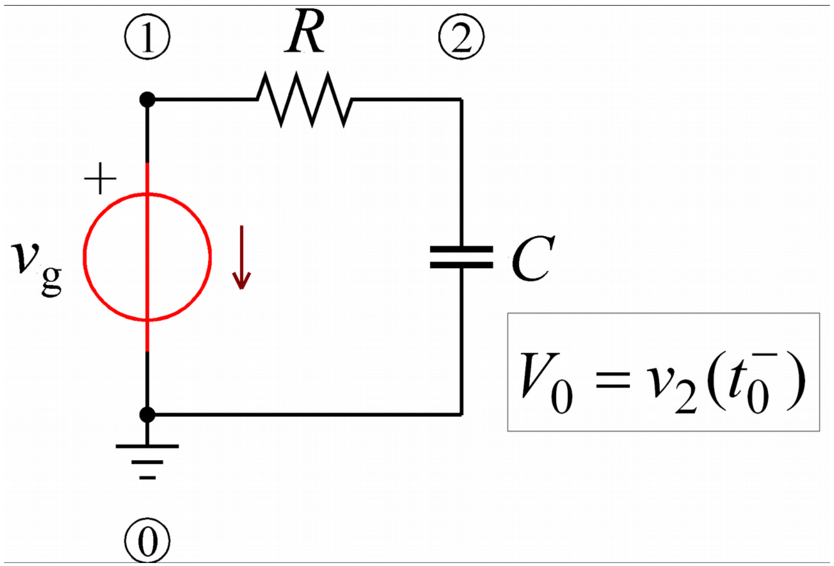
Let us solve a simple capacitor circuit.

Assume that SALECx has been installed in the directory "C:\SALECx\" as the **mac** file "SALECx.mac".

Open a **wxMaxima** notebook and load SALECx.



Create the Circuit Netlist



The circuit is textually specified as a list, **netlist**, of element specifications. Nodes are numbered by consecutive integers starting from zero, 0.

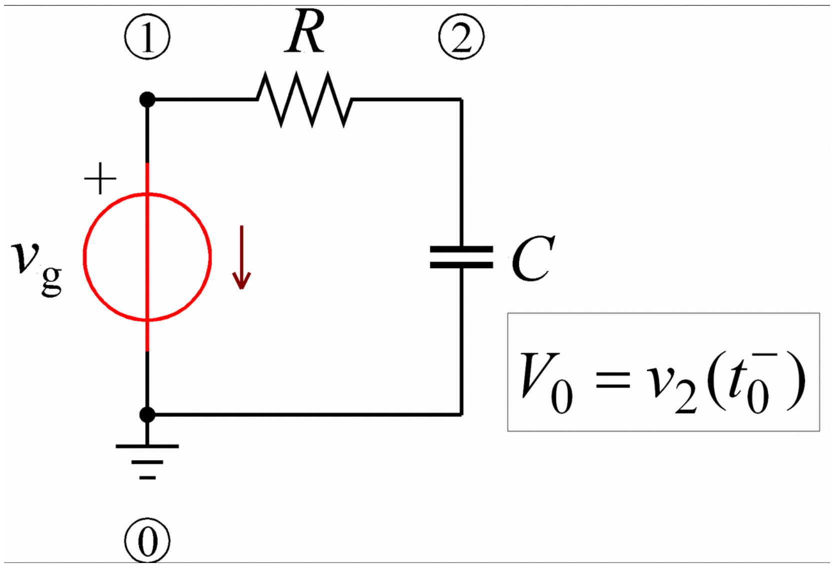
Each one-port circuit element is specified as a list of the form

```
[type, label, a, b, p]
[type, label, a, b, p, IC]
```

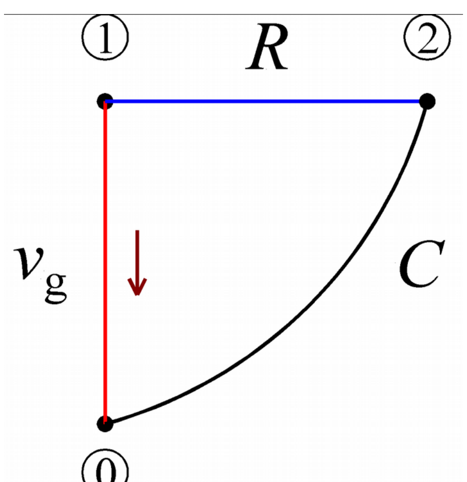
type – string that specifies the element type:"R" for resistors, "C" for capacitors, "V" for voltage sources (independent voltage generators). **label** – string that uniquely identifies circuit element. **a** – positive terminal, integer, **b** – negative terminal, integer. **p** – parameter, element value, resistance, capacitance, excitation. **IC** – initial condition, initial voltage Vo for capacitors $v_C(t_0-)$.

```
(%i2)    VgRCVo_Shema: [
           ["V", "Vg", 1, 0, Vg],
           ["R", "R", 1, 2, R],
           ["C", "C", 2, 0, C, Vo]];
(VgRCVo_Shema) [[V,Vg,1,0,Vg],[R,R,1,2,R],[C,C,2,0,C,Vo]]
```

Solve the Capacitor Circuit



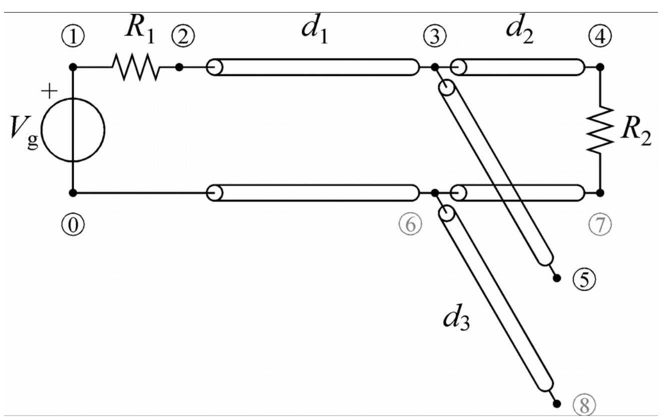
When we say "**Solve a circuit**" we mean "*Find all or some voltages and currents at the ports of the circuit elements*". Sometimes, we might be interested in finding power at some ports or finding circuit functions, such as voltage gain, transfer function or input impedance between two given nodes or ports.

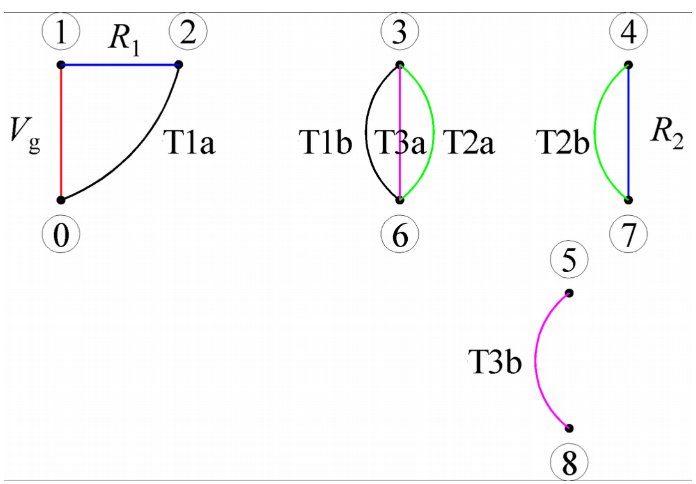


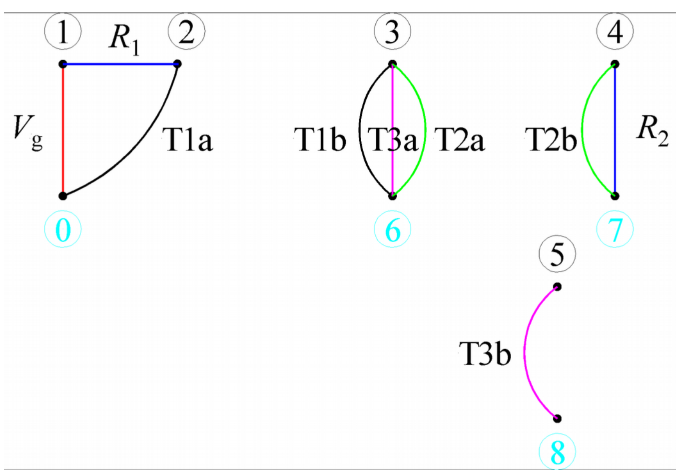
SALECx computes *node voltages* and currents at the ports that are not voltage controlled, i.e. for ports whose currents cannot be expressed in terms of node voltages. In addition, **SALECx** expects that one node is labeled by zero, 0, (*ground node*) and that it serves as a reference node for computing the node voltages. Finally, **SALECx** assumes that the circuit graph is *connected*.

If the circuit graph is not connected then ...

- Identify the disconnected components.
- Choose one node in each component.
- Connect the chosen nodes, join together, to make the graph connected.

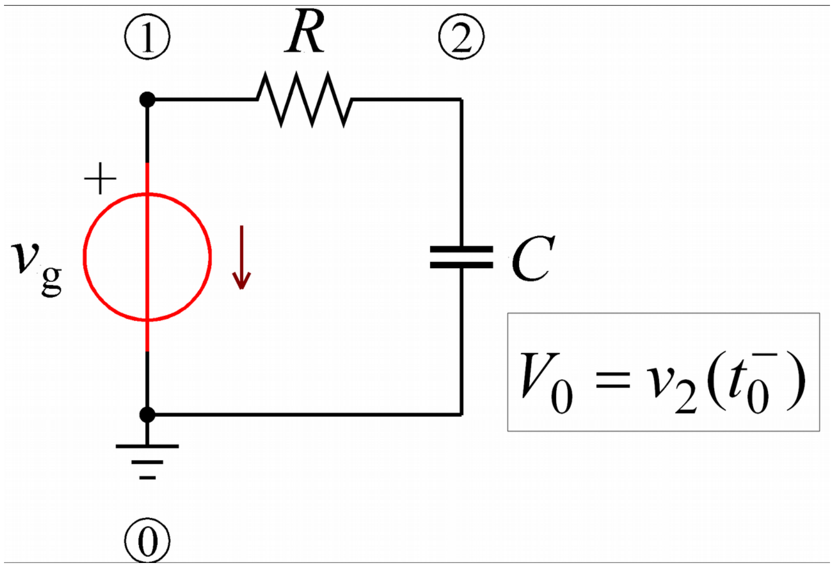






Node 6, Node 7, Node 8 are connected to **Node 0**.

SALECx Solve. Phasor Transform



SALECx can compute complex node voltages and some complex currents in the domain of the *Phasor Transform*. The initial conditions are ignored and the complex response corresponds to the sinusoidal steady-state response for a given angular frequency *omega* [rad/s]. I_{Vg} is the voltage source current directed from Node 1 to Node 0.

```
(%i3)   VgRCVo_Response_PT: SALECx(VgRCVo_Shema,omega);
```

Phasor Transform at angular frequency ω

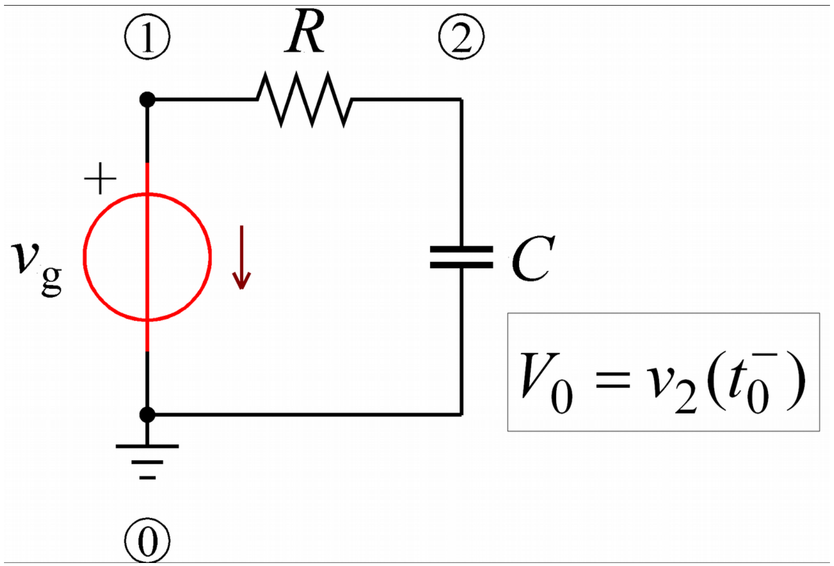
(VgRCVo_Response_PT) $$\left[V_1 = Vg,\ V_2 = \frac{Vg}{\%i\ C\ R\ \omega + 1},\ I_{Vg} = -\frac{\%i\ C\ Vg\ \omega}{\%i\ C\ R\ \omega + 1}\right]$$

```
(%i4)   V2PT: V[2], VgRCVo_Response_PT;
```

(V2PT) $$\frac{Vg}{\%i\ C\ R\ \omega + 1}$$

V2PT is the capacitor complex voltage.

SALECx Solve. Laplace Transform



SALECx can compute complex node voltages and some complex currents in the domain of the *Unilateral Laplace Transform*. The initial conditions are taken into account and the *Laplace variable* is the complex angular frequency ***s*** [rad/s], which is a SALECx reserved symbol.

```
(%i5)    VgRCVo_Response: SALECx(VgRCVo_Shema),
          SALECxPrint: true;
```

The option "**SALECxPrint: true**" instructs SALECx to print some analysis details. Use this option if you want to display the equations formulated by SALECx.

Dejan V. Tošić, Milka M. Potrebić, **Symbolic analysis of linear electric circuits with Maxima CAS**, *Application of Free Software and Open Hardware*, PSSOH 2019, International Conference, University of Belgrade – School of Electrical Engineering, Belgrade, Serbia, Oct. 26, 2019. http://pssoh.etf.bg.ac.rs/

SALECx Solution

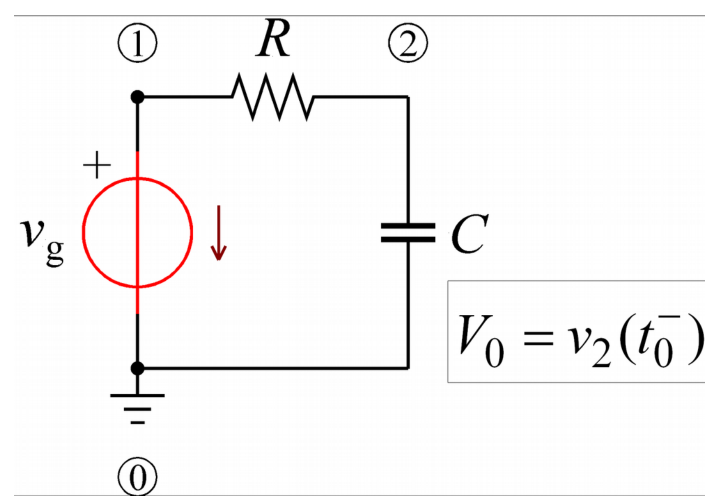
Symbolic Analysis of Linear Electric Circuits with Maxima
SALECx version 1.0, Prof. Dr. Dejan Tošić, tosic@etf.rs
Number of nodes excluding 0 node: 2
Electric circuit specification: [[*V*,*Vg*,1,0,*Vg*],[*R*,*R*,1,2,*R*],[*C*,*C*,2,0,*C*,*Vo*]]
Supported element: [true,true,true]
Element values: [*Vg*,*R*,*C*]
Initial conditions: [false,false,*Vo*]

MNA equations: $\left[\frac{V_1-V_2}{R}+I_{Vg}=0,\ V_2\,C\,s-C\,Vo+\frac{V_2-V_1}{R}=0,\ V_1=Vg\right]$

MNA variables: $[V_1, V_2, I_{Vg}]$

(VgRCVo_Response) $\left[V_1=Vg,\ V_2=\frac{C\,R\,Vo+Vg}{C\,R\,s+1},\ I_{Vg}=-\frac{C\,Vg\,s-C\,Vo}{C\,R\,s+1}\right]$

SALECx formulates the ***Modified Nodal Analysis*** (**MNA**) equations to symbolically solve a circuit.
Complex node voltages and some complex currents are returned as the complex response in terms of parameters, element values, initial conditions and the Laplace variable, complex frequency, **s**.



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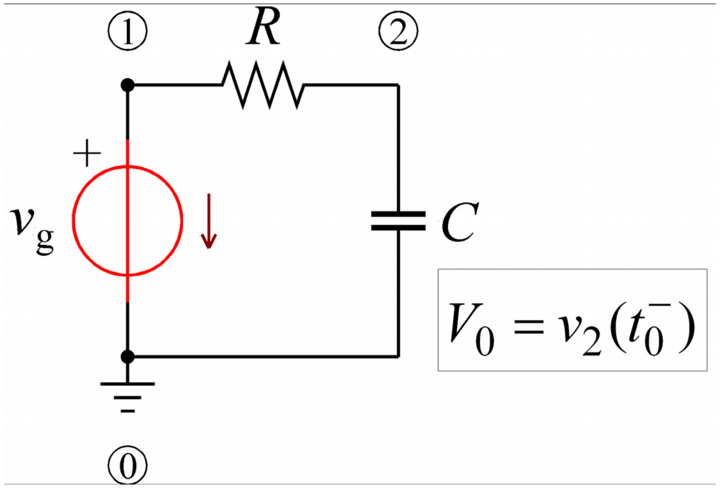
Postprocessing SALECx Solution

```
(%i6) V2s: V[2], VgRCVo_Response, Vg=Vstep/s;
```

(V2s) $$\frac{\frac{Vstep}{s}+C\,R\,Vo}{C\,R\,s+1}$$



The excitation is assumed to be a step function. The time-domain transient response is computed by the *Inverse Unilateral Laplace Transform*, the Maxima **ilt** function.

```
(%i7) v2ilt: ilt(V2s,s,t), expand;
```

(v2ilt) $$-Vstep\,\%e^{-\frac{t}{C\,R}}+Vo\,\%e^{-\frac{t}{C\,R}}+Vstep$$

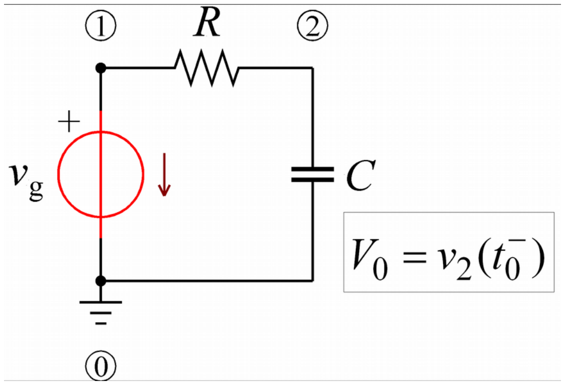
```
(%i8) v2t: factorout(v2ilt,Vstep,Vo);
```

(v2t) $$\left(Vo-Vstep\right)\%e^{-\frac{t}{C\,R}}+Vstep$$

What does SALECx return?

- SALECx returns the complex response as a list of equations of the form V[node]=expression or I[“id”]=expression, or I[“id”,node]=expression.
- Complex node voltages are V[1], V[2], V[3], …
- Complex currents are the currents of the ports which cannot be expressed in terms of node voltages.
- The symbol s is a SALECx reserved symbol.
- The symbols V and I are Maxima arrays.

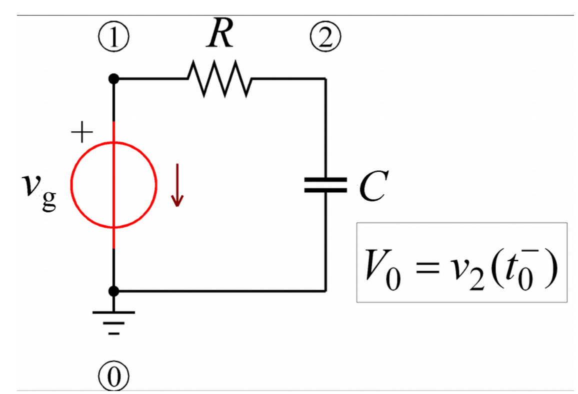
$$[\, V_1 = Vg \,,\; V_2 = \frac{C\,R\,Vo + Vg}{C\,R\,s+1} \,,\; I_{Vg} = -\frac{C\,Vg\,s - C\,Vo}{C\,R\,s+1} \,]$$



How does wxMaxima prints V[n]?

- wxMaxima prints V[1], V[2], V[3], … as subscripted italic symbols V_1, V_2, V_3, …
- If the voltage source is specified as ["V", **"Vg"**, 1, 0, Vg] then …
- … the corresponding voltage source current is **I["Vg"]** and wxMaxima prints that designation as subscipted italic symbol I_{Vg} omitting the quotes **""**.
- The current is directed from Node 1 to Node 0. It is referred to as a current into pin 1.

$$[\, V_1 = Vg \,,\; V_2 = \frac{C\,R\,Vo + Vg}{C\,R\,s + 1} \,,\; I_{Vg} = -\frac{C\,Vg\,s - C\,Vo}{C\,R\,s + 1} \,]$$



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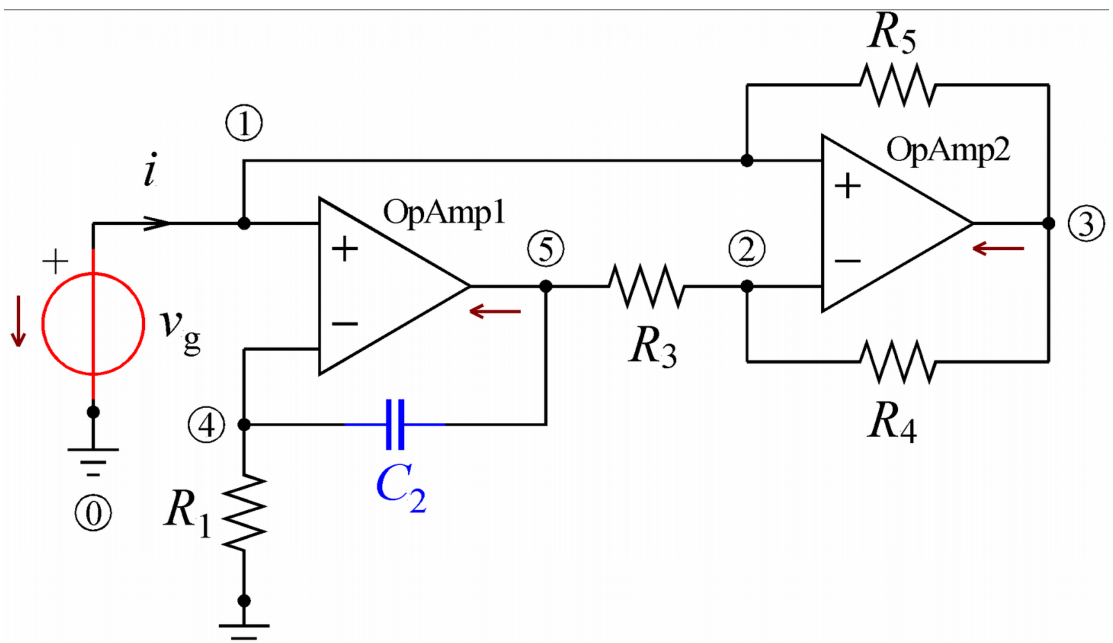
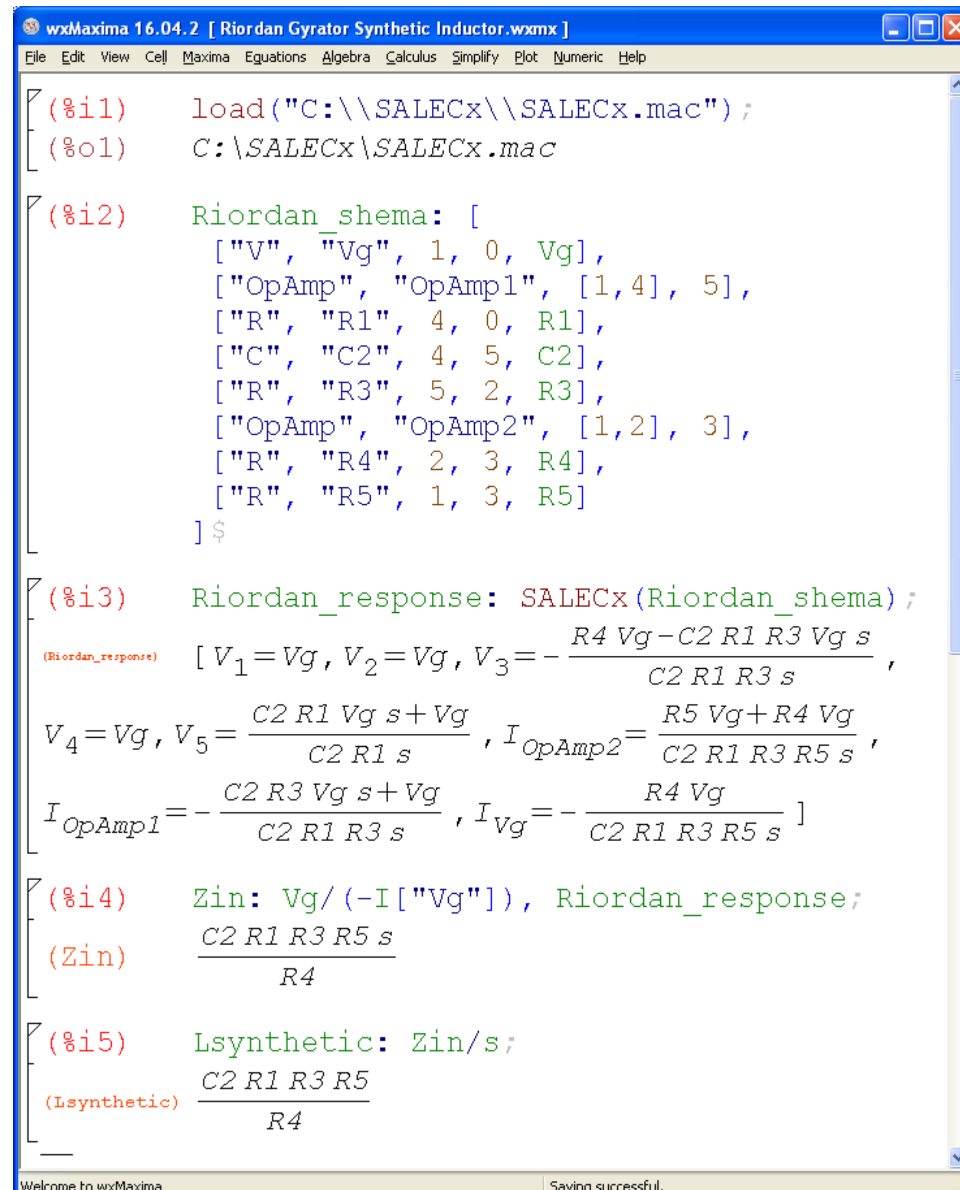
Proof-of-concept symbolic analysis





Synthetic inductor, which is realized with the Riordan gyrator network, can serve as a theoretical basis for implementation of **coilless** inductors.
The circuit is **inductorless** but, theoretically, the impedance seen by the source is purely inductive.

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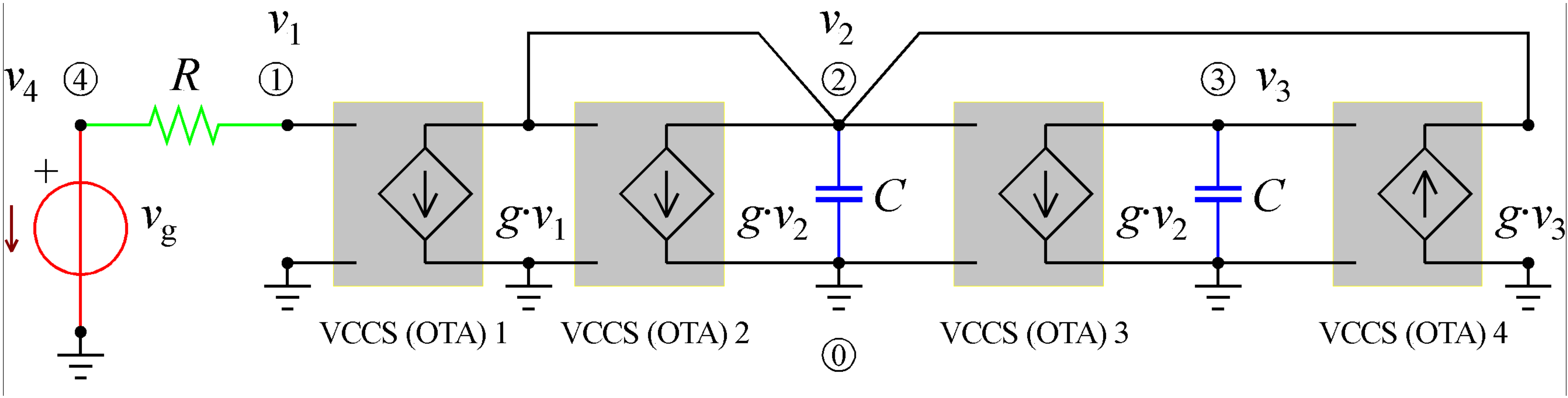
OTA-C lowpass and highpass filter




```
(%i2)   OTA_C_shema: [
         ["V", "Vg", 4, 0, Vg],
         ["R", "R", 4, 1, R],
         ["VCCS", "OTA1", [1,0], [2,0], g],
         ["VCCS", "OTA2", [2,0], [2,0], g],
         ["VCCS", "OTA3", [2,0], [3,0], g],
         ["VCCS", "OTA4", [3,0], [0,2], g],
         ["C", "C1", 2, 0, C],
         ["C", "C2", 3, 0, C]
        ]$
```

```
(%i4)   Hs2bandpass: V[2]/Vg, OTA_C_response;
```

(Hs2bandpass) $-\frac{C\, g\, s}{C^2\, s^2 + C\, g\, s + g^2}$

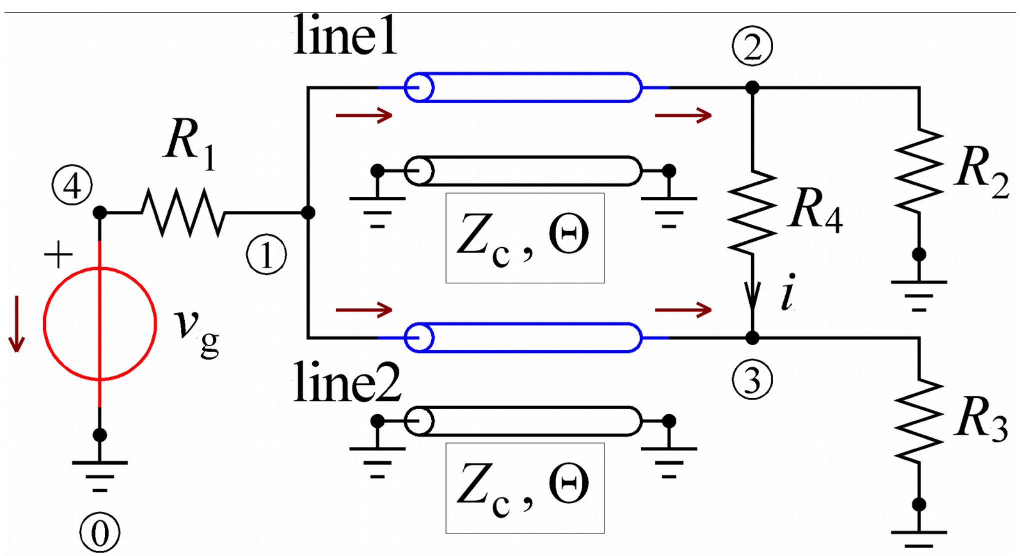
```
(%i5)   Hs3lowpass: V[3]/Vg, OTA_C_response;
```

(Hs3lowpass) $\frac{g^2}{C^2\, s^2 + C\, g\, s + g^2}$

```
(%i3)   OTA_C_response: SALECx(OTA_C_shema);
```

(OTA_C_response) $[\, V_1 = Vg\, ,\, V_2 = -\frac{C\, Vg\, g\, s}{C^2\, s^2 + C\, g\, s + g^2}\, ,\, V_3 = \frac{Vg\, g^2}{C^2\, s^2 + C\, g\, s + g^2}\, ,\, V_4 = Vg\, ,\, I_{Vg} = 0\,]$

Wilkinson power divider



Wilkinson power divider is realized with ideal lossless transmission line sections. The corresponding symbolic analysis with SALECx, performed in the Phasor Transform domain, verifies that the circuit equally splits (divides) input power to the loads.

The reference directions for the output transmission line currents are OUT OF pin 2 and OUT OF pin 3.

wxMaxima 16.04.2 [Wilkinson Power Divider.wxmx]

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

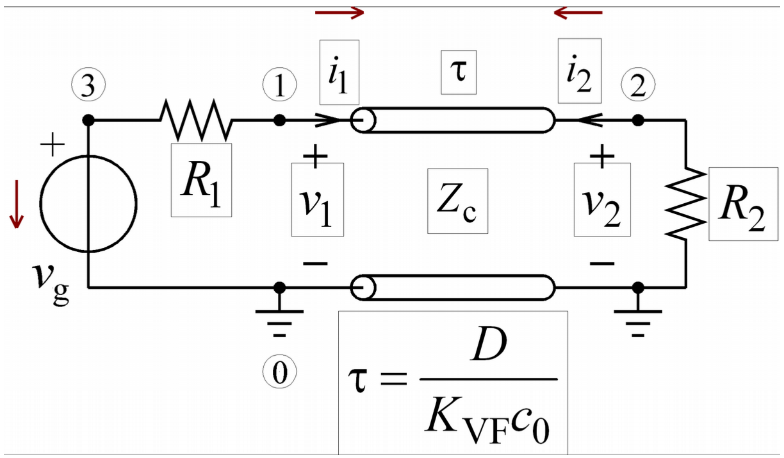
```
(%i1) load("C:\\SALECx\\SALECx.mac");
(%o1) C:\SALECx\SALECx.mac
(%i2) Wilkinson_shema: [
        ["V", "Vg", 4, 0, Vg],
        ["R", "R1", 1, 4, R],
        ["R", "R2", 2, 0, R],
        ["R", "R3", 3, 0, R],
        ["R", "R4", 2, 3, 2*R],
        ["T", "T1", [1,0], [2,0], [√(2)*R,π/2]],
        ["T", "T2", [1,0], [3,0], [√(2)*R,π/2]]
      ]$
(%i3) Wilkinson_response:
        SALECx(Wilkinson_shema, omega),
        ratsimp;
Phasor Transform at angular frequency ω
```

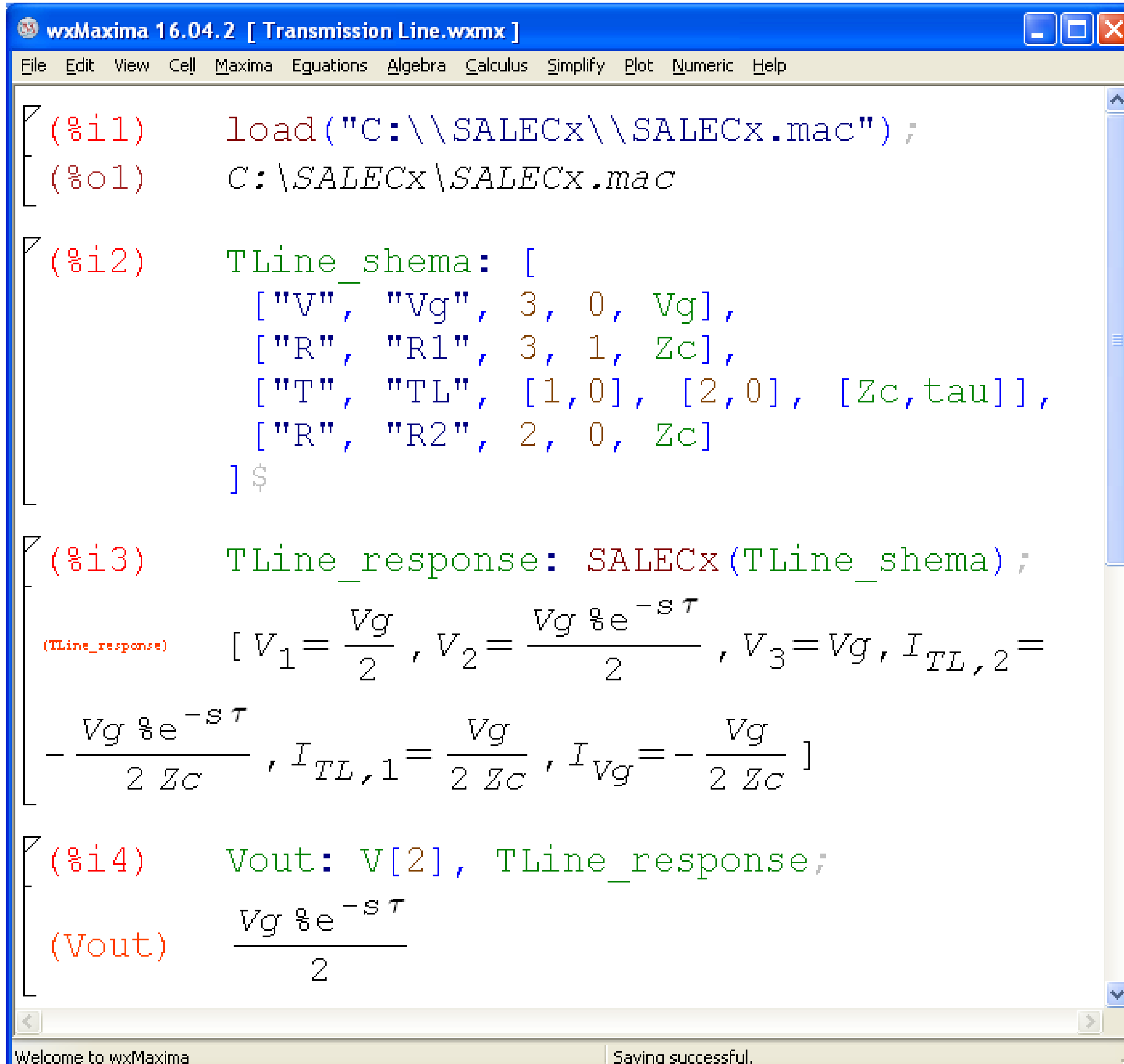
(Wilkinson_response) $[V_1=\frac{Vg}{2}, V_2=-\frac{\%i\ Vg}{2^{3/2}}, V_3=-\frac{\%i\ Vg}{2^{3/2}}, V_4=Vg, I_{T2,3}=-\frac{\%i\ Vg}{2^{3/2}\ R}, I_{T2,1}=\frac{Vg}{4\ R}, I_{T1,2}=-\frac{\%i\ Vg}{2^{3/2}\ R}, I_{T1,1}=\frac{Vg}{4\ R}, I_{Vg}=-\frac{Vg}{2\ R}]$

```
(%i4) is(
        ev(V[2]=V[3], Wilkinson_response)
      );
(%o4) true
```

Welcome to wxMaxima   Saving successful.

Ideal Transmission Line Section Laplace Transform

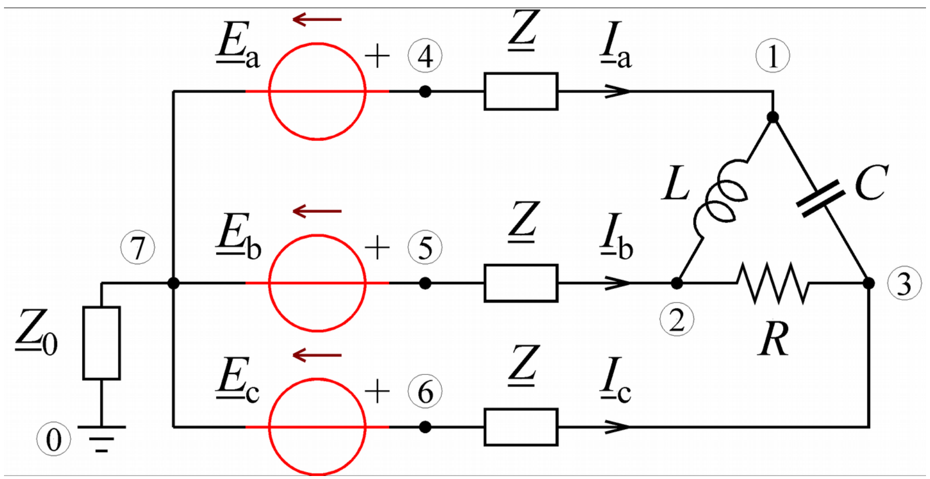




Doubly terminated lossless transmission line section. The corresponding symbolic analysis with SALECx, performed in the Unilateral Laplace Transform domain, verifies that the circuit acts as a delay line.

The reference directions for the transmission line currents are into the corresponding pins 1 and 2.

Three-phase Circuit: netlist




```
(%i1) load("C:\\SALECx\\SALECx.mac");
(%o1) C:\SALECx\SALECx.mac
(%i2) domain: complex$
(%i3) declare([Ea, Eb, Ec, Z, Z0],
      complex)$
(%i4) declare([C, L, R, omega],
      real)$
(%i5) assume(C > 0, L > 0, R > 0, omega > 0)$
(%i6) alias(j, %i)$
(%i7) ThreePhase_shema: [
       ["Z", "Z0", 7, 0, Z0],
       ["V", "Ea", 4, 7, Ea],
       ["V", "Eb", 5, 7, Eb],
       ["V", "Ec", 6, 7, Ec],
       ["Z", "Zv1", 1, 4, Z],
       ["Z", "Zv2", 2, 5, Z],
       ["Z", "Zv3", 3, 6, Z],
       ["L", "L", 1, 2, L],
       ["R", "R", 2, 3, R],
       ["C", "C", 3, 1, C]
      ]$
```

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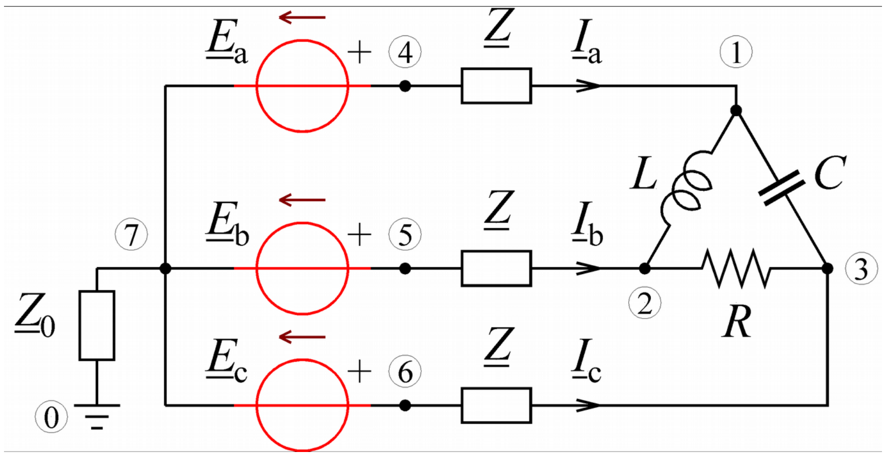
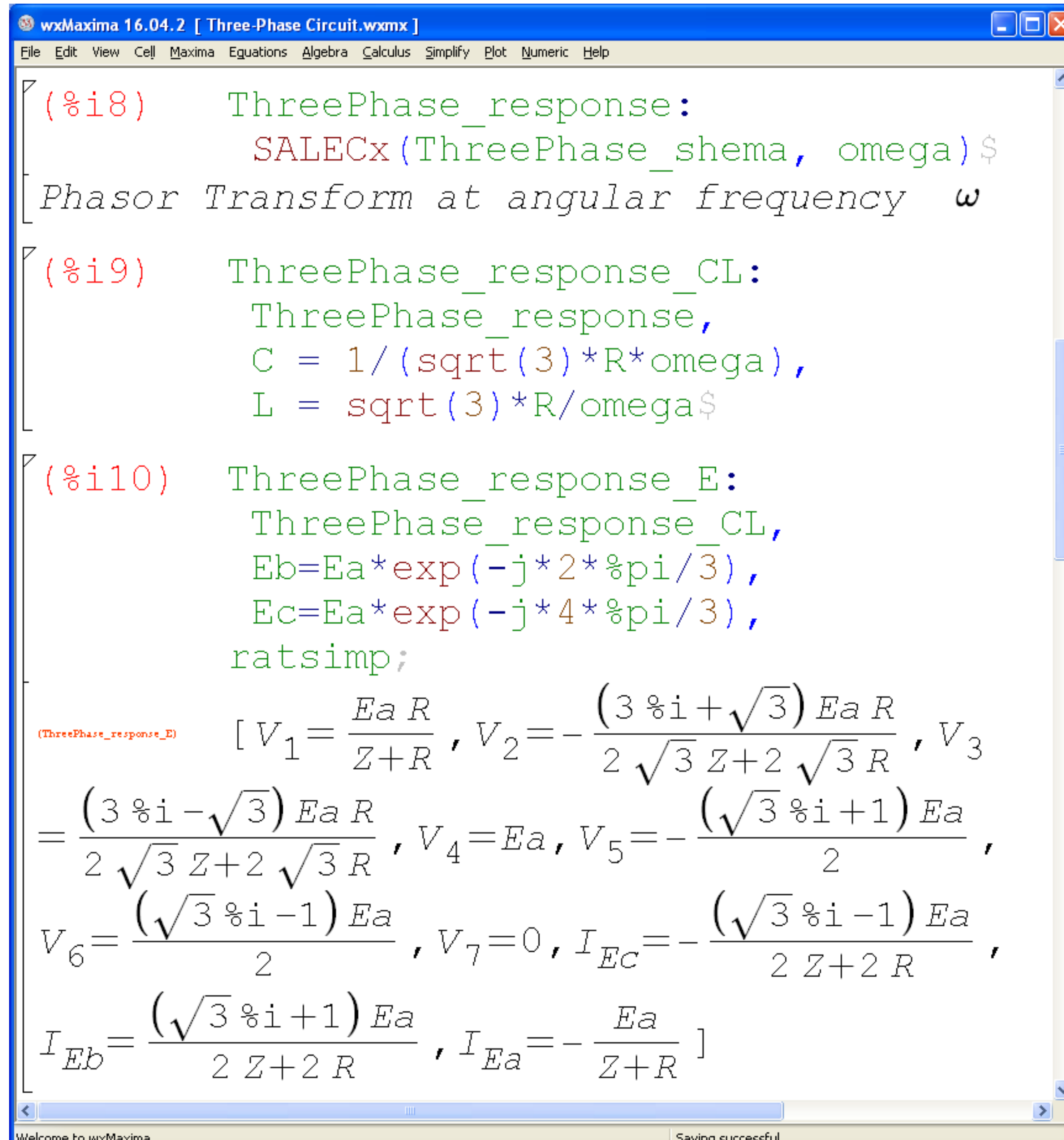
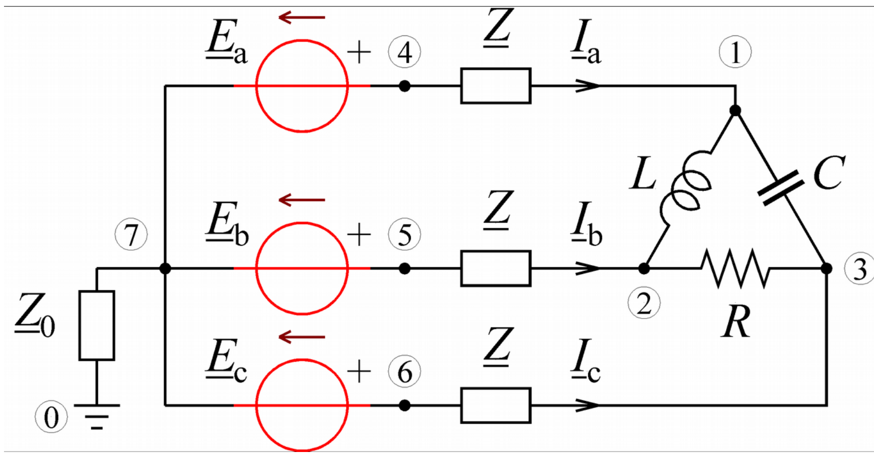
Three-phase Circuit: response

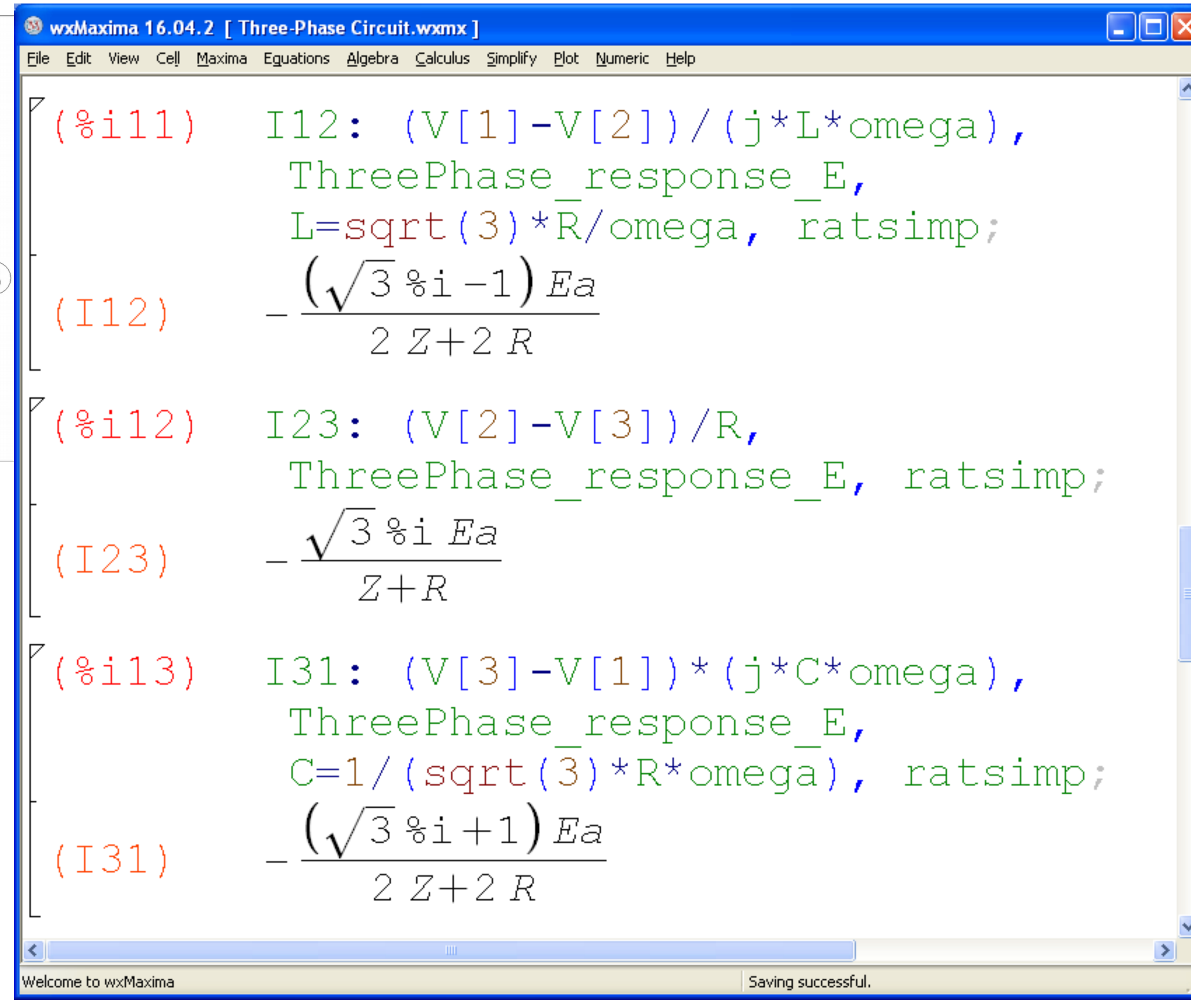




Dejan V. Tošić, Milka M. Potrebić, **Symbolic analysis of linear electric circuits with Maxima CAS**, *Application of Free Software and Open Hardware*, PSSOH 2019, International Conference, University of Belgrade – School of Electrical Engineering, Belgrade, Serbia, Oct. 26, 2019. http://pssoh.etf.bg.ac.rs/

Three-phase Circuit: currents





Three-phase Circuit: Symmetrical Components

wxMaxima 16.04.2 [Three-Phase Circuit.wxmx]

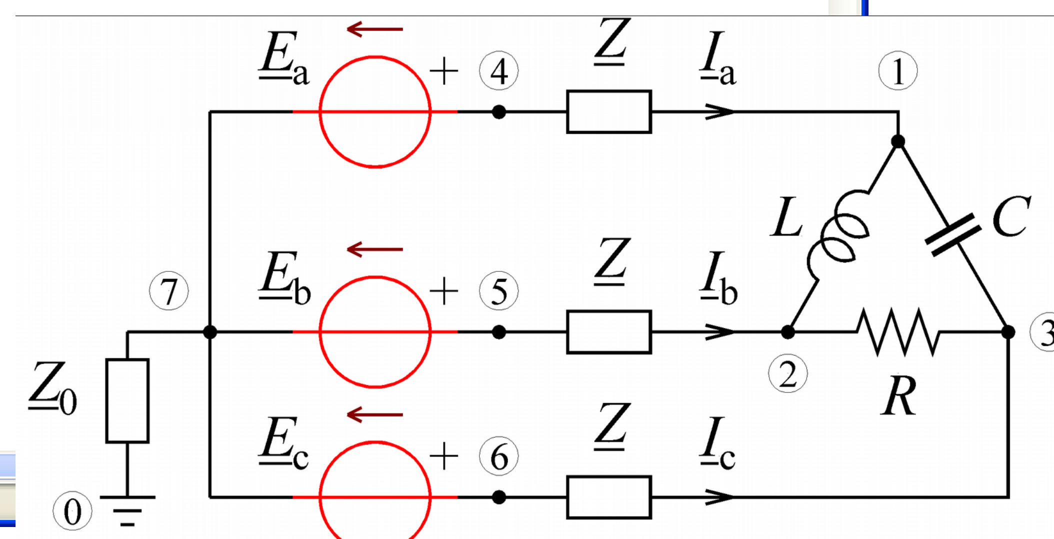
File Edit View Cell Maxima Equations Algebra Calculus Simplify Plot Numeric Help

```
(%i14)  IsymmetricalComponents:
         invert(matrix(
         [1,                    1,                    1],
         [1,  (exp(j*2*%pi/3))^2,        exp(j*2*%pi/3)],
         [1,       exp(j*2*%pi/3),  (exp(j*2*%pi/3))^2]
                                )
                 )
         . matrix([I12],[I23],[I31]),
        ratsimp, factor;
```

(IsymmetricalComponents)

$$\begin{bmatrix} -\dfrac{2\,\%i\,Ea}{\sqrt{3}\,(Z+R)} \\ -\dfrac{\%i\left(\sqrt{3}\,\%i-1\right)Ea}{2\,\sqrt{3}\,(Z+R)} \\ 0 \end{bmatrix}$$

Welcome to wxMaxima



Conclusion

- Automated computer-aided symbolic analysis of linear time-invariant finite electric circuits, implemented in software SALECx, has been presented.
- Symbolic simulator SALECx, written in Maxima CAS, receives a textual circuit description in the form of a netlist and generates closed-form analytical expressions for the circuit response.
- The analysis is performed in the complex domain of the Unilateral Laplace Transform or the Phasor transform.
- Engineers, educators and students can benefit from SALECx when exploring design alternatives, verifying the circuit performance, or carrying out the proof-of-concept analyses.
- The future directives might be an integration of SALECx with a schematic capture editor so the user can specify circuits pictorially.

References: Classics

- C. A. Desoer, E. S. Kuh, *Basic Circuit Theory*. New York, NY: McGraw-Hill, 1969.
- L. O. Chua, C. A. Desoer, and E. S. Kuh, Linear and Nonlinear Circuits. New York, NY: McGraw-Hill, 1987.
- Hendrik Wade Bode, *Network Analysis and Feedback Amplifier Design*. New York, NY: D. Van Nostrand, 1945. (Reprinted 1953.)

References: Contemporary

- C. K. Alexander, M. N. O. Sadiku, *Fundamentals of Electric Circuits*, 6/e. New York, NY: McGraw-Hill, 2017.
- J. W. Nilsson, S. A. Riedel, *Electric Circuits*, 10/e. Upper Saddle River, NJ: Prentice Hall, 2015.
- J. D. Irwin, R. M. Nelms, *Basic Engineering Circuit Analysis*, 11/e. Hoboken, NJ: Wiley, 2015.
- J. A. Svoboda, R. C. Dorf, *Introduction to Electric Circuits*, 9/e. Hoboken, NJ: Wiley, 2014.
- W. H. Hayt, Jr., J. E. Kemmerly, S. M. Durbin, *Engineering circuit analysis*, 8/e. New York, NY: McGraw-Hill, 2012.

References: Special

- F. N. Najm, *Circuit Simulation*. Hoboken, New Jersey: John Wiley & Sons, 2010.
- O. Wing, *Classical Circuit Theory*. New York, NY: Springer Science+Business Media, LLC, 2008.
- W.-K. Chen (Ed.), *Circuit Analysis and Feedback Amplifier Theory*. Boca Raton, FL: CRC Press, Taylor & Francis Group, 2006.
- A. L. Shenkman, *Transient Analysis of Electric Power Circuits Handbook*. Dordrecht, The Netherlands: Springer, 2005.
- A. L. Shenkman, *Circuit Analysis for Power Engineering Handbook*. Dordrecht, The Netherlands: Springer, 1998.
- P. R. Clayton, *Analysis of Multiconductor Transmission Lines*, 2/e. Hoboken, NJ: Wiley IEEE Press, 2008.

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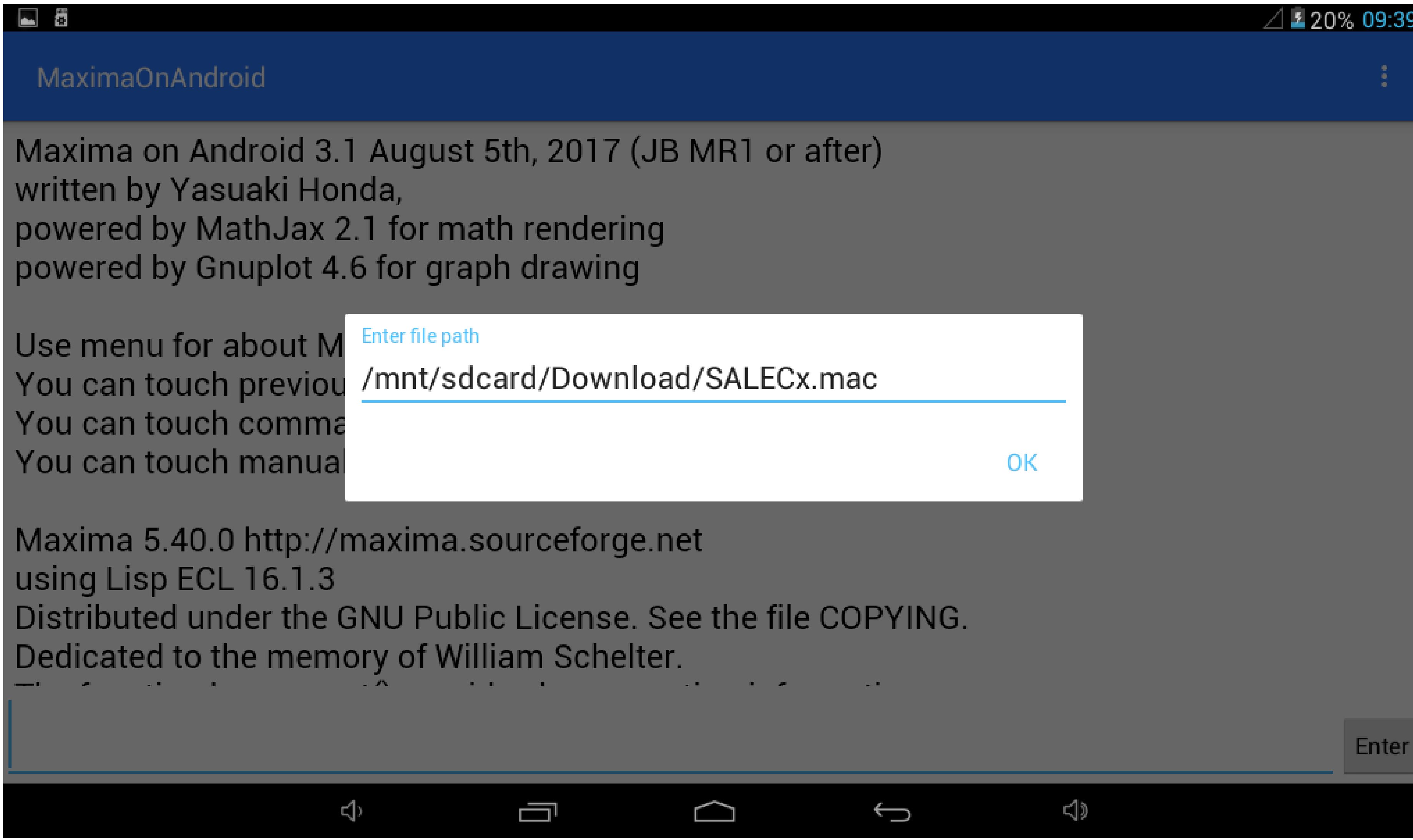
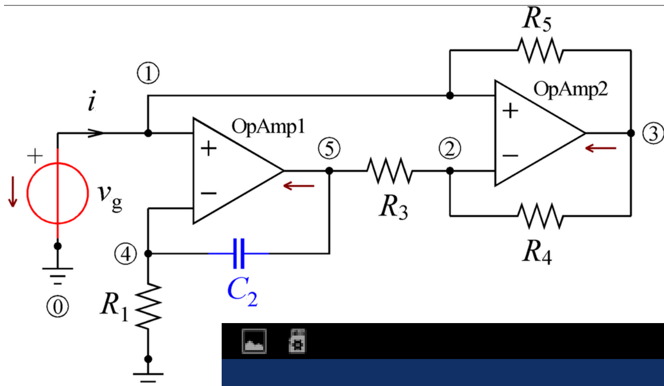
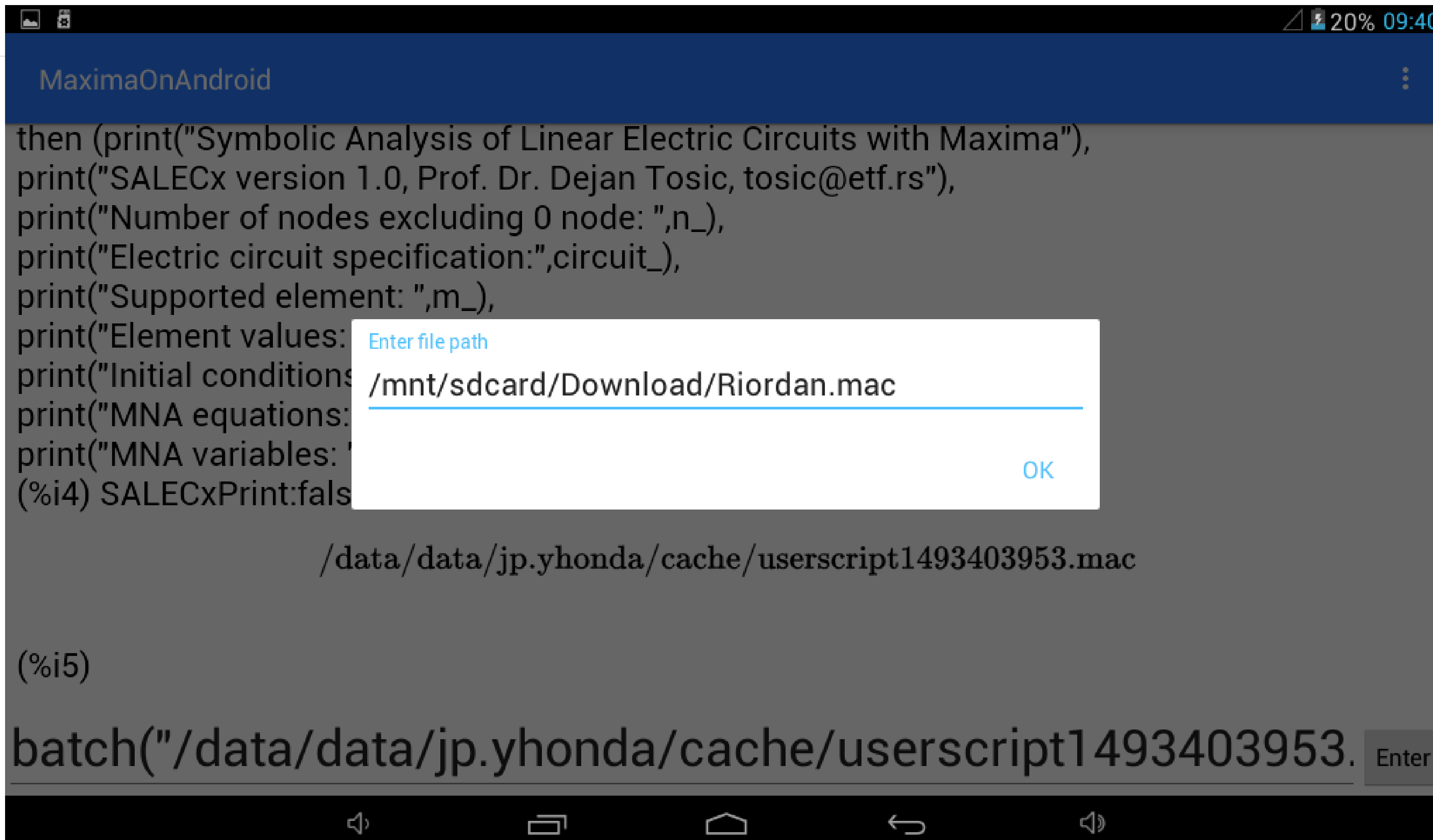
SALECx with MaximaOnAndroid



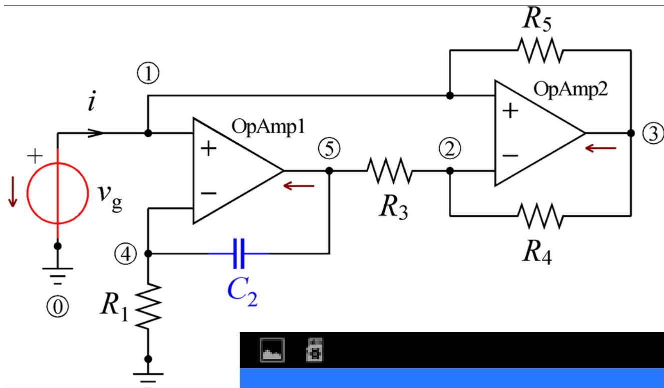
Dejan V. Tošić, Milka M. Potrebić, **Symbolic analysis of linear electric circuits with Maxima CAS**, *Application of Free Software and Open Hardware*, PSSOH 2019, International Conference, University of Belgrade – School of Electrical Engineering, Belgrade, Serbia, Oct. 26, 2019. http://pssoh.etf.bg.ac.rs/

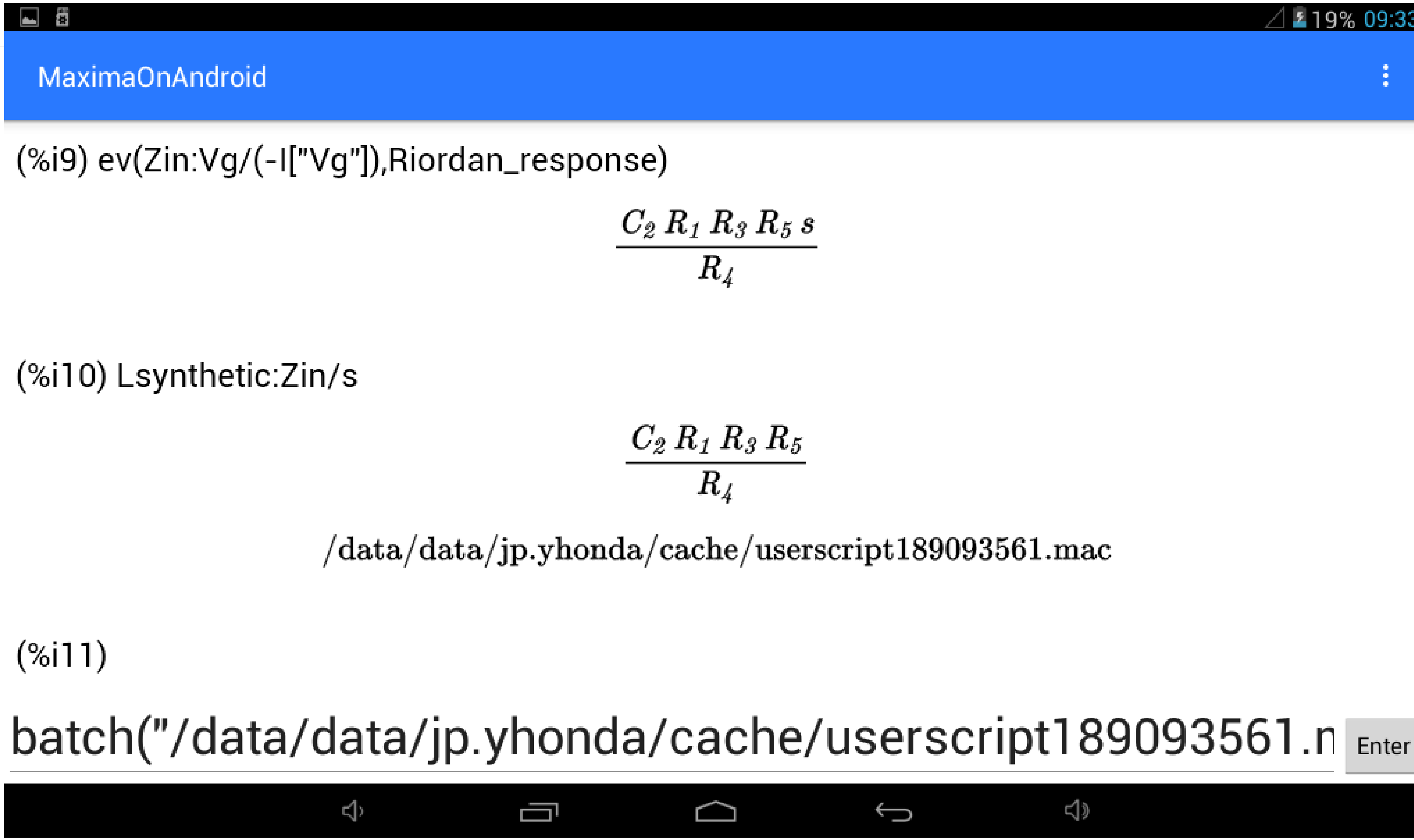


Netlist Script

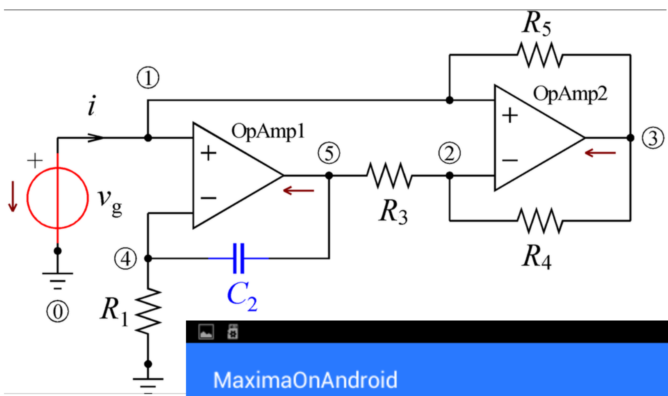


Behavior

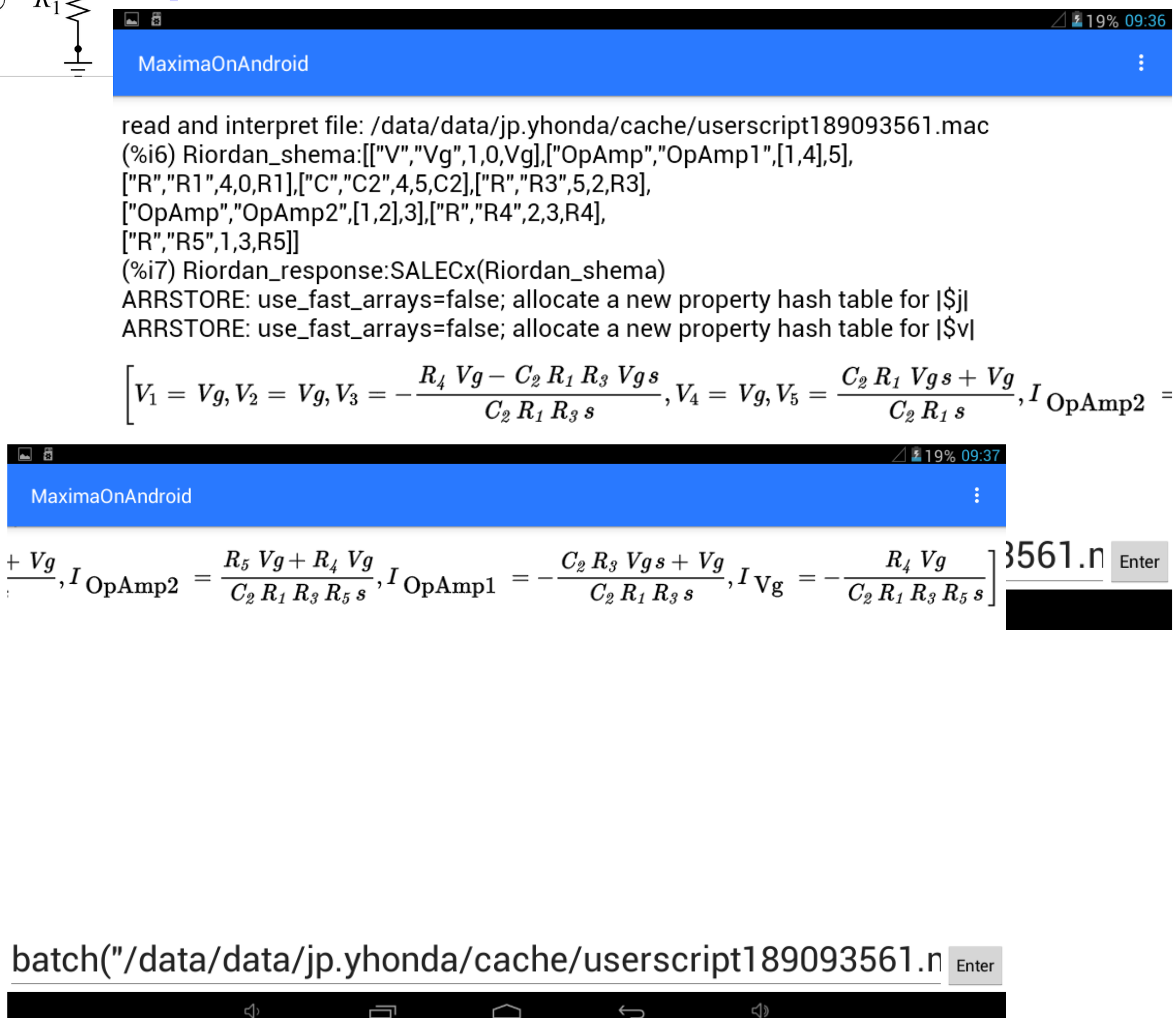

R5
1
i
OpAmp1
OpAmp2
5
2
3
vg
R3
R4
4
C2
0
R1


19% 09:33
MaximaOnAndroid
(%i9) ev(Zin:Vg/(-I["Vg"]),Riordan_response)
$\frac{C_2 R_1 R_3 R_5 s}{R_4}$
(%i10) Lsynthetic:Zin/s
$\frac{C_2 R_1 R_3 R_5}{R_4}$
/data/data/jp.yhonda/cache/userscript189093561.mac
(%i11)
batch("/data/data/jp.yhonda/cache/userscript189093561.n
Enter

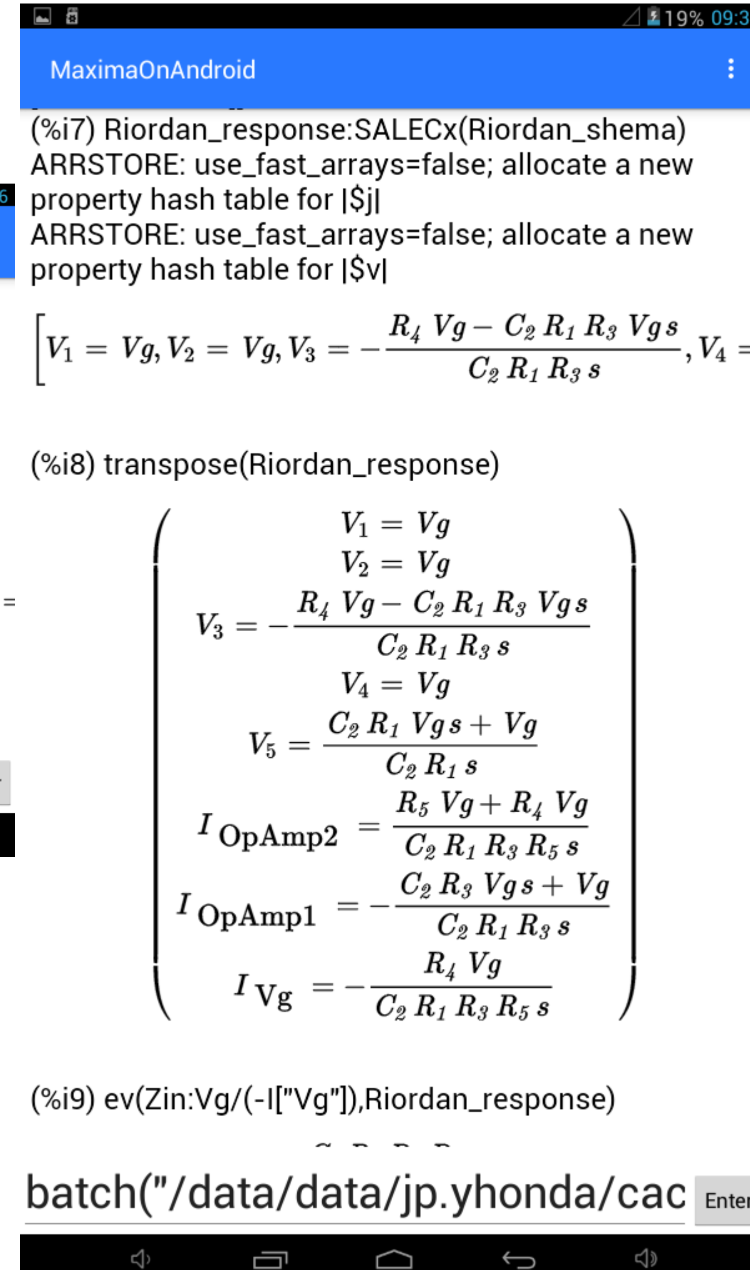
Response



R5
OpAmp2
i
OpAmp1
vg
R3
R4
C2
R1

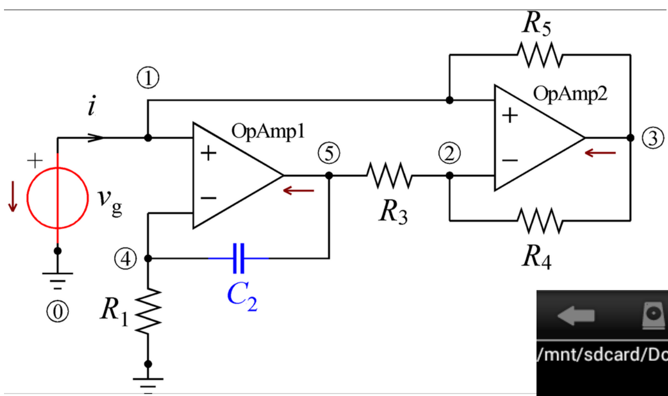


19% 09:36
MaxímaOnAndroid
read and interpret file: /data/data/jp.yhonda/cache/userscript189093561.mac
(%i6) Riordan_shema:[["V","Vg",1,0,Vg],["OpAmp","OpAmp1",[1,4],5],
["R","R1",4,0,R1],["C","C2",4,5,C2],["R","R3",5,2,R3],
["OpAmp","OpAmp2",[1,2],3],["R","R4",2,3,R4],
["R","R5",1,3,R5]]
(%i7) Riordan_response:SALECx(Riordan_shema)
ARRSTORE: use_fast_arrays=false; allocate a new property hash table for |$j|
ARRSTORE: use_fast_arrays=false; allocate a new property hash table for |$v|
$[V_1 = Vg, V_2 = Vg, V_3 = -\frac{R_4\,Vg - C_2\,R_1\,R_3\,Vg\,s}{C_2\,R_1\,R_3\,s}, V_4 = Vg, V_5 = \frac{C_2\,R_1\,Vg\,s + Vg}{C_2\,R_1\,s}, I_{OpAmp2} =$
19% 09:37
MaxímaOnAndroid
$I_{OpAmp2} = \frac{R_5\,Vg + R_4\,Vg}{C_2\,R_1\,R_3\,R_5\,s}, I_{OpAmp1} = -\frac{C_2\,R_3\,Vg\,s + Vg}{C_2\,R_1\,R_3\,s}, I_{Vg} = -\frac{R_4\,Vg}{C_2\,R_1\,R_3\,R_5\,s}]$
batch("/data/data/jp.yhonda/cache/userscript189093561.n
Enter

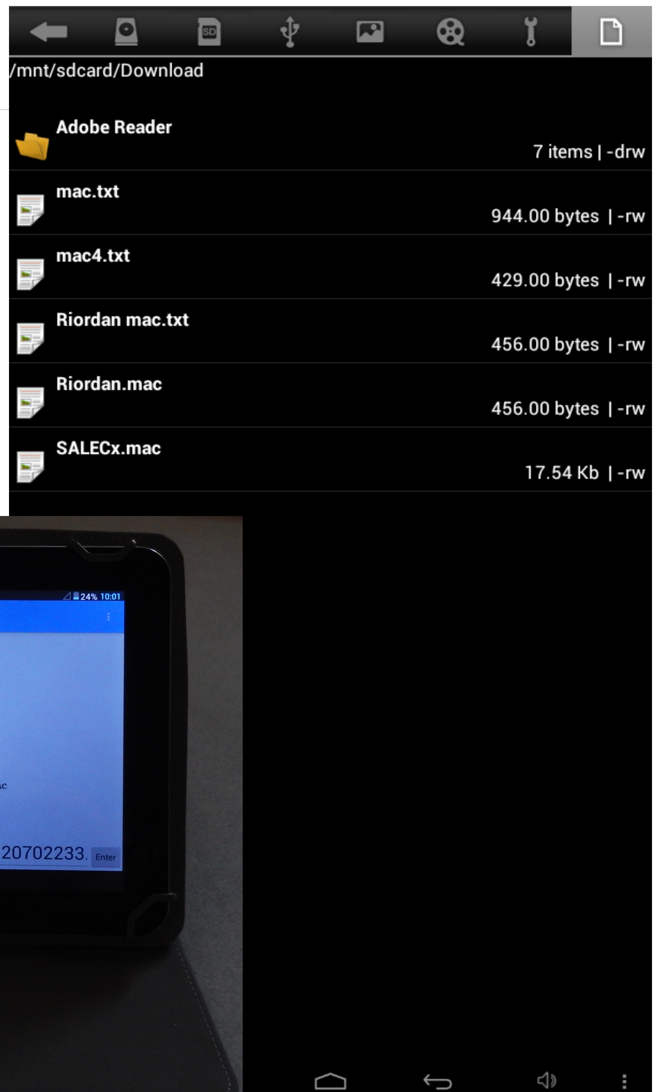


19% 09:34
MaxímaOnAndroid
(%i7) Riordan_response:SALECx(Riordan_shema)
ARRSTORE: use_fast_arrays=false; allocate a new property hash table for |$j|
ARRSTORE: use_fast_arrays=false; allocate a new property hash table for |$v|
$[V_1 = Vg, V_2 = Vg, V_3 = -\frac{R_4\,Vg - C_2\,R_1\,R_3\,Vg\,s}{C_2\,R_1\,R_3\,s}, V_4 =$
(%i8) transpose(Riordan_response)
$V_1 = Vg$
$V_2 = Vg$
$V_3 = -\frac{R_4\,Vg - C_2\,R_1\,R_3\,Vg\,s}{C_2\,R_1\,R_3\,s}$
$V_4 = Vg$
$V_5 = \frac{C_2\,R_1\,Vg\,s + Vg}{C_2\,R_1\,s}$
$I_{OpAmp2} = \frac{R_5\,Vg + R_4\,Vg}{C_2\,R_1\,R_3\,R_5\,s}$
$I_{OpAmp1} = -\frac{C_2\,R_3\,Vg\,s + Vg}{C_2\,R_1\,R_3\,s}$
$I_{Vg} = -\frac{R_4\,Vg}{C_2\,R_1\,R_3\,R_5\,s}$
(%i9) ev(Zin:Vg/(-I["Vg"]),Riordan_response)
batch("/data/data/jp.yhonda/cac
Enter

About



R5
OpAmp2
OpAmp1
i
+
−
vg
R3
R4
R1
C2



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Adobe Reader
7 items | -drw
mac.txt
944.00 bytes | -rw
mac4.txt
429.00 bytes | -rw
Riordan mac.txt
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SALECx.mac
17.54 Kb | -rw

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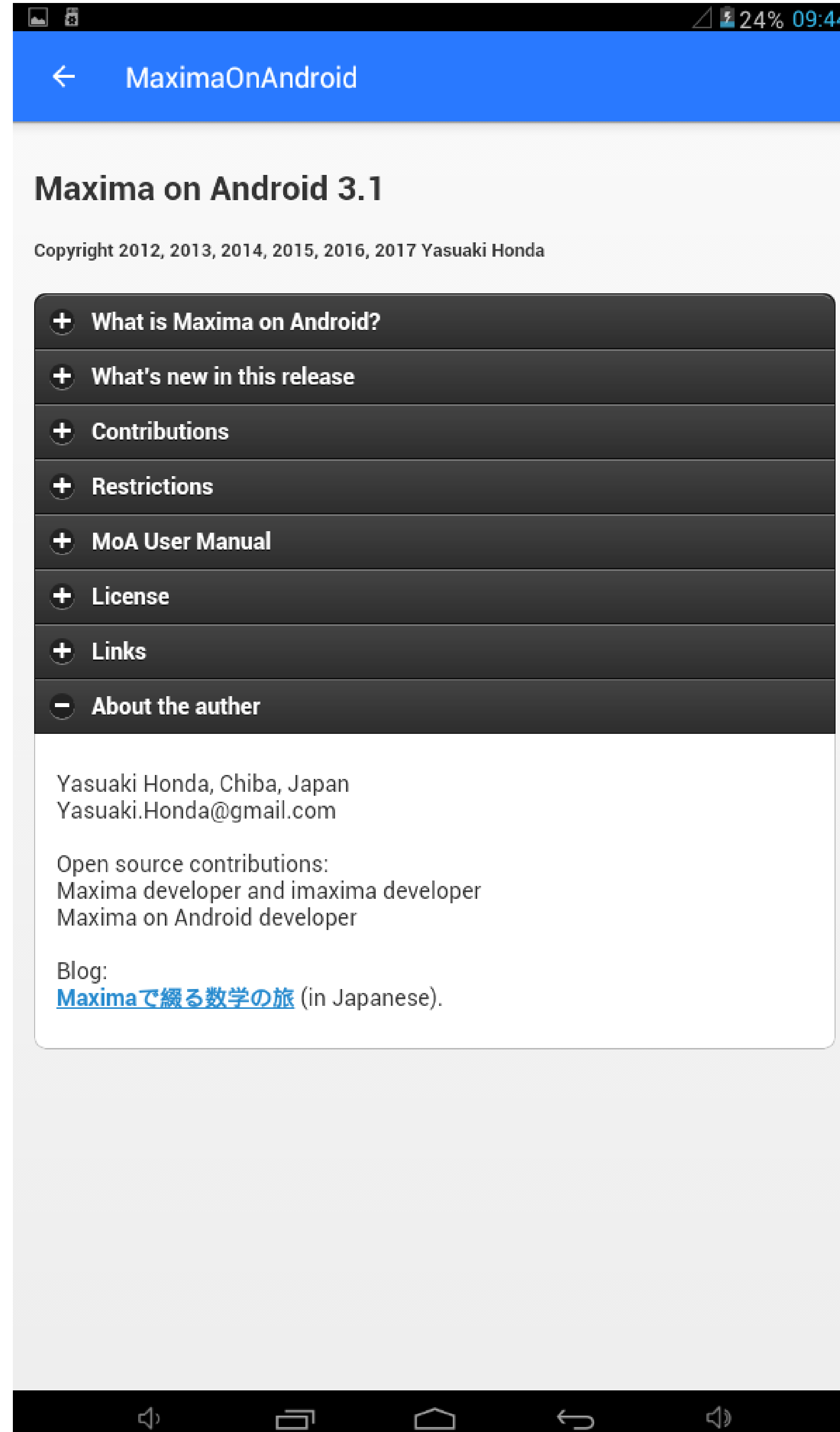
batch("/data/data/jp.yhonda/cache/userscript1120702233.



24% 09:44
MaximaOnAndroid
Maxima on Android 3.1
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