Electronics for Pedestrians

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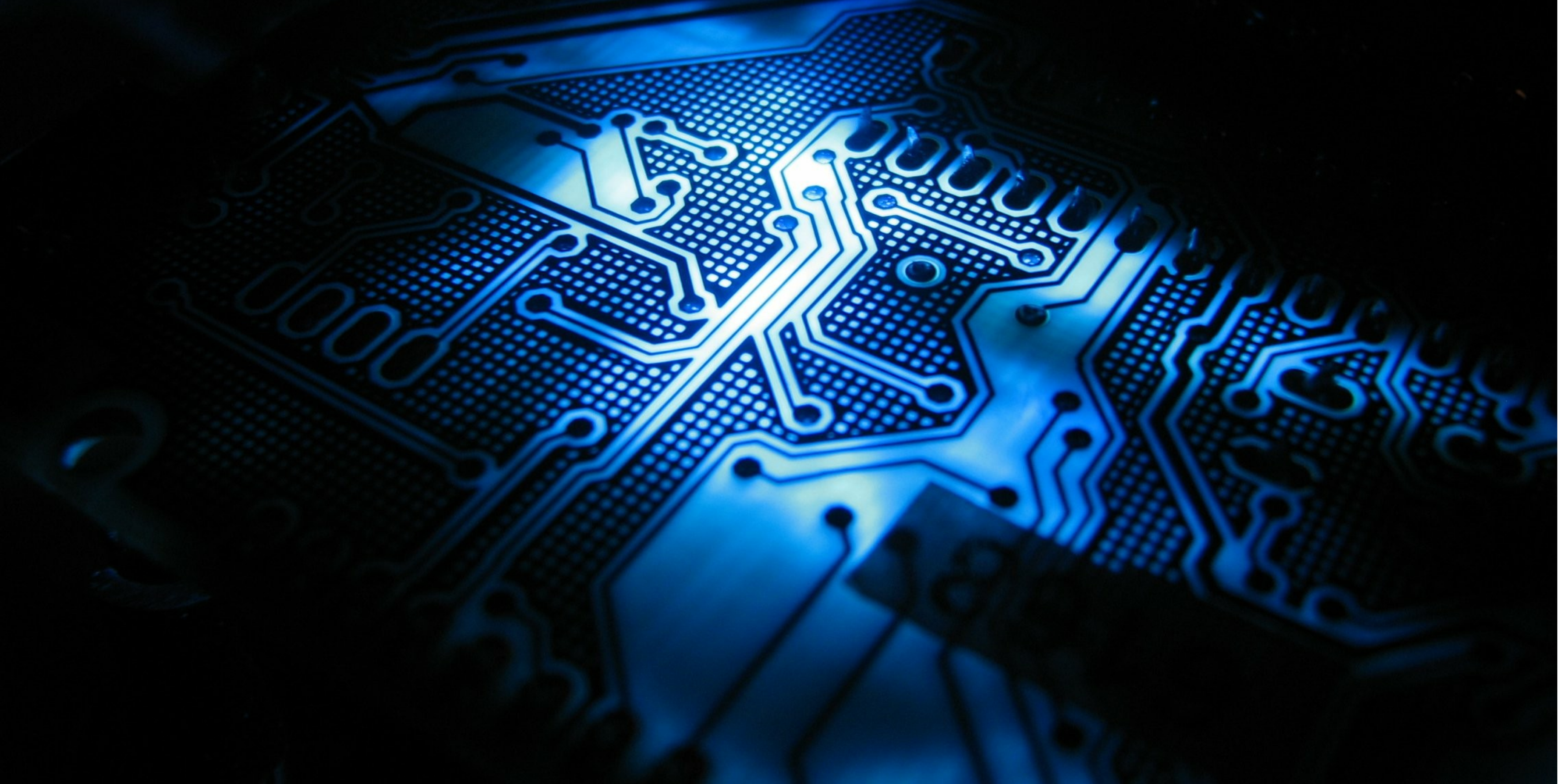
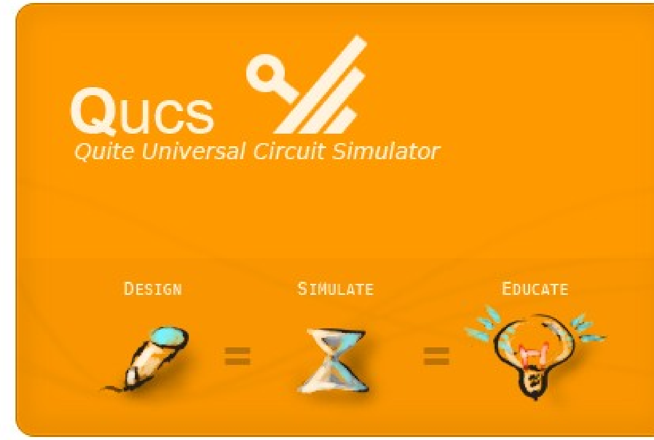
– Tutorial I/II –



“In theory, 'theory' and 'praxis' are the same, in praxis they aren't”

Quick getting started with Qucs

- QUCS – Quite universal circuit simulator: http://qucs.sourceforge.net/
  - similar to Spice™ & derivatives but open-source
  - DC, AC, S-parameter, harmonic balance analysis, noise analysis, RF structures, etc.

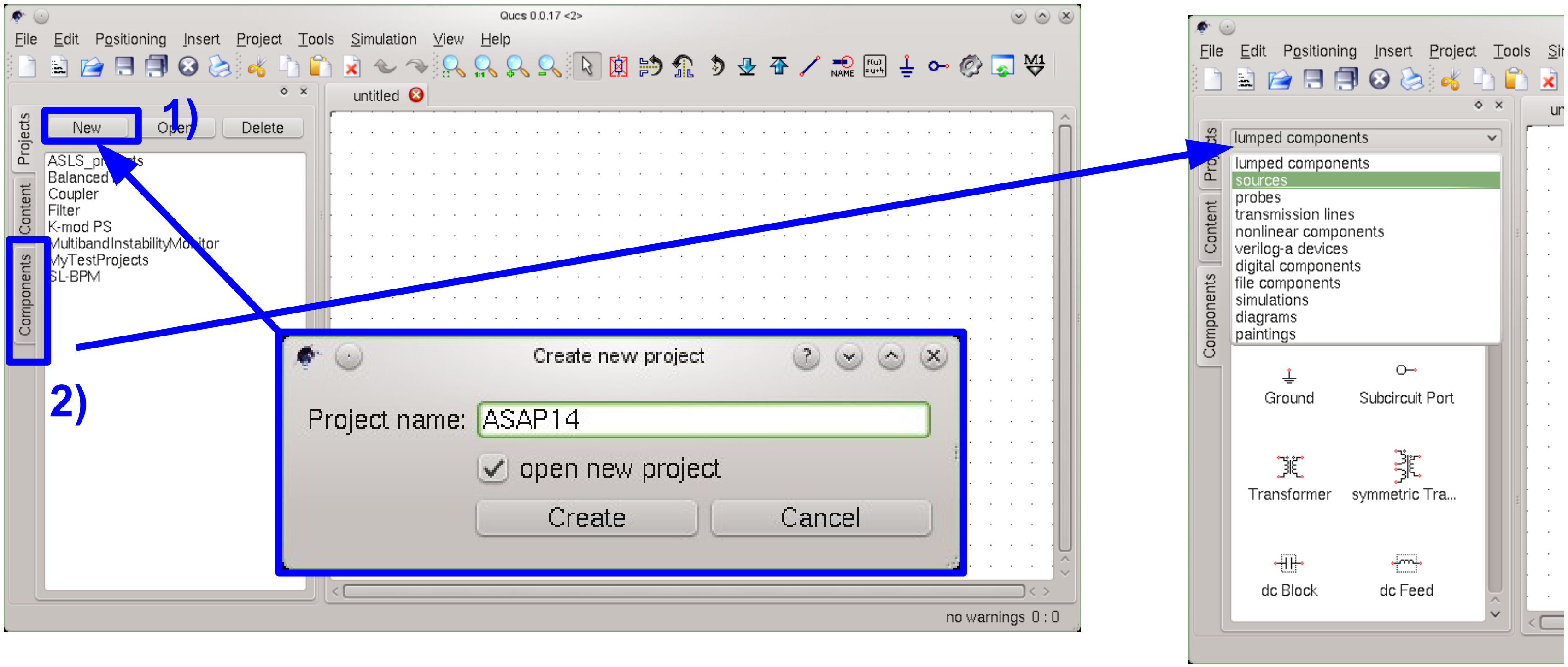


- If you haven't it already: Linux, Mac & Windows version available at: http://qucs.sourceforge.net/download.html
  - Linux: install from your favourite repository, we use version 0.0.17 but earlier should work as well.
  - Mac: you may need the following steps to temporarily disable security settings: http://osxdaily.com/2012/07/27/app-cant-be-opened-because-it-is-from-an-unidentified-developer/
  - Windows installation (+ dependent packages) should be straight forward

Quick getting started with Qucs

1) Project → New Project → *<type and confirm project name>*

- This creates a new projects and switches to '**Content**' tab



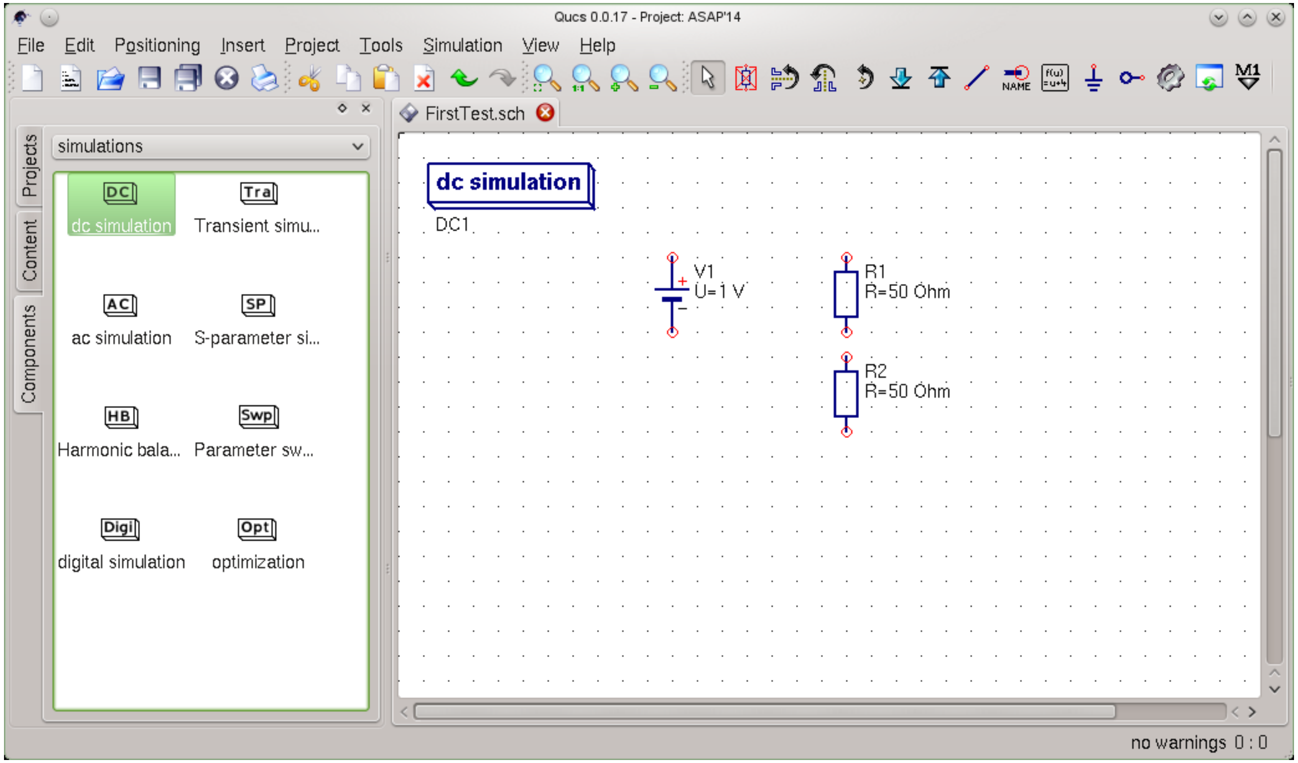
2) Now you can start editing your schematic. The available components can be found in the '**components**' tab.

- there is a sub-menu for different categories of components → feel free and encouraged to browse
- more precise parts and pre-configured elements can be found in: Tools → 'Component Library' (or via 'Ctrl + 4')

Quick getting started with Qucs

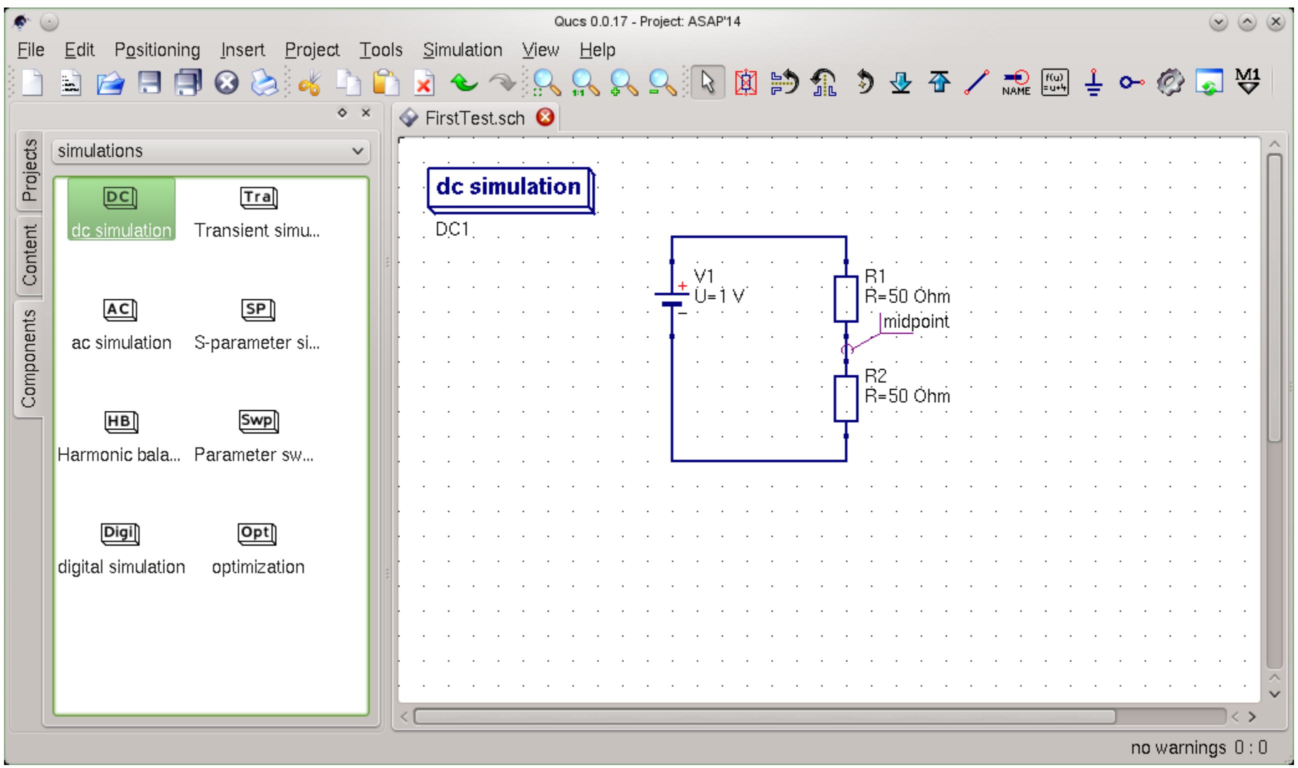
Design and simulate a simple voltage divider:

- Place two resistors (i.e. drag-and drop) onto the schematic:
  Components → lumped components → resistor
  - N.B. You can rotate the components via 'Ctrl+R'
- Place a dc voltage onto the schematic:
  Components → sources → dc Voltage Source



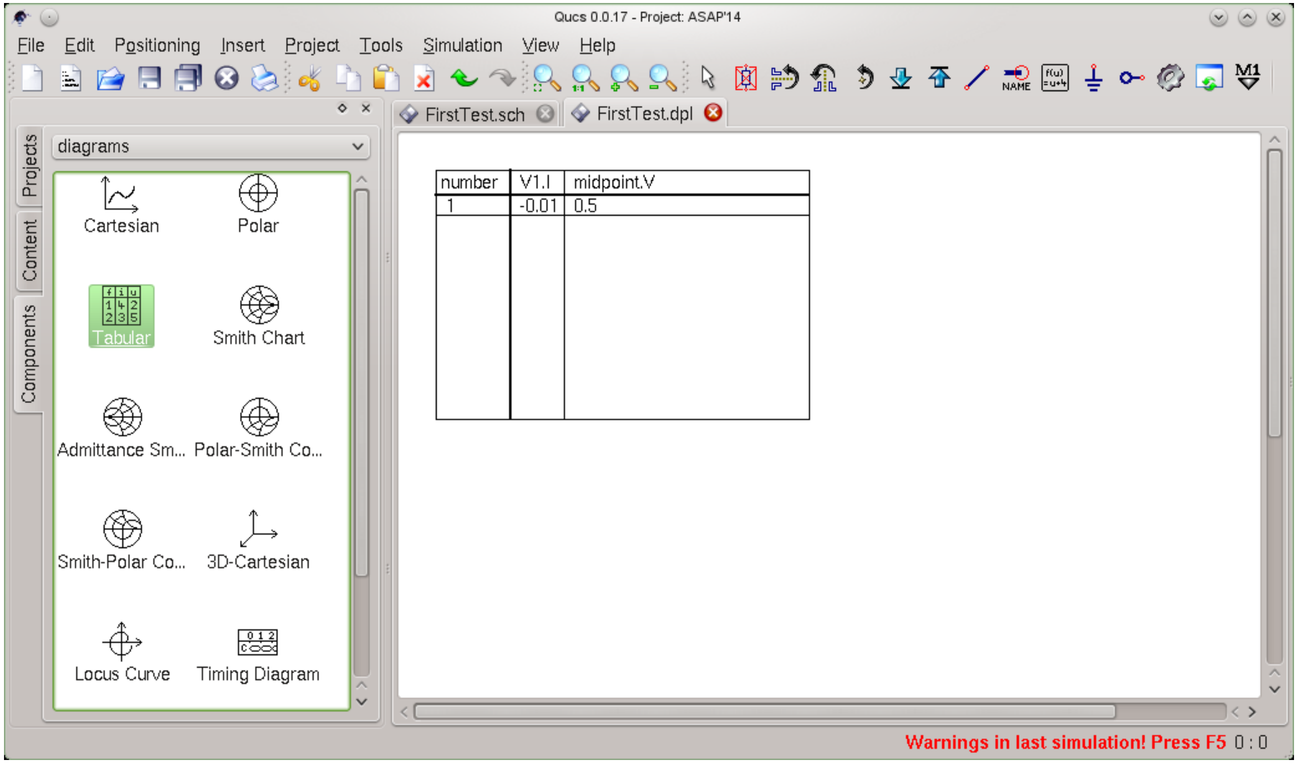
Quick getting started with Qucs

- Wire the parts either using the 'wire' button, or 'Ctrl+E')
- Place a simulation block – in our case 'DC':
  Components → simulations → dc simulation
- Label wires to calculate voltages of give nodes:
  Insert → Wire Label (or 'Ctrl+L') – <type/confirm name>
- N.B. if you haven't already → save the schematic:
  File → Save (as) (or 'Ctrl+S')→ <type descriptive name>



Quick getting started with Qucs

- Issue a Simulation: *Simulation → Simulate* (or 'F2')
  - This opens a new panel (<name>.dpl) which can house the results and opens the 'Components→diagrams' sub-panel on the left (you can switch back and forth with 'F4') (you may change this via 'File → Document Settings → 'open data display …' check-box)
- You can add e.g. a table and select (double-click) the nodes for which the currents and voltages have been calculated (here: 'V1.I' & 'midpoint.V')



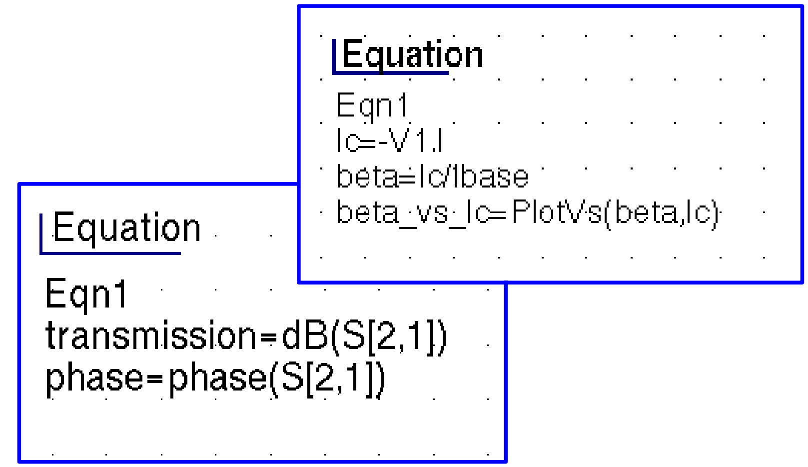
Quick getting started with Qucs

Available dataset items

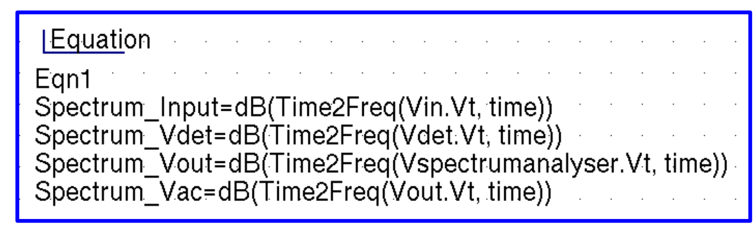
- Depending on the type of simulation performed you find the following types of items in the dataset:
  - *node*.V – DC voltage at node *node*
  - *name*.I – DC current through component *name*
  - *node*.v – AC voltage at node *node*
  - *name*.i – AC current through component *name*
  - *node*.vn – AC noise voltage at node *node*
  - *name*.in – AC noise current through component *name*
  - *node*.Vt – transient voltage at node *node*
  - *name*.It – transient current through component *name*
  - S[1,1] – S-parameter value
- N.B. Please note that all voltages and currents are peak values and all noise voltages are RMS values at 1Hz bandwidth

Quick getting started with Qucs

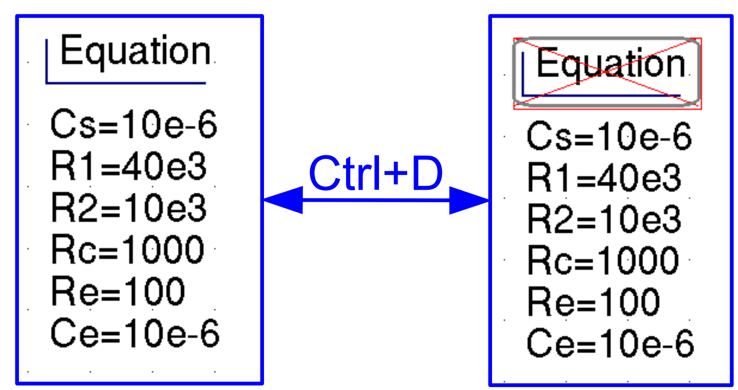
- Additional functions:
  - read & write data to file
  - execute octave (matlab) scripts
  - (simple) equations
  - … extend missing functionality (i.e. it's open-source)



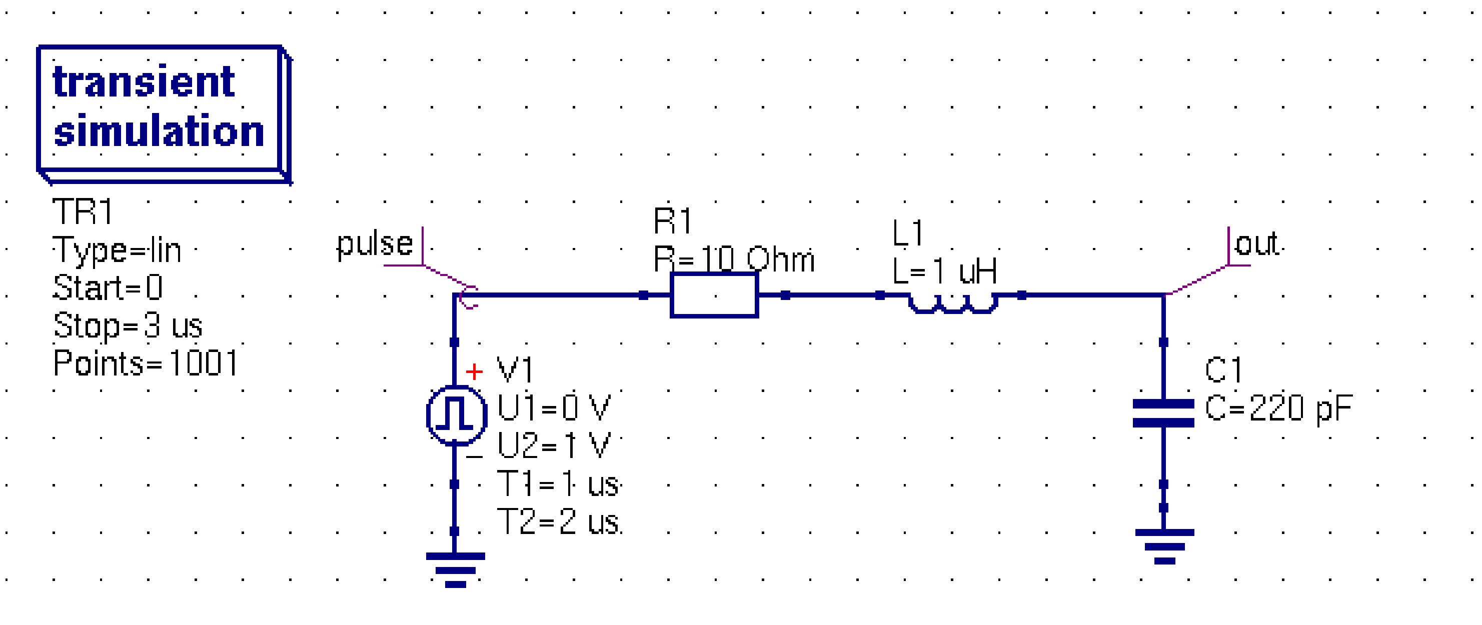
- Equations:
  - … = PlotVs(<variable a>, <variable b>, …)
  - … = dB(<variable a>) or … = a*b
  - … = Time2Freq(<variable y>, <time vector>)
  - variables/component value definition → useful if you e.g. want to test two scenarios – just disable ('Ctrl+D') the equation set that isn't in use

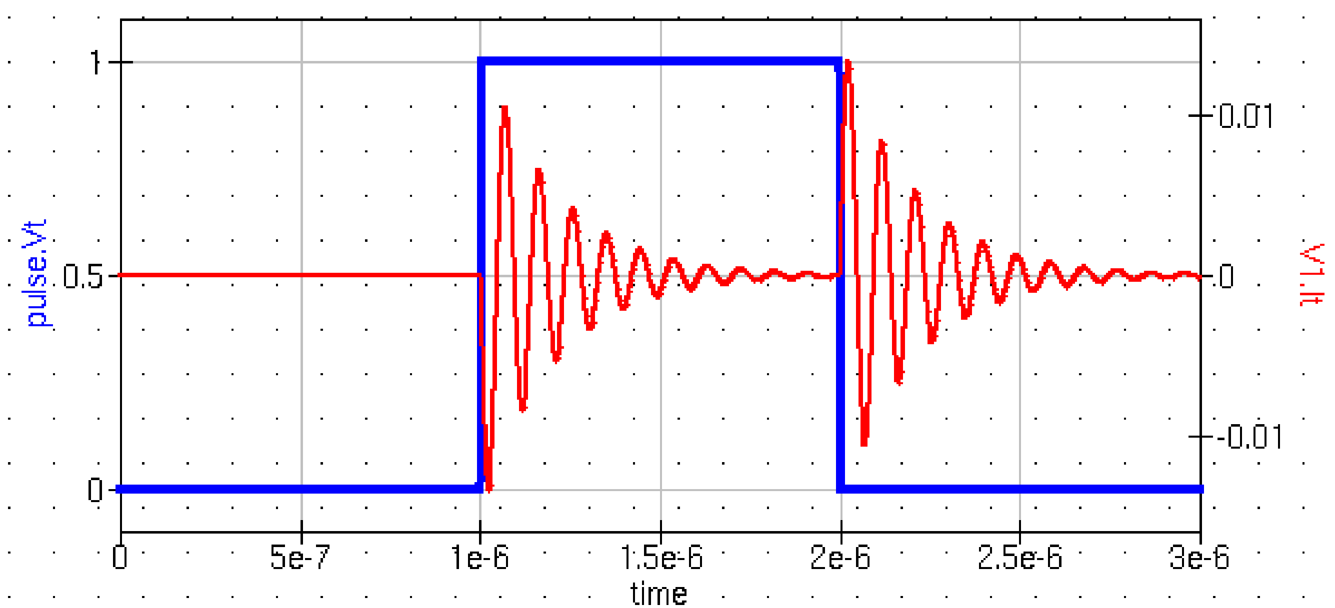


- More detailed info:
  - Help → Tutorials → Equations.pdf
  - Help → Tutorials → Functions.pdf



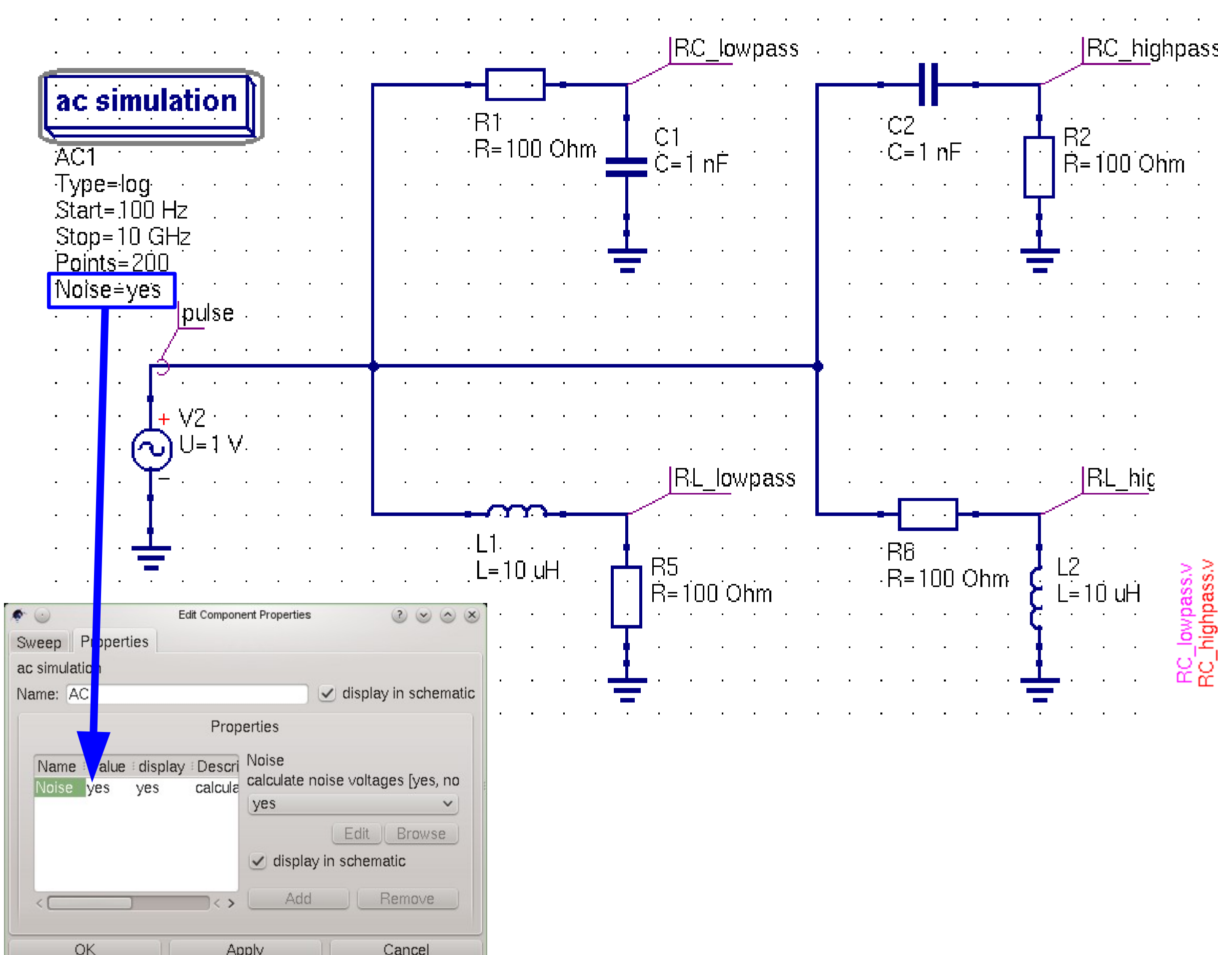
Qucs – Resonant Circuit

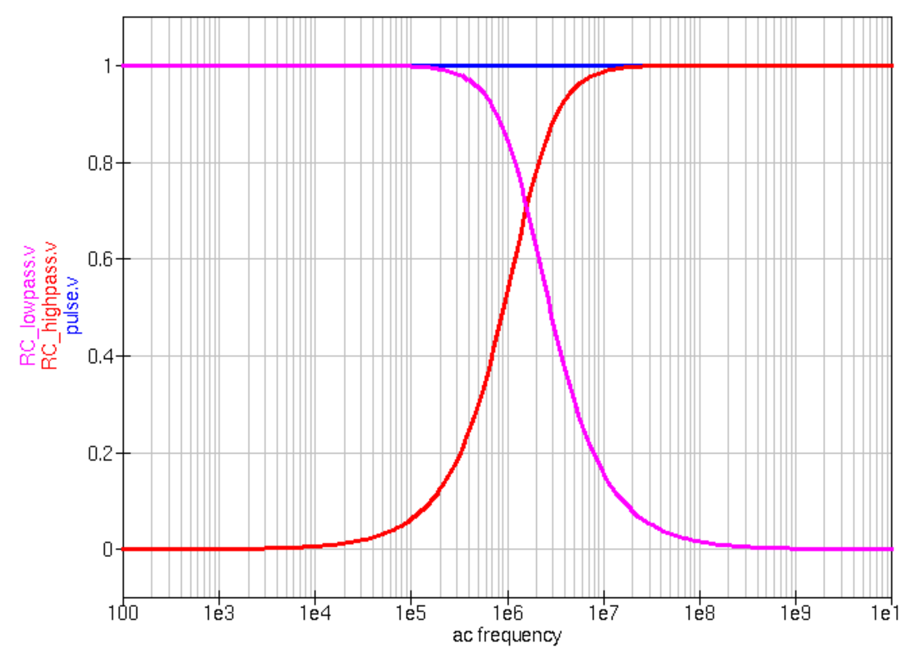




Qucs – AC Simulation

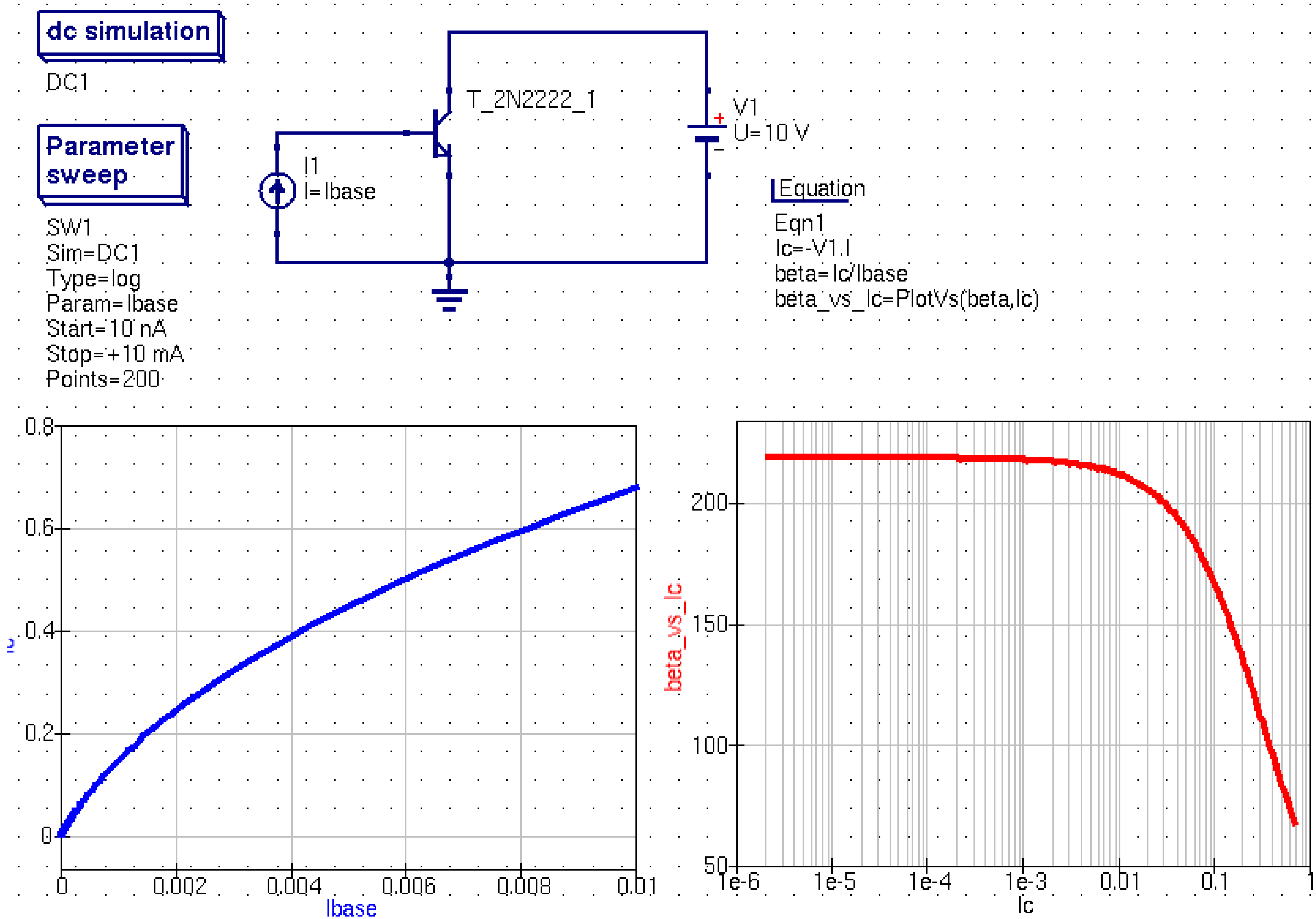
- … going to be used more frequently during RF tutorial
  - N.B. Noise simulation needs to be manually enabled:
    ac simulations → 'Properties' tab → Noise = <yes/no> (optional: 'display in schematic')





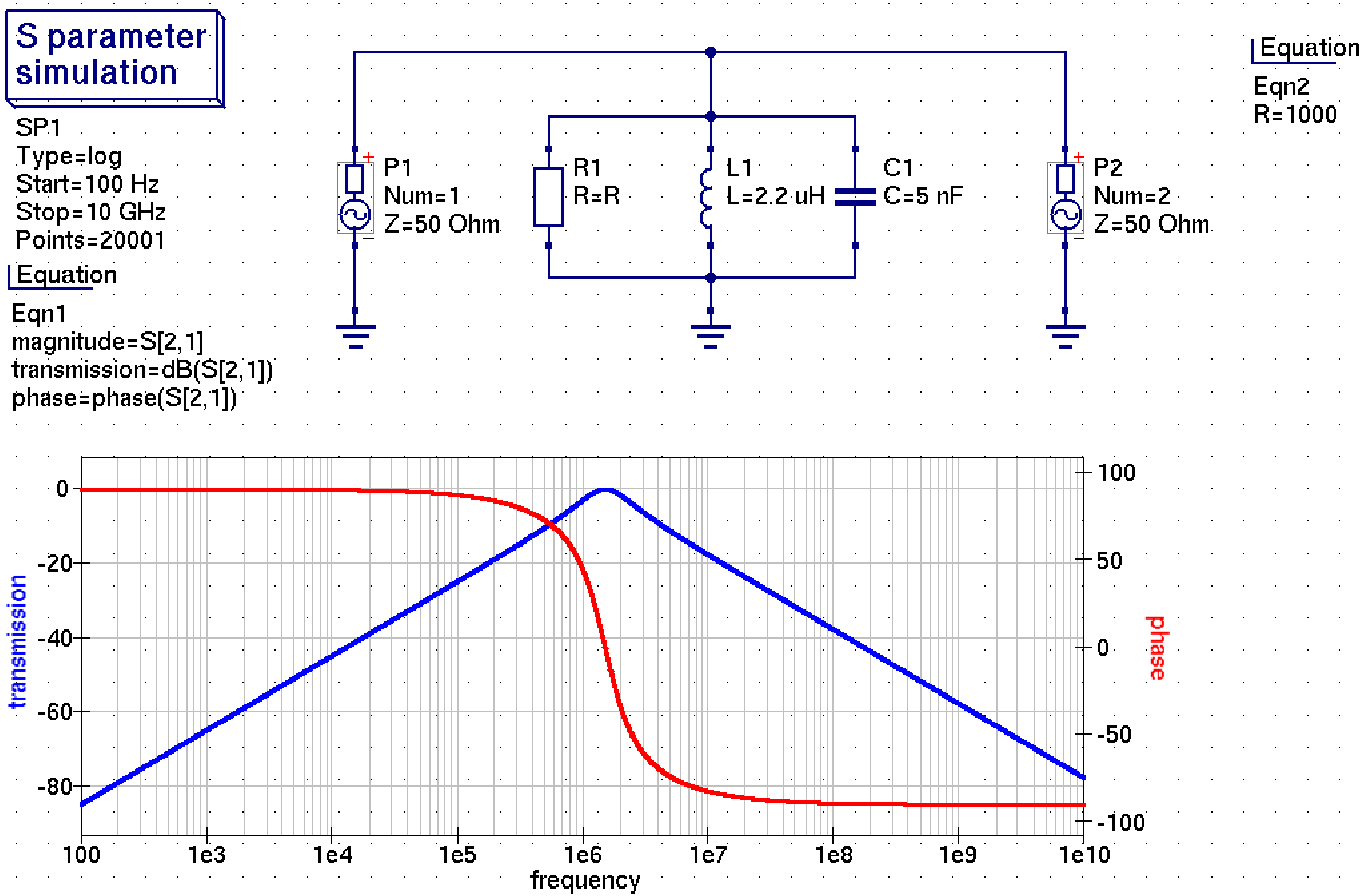
Quick getting started with Qucs

- Parameter sweeps – can be also cascaded

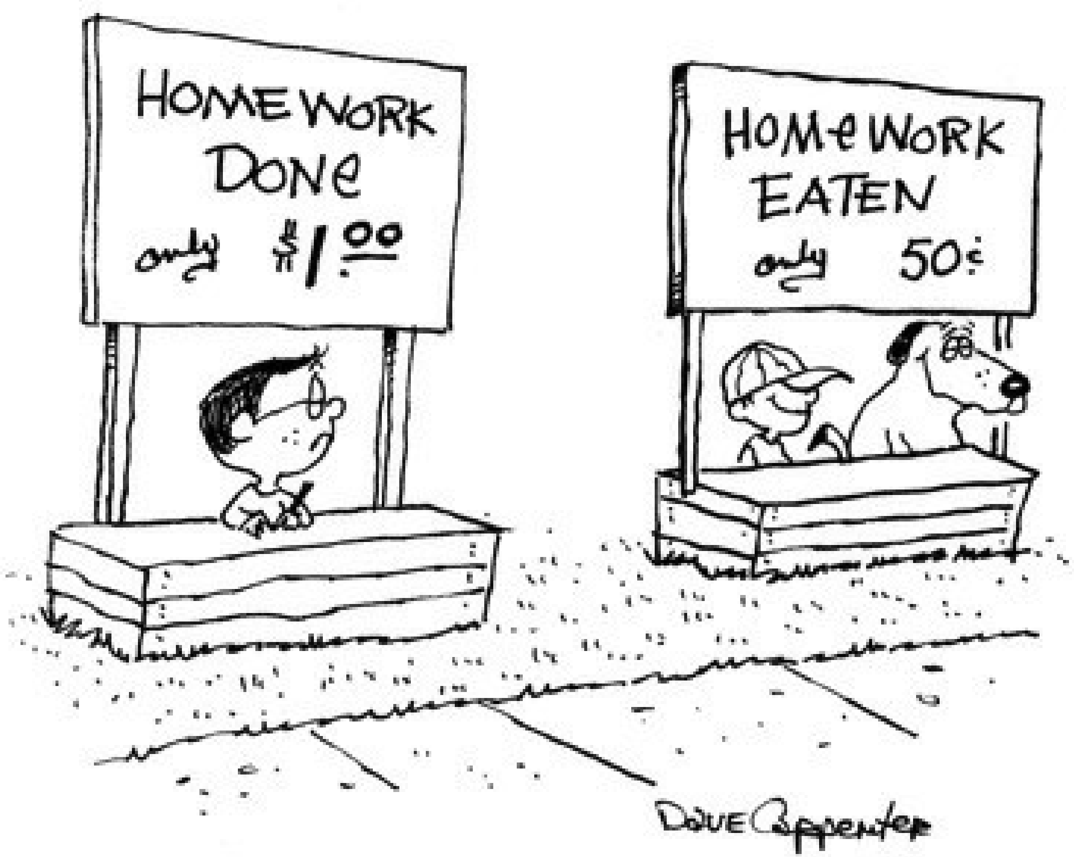


S-Parameter Simulation – Bode Plot (guided)

- This will be more discussed during the RF tutorial

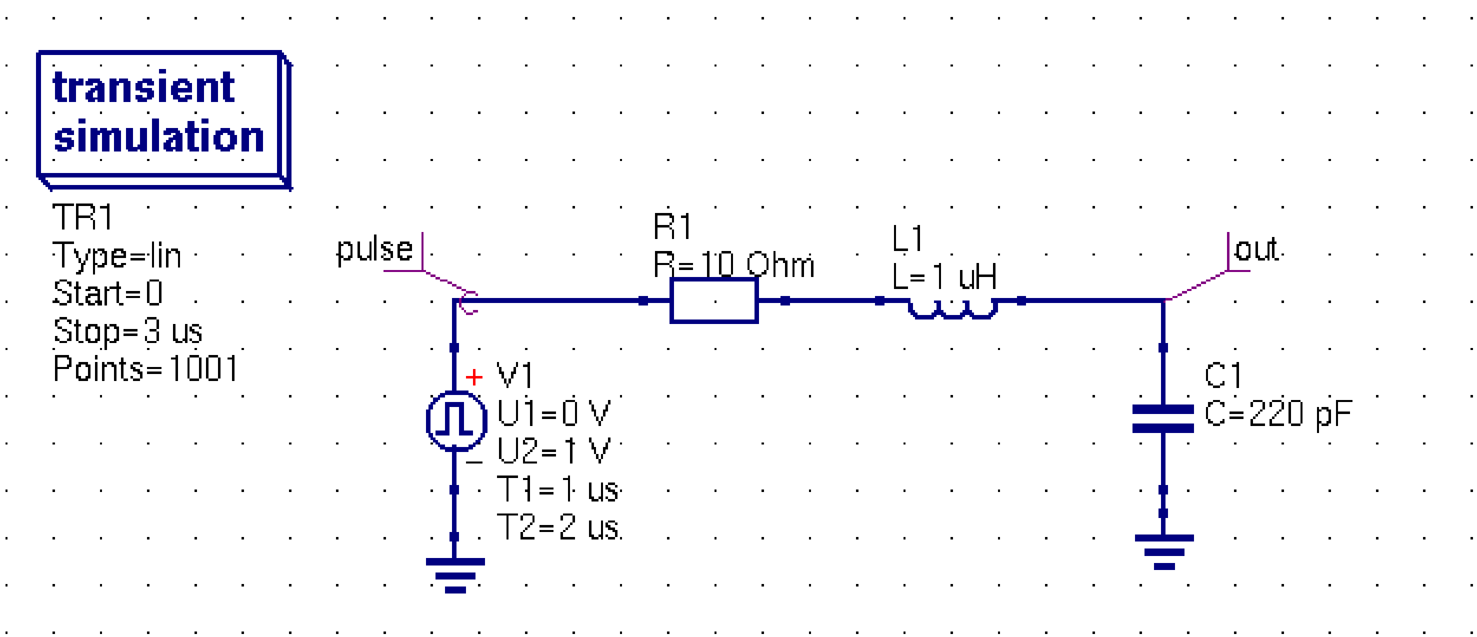


Exercises – your turn



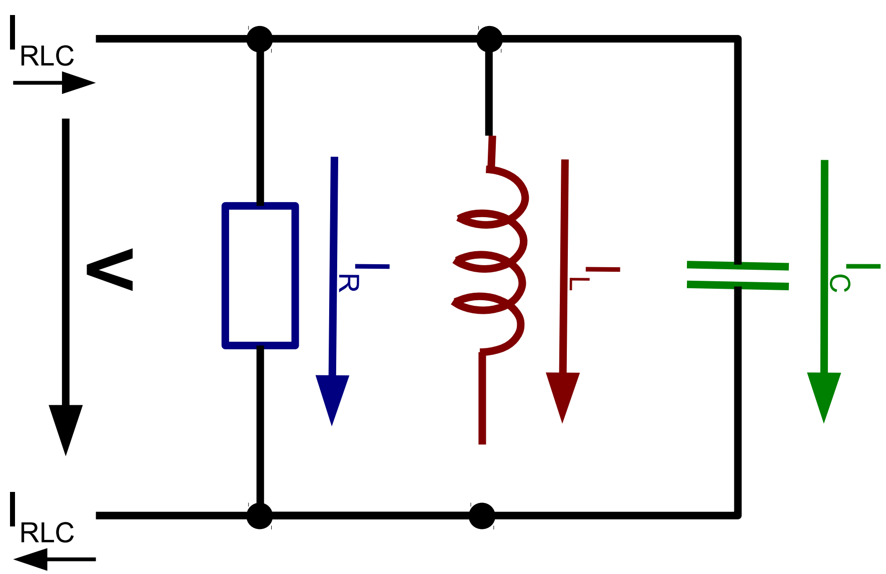
Exercise I

- Get acquainted with Qucs – Repeat the examples for the RC and RL high- and low-pass filters
  a) Simulate and plot the transient response.
  b) Simulate and plot (Bode) the frequency response
  c) Can you make a band-pass out of R, C, and Ls?
  d) Discuss the results



Exercise II

- A frequency generator (Z_i = 50 Ω) is connected to a lossy LC resonator.
  - – N.B. This type of structure is important for discussing cavities, impedances and beam instabilities.
  - a) You have seen the magnitude response for the circuit. Derive the corresponding phase response as a function of ω, ω_0, and ζ.
  - – “Construct“ a parallel RLC resonance circuit schematic with L=2.2 uH, C=5 nF, and R being variable (N.B. use 'Parameter Sweep')..
  - a) Calculate the resonance frequency for R = 0Ω.
  - b) Plot and calculate the quality factor Q for R = 0.1, 1, 2, 10, 20, ...Ω (N.B. use 'Parameter Sweep').
  - c) Discuss the results.



Exercise III

- We want to study minute 'betatron motion'* at the Australian Synchrotron (circumference≈216 m).
  - Construct a notch filter that suppresses the first revolution lines and main RF frequency (assume: f_{RF}=500 MHz) using only passive components. N.B. There is more than one option!
  - Find the optimal values that would do the job.
    - Somebody mentioned to you that most components are only available for a limited number of values. Find the canonical component values that would match your ideal filter response best.
    - Compare your solution with the real-world R, L, C components including the discussed parasitics.
  - Discuss the pro's, con's and limitations of your solution.

*These are small transverse oscillations of the electron bunches as they circulate around the machine.

Exercise IV – Optional

- Re-use your RLC resonant circuit from exercise II.
  a) Simulate the transient response to an AC source operating at the LC resonance frequency, and while being
     - switched-on (let the transient stabilise), and
     - subsequently switched-off.
  b) What are your observations when you increase or decrease the quality factor of the resonance?
  – What impact might this have on e.g. bunch-by-bunch diagnostics?