Behavioral Sources, Parameters and Expression Evaluation

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Expression Evaluation

- When curly braces { } are encountered, the enclosed expression is evaluated on the basis of all relations available at the scope and reduced to a floating point value (evaluated before simulation begins).

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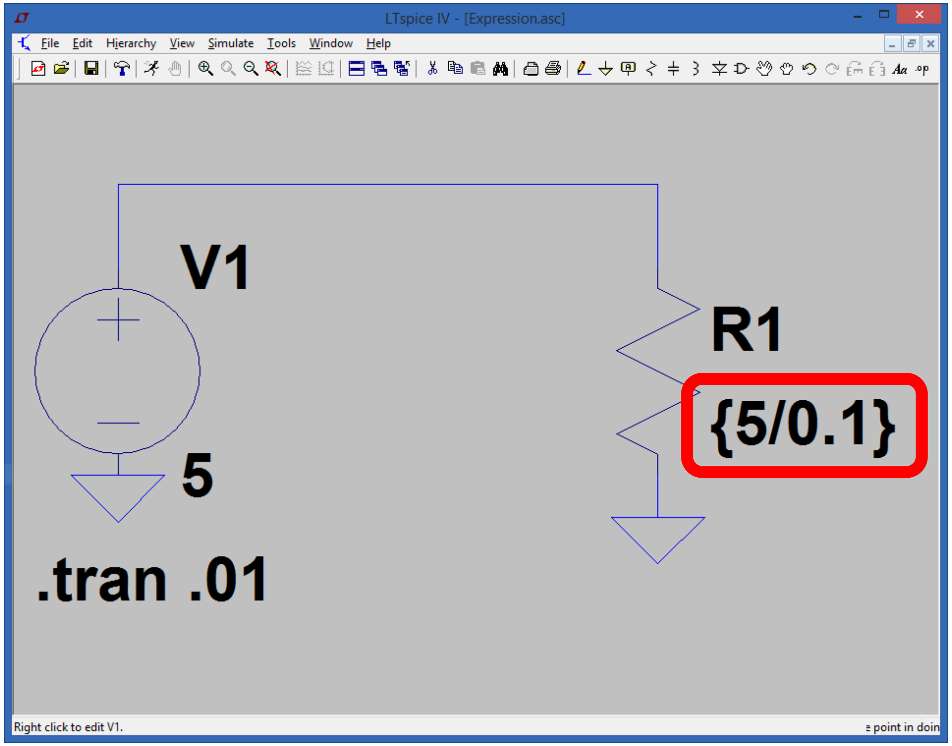


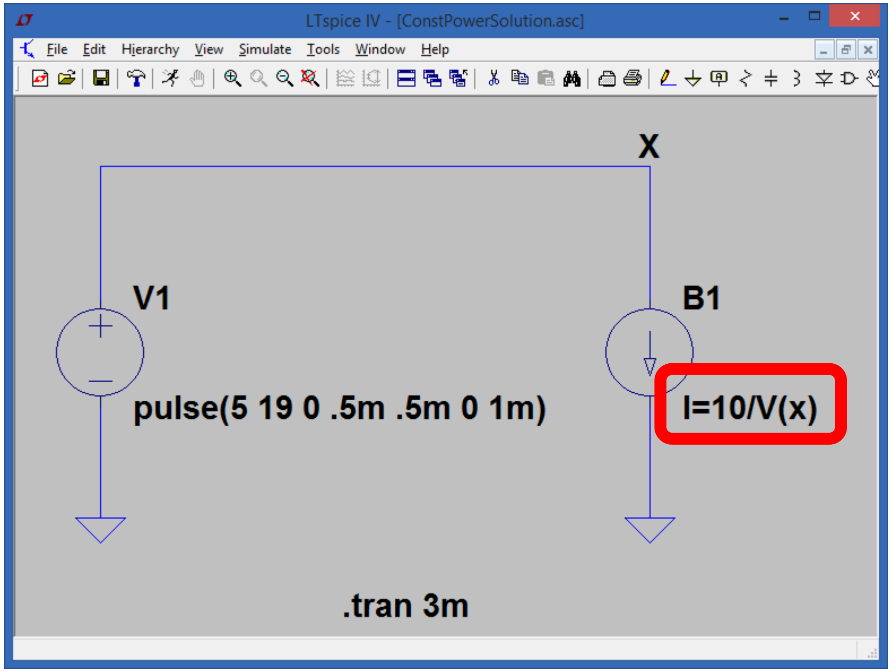
Expression.asc

Behavioral Sources (BV, BI)

- Behavioral sources are used when the user would like to define a source with an arbitrary expression.
- Expressions can contain the following:
  - Node voltages, e.g., V(n001)
  - Node voltage differences, e.g., V(n001, n002)
  - Circuit element currents; for example, I(S1), the current through switch S1 or Ib(Q1), the base current of Q1.
    - It is assumed that the circuit element current is varying quasi-statically, that is, there is no instantaneous feedback between the current through the referenced device and the behavioral source output.
    - Similarly, any ac component of such a device current is assumed to be zero in a small signal linear .AC analysis.
  - Various functions and operations as defined in the help file.
    - Search “Arbitrary Behavioral Voltage or Current Sources” in help
  - The only difference between Bi1 and Bi2 is the direction of current.

Places to use Expressions & Behavioral Sources

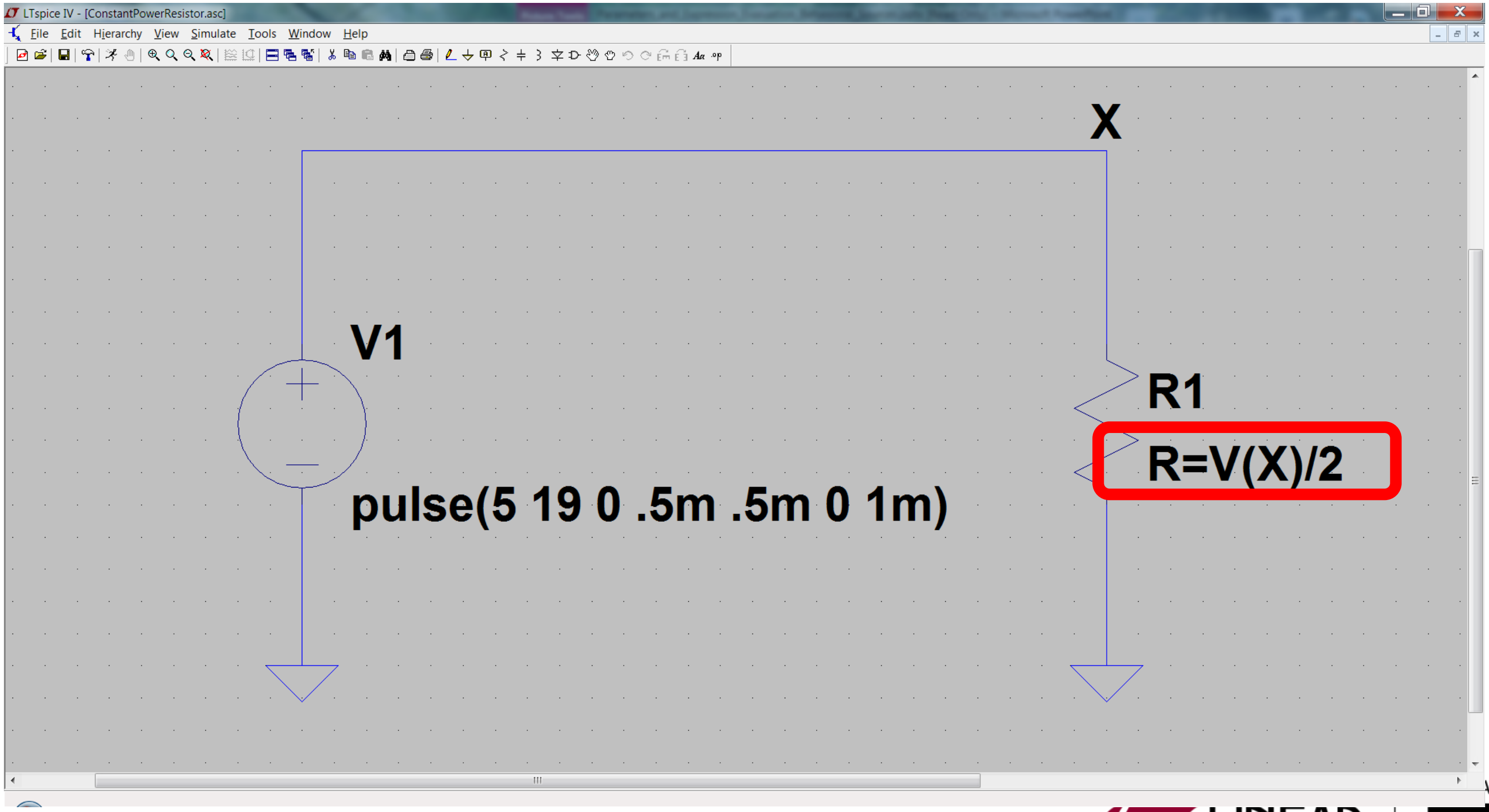
- Without { }, the expression is not reduced to a value before simulation, but is calculated during simulation in real time. Below it is used within a behavioral source.
- In this example, we will create a load that dissipates a constant power regardless of the voltage across it.



ConstantPower.asc

Places to use Expressions & Behavioral Sources

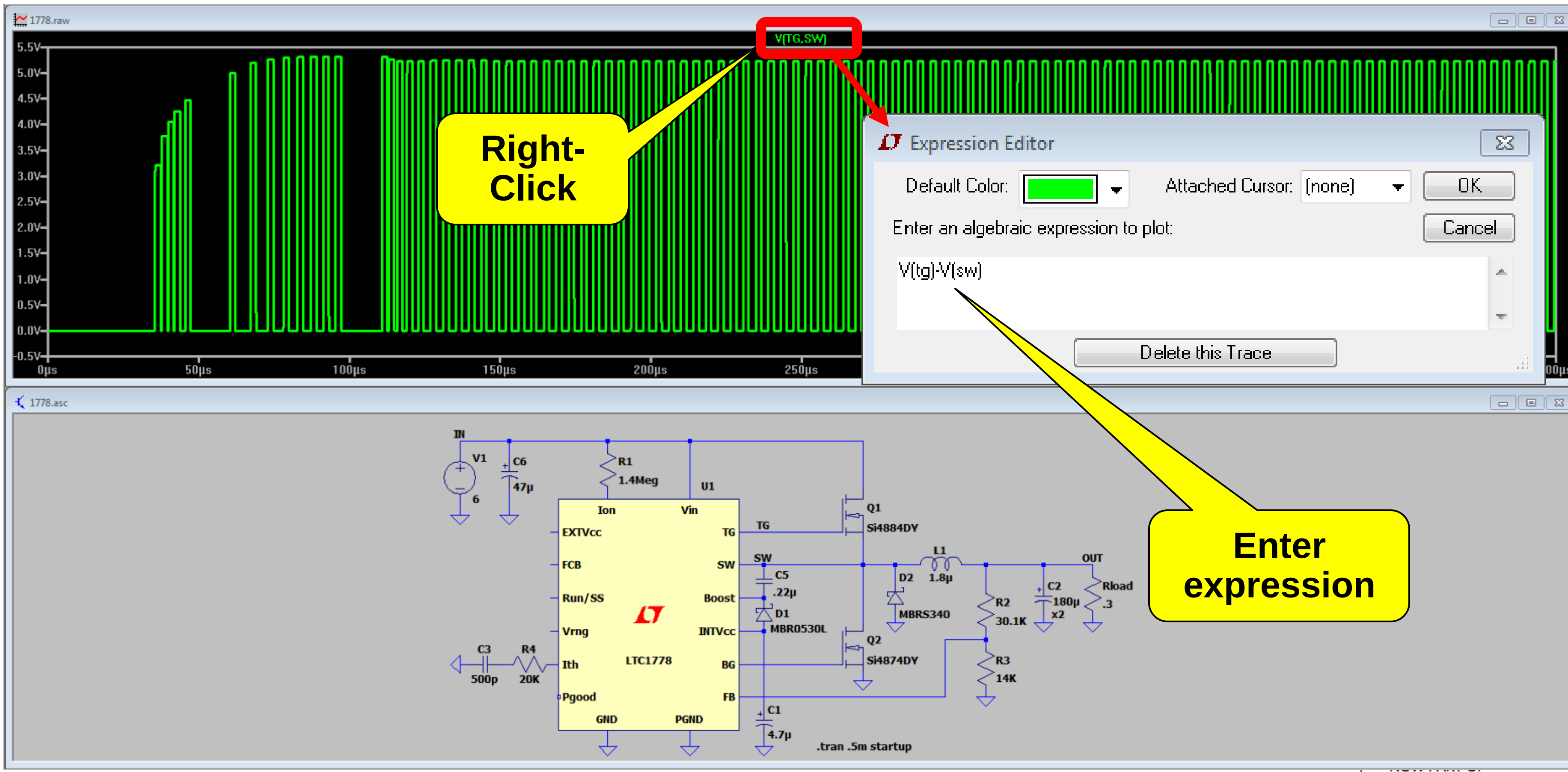
- Expressions for component values can also be calculated in real time.



ConstantPowerResistor.asc

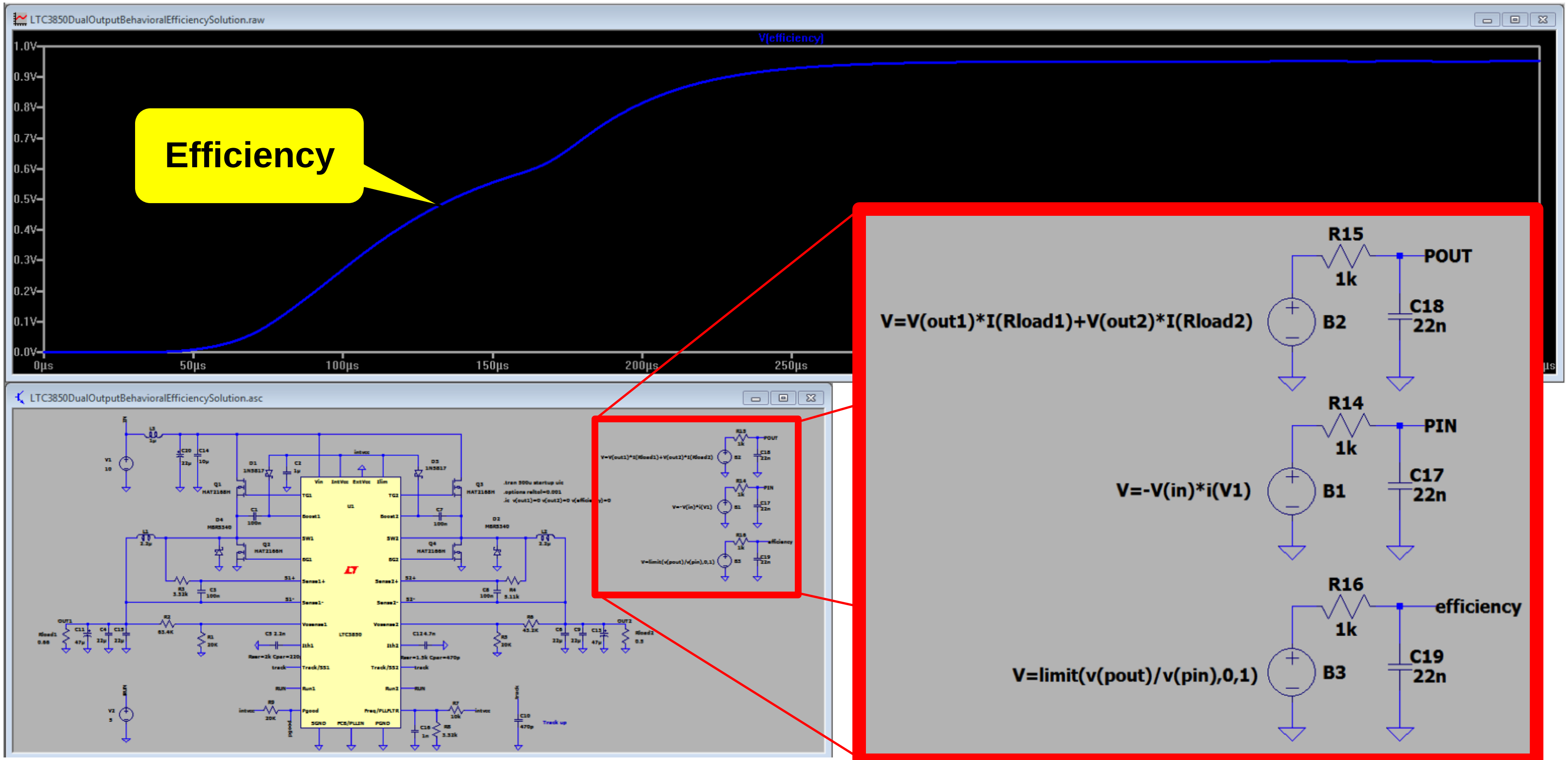
Places to use Expressions & Behavioral Sources

- Within the waveform editor (right click on trace name or via the ‘*Plot Settings*’ menu then ‘*Add Trace*’)



Places to use Expressions & Behavioral Sources

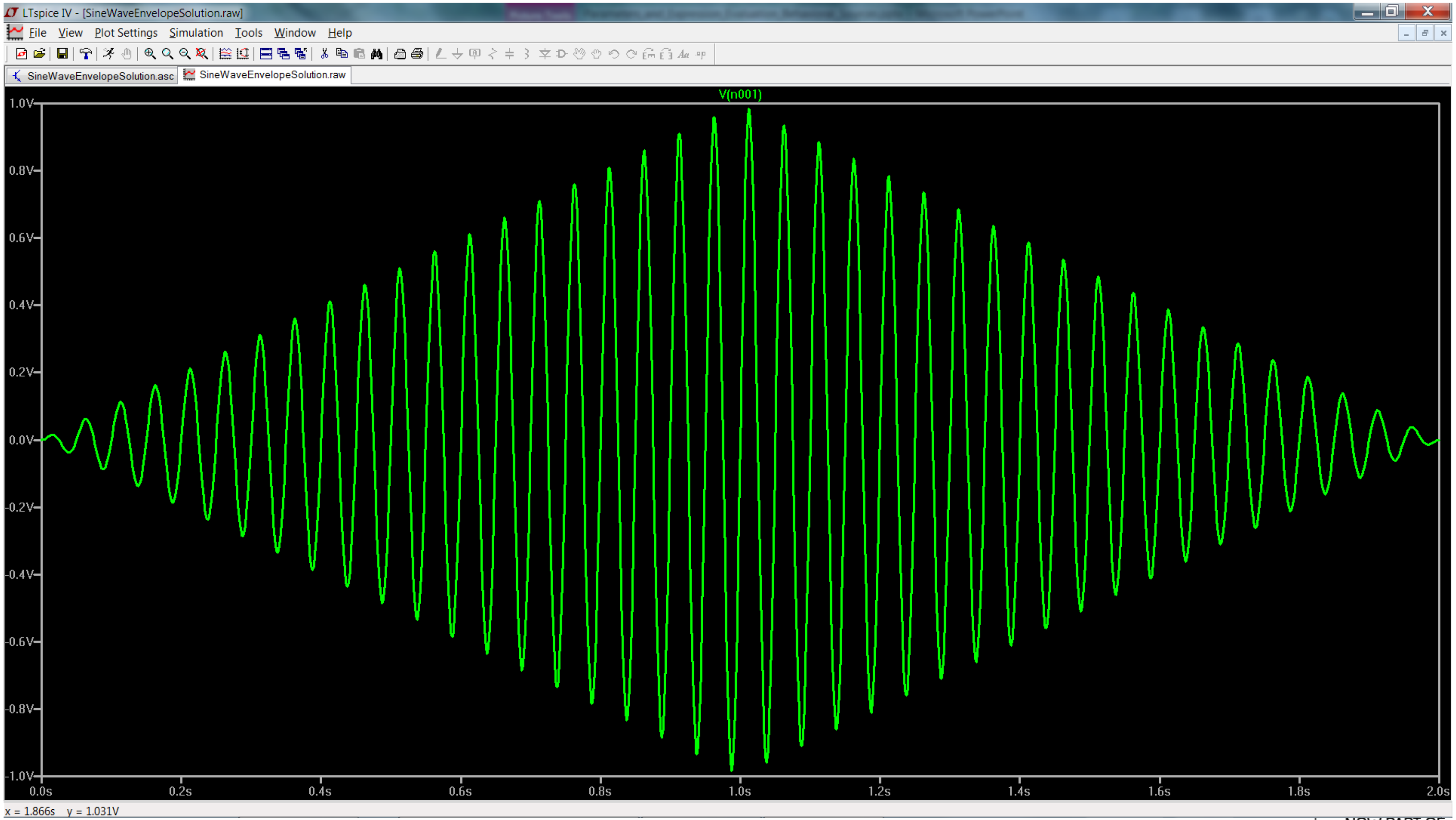
- Behavioral sources can be used to do on the fly calculations during simulations. One example is calculating efficiency.



LTC3850DualOutputBehavioralEfficiencySolution.asc

Places to use Expressions & Behavioral Sources

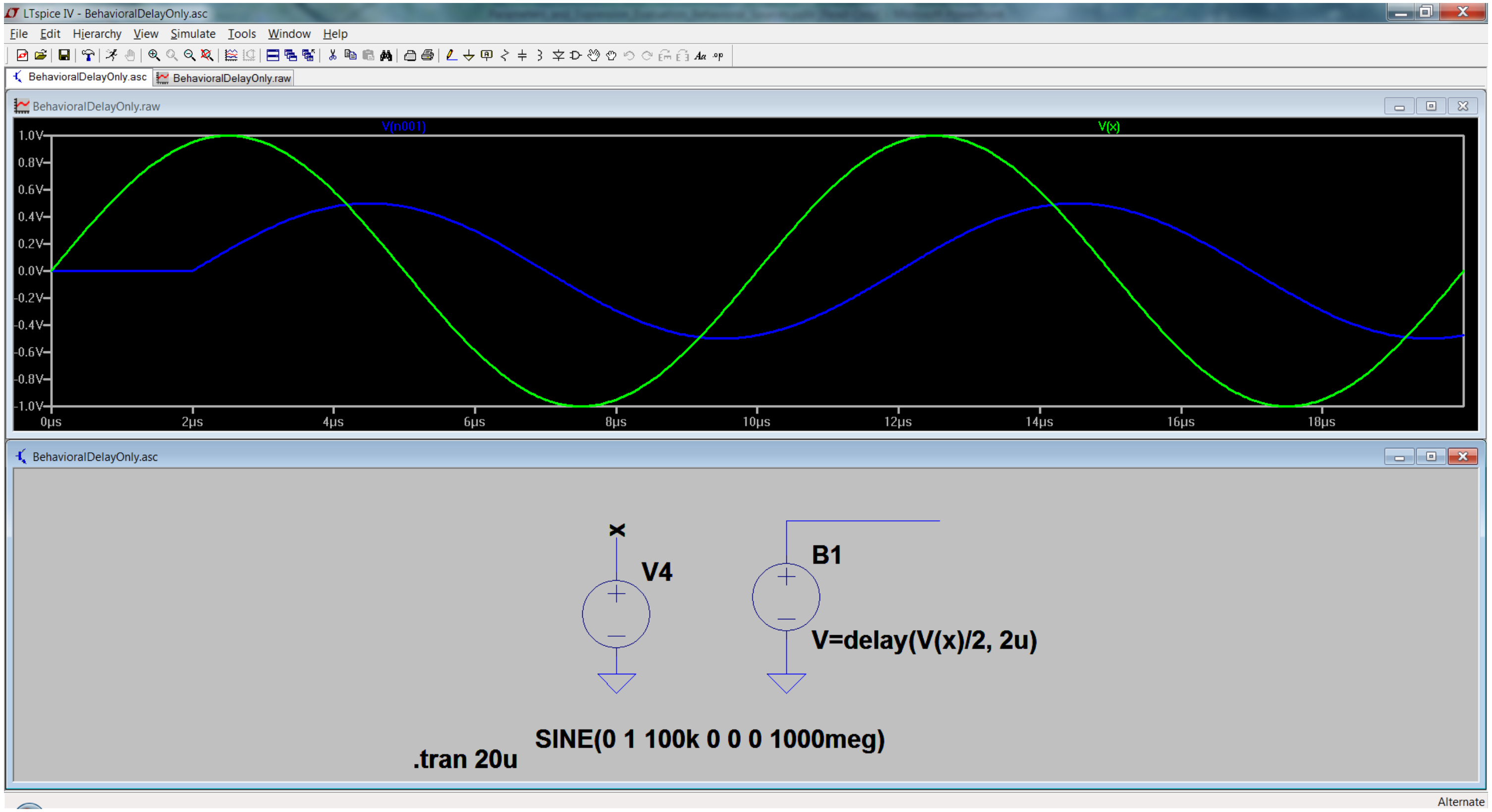
- Try to create this waveform using behavioral sources.



SineWaveEnvelopeExcercise.asc

Behavioral Source with Delay

- The “Delay” function can be used to insert a time delay into the behavioral source.

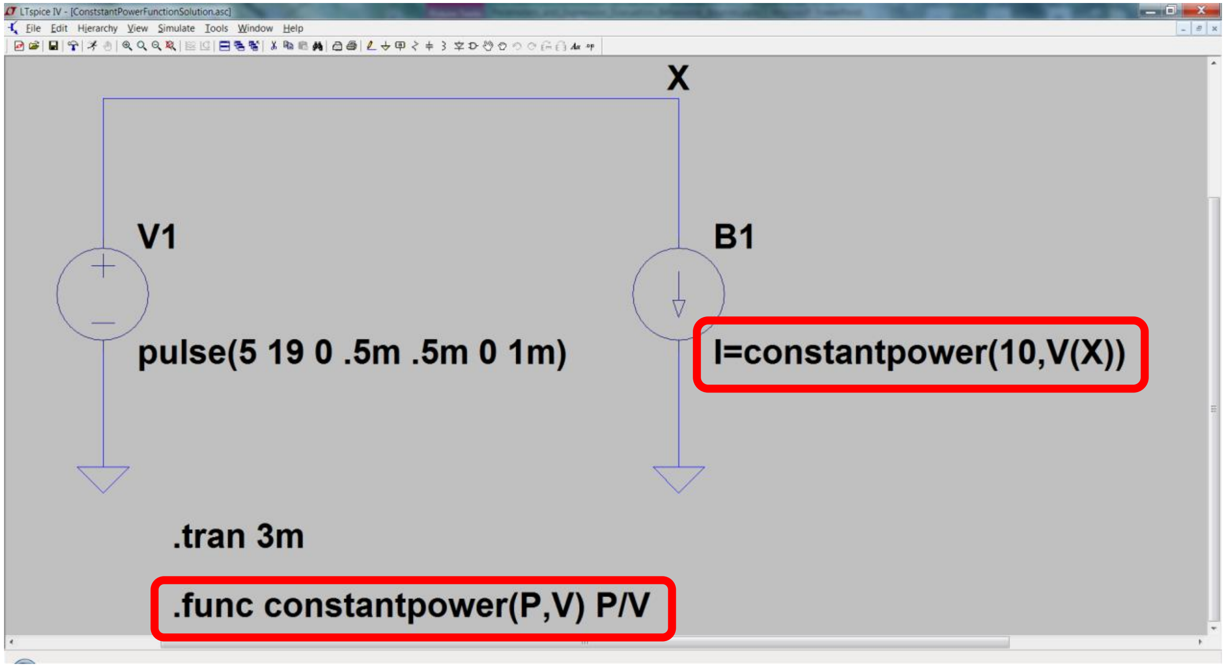


User-Defined Functions/Parameters

- The .func directive allows the creation of user-defined functions for use with user parameterized circuits and behavioral sources
- .func <name>([args]) {<expression>}
  - Ex. .func myfunc(x,y) {sqrt(x*x+y*y)}
- This is useful for associating a name with a function for the sake of clarity and parameterizing subcircuits so that abstract circuits can be saved in libraries.
- The .func statement can be included inside a subcircuit definition to limit the scope of the function to that subcircuit and the subcircuits invoked by that subcircuit.

User-Defined Functions/Parameters

- In this example the source B1 calls the function constantpower and sends it the parameters of “10” and “V(X)” (the voltage at the node labeled “X”).
- .func constantpower calculates 10 divided by the voltage at “X” and returns the result to source B1 in real time.

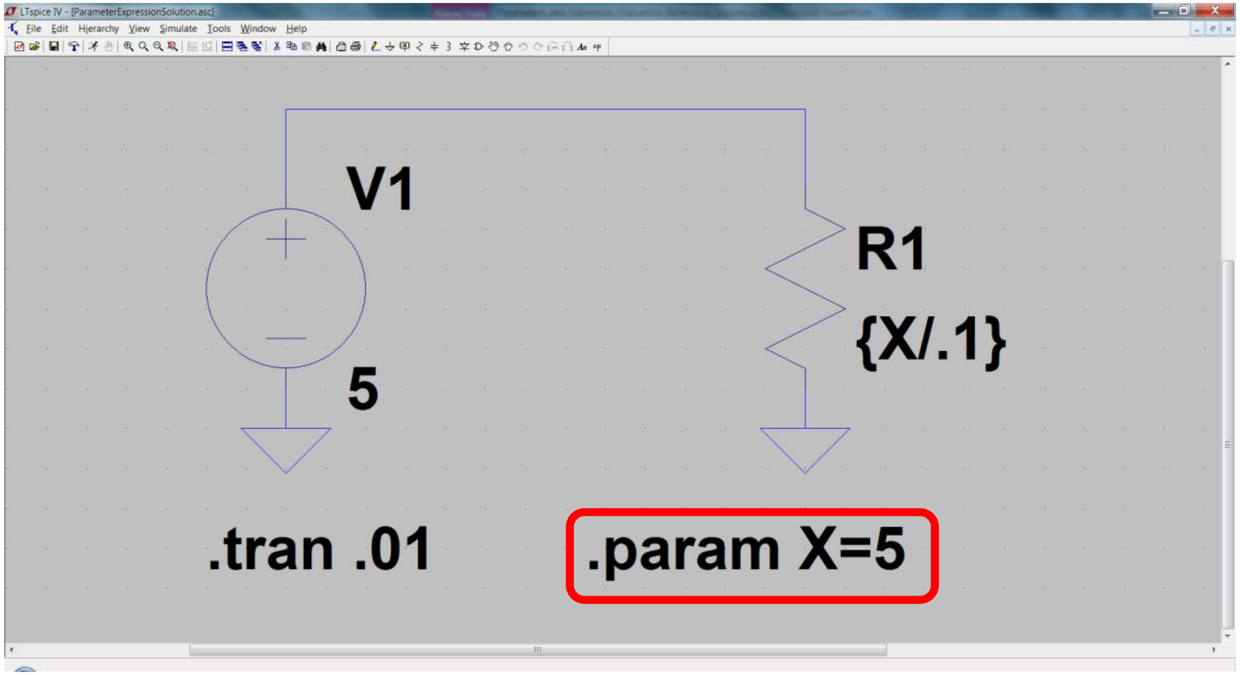


ConstantPowerFunction.asc

NOW PART OF

User-Defined Functions/Parameters

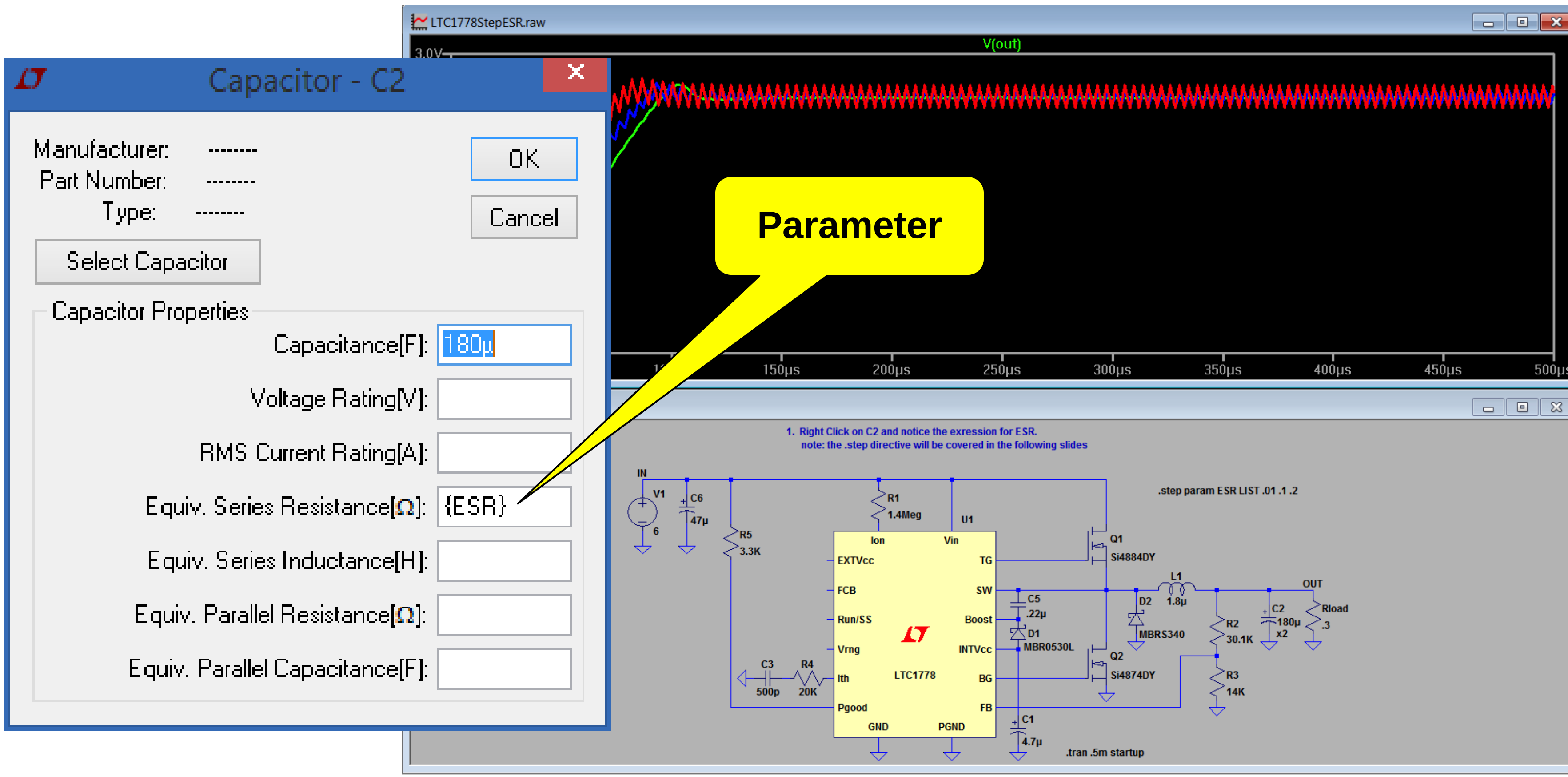
- The .param directive allows the creation of user defined variables
- Useful for varying component values without actually editing component properties
- All parameter substitution evaluation is done before the simulation begins.
- Example syntax: .param x=y   y=z   z=1k*tan(pi/4+.1)



ParameterExpression.asc

User-Defined Functions/Parameters

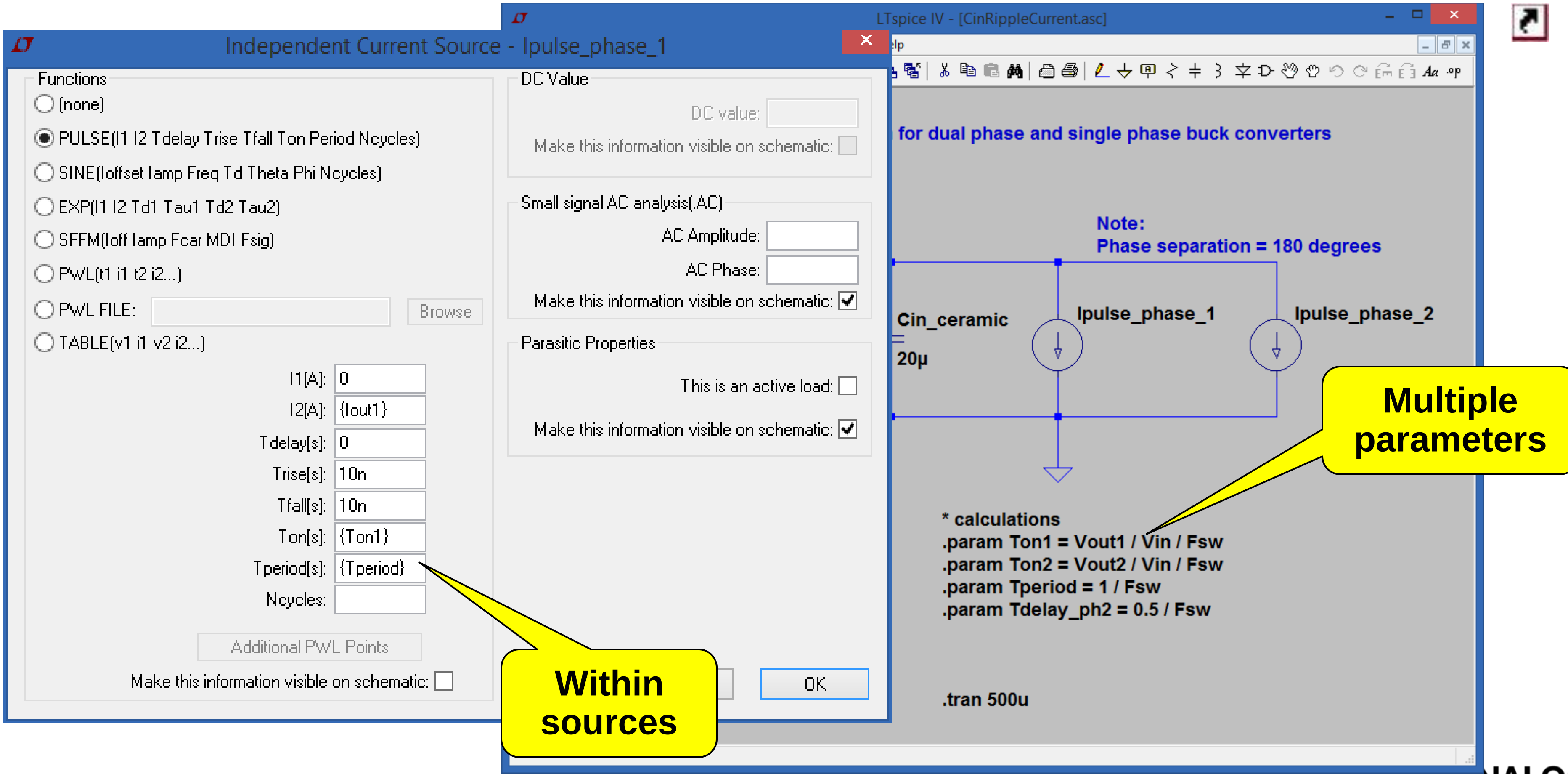
- Parameters can be used within components



LTC1778StepESRSolution.asc

User-Defined Functions/Parameters

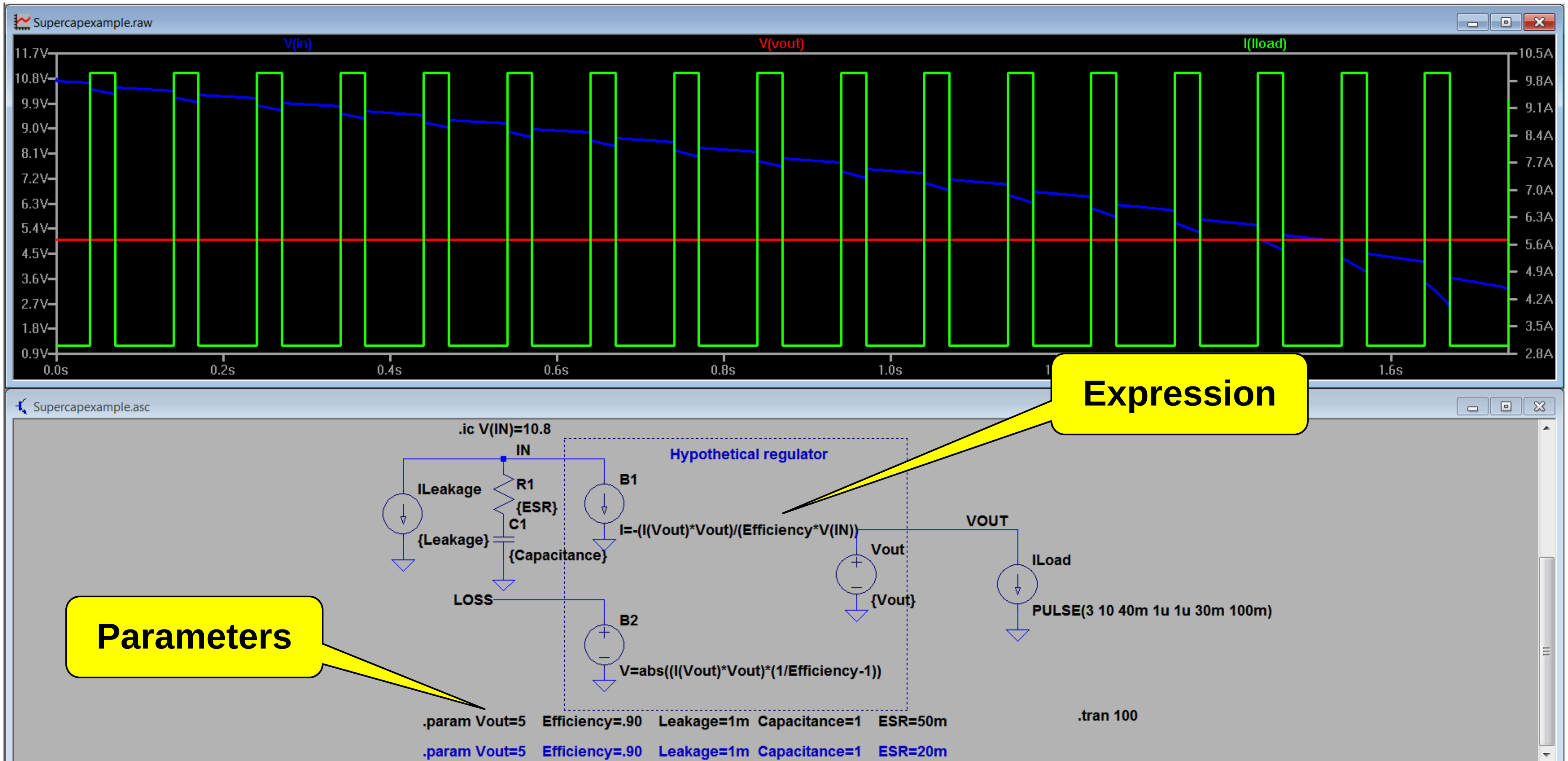
- Parameters can also be used within sources.
- Multiple parameters can be used simultaneously



CinRippleCurrentSolution.asc

User-Defined Functions/Parameters

- Supercap example:



Supercapexample.asc

Parameter Sweeps

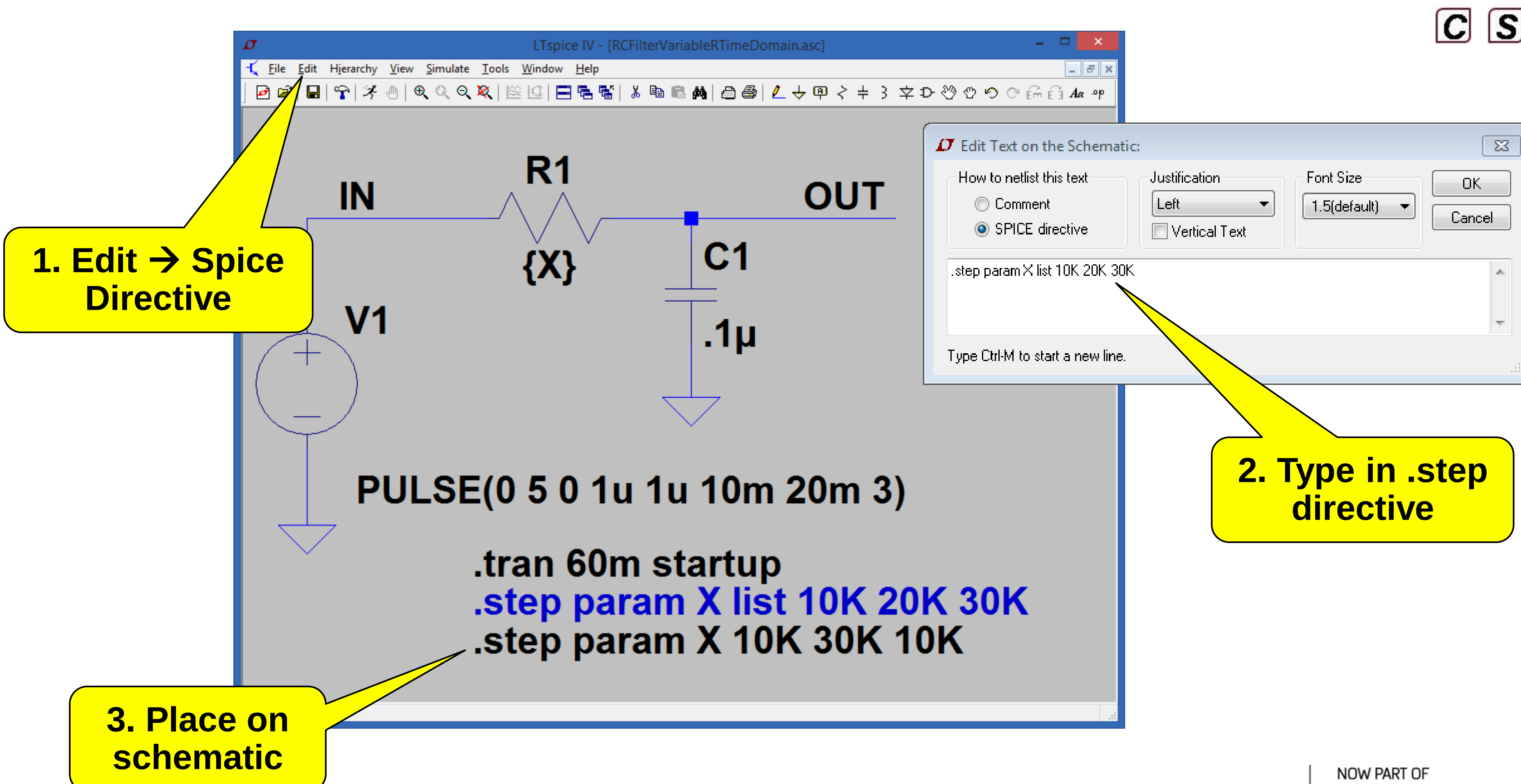
- The .step command causes the analysis to be repeatedly preformed while stepping a model parameter
- Multiple back-to-back simulation results are kept instead of being discarded
- Steps may be linear, logarithmic, or specified as a list of values:
  - Linear: *.step <stepped element> <start> <stop> <increment>*
  - Octave: *.step oct <element> <start> <stop> <#pts per octave>*
  - Decade: *.step dec <element> <start> <stop> <#pts per decade>*
  - List: *.step <element> list <value1> <value2> … <value*$_n$*>*

Parameter Sweeps example syntax

- Example: .step I1 10u 100u 10u
  - Step independent current source I1 from 10u to 100u in step increments of 10u (Linear).
- Example: .step oct v1 1 20 5
  - Step independent voltage source V1 from 1 to 20 logarithmically with 5 points per octave.
- Example: .step dec param X 10k 1Meg 10
  - Step global parameter X from 10k to 1Meg logarithmically with 10 points per decade.
- Example: .step NPN 2N2222(VAF) LIST 50 75 100
  - Perform the simulation three times with NPN model parameter VAF being 50, 75, and 100.
- Example: .step temp -55 125 10
  - Step the temperature from -55°C to 125°C in 10-degree step (Linear).

Parameter Sweeps

- Example: RC network and stepping a list of values



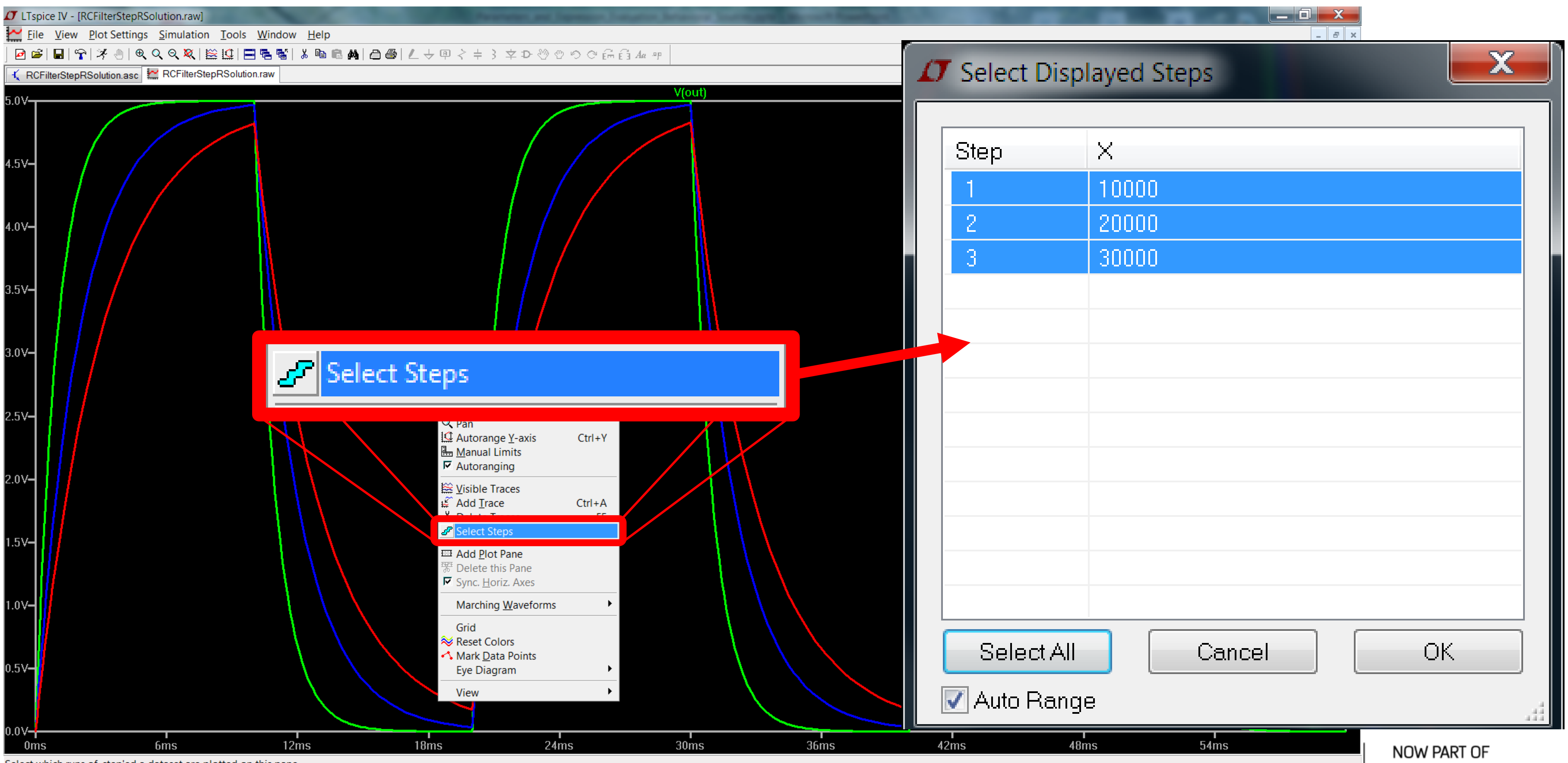
RCFilterStepR.asc

Parameter Sweep – Identifying Runs

RCFilterStepRSolution.asc

Parameter Sweep – Choosing Runs

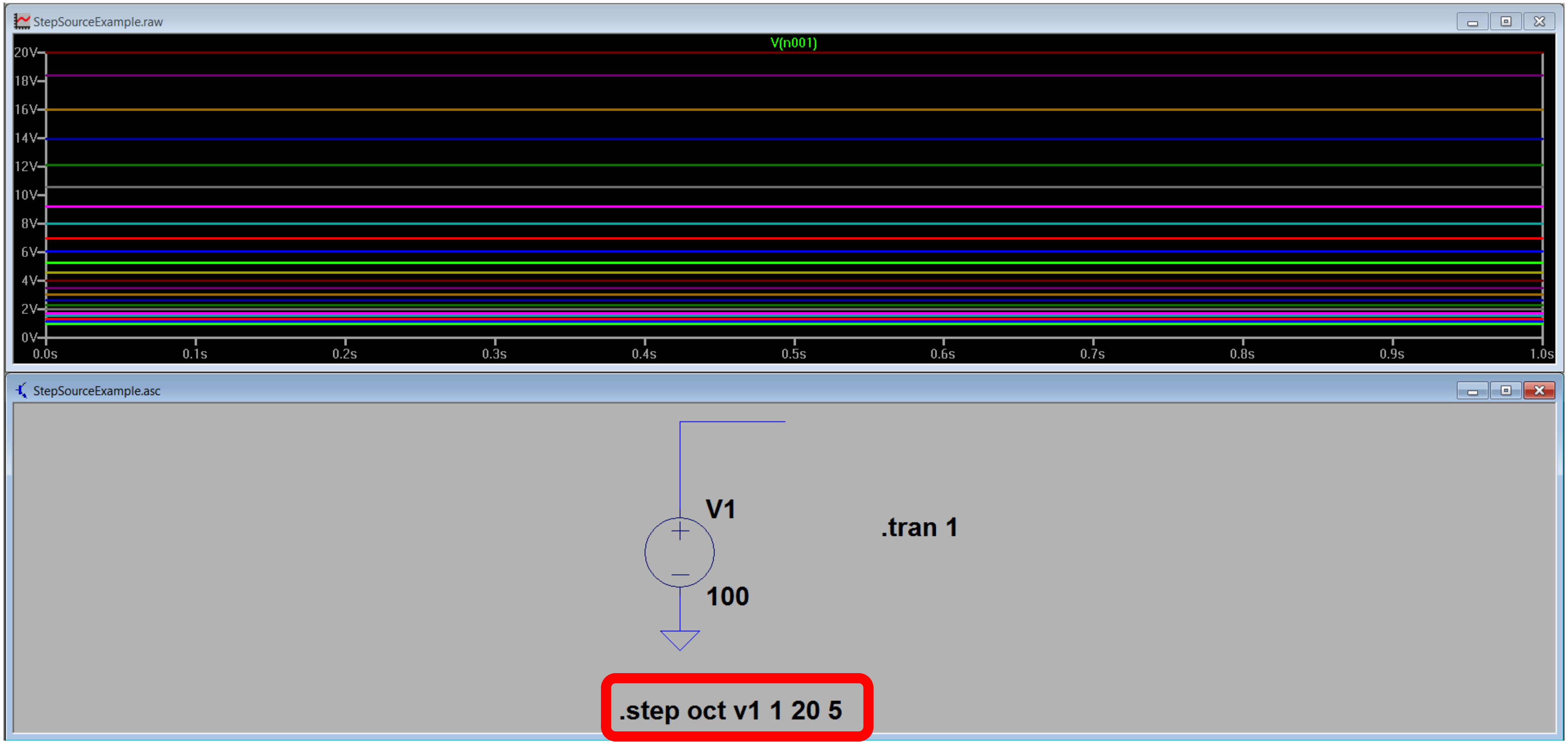
- Use the “Select Steps” option to choose which runs are shown (Right click on the Plot Pane)



NOW PART OF

Parameter Sweeps

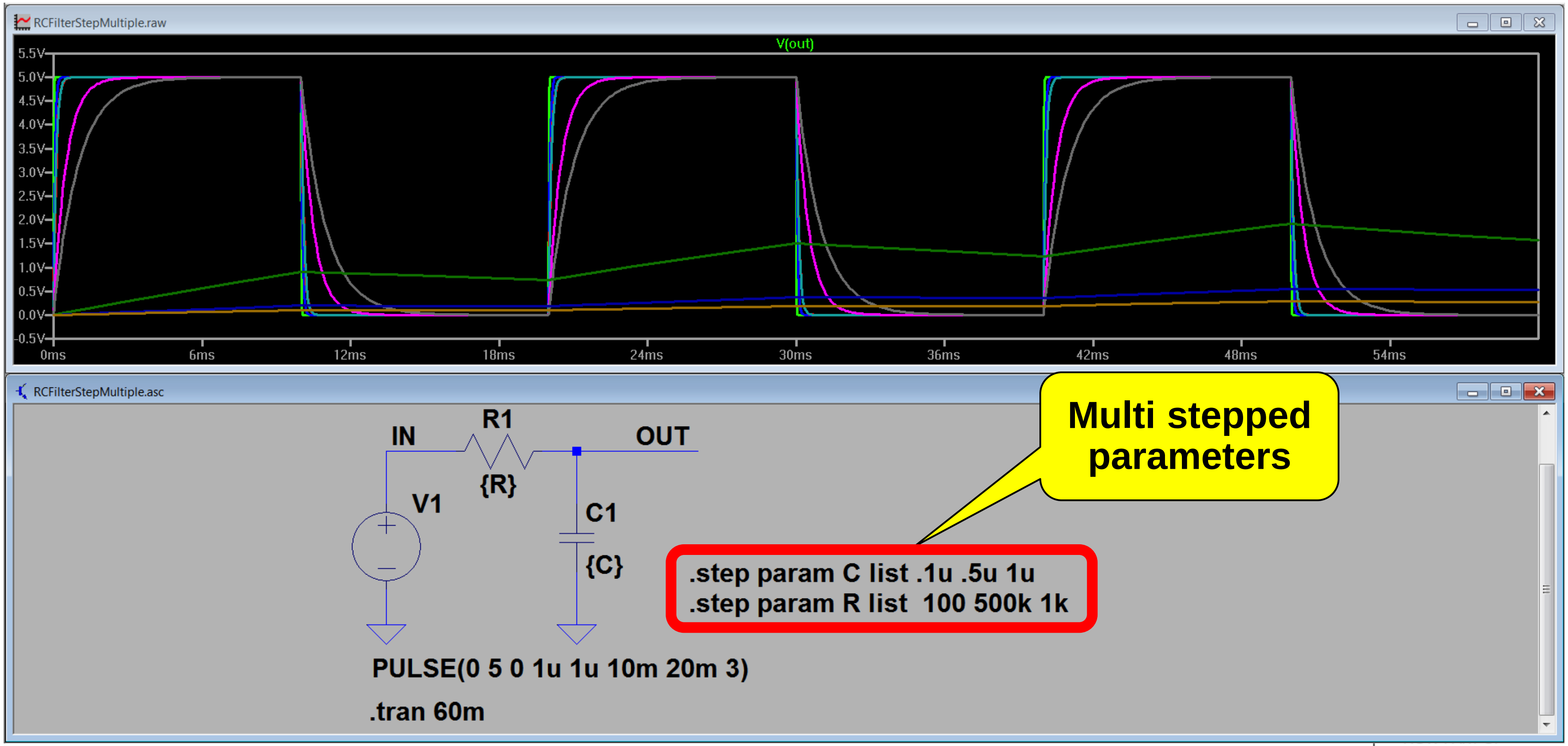
❖ Example: Stepping a source directly



StepSourceExample.asc

Stepping Multiple Parameters

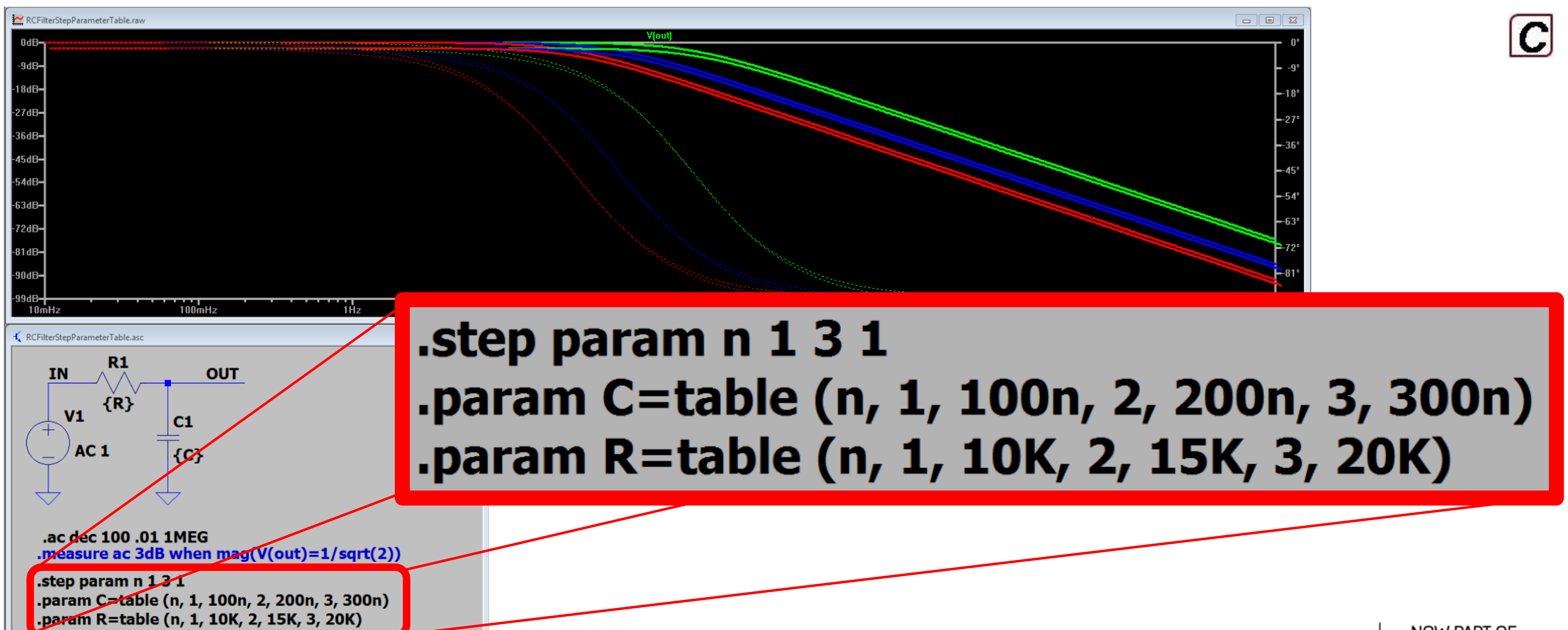
- If you have multiple stepped parameters, all the combinations will be stepped (Step sweeps may be nested up to three levels deep)



RCFilterStepMultiple.asc

Stepping Multiple Parameters

- The table function can be used to step multiple parameters simultaneously using a table format (ex. pairs of values can be defined and simulated)
- table(x,a,b,c,d,...) function interpolates a value for x based on a look up table given as a set of pairs of points.

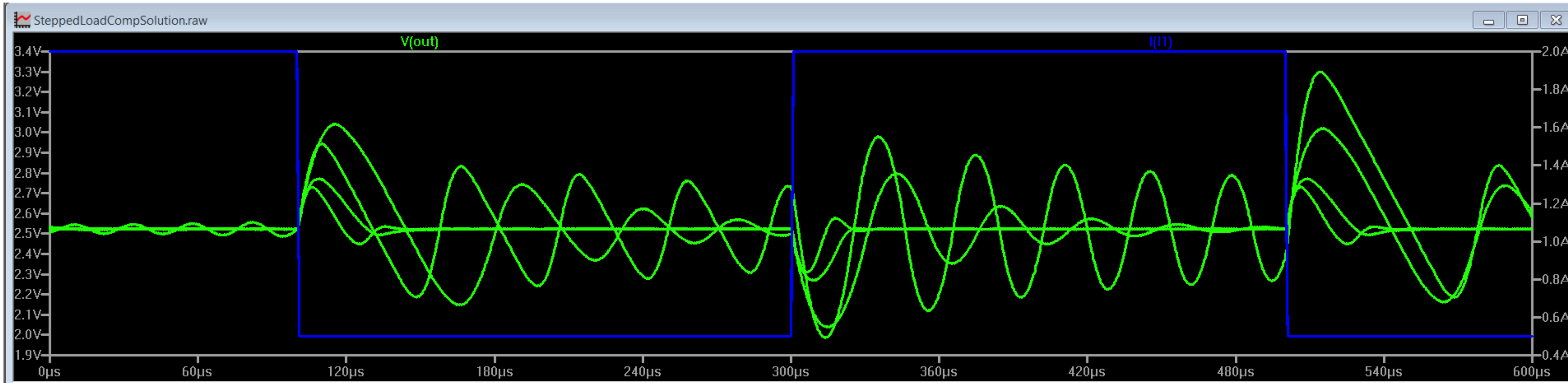


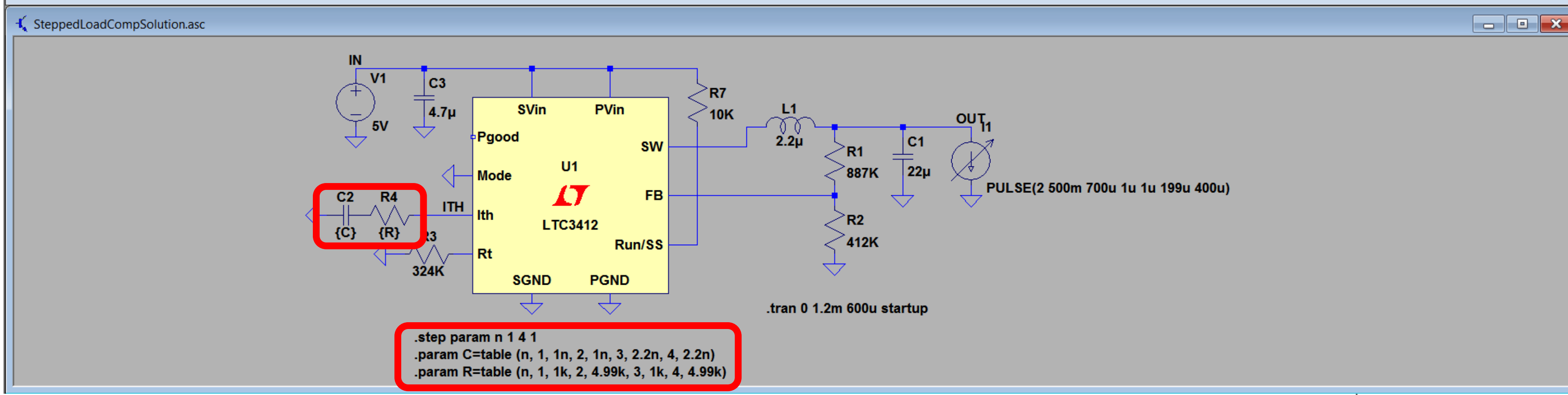
RCFilterStepParameterTable.asc

NOW PART OF ANALOG DEVICES

Stepping Multiple Parameters

- Example: Stepping compensation components

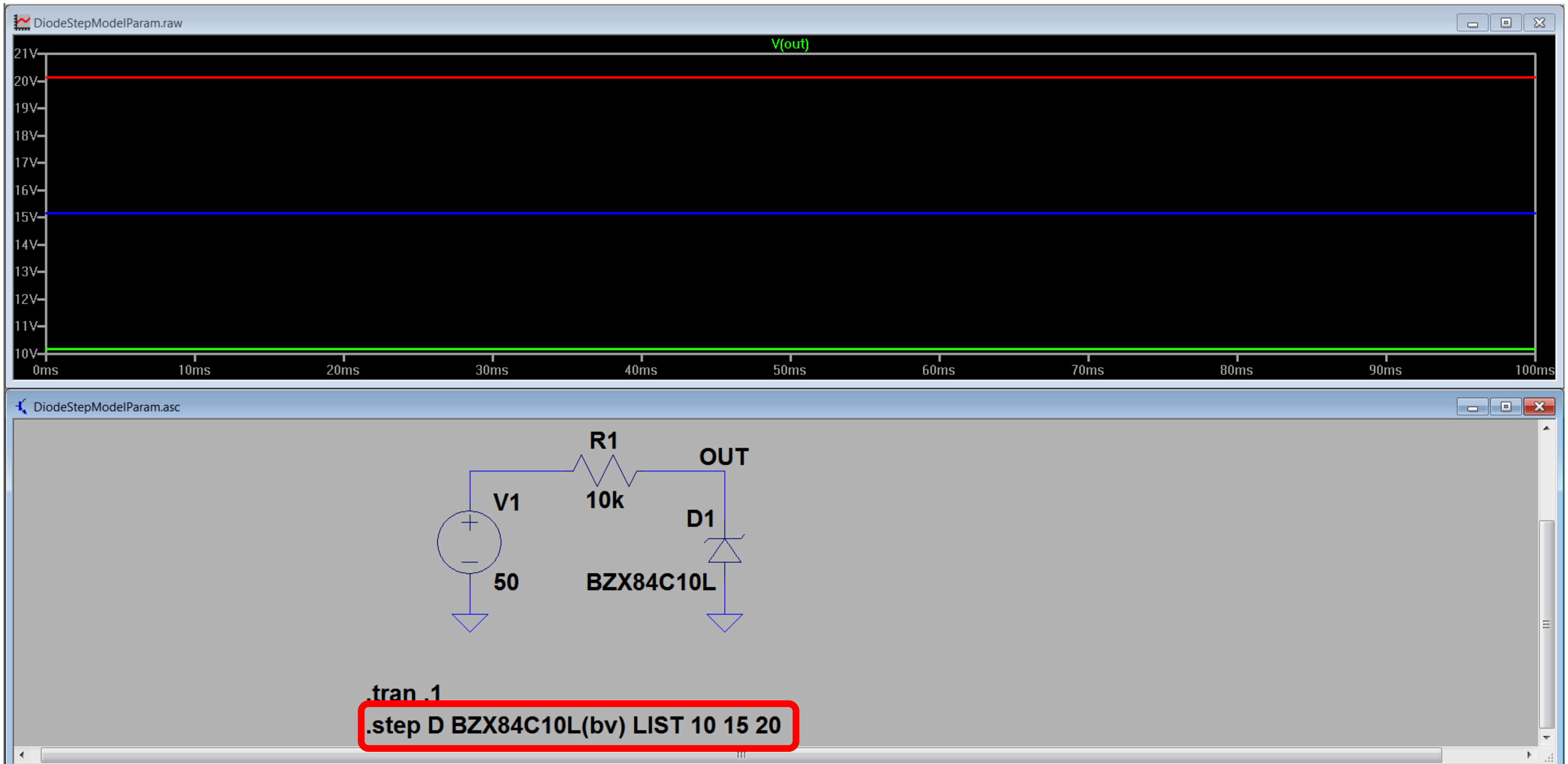




SteppedLoadCompSolution.asc

User-Defined Functions/Parameters

- .Model parameters can be stepped.



DiodeStepModelParam.asc

Monte Carlo Examples

- Example using the built in MC function

  MonteCarloMC.asc
  - mc(val, tol) is a function that uses a random number generator to return a value between val-tol*val and val+tol*val
- Example passing variables to a function using a flat or Gaussian distribution

  MonteCarloFunc.asc
  - flat(x): a function that uses a random number generator to return a value between -x and x.
  - {Val * (1 + FLAT(TOL))} is the same as mc(val, tol)
  - gauss(x): a function that uses a random number generator to return a value with a Gaussian distribution and sigma x.

"Worst Case" Examples

- Example that randomly selects the max or min value based on tolerance

WorstCase.asc

  - Be careful and understand the sensitivities of your circuit. Worst case values doesn't always give you worst case operation. Ex. imagine a circuit that unintentionally resonates at nominal values, but is fine at "worst case" values.

- Example that exercises every combination of worst case values without repeating any (minimum number of runs used)

WorstCase2.asc

Saving the values for multiple runs

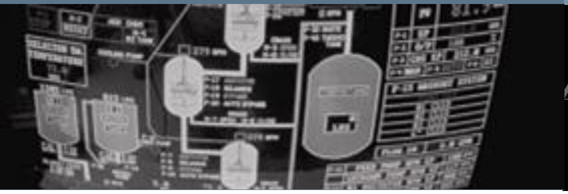
- Example that prints the values chosen to a log file

MonteCarloFuncOutputTable.asc

- When doing a .AC simulation, the values are shown in dB by default (we don't normally think of component values in dB). This example converts them back.

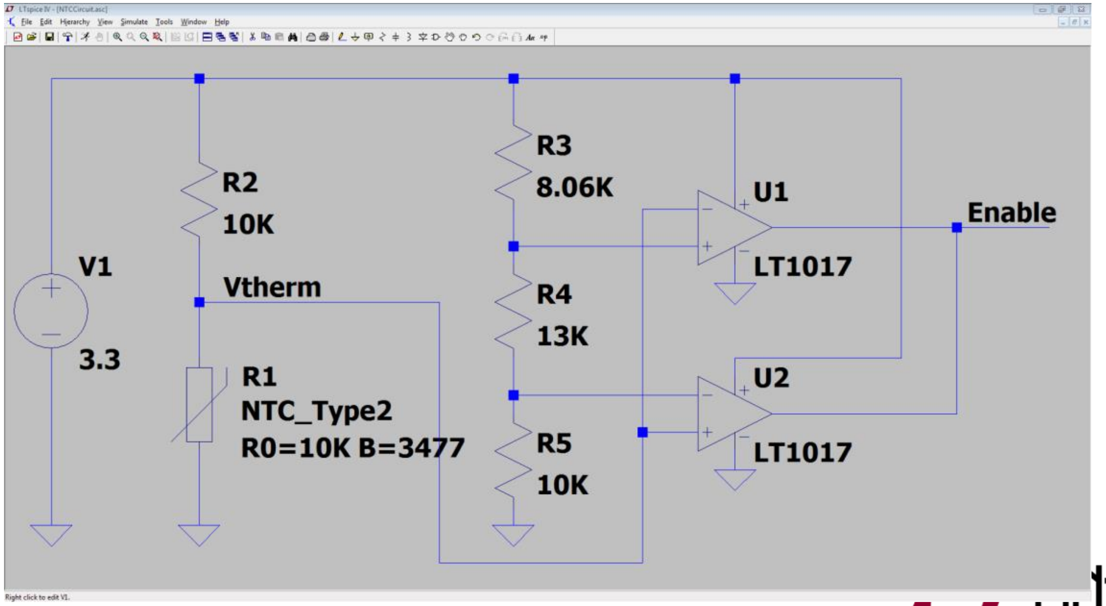
MonteCarloRCFilterStepRSolutionACOutputTable.asc

Thermistor Simulations: Plotting Temperature and Resistance



Plotting Temperature and Resistance

- Voltage and/or current are typically plotted on the vertical axis and time is typically plotted on the horizontal axis
- It is possible to plot resistance, temperature, and other parameters on the horizontal and vertical axes
- Thermistor simulation example: navigate to the NTCCircuit.asc simulation file and follow the instructions. C S



Plotting Temperature and Resistance

Important items to note for the NTCCircuit.asc simulation:

- The DC operating point ".op" simulation command must be used (see LTspice help regarding DC operating point definition)
- The SPICE model for the thermistor is included in the simulation file
- A two terminal thermistor schematic symbol with the appropriate device parameters is required
- Additional instructions / information is included in the simulation file.
- Voltages can be labeled and in this case the voltage across thermistor R1 is labeled Vtherm

Plotting Temperature and Resistance

Important items to note for the NTCCircuit.asc simulation (cont.):

- Currents cannot be labeled, thus we must determine what LTspice has called the current flowing into thermistor R1
- Probing the top terminal of R1 we see the current has been labeled by LTspice as “Ix(R1:A)
- Plotting the expression V(vtherm)/Ix(R1:A) therefore plots resistance of R1
- Note that probing the bottom terminal of R1 we see that the current has been labeled Ix(R1:B) by LTspice even though in this case the current is the same as the top terminal (but reversed)!

Examples

- Time domain capacitor-based crystal test fixture — QuartzTransistorTimeDomainExample.asc
- Freq domain capacitor-based crystal test fixture — QuartzFrequencyDomainExample.asc
- LTC1696 fuse crowbar — SCRFuseCrowbarLTC1696.asc
- Intrinsically safe circuit breaker — IntriniscallySafeCircuitBreakerLTC4231-1.asc
- Intrinsically safe circuit breaker (plot expressions) — IntriniscallySafeCircuitBreakerExpressionLTC4231-1.asc
- Stepping a resistor current limited boost converter — IntrinsicallySafeStepParamLTC3526L.asc
- Gear vs. Trapezoidal vs. Modified Trapezoidal Comparison — ImplicitIntegrationMethodsExample.asc
- Arbitrary capacitance: write an expression for the charge — ArbitraryCapacitance.asc
- Arbitrary inductor: write an expression for the flux — ArbitraryInductance.asc
- On the fly RMS calculation — RMS.asc
- Charge/Energy calculation — EnergyChargeCountingLTC3388.asc
- Worst Case/Monte Carlo comparison for an amplifier circuit (downloaded from the LTspice Yahoo! User Group) — MontsCarloWorstCaseAmplifier.asc