Using SPICE Monte Carlo Tool for Statistical Error Analysis

TIPL 4203
TI Precision Labs – ADCs

Created by Art Kay

Presented by Peggy Liska

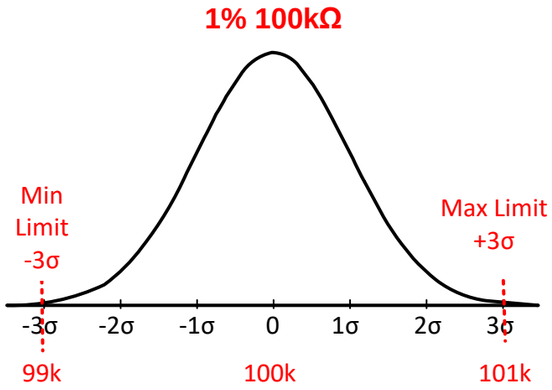
Discrete resistor tolerance sets gain error

$$G_{diff} = 2 \cdot \left(\frac{R_f}{R_g}\right)$$

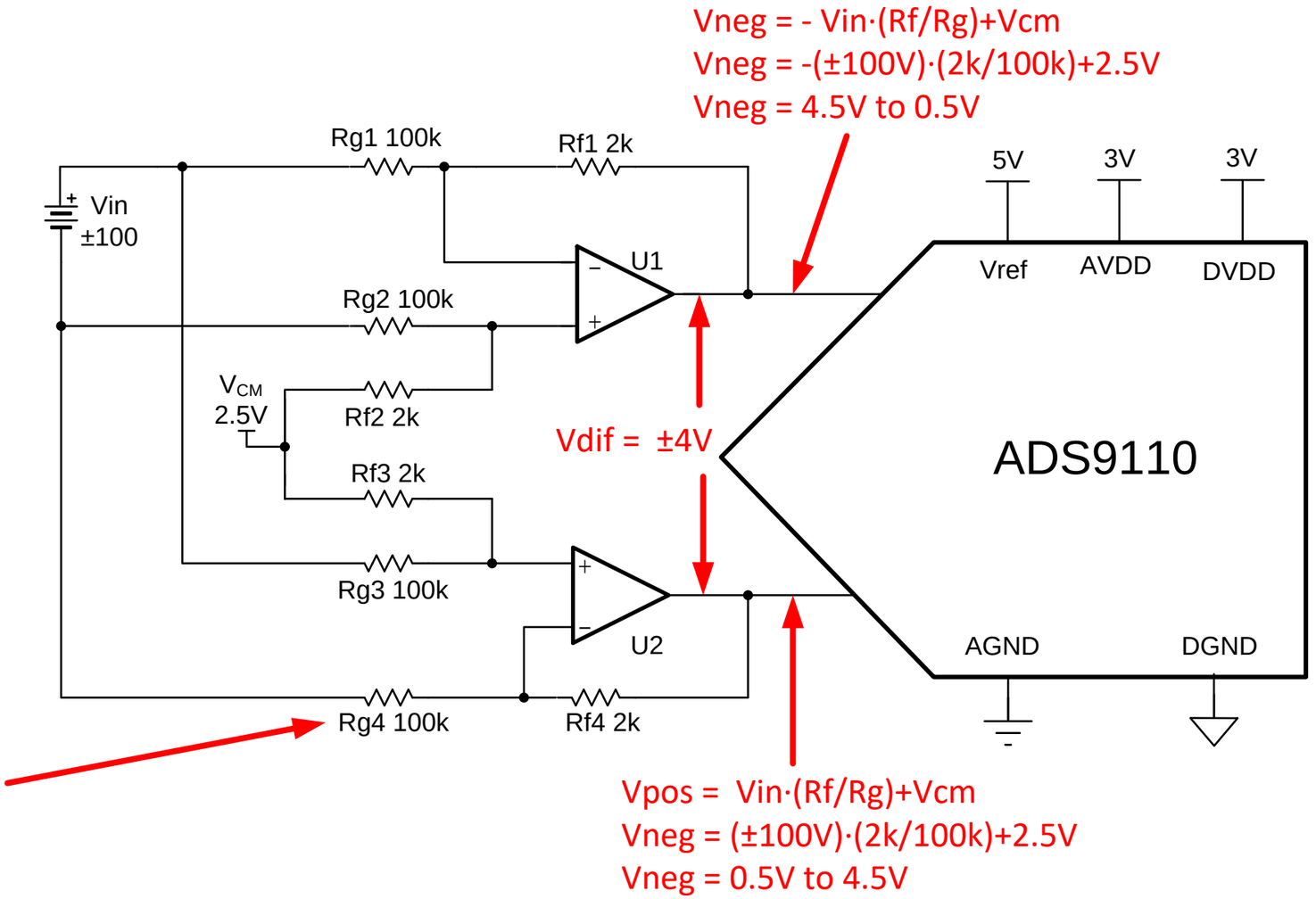
$$G_{diff} = 2 \cdot \left(\frac{2k\Omega}{100k\Omega}\right) = 0.04$$

$$V_{out} = G_{diff} \cdot V_{in}$$

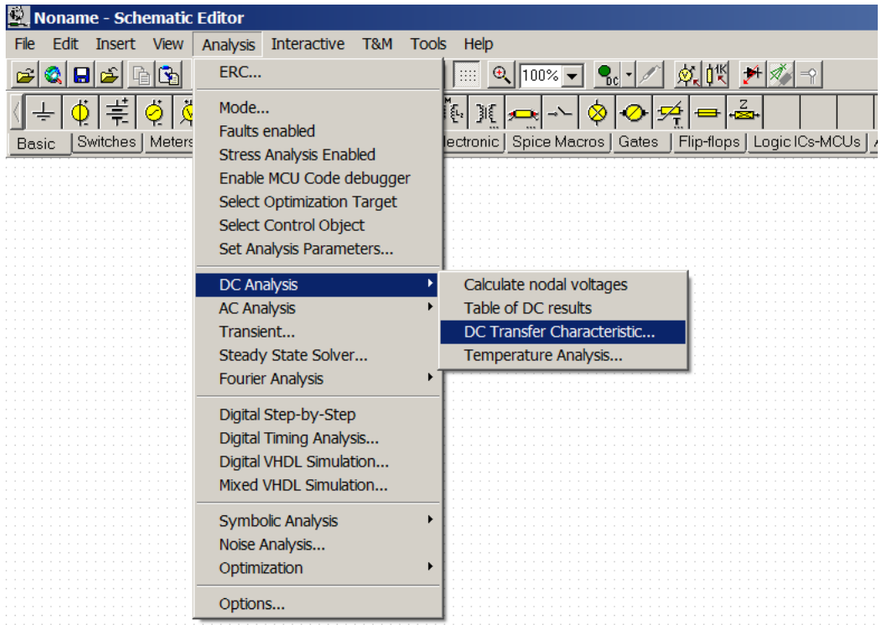
$$V_{out} = (0.04) \cdot (\pm 100V) = \pm 4V$$

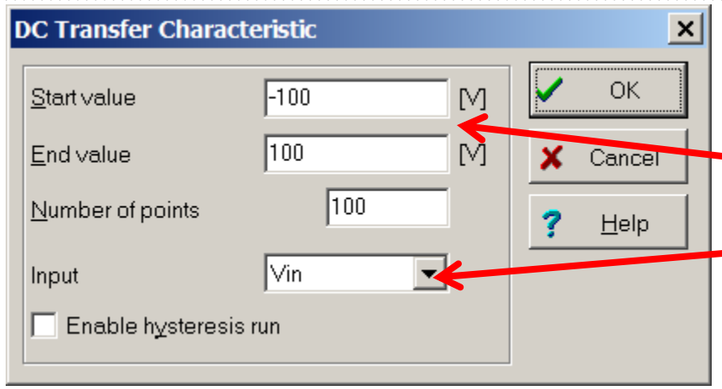


Devices outside the minimum and maximum limits are discarded

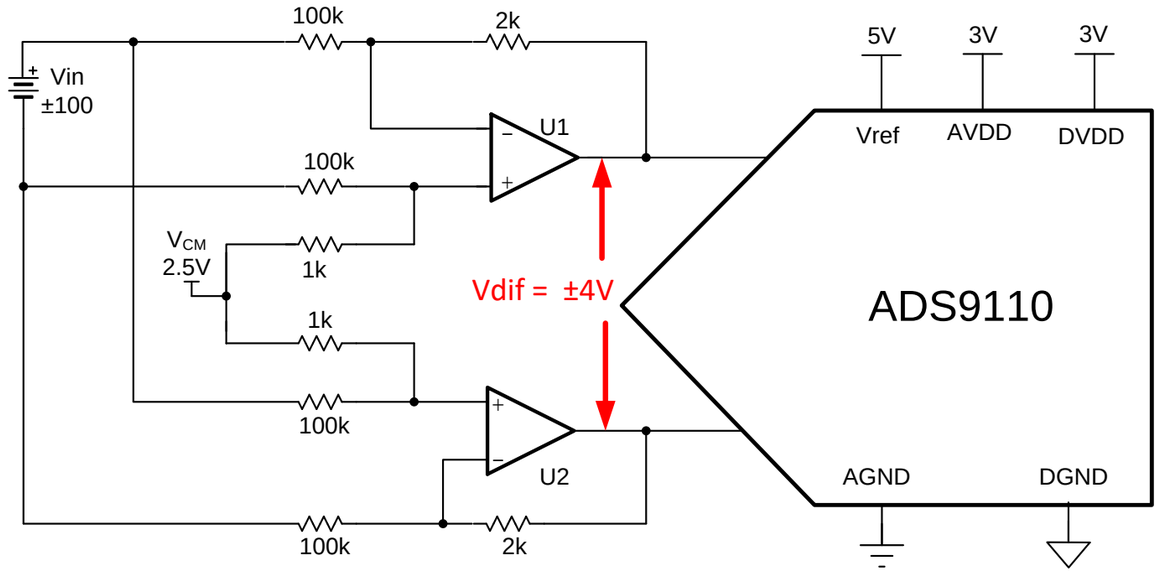


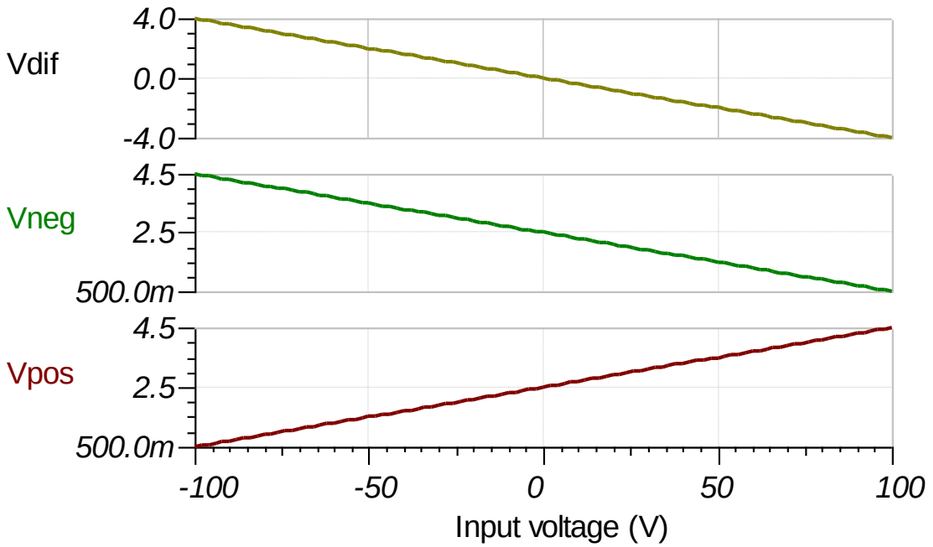
DC Transfer Function



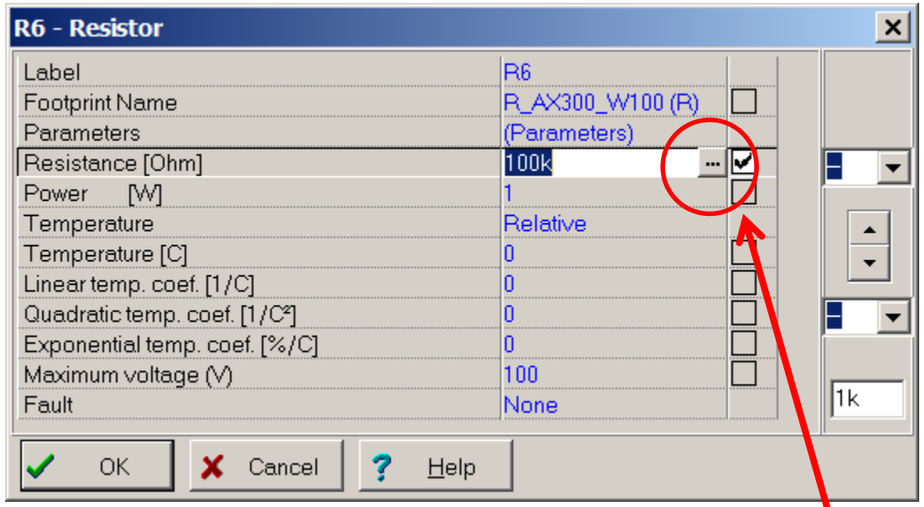


Select “Vin” for the input and enter the range from “Start value” to “End value”



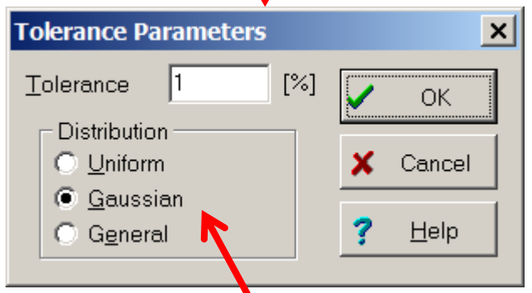


Set tolerance on resistors and capacitors



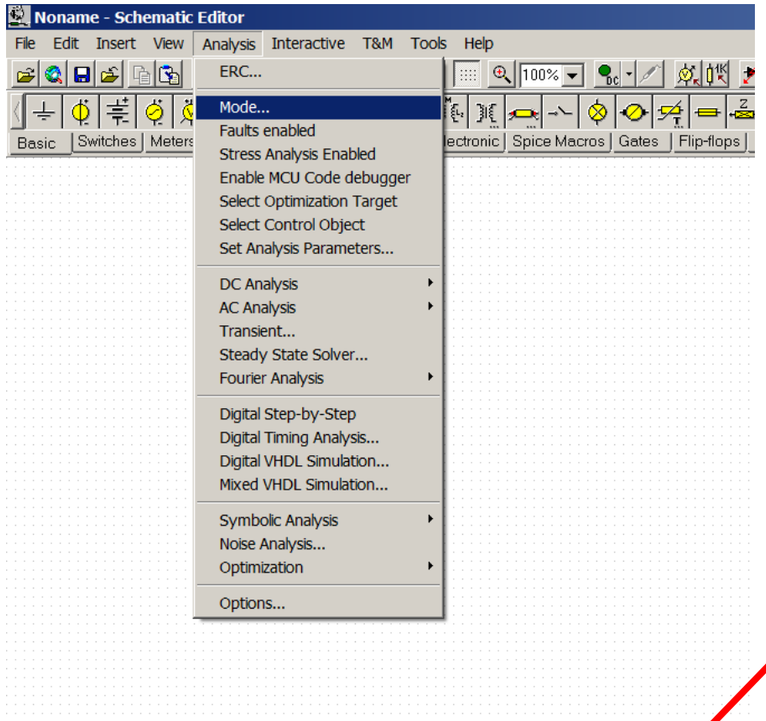
Click here to set the tolerance.

Set to 1% or 0.1% per resistor spec

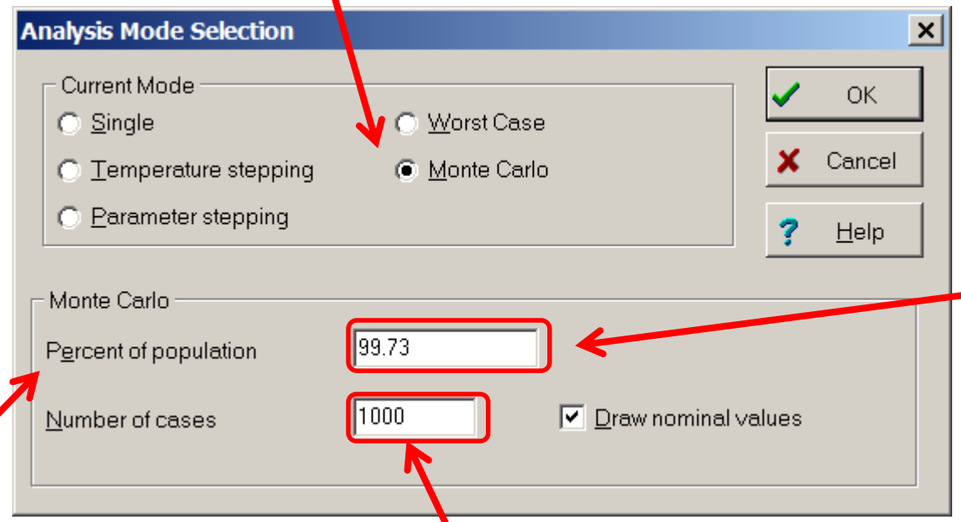


Gaussian Distribution

Monte Carlo Analysis



Select “Monte Carlo”

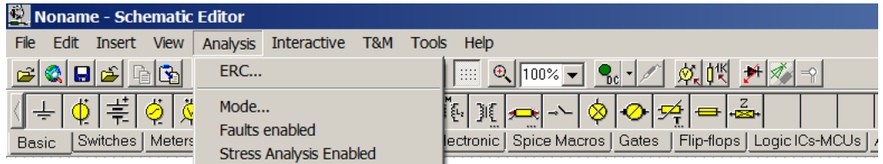


99.73% sets the component tolerance to ±3 Standard deviations

Note the default of 68.26% will *not* give realistic results for resistor and capacitor tolerance.

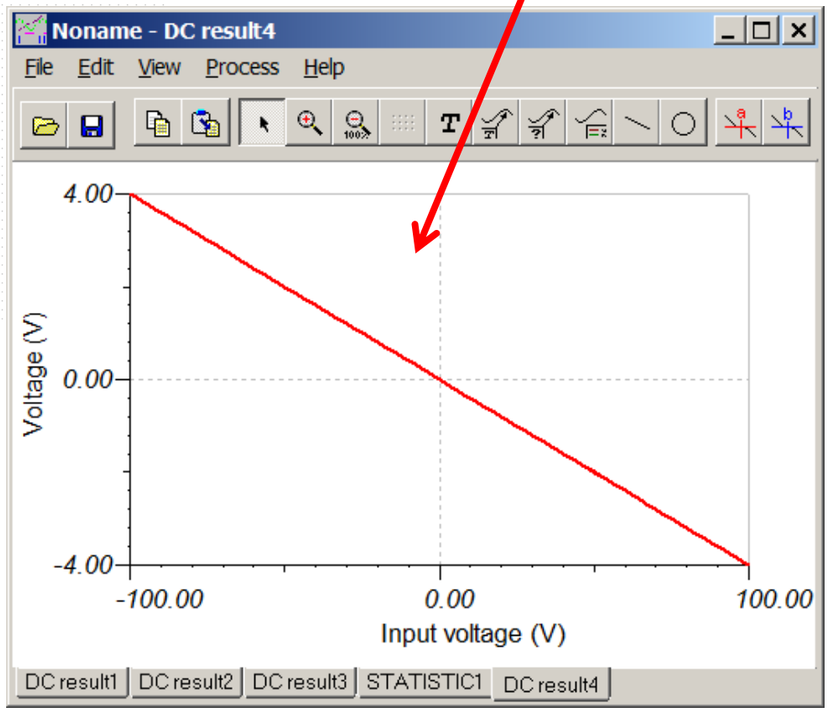
More cases will give you a better statistical distribution. The max is 1000.

Monte Carlo for DC Transfer Characteristic

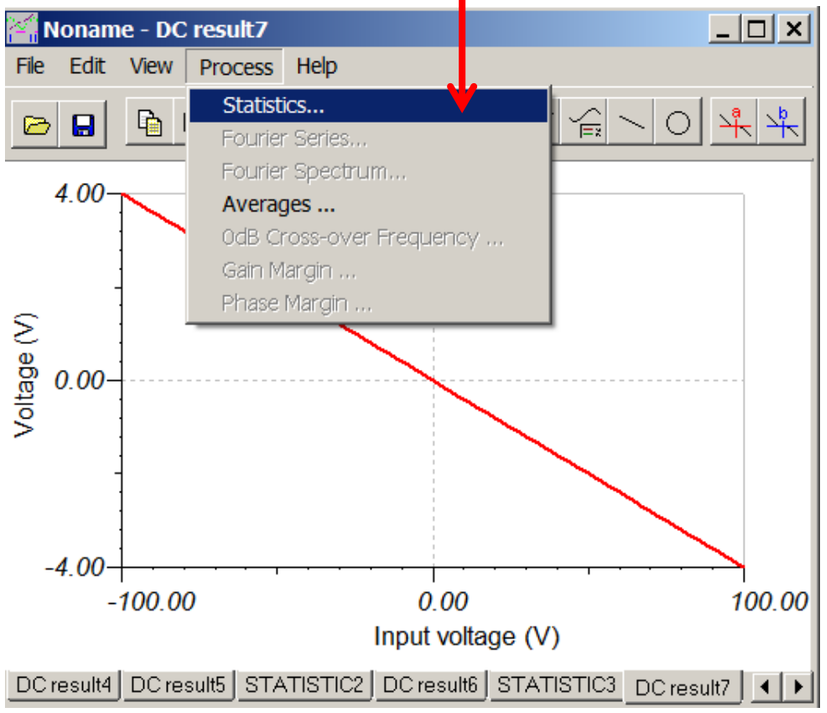


1. Run a dc transfer characteristic

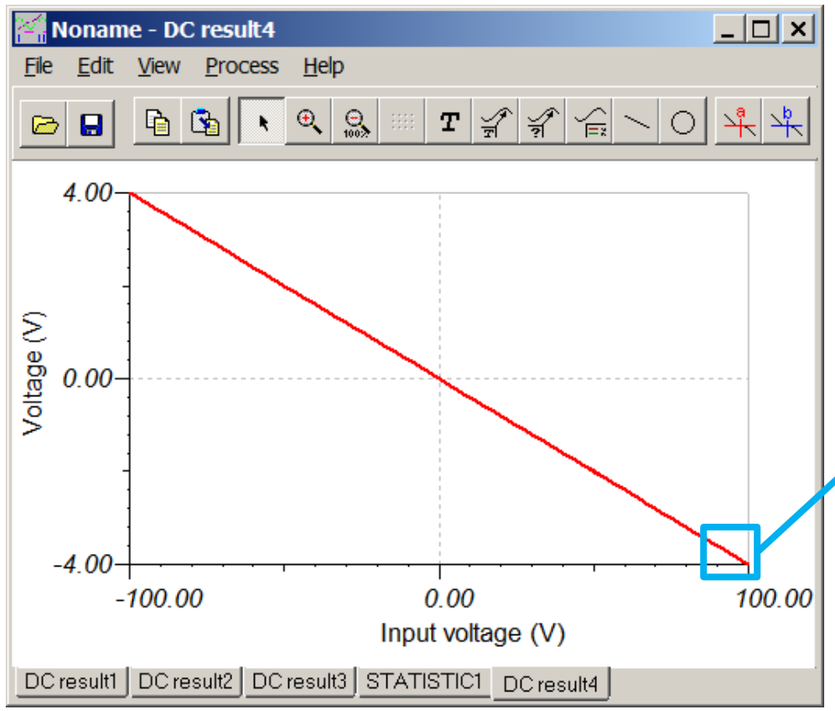
2. Press CTRL+Alt to select all

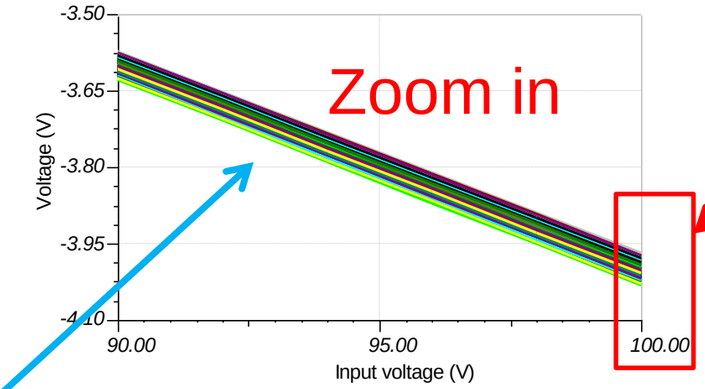


3. Select Process>Statistics



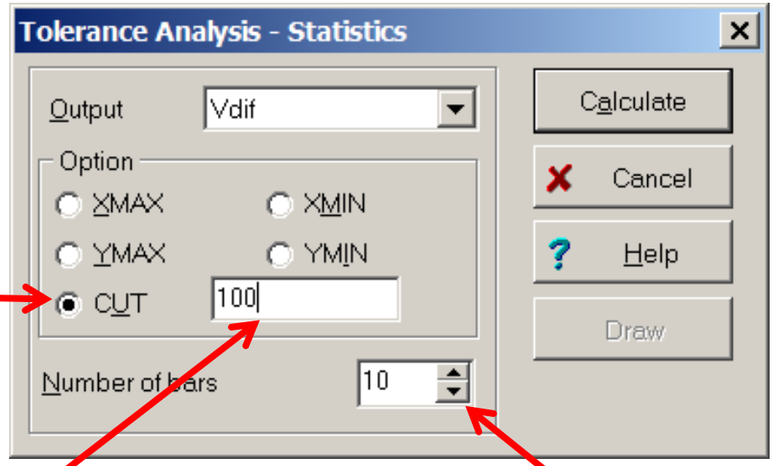
The cut option





Zoom in

We generate the distribution from the vertical section at x=100

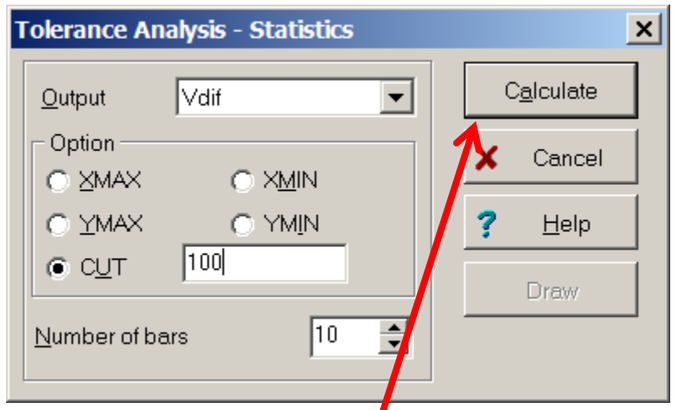


Use Cut option

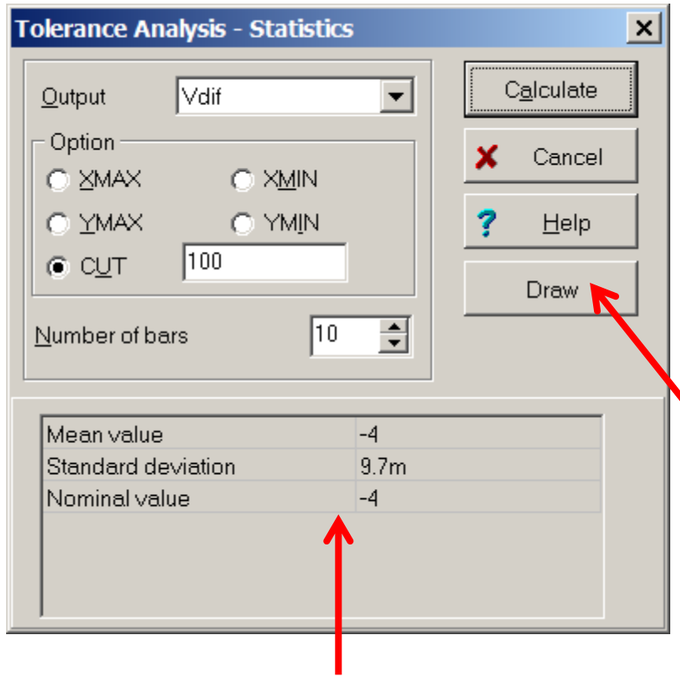
Enter the X-axis value where the cut set is taken

Number of bins in histogram. 10 is usually sufficient

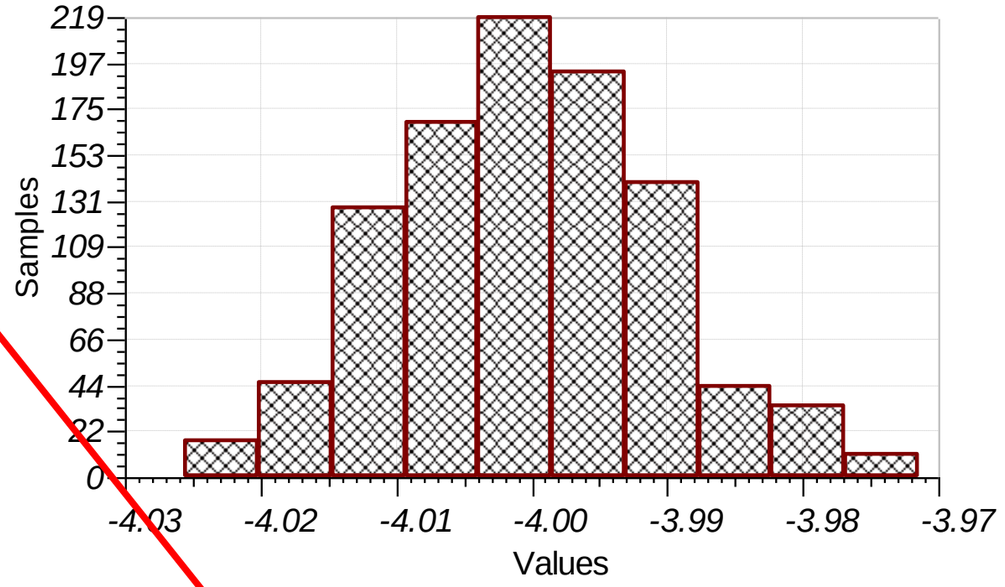
Generate the statistical data and histogram



Press Calculate to get statistics, and draw to show histogram



Use to calculate gain error.



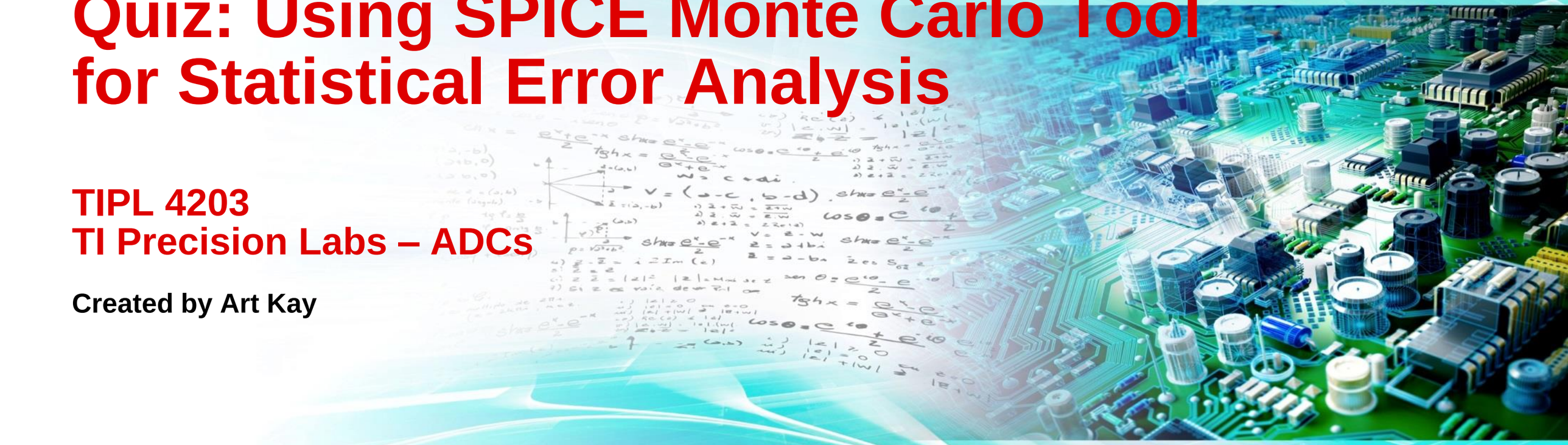
Press draw to get a graph of the histogram

$$TypGainError = \frac{standard\ deviation}{Mean} \cdot 100 = \left(\frac{9.7m}{4}\right) \cdot 100 = \pm 0.24\%$$ For 68.26% of the population

$$MaxGainError = 3 \cdot Typical = 3 \cdot (\pm 0.24\%) = 0.73\%$$ For 99.73% of the population

Thanks for your time!
Please try the quiz.

Quiz: Using SPICE Monte Carlo Tool for Statistical Error Analysis



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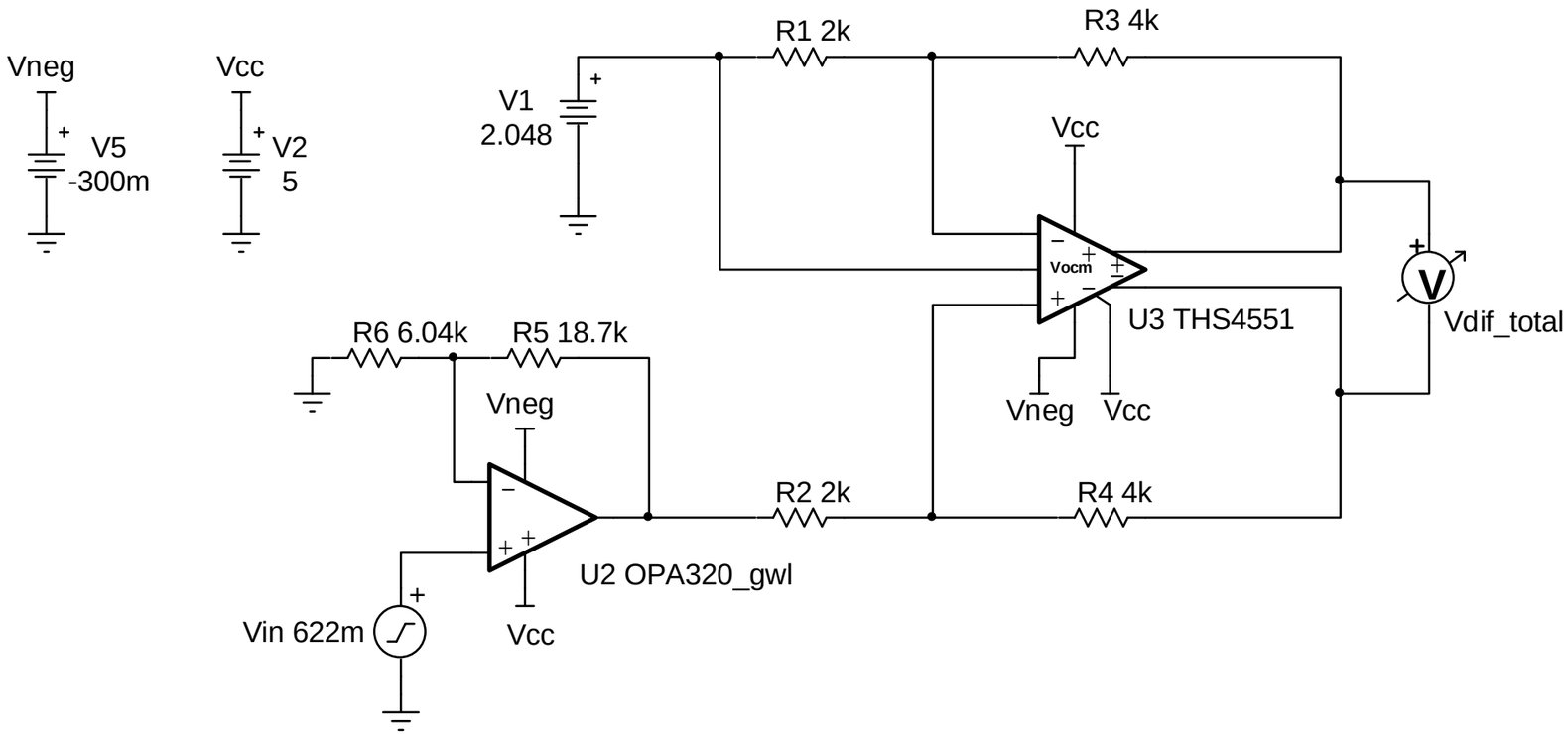
Quiz: SPICE Monte Carlo Tool

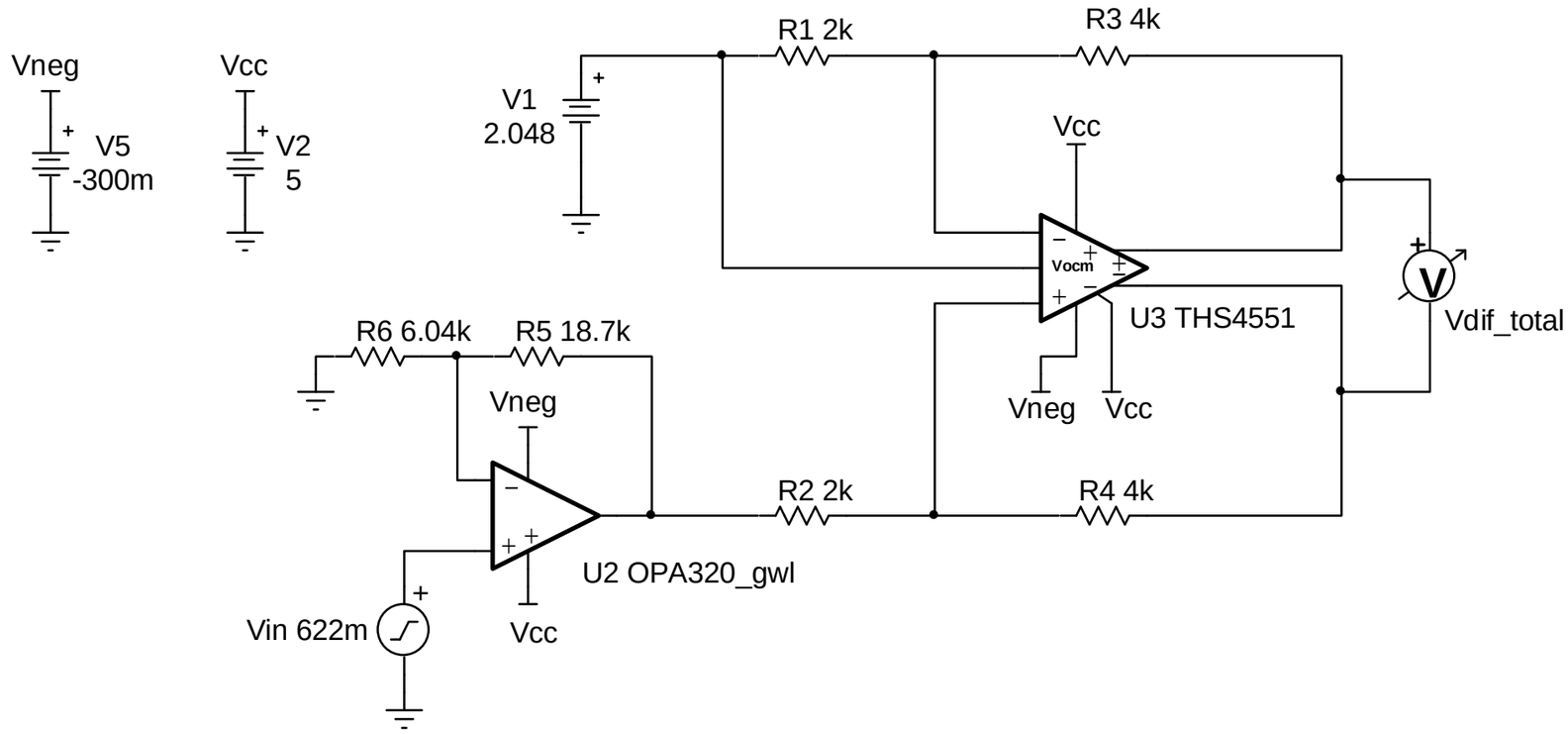
1. Use Monte Carlo analysis to determine a statistical estimate of typical and worst case gain error. Assume each resistor has a ±0.1% tolerance. Note: this exercise assumes that you are using the “Industrial” version of TINA SPICE. TINA-TI does not include this feature. Many other SPICE simulators also include Monte Carlo capabilities, so you should get similar results if you are using another simulator.



Solutions

Quiz: SPICE Monte Carlo Tool

1. Use Monte Carlo analysis to determine a statistical estimate of typical and worst case gain error. Assume each resistor has a ±0.1% tolerance. Note: this exercise assumes that you are using the "Industrial" version of TINA SPICE. TINA-TI does not include this feature. Many other SPICE simulators also include Monte Carlo capabilities, so you should get similar results if you are using another simulator.

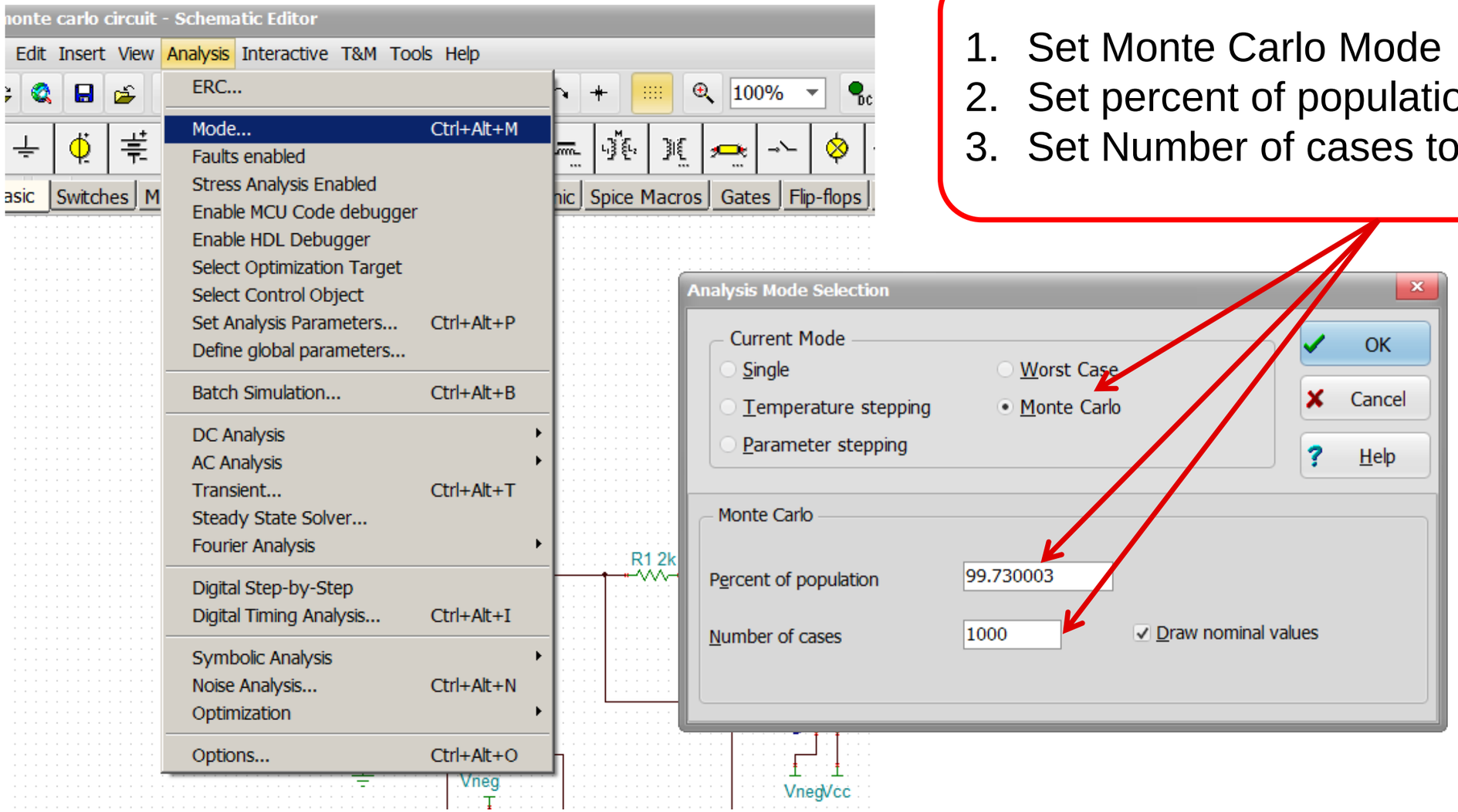


Click on this imbedded file, for the TINA spice file used in this solution.

monte carlo circuit.TSC

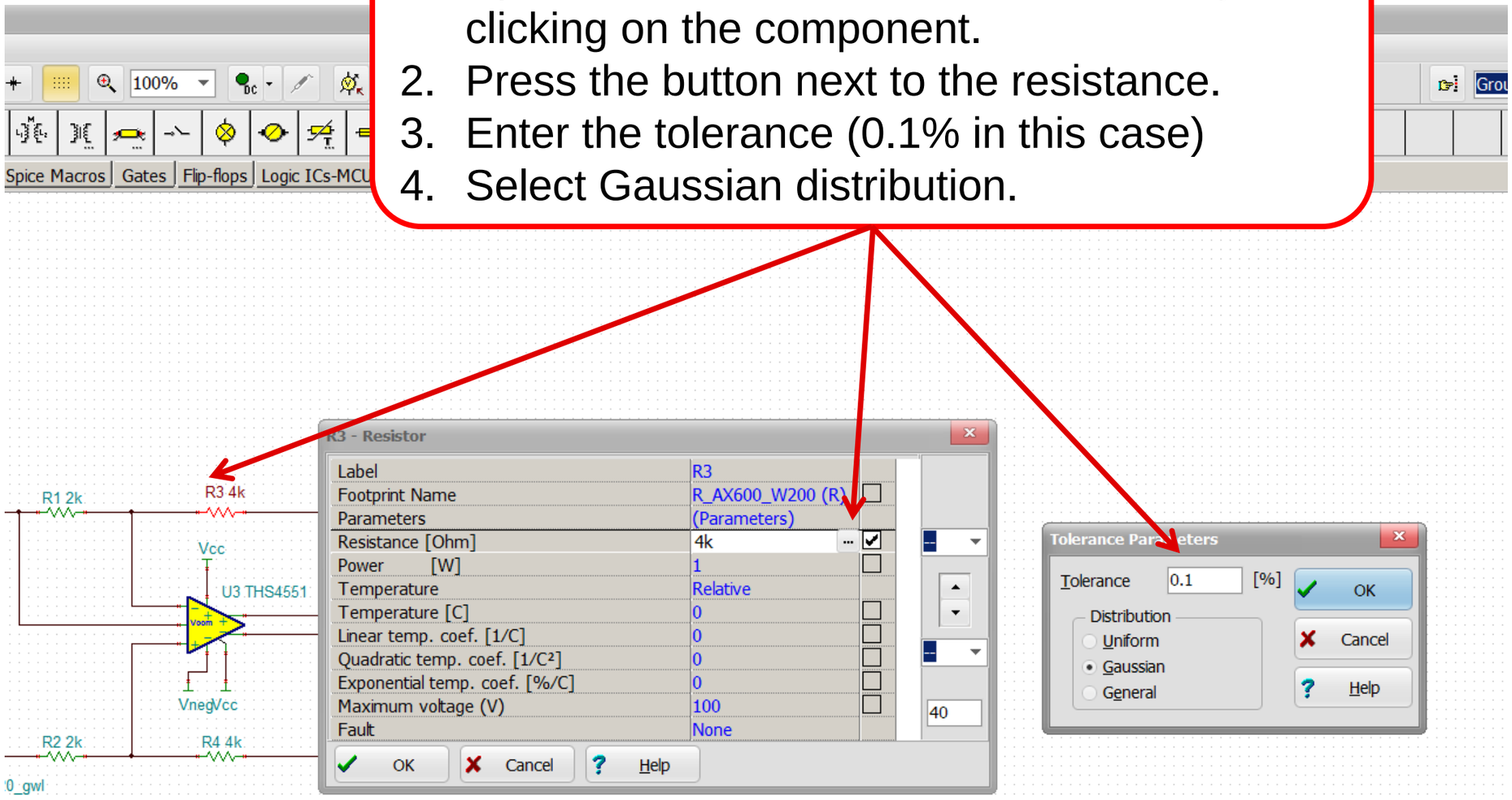
Quiz: SPICE Monte Carlo Tool

1. Set Monte Carlo Mode
2. Set percent of population to 99.73%
3. Set Number of cases to 1000



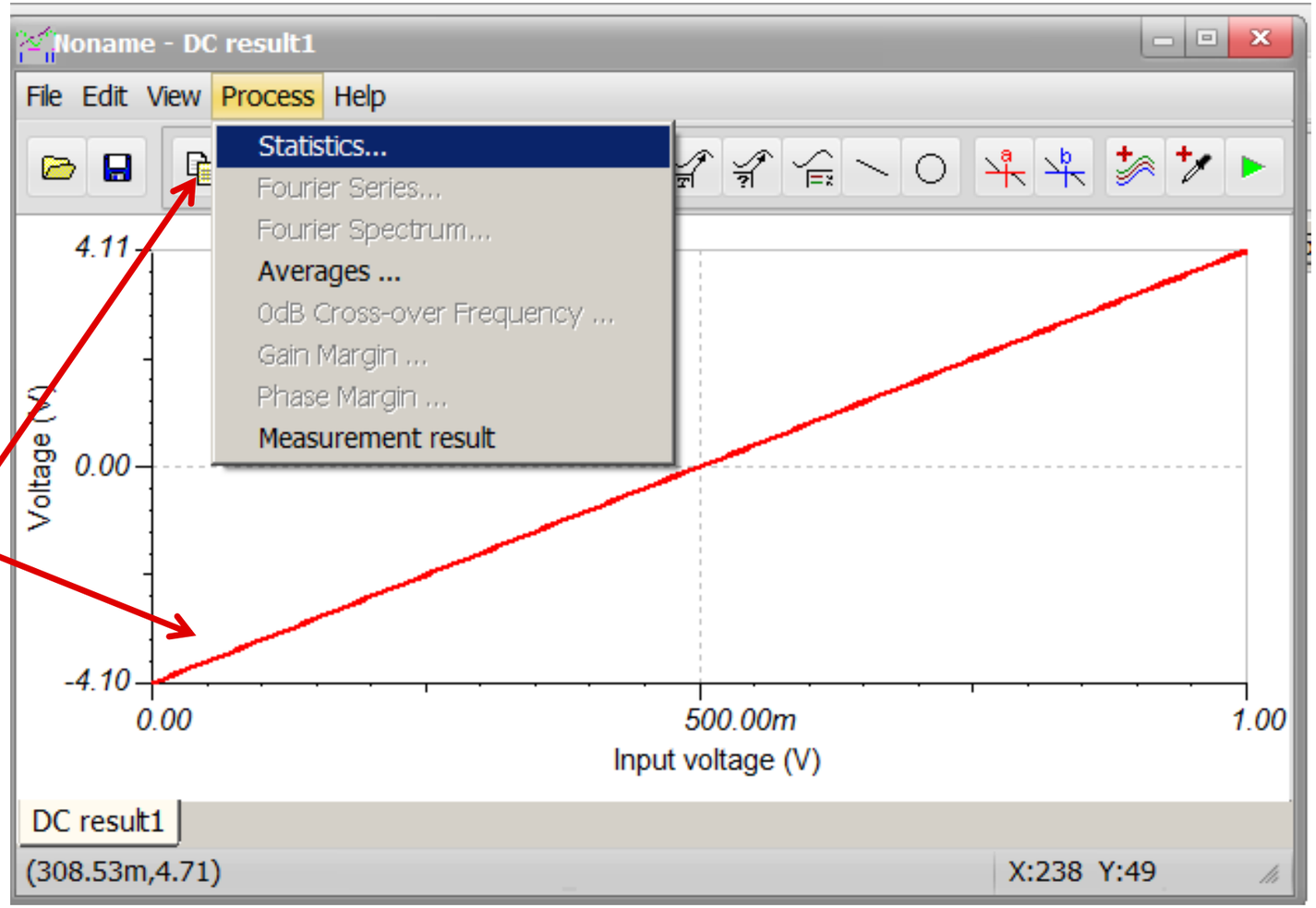
Quiz: SPICE Monte Carlo Tool

1. Update the tolerance of each resistor by clicking on the component.
2. Press the button next to the resistance.
3. Enter the tolerance (0.1% in this case)
4. Select Gaussian distribution.



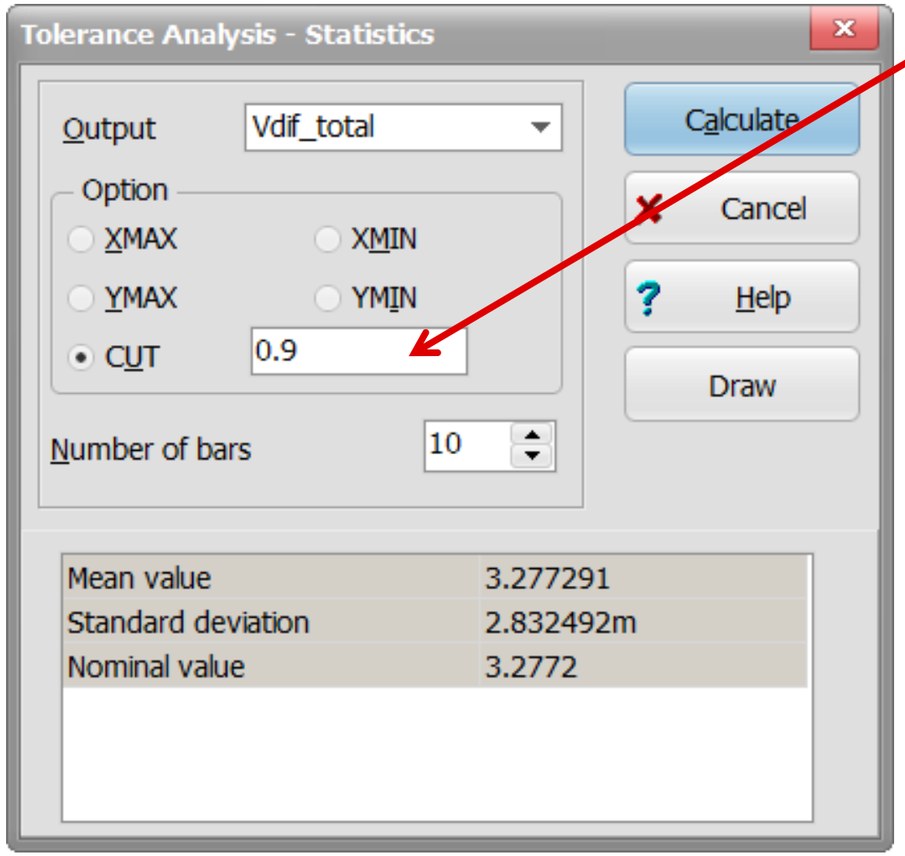
Quiz: SPICE Monte Carlo Tool

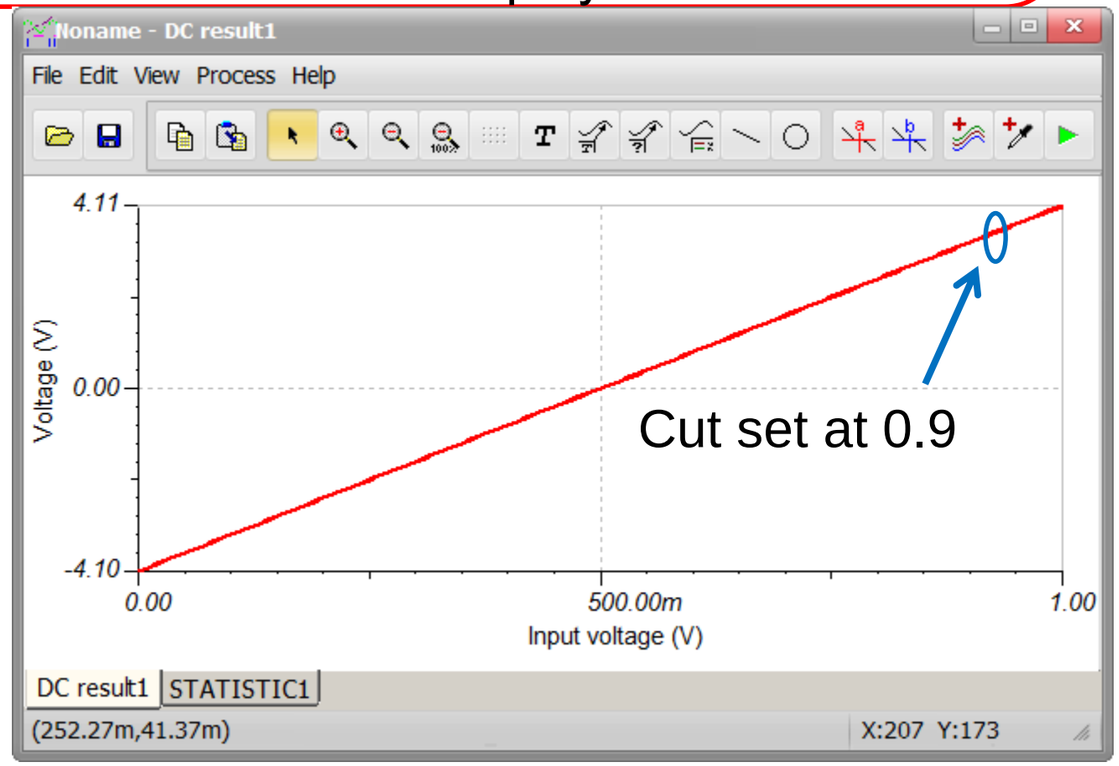
1. Click on graph and press “Ctrl+A” to select all the curves. It will highlight red when selected.
2. Select “Process>Statistics”



Quiz: SPICE Monte Carlo Tool

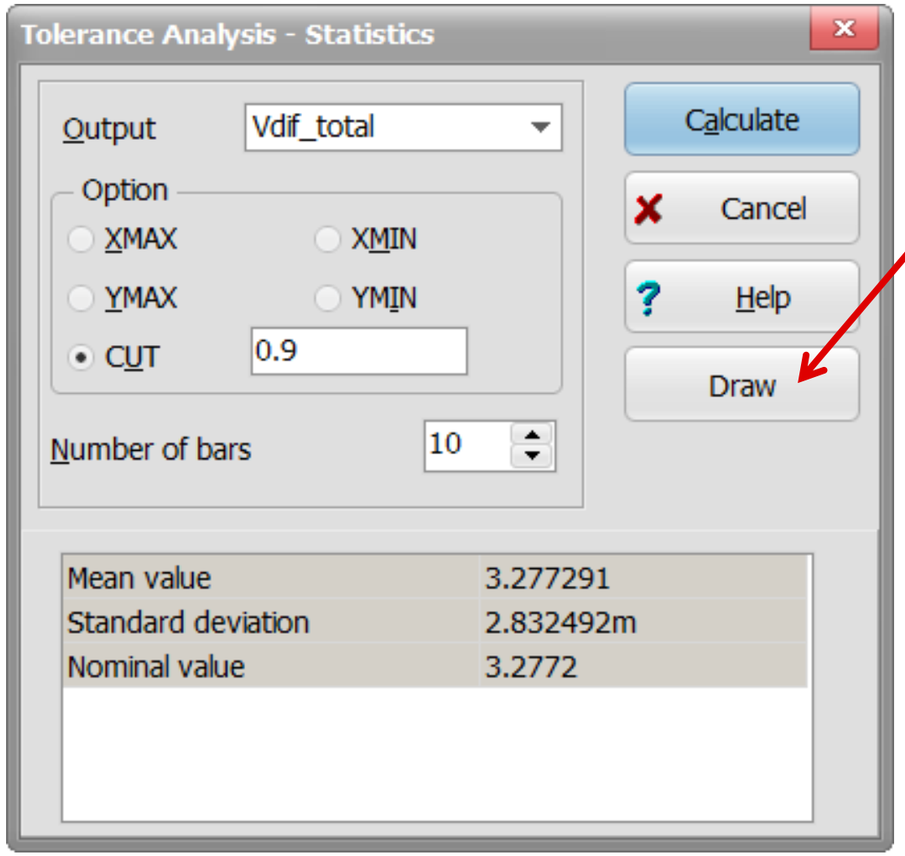
1. Select “Cut” for a cut set of the curves. Enter a value for the cut set. In this case 0.9 is used to avoid the end points of the curve which may have non-linearity.
2. Press “Calculate”. This will display the statistics.

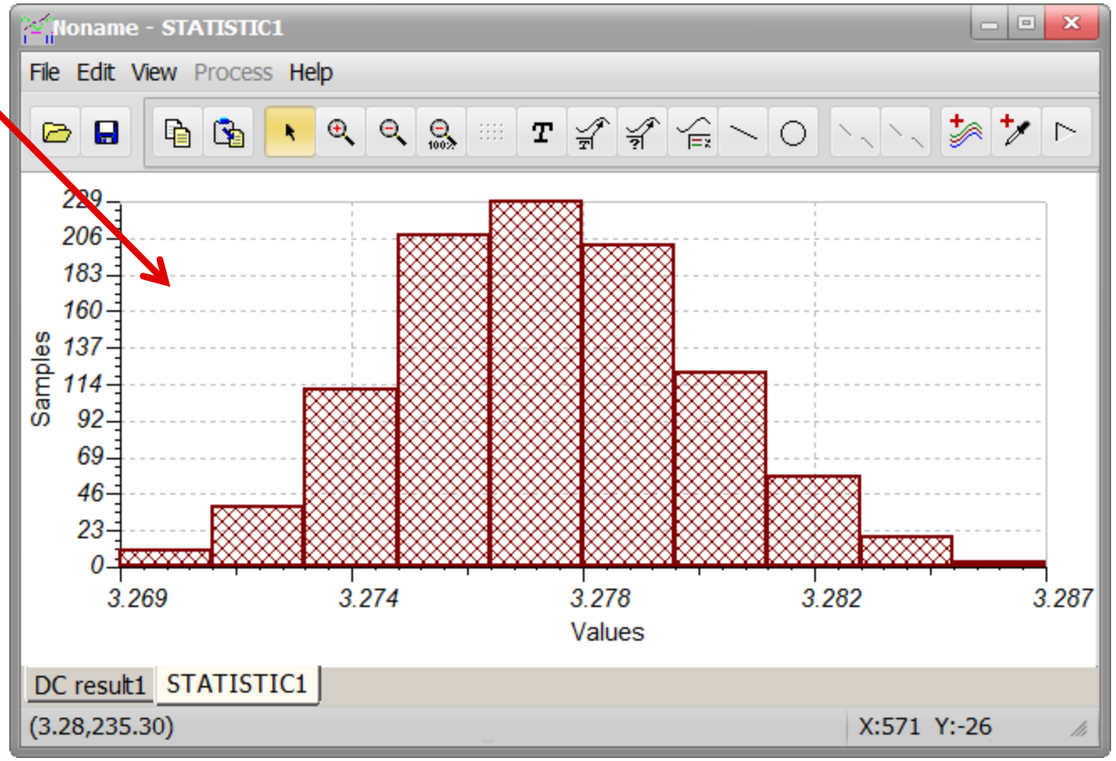




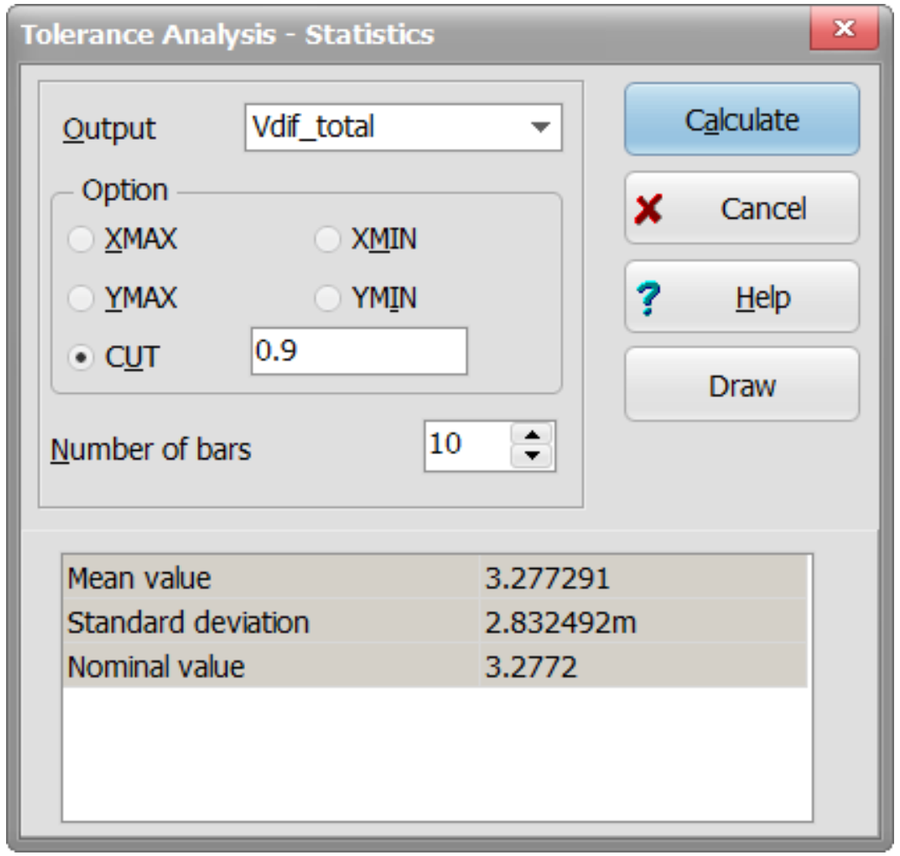
Quiz: SPICE Monte Carlo Tool

1. Press “Draw” to show the histogram.





Quiz: SPICE Monte Carlo Tool



$TypicalGainError = \frac{StandardDeviation}{NominalValue} \cdot 100$
$TypicalGainError = \frac{3.83mV}{3.2777V} \cdot 100 = \pm 0.11\%$
$MaximumGainError = TypicalGainError \cdot 3 = \pm 0.33\%$
Note: Typical gain error represents one standard deviation of gain error or 68.3% of the population. Maximum gain error represents ±3 standard deviations or 99.73