

# **Virtuoso Variation Option User Guide**

**Product Version ICADVM20.1  
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# Preface

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Virtuoso Variation Option provides you advanced run modes that you can use to run simulations for your designs.

The Virtuoso ADE Assembler is an advanced design and simulation environment. By using, ADE Assembler, you can set up tests, simulate your designs, and analyze outputs.

This user guide is aimed at integrated circuit designers and assumes that you are familiar with analog design and simulation.

This preface describes the following:

- [Scope](#)
- [Licensing Requirements](#)
- [Related Documentation](#)
- [Additional Learning Resources](#)
- [Customer Support](#)
- [Feedback about Documentation](#)
- [Typographic and Syntax Conventions](#)

## Scope

Unless otherwise noted, the functionality described in this guide can be used in both mature node (for example, IC6.1.8) and advanced node and methodologies (for example, ICADVM20.1) releases.

Label	Meaning
<b>(ICADVM20.1 Only)</b>	Features supported only in the ICADVM20.1 advanced nodes and advanced methodologies releases.
<b>(IC6.1.8 Only)</b>	Features supported only in mature node releases.

## Licensing Requirements

In the IC6.1.7 release, Virtuoso Variation Option is available with the 95265, Virtuoso Variation Option license. In addition, it also requires the license for ADE Explorer or ADE Assembler depending on the tool it is used with.

For information on licensing in the Virtuoso design environment, see [\*Virtuoso Software Licensing and Configuration Guide\*](#).

## Related Documentation

The following documents provide more information about the topics discussed in this guide.

### What's New and KPNS

- [\*Virtuoso ADE Assembler What's New\*](#)
- [\*Virtuoso ADE Assembler Known Problems and Solutions\*](#)

### Installation, Environment, and Infrastructure

- [\*Cadence Installation Guide\*](#)
- [\*Virtuoso Design Environment User Guide\*](#)
- [\*Virtuoso Design Environment SKILL Reference\*](#)
- [\*Virtuoso ADE Explorer and ADE Assembler SKILL Reference\*](#)
- [\*Cadence Application Infrastructure User Guide\*](#)

### Technology Information

- [\*Virtuoso Technology Data User Guide\*](#)
- [\*Virtuoso Technology Data ASCII Files Reference\*](#)
- [\*Virtuoso Technology Data SKILL Reference\*](#)

### Virtuoso Tools

- [\*Virtuoso ADE Explorer User\*](#)

- [\*Virtuoso Schematic Editor User Guide\*](#)
- [\*Spectre Circuit Simulator and Accelerated Parallel Simulator User Guide\*](#)
- [\*Spectre Circuit Simulator Reference\*](#)
- [\*Spectre Circuit Simulator and Accelerated Parallel Simulator RF Analysis in ADE Explorer User Guide\*](#)
- [\*Virtuoso UltraSim Simulator User Guide\*](#)
- [\*Spectre AMS Designer Simulator User Guide\*](#)
- [\*Virtuoso Parasitic Estimation and Analysis User Guide\*](#)
- [\*Virtuoso Visualization and Analysis Tool User Guide\*](#)
- [\*Component Description Format User Guide\*](#)
- [\*Analog Expression Language Reference\*](#)

## **Additional Learning Resources**

### **Video Library**

The [Video Library](#) on the Cadence Online Support website provides a comprehensive list of videos on various Cadence products.

To view a list of videos related to a specific product, you can use the *Filter Results* feature available in the pane on the left. For example, click the *Virtuoso Layout Suite* product link to view a list of videos available for the product.

You can also save your product preferences in the Product Selection form, which opens when you click the *Edit* icon located next to *My Products*.

### **Virtuoso Videos Book**

You can access certain videos directly from Cadence Help. To learn more about this feature and to access the list of available videos, see [Virtuoso Videos](#).

## Rapid Adoption Kits

Cadence provides a number of [Rapid Adoption Kits](#) that demonstrate how to use Virtuoso applications in your design flows. These kits contain design databases and instructions on how to run the design flow.

In addition, Cadence offers the following training courses on the Virtuoso ADE Assembler and the related flows:

- [Virtuoso ADE Assembler](#)
- [Variation Analysis Using the Virtuoso ADE Assembler](#)
- [Virtuoso Analog Design Environment](#)
- [Virtuoso Schematic Editor](#)
- [Analog Modeling with Verilog-A](#)
- [Behavioral Modeling with Verilog-AMS](#)
- [Real Modeling with Verilog-AMS](#)
- [Spectre Simulations Using Virtuoso ADE](#)
- [Virtuoso UltraSim Full-Chip Simulator](#)
- [Virtuoso Simulation for Advanced Nodes](#)
- [Virtuoso Electrically-Aware Design with Layout Dependent Effects](#)

To explore the full range of training courses provided by Cadence in your region, visit [Cadence Training](#) or write to [training\\_enroll@cadence.com](mailto:training_enroll@cadence.com).

**Note:** The links in this section open in a separate web browser window when clicked in Cadence Help.

## Help and Support Facilities

Virtuoso offers several built-in features to let you access help and support directly from the software.

- The Virtuoso *Help* menu provides consistent help system access across Virtuoso tools and applications. The standard Virtuoso *Help* menu lets you access the most useful help and support resources from the Cadence support and corporate websites directly from the CIW or any Virtuoso application.



- The Virtuoso Welcome Page is a self-help launch pad offering access to a host of useful knowledge resources, including quick links to content available within the Virtuoso installation as well as to other popular online content.

The Welcome Page is displayed by default when you open Cadence Help in standalone mode from a Virtuoso installation. You can also access it at any time by selecting *Help – Virtuoso Documentation Library* from any application window, or by clicking the *Home* button on the Cadence Help toolbar (provided you have not set a custom home page).

For more information, see [Getting Help](#) in *Virtuoso Design Environment User Guide*.

## Customer Support

For assistance with Cadence products:

- Contact Cadence Customer Support

Cadence is committed to keeping your design teams productive by providing answers to technical questions and to any queries about the latest software updates and training needs. For more information, visit <https://www.cadence.com/support>.

- Log on to Cadence Online Support

Customers with a maintenance contract with Cadence can obtain the latest information about various tools at <https://support.cadence.com>.

## Feedback about Documentation

You can contact Cadence Customer Support to open a service request if you:

- Find erroneous information in a product manual
- Cannot find in a product manual the information you are looking for
- Face an issue while accessing documentation by using Cadence Help

You can also submit feedback by using the following methods:

- In the Cadence Help window, click the *Feedback* button and follow instructions.
- On the Cadence Online Support [Product Manuals](#) page, select the required product and submit your feedback by using the *Provide Feedback* box.

## Typographic and Syntax Conventions

The following typographic and syntax conventions are used in this manual.

<i>text</i>	Indicates names of manuals, menu commands, buttons, and fields.
text	Indicates text that you must type exactly as presented. Typically used to denote command, function, routine, or argument names that must be typed literally.
<i>z_argument</i>	Indicates text that you must replace with an appropriate argument value. The prefix (in this example, <i>z_</i> ) indicates the data type the argument can accept and must not be typed.
	Separates a choice of options.
{ }	Encloses a list of choices, separated by vertical bars, from which you <b>must</b> choose one.
[ ]	Encloses an optional argument or a list of choices separated by vertical bars, from which you <b>may</b> choose one.
[ ?argName <i>t_arg</i> ]	Denotes a <i>key argument</i> . The question mark and argument name must be typed as they appear in the syntax and must be followed by the required value for that argument.
...	Indicates that you can repeat the previous argument.
	Used with brackets to indicate that you can specify zero or more arguments.
	Used without brackets to indicate that you must specify at least one argument.
, ...	Indicates that multiple arguments must be separated by commas.
=>	Indicates the values returned by a Cadence SKILL language function.
/	Separates the values that can be returned by a Cadence SKILL language function.

If a command-line or SKILL expression is too long to fit within the paragraph margins of this document, the remainder of the expression is moved to the next line and indented. In code excerpts, a backslash ( \ ) indicates that the current line continues on to the next line.

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# Introduction to Virtuoso Variation Option

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## Overview

Virtuoso Variation Option is a special license required to run a set of advanced statistical capabilities from Virtuoso ADE Explorer or Virtuoso ADE Assembler environment. If available, the required license, 95265, Virtuoso Variation Option, is automatically checked out when you run simulations using the following run modes:

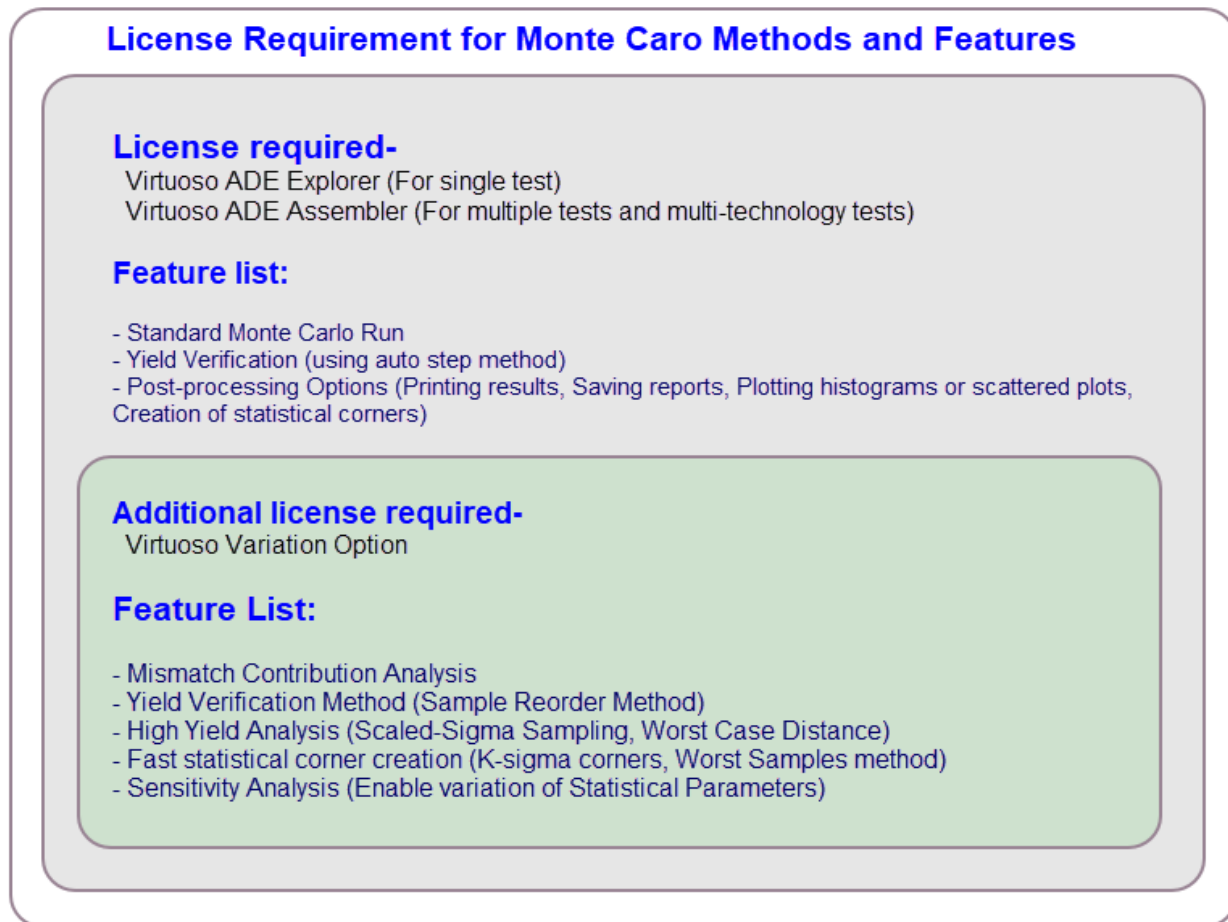
- ☐ Advanced options of the Monte Carlo run mode
- ☐ Improve Yield

## Virtuoso Variation Option User Guide

### Introduction to Virtuoso Variation Option

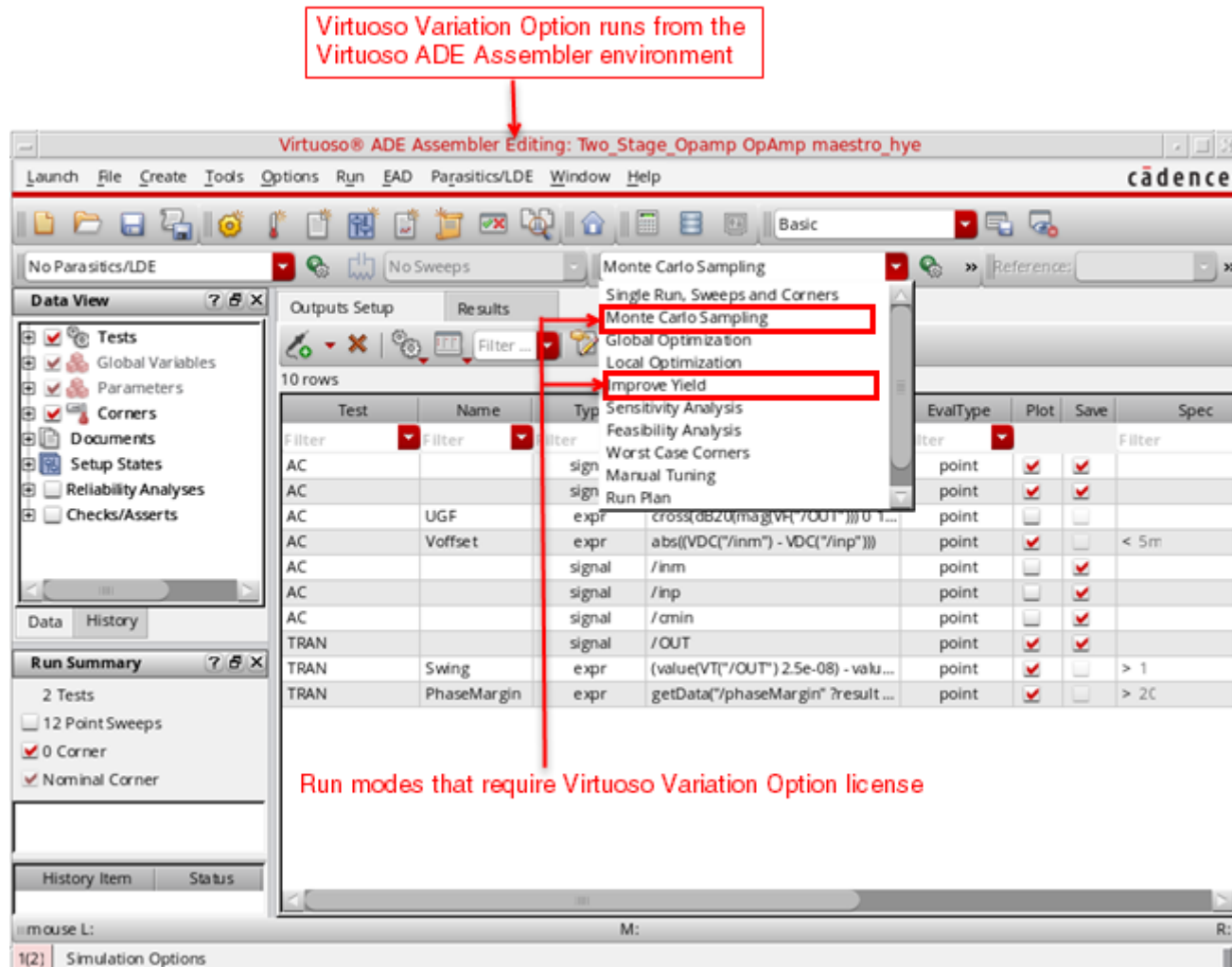
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The following figure gives a snapshot of the licenses required to run various Monte Carlo methods and features.



## Virtuoso Variation Option User Interface

Virtuoso Variation Option uses the environment and workspaces available in ADE Explorer or ADE Assembler. For example, the figure given below shows how the run modes for Virtuoso Variation Option are available in ADE Assembler.



Refer to the following links for information about the ADE Explorer and ADE Assembler environments:

[Virtuoso ADE Explorer User Guide](#)

[Virtuoso ADE Assembler User Guide](#)

# **Virtuoso Variation Option User Guide**

## Introduction to Virtuoso Variation Option

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## Virtuoso Variation Option Advanced Features

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Virtuoso Variation Option provides advanced statistical analysis features. These features include mismatch contribution analysis, efficient yield verification and statistical corner creation, and analysis methods specifically for high sigma design.

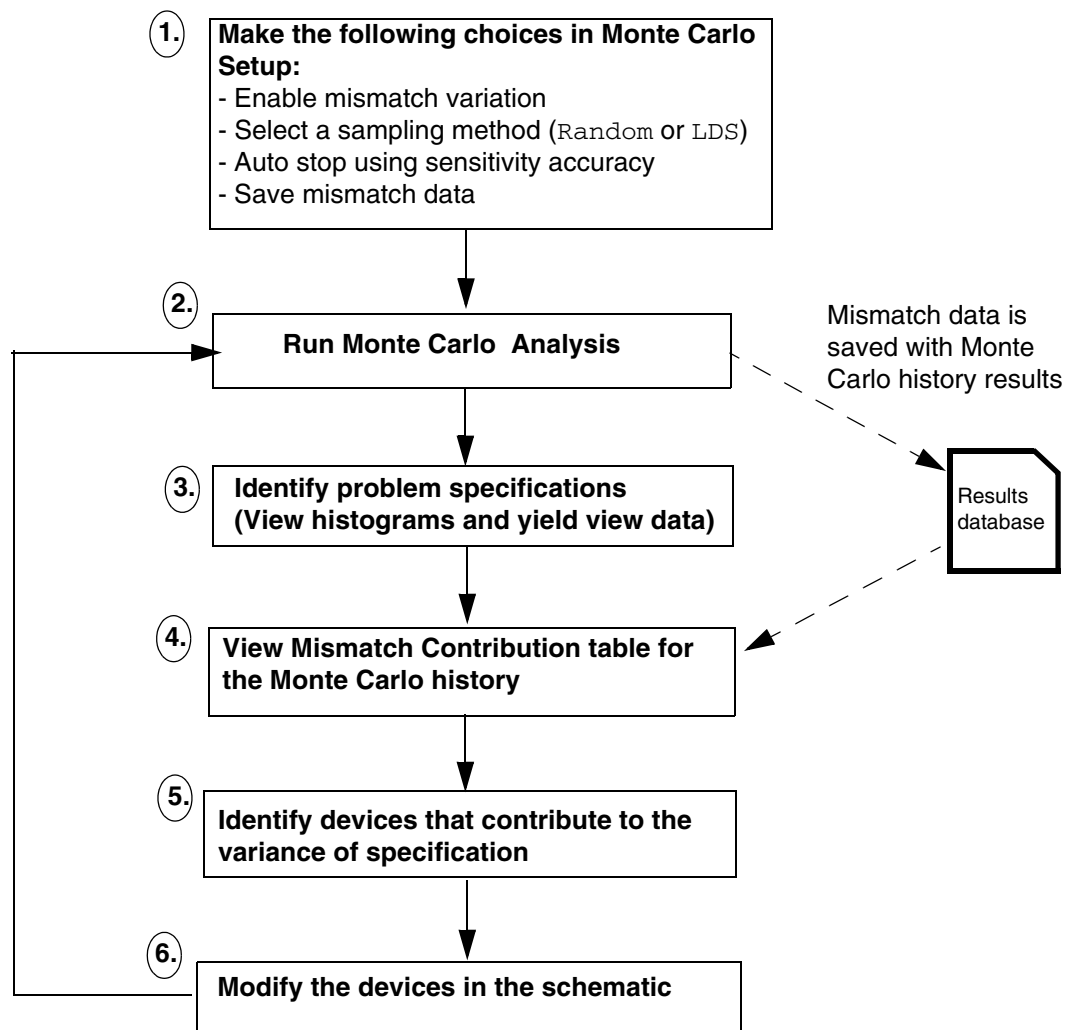
This chapter describes these features and explains how to use them.

- [Mismatch Contribution Analysis](#)
- [Yield Verification](#)
- [Creating Statistical Corners](#)
- [High Yield Verification and Corner Creation](#)

## Mismatch Contribution Analysis

Mismatch Contribution analysis is a Monte Carlo post-processing feature that helps in identifying the important contributors to mismatch variation. You can then modify the identified devices in the schematic and make the design less sensitive to mismatch variation. You can use the Sensitivity Accuracy method to automatically run the minimum required number of points. For more information about this method, see [Viewing Mismatch Contribution Results](#) on page 19.

The following illustration describes how you can save and analyze the mismatch contribution data to improve your design.





## Setting up Monte Carlo

You can set up Monte Carlo using the run options form.

1. In the *Guided Mode* section, ensure that *Run a fixed number of points* field is selected.
2. In the *Advanced - Show All Options* section, in the *Method* drop-down, select the *Sensitivity Accuracy* method.

The figure below shows the form fields that appear when the *Sensitivity Accuracy* method is selected.

The screenshot shows the 'Monte Carlo' dialog box. In the 'Guided Mode' section, the 'Run a fixed number of points' radio button is selected, and the 'auto' value is shown in the adjacent field. In the 'Advanced - Show All Options' section, the 'Variation' drop-down menu is set to 'Mismatch'. The 'Max Points' field is set to 'auto'. The 'Target Yield' field is set to '3', and the 'sigma' drop-down menu is set to 'sigma'. The 'Method' drop-down menu is set to 'Sensitivity Accuracy'. The 'Save Waveforms (Simulation Data)' checkbox is unchecked. The 'Sampling Method' drop-down menu is set to 'Low-Discrepancy Sequence'. The 'Seed' field is set to '12345'. The 'First Point' field is set to '1'. The 'Netlist Options' field is empty. At the bottom, there is a button labeled 'Specify Instances/Devices (Not Specified)'. The 'OK', 'Cancel', 'Defaults', and 'Help' buttons are at the bottom right.

Fixed number of points  
changed to **auto**

Select **Variation** as  
**Mismatch**

Specify the following field values:

1. In the *Variation* drop-down, select variation as *Mismatch*.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

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2. The *Max Points* field is set to *auto*, when the *Sensitivity Accuracy* method is selected.

**Note:** This value specifies the maximum number of sample points to simulate while trying to build an accurate model. If a model cannot be constructed even after simulating the maximum number of points, the run is stopped.

3. From the *Method* drop-down list, choose *Sensitivity Accuracy*.

This method is used to post-process the Monte Carlo results and view the Mismatch Contribution table when you are not sure about the number of samples required to view the mismatch contribution results. This method helps in automatically determining the number of samples required to be run to meet the target accuracy level so that post-processing for mismatch contribution analysis can be done. The number of samples depends on the design and the number of statistical parameters defined by the model files. When you choose this method, the Monte Carlo run is stopped as soon as a model for variation contribution can be built for every output.

4. Select the *Save Waveform (Simulation Data)* if you want to save the waveform data (`psf dir`) for plotting.

The modeling of variation in the outputs due to statistical variation can be done by using the post-processing option to view and analyze the mismatch contribution results. Therefore, for mismatch contribution analysis, it is required that you choose to select the *Save Waveforms (Simulation Data)* option to save the data for Monte Carlo analysis so that it can be later used for post-processing.

5. In the *Sampling Method* drop-down, select the method as *Random* or *Low-Discrepancy Sequence*.

**Note:** The *Latin Hypercube* sampling method is not available with *Sensitivity Accuracy* method.

For more information about these form fields on this form, see [Performing a Standard Monte Carlo Run](#) in *Virtuoso ADE Explorer User Guide*.


For more information about Sensitivity Analysis, see [Sensitivity Analysis](#) in *Virtuoso ADE Assembler User Guide*.

**Note:** When performing mismatch contribution, by default the iterated instances are considered to have the same contribution. It helps reduce the number of simulations required for the mismatch contribution analysis. For example, the iterated instances, `M0<0>:stat1` and `M0<1>:stat1`, are combined into a single parameter and displayed as `M0:stat1` in the mismatch contribution table.

## Viewing Mismatch Contribution Results

After the Monte Carlo run for mismatch variation is complete, the run log window and the Sensitivity Analysis window showing the *Mismatch Contribution* tab is displayed.

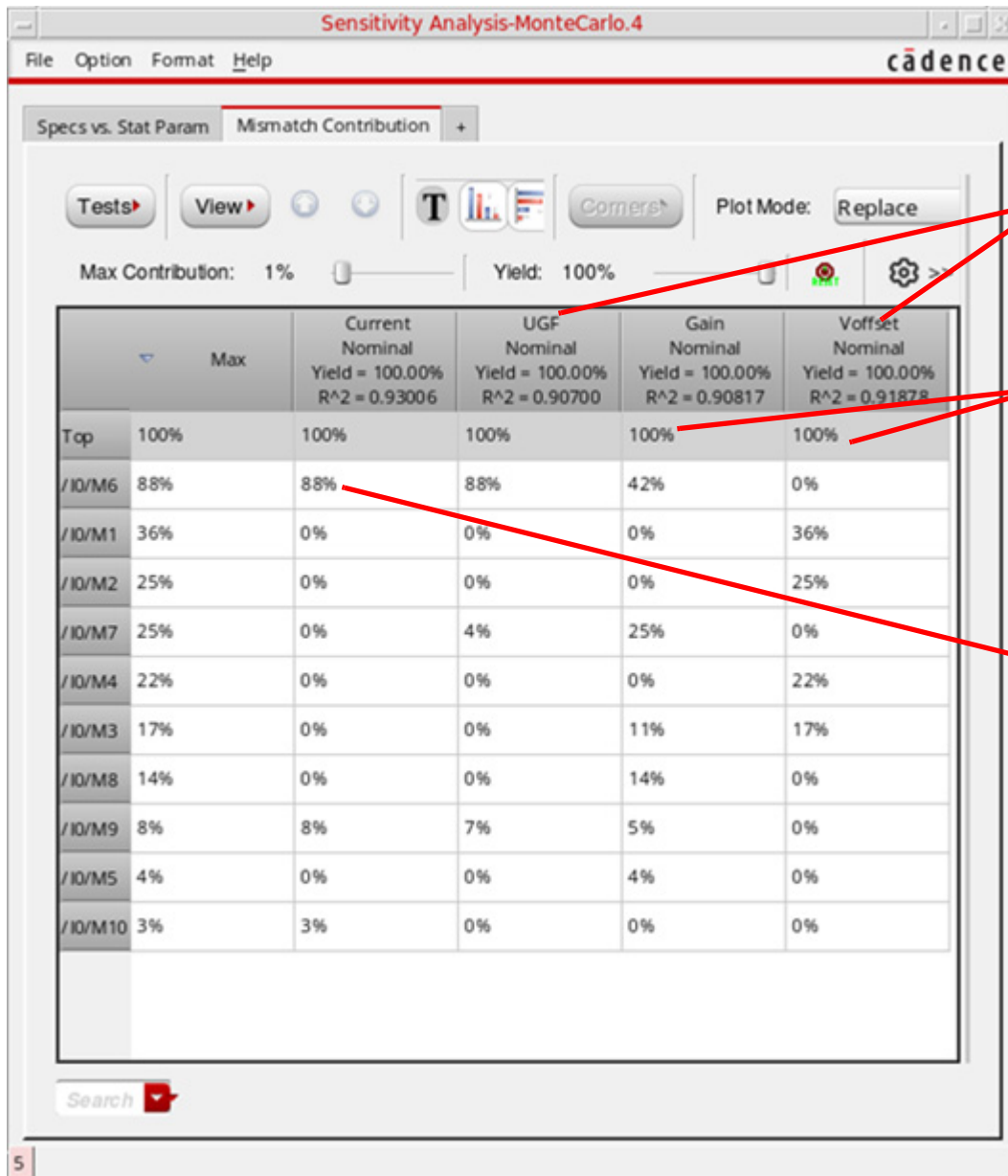
Later on as well, you can view the mismatch contribution data by doing one of the following:

- ➔ Click *Mismatch Contribution*  on the toolbar in the Results tab.
- ➔ In the *History* tab on the Data View pane, right-click a Monte Carlo history item and choose *Mismatch Contribution*.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

The Mismatch Contribution tab in the Sensitivity Analysis window is displayed, as shown below.



Each column represents a specification (here, results are sorted by Current)

The top row shows the total contributions for a hierarchical level normalized to 100%

Each row shows the contribution from each instance towards each spec (here, M6 is the largest contributor to variation in the Current spec)

In the example shown above, each row in the mismatch contribution table represents an instance of the design and each column represents the output specifications.

Each cell shows the contribution (in percentage) of an instance towards the variance of the corresponding specification. All the contributions are normalized to 100%.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

#### **Important**

By default, the tool computes the proportions of a Monte Carlo sample variation by using a linear model. This is indicated by the  $R^2$  (R squared) value in the column headers. The tooltip for column headers also shows how these proportions are calculated.

Max		Current Nominal Yield = 100.00% $R^2 = 0.93006$	UGF Nominal Yield = 100.00% $R^2 = 0.90700$	Gain Nominal Yield = 100.00% $R^2 = 0.90817$	Voffset Nominal Yield = 100.00% $R^2 = 0.91878$
Top	100%	100%	88%	42%	0%
/I0/M6	88%	88%	88%	42%	0%

Proportion of Monte Carlo sample variance explained by multivariate linear model = 93.006%

If the  $R^2$  value is lower than the threshold value of 90%, the results of the linear model might not be useful. Therefore, in such cases, the tool automatically switches to the quadratic model to calculate variance data for a particular specification more accurately. The column header is also updated to indicate this change.

#### **Important point to note**

If you run the mismatch contribution analysis by selecting All as Variation, an additional *Process* row is displayed in the mismatch contribution results, as shown in the following figure. This row shows the contributions of all the process parameters to mismatch variation.

Max		Current Nominal Yield = 94.00% $R^2 = 0.91248$	Voffset Nominal Yield = 100.00% $R^2 = 0.94195$
Top	100%	100%	100%
Process	86%	86%	0%
/I0/Ampln/M1	45%	0%	45%
/I0/Ampln/NM0	36%	0%	36%
/I0/AmpOut/M6	14%	14%	0%
/I0/Ampln/M4	10%	0%	10%
/I0/Ampln/M3	9%	0%	9%

## Virtuoso Variation Option User Guide

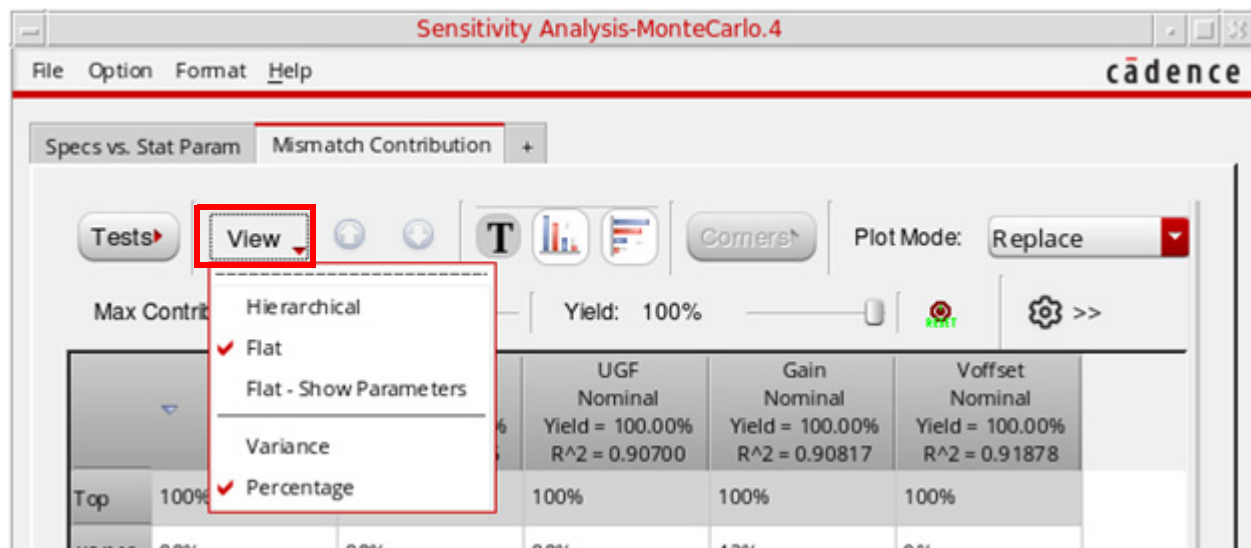
### Virtuoso Variation Option Advanced Features

The following topics show how to modify the data view in the Mismatch Contribution table:

- [Switching the Data View](#)
- [Changing the Test](#)
- [Sorting Data](#)
- [Applying Filters to View Relevant Data](#)
- [Identifying the Impact of Device Size Changes on the Variation of Circuit Output](#)
- [Highlighting a Device on Schematic](#)

### Switching the Data View

By default, instances are displayed in the flat view and the variance data is displayed in the percentage format. You can change the view by choosing the commands from the *View* drop-down command list.





Choose:

- *Hierarchical* to view the mismatch contribution data on a per instance basis, where the contribution attributed to an instance is the sum of the individual mismatch parameter variance.

In the hierarchical view, the top level is displayed first. Double-click in a cell to descend into the lower levels in the hierarchy. Alternatively, right-click in a cell and choose *Descend*.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

After that, you can use the up and down arrow buttons (   ) given at the top of the tab to traverse through the hierarchy levels.

**Note:** The lowest level in the hierarchy shows the parameters for a given instance.

- *Flat* to view the mismatch contribution on parameter basis. This is the default view.
- *Flat - Show Parameters* to view each statistical parameter in the `<instance-name>:<parameter-name>` format. As there can be multiple parameters for a device, each parameter is shown in a separate row, as shown in the example below.

	Max	Current Nominal Yield = 100.00% R^2 = 0.93006	UGF Nominal Yield = 100.00% R^2 = 0.90700	Gain Nominal Yield = 100.00% R^2 = 0.90817	Voffset Nominal Yield = 100.00% R^2 = 0.91878
/IO/M10:par1	3%	3%	0%	0%	0%
/IO/M1:par1	36%	0%	0%	0%	36%
/IO/M2:par1			0%	0%	25%
/IO/M3:par1			0%	11%	17%
/IO/M4:par1			0%	0%	22%
/IO/M5:par1	4%	0%	0%	4%	0%
/IO/M6:par1	88%	85%	88%	42%	0%
/IO/M6:plo_tox	4%	4%	0%	0%	0%
/IO/M7:par1	25%	0%	4%	25%	0%


Each parameter for an instance is shown in a separate row. The name is displayed in the `<inst-name>:<param-name>` format.

- *Variance* to view the variance values for each instance or parameter.
- *Percentage* to view the contribution of each device or parameter in the percentage format. This is the default view for data format.

### Changing the Test

The mismatch contribution table can display data for only one test at a time. By default, it shows the data for the first test in the setup.

To view data for another test, do the following:

- ➔ Click  at the top of the tab and choose a test name from the drop-down list.

Mismatch data for the selected test is displayed in the table.

## Sorting Data

By default, the order of devices or parameters in the mismatch contribution table is the same as the order of occurrence in the design. For better data analysis, you can sort the data in a row or column using the percentage or variance values in the increasing or decreasing order.

To sort the data in a row or column, do this:


- ➡ Right-click the header of the row or column and choose any one of the following commands:
  - ☐ *Sort by value*
  - ☐ *Sort by absolute value*

Alternatively, double-click in the title for a column to sort the data displayed in that.

## Applying Filters to View Relevant Data

In case of large number of instances, you can use the following filters to view the most relevant mismatch contribution data:

- **Max Contribution:** Hides the rows that have a contribution value smaller than the max contribution specified using the given percentage value. Use this filter to focus on the devices that have high contribution to the variance of the circuit.  
**Note:** The instances with contribution less than 1% are not displayed.
- **Yield:** Hides the columns when the spec yield exceeds the filter value. Use this filter when you need to focus on the outputs that are not achieving the required spec yield.

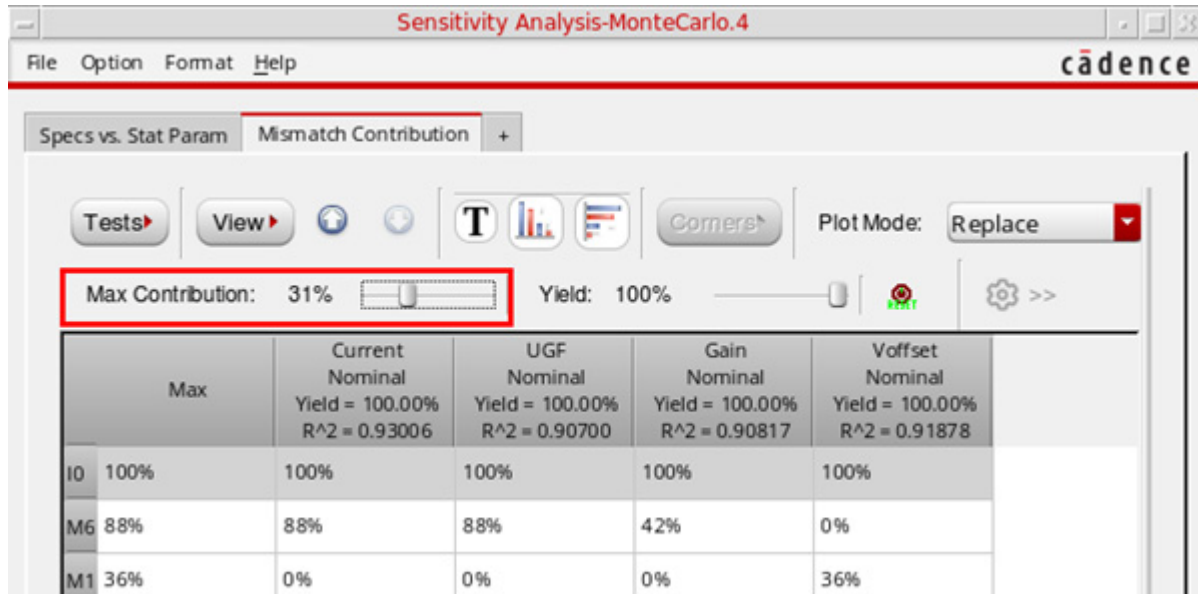
To reset the filters to their default value, click (  ).



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### Virtuoso Variation Option Advanced Features

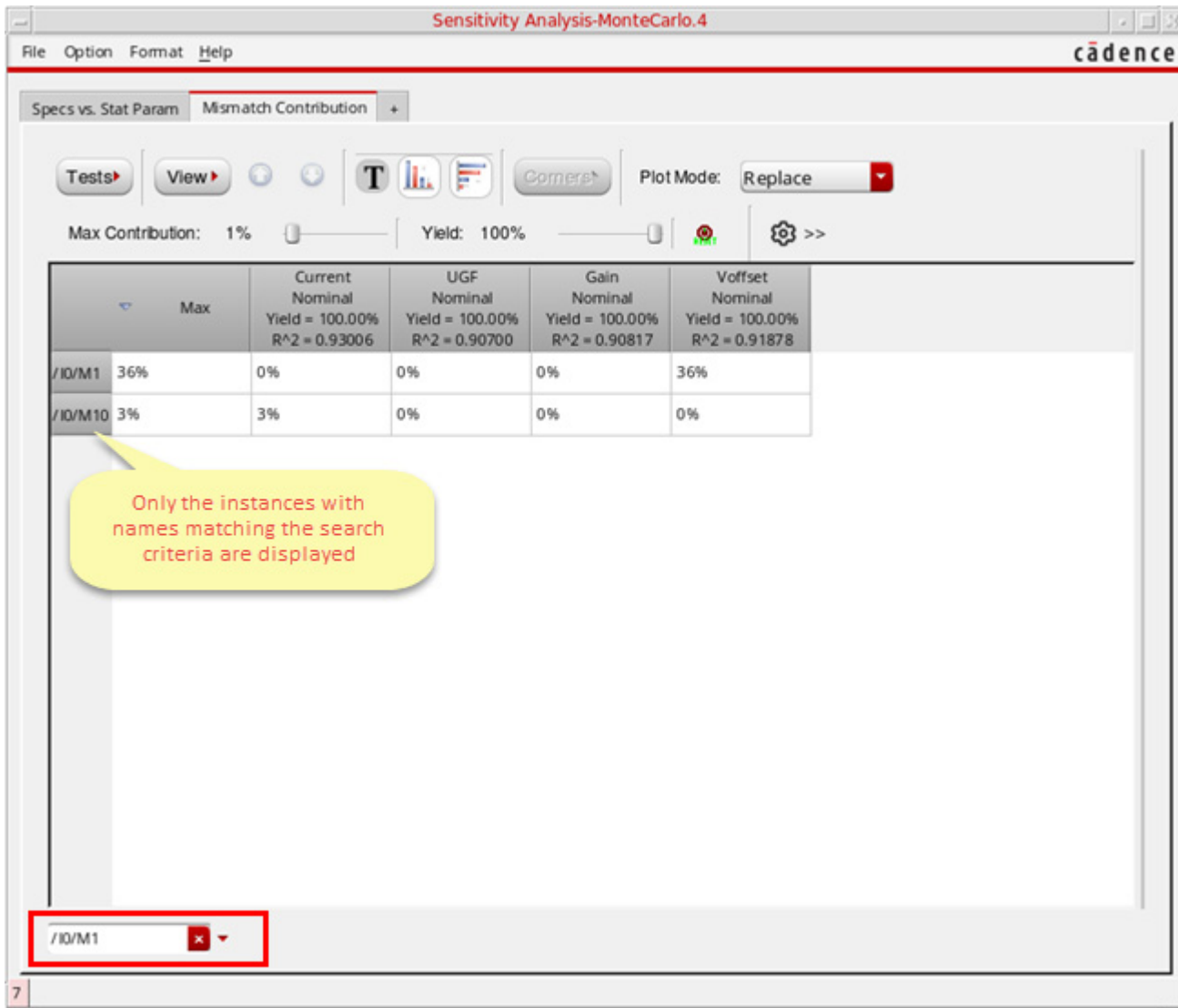
In the example shown below, a filter has been applied to view the devices (rows) that have a contribution value higher than 31%.



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In addition, you can use the *Search* field given at the bottom of this tab to view only those instance whose names match the given expression, as shown below.



### Identifying the Impact of Device Size Changes on the Variation of Circuit Output

You can use the Mismatch Tuner on the Mismatch Contribution tab to identify how a change in the size of any device instance impacts the variation of circuit output. The mismatch tuner helps you tune the contribution of an instance while changing its area multiplier.


The predicted changes are based on mismatch contribution modeling. No additional simulations are performed in estimating the changes to output variation. The assumption is that there is little change in the output distribution after making changes to the device size.


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### Virtuoso Variation Option Advanced Features

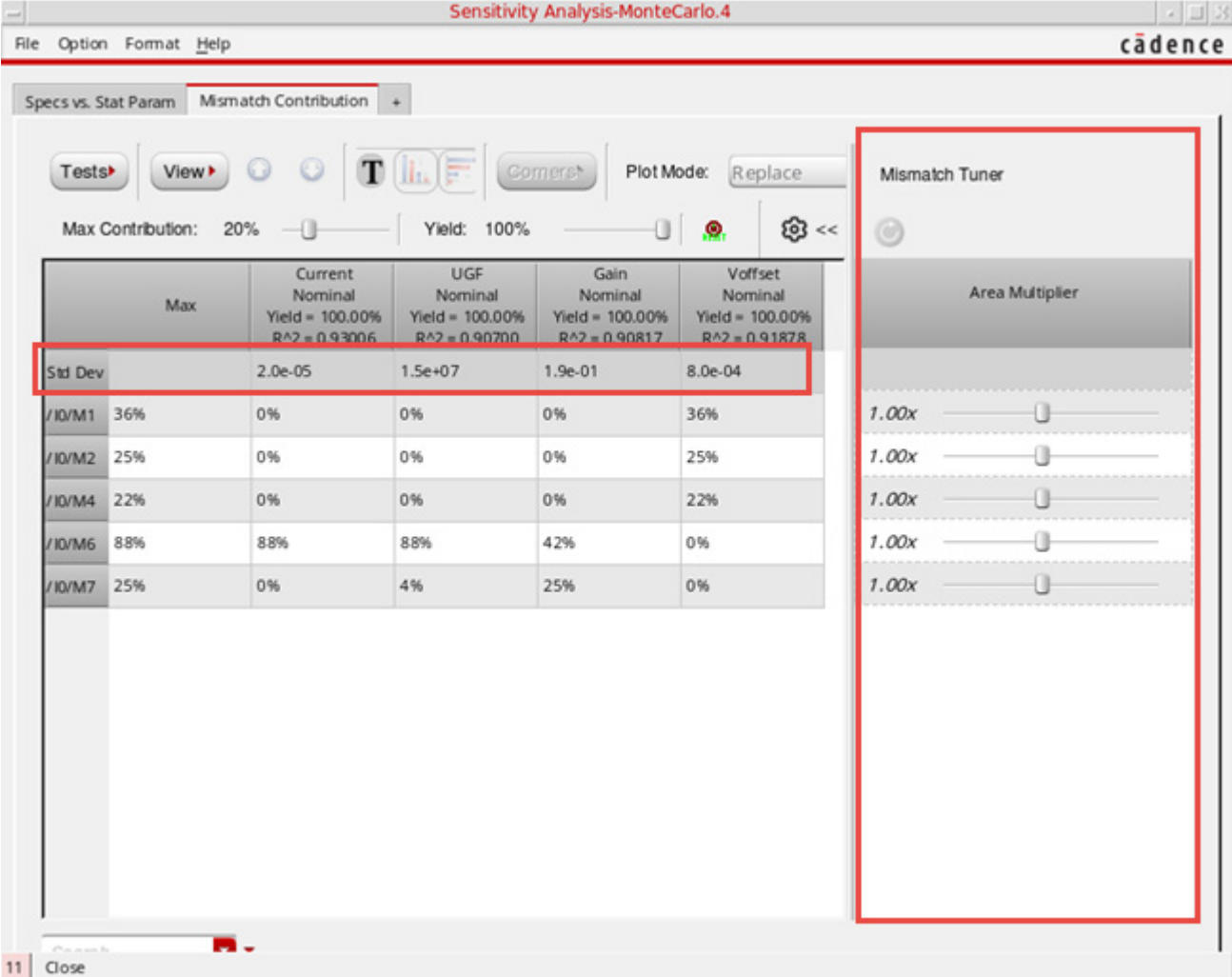
Whether the assumption holds true is design dependent and also depends on the extent of the device changes from the nominal condition.

To open the *Mismatch Tuner*:

- ➔ Click  >> at the top of the tab.

**Note:** The  >> command is disabled if the instances are displayed in the hierarchical view. You need to change the view to flat view.

The Mismatch Tuner pane is displayed on the right side of the Mismatch Contribution tab.



The screenshot shows the 'Sensitivity Analysis-MonteCarlo.4' window with the 'Mismatch Contribution' tab selected. The 'Mismatch Tuner' pane is visible on the right, containing an 'Area Multiplier' section with five sliders, each set to 1.00x. The main table displays mismatch contribution data for various parameters.

	Max	Current Nominal Yield = 100.00% R^2 = 0.93006	UGF Nominal Yield = 100.00% R^2 = 0.90700	Gain Nominal Yield = 100.00% R^2 = 0.90817	Voffset Nominal Yield = 100.00% R^2 = 0.91878
Std Dev		2.0e-05	1.5e+07	1.9e-01	8.0e-04
/IO/M1	36%	0%	0%	0%	36%
/IO/M2	25%	0%	0%	0%	25%
/IO/M4	22%	0%	0%	0%	22%
/IO/M6	88%	88%	88%	42%	0%
/IO/M7	25%	0%	4%	25%	0%

If the mismatch contribution table was showing the parameters of a lower level in the hierarchy, the hierarchy is automatically reset to show the instances at the top level. For each instance on this tab, a row is added on the Mismatch Tuner pane. Each row has a slider to

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change the area multiplier. In addition, the *Std Dev* row is displayed as the first row in the Mismatch Contribution table. This row displays the standard deviation for each output.

Drag the slider on a row to increase or decrease the size of the instance or type a value (in the range of 0.1 to 10) in the text field to the left of the slider. The predicted standard deviation values due to the change in the instance size are shown in the *Std Dev* row. In addition, the value in parenthesis shows the percent change in value. If there is any change in the standard deviation of any specification, its value is displayed in red or blue to indicate a negative or positive impact on the variation of that specification.

The screenshot shows the 'Sensitivity Analysis-MonteCarlo.4' window with the 'Mismatch Contribution' tab selected. The table below represents the data shown in the interface:


	Max	Current Nominal Yield = 100.00% R^2 = 0.93006	UGF Nominal Yield = 100.00% R^2 = 0.90700	Gain Nominal Yield = 100.00% R^2 = 0.90817	Voffset Nominal Yield = 100.00% R^2 = 0.91878
Std Dev		2.5e-05 (+24.01%)	1.8e+07 (+22.71%)	2.1e-01 (+11.65%)	7.6e-04 (-5.98%)
/IO/M6	93%	93%	93%	54%	0%
/IO/M1	27%	0%	0%	0%	27%
/IO/M2	28%	0%	0%	0%	28%
/IO/M7	19%	0%	3%	19%	0%
/IO/M4	25%	0%	0%	0%	25%
/IO/M3	20%	0%	0%	8%	20%
/IO/M8	11%	0%	0%	11%	0%
/IO/M9	5%	5%	5%	4%	0%
/IO/M5	3%	0%	0%	3%	0%
/IO/M10	2%	2%	0%	0%	0%

The 'Mismatch Tuner' section on the right shows sliders for the 'Area Multiplier' for each instance. The /IO/M1 instance is highlighted in red, showing a multiplier of 1.50x.

The variance contribution value for that instance is also updated in the corresponding row. The updated values are displayed in blue or red.

Continue to change the area multiplier for different devices until the desired changes in the standard deviation for the specifications is achieved. You can later reflect these changes in the design by modifying the instance parameters in the Variables and Parameters assistant or by modifying the schematic.

### ***Important Points to Note***

- You can clear all the multipliers by using the *Reset table to original contribution values*  button on top of the Mismatch Tuner pane.
- When Mismatch Tuner is open, the variance contribution values are displayed only in the numerical format. If data is already displayed in vertical or horizontal bar graphs, when you open Mismatch Tuner, the data format is changed to numerical.
- The mismatch contribution and yield filters are hidden when the Mismatch Tuner is in progress.
- You cannot descend or ascend through the hierarchy while the Mismatch Tuner is displayed.

### **Exporting Results to a CSV File**

You can export the results of mismatch contribution analysis to a CSV file for post-processing. Follow these steps to export the mismatch contribution results to a CSV file:

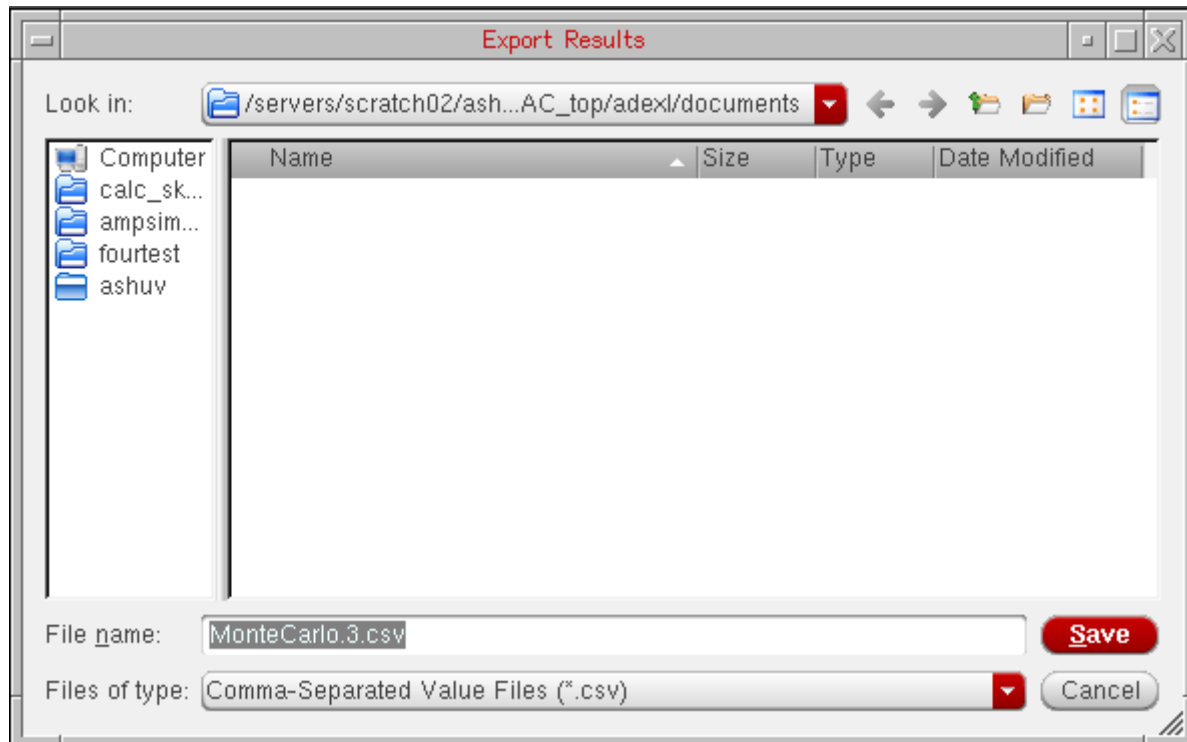
1. In the *Sensitivity Analysis* window, choose *File – Export Result to CSV – Current Tab* or *All Tabs*.

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When you choose *Current Tab*, the *Export Results* form appears and the sensitivity analysis results displayed only on the currently selected tab are exported to the CSV file.



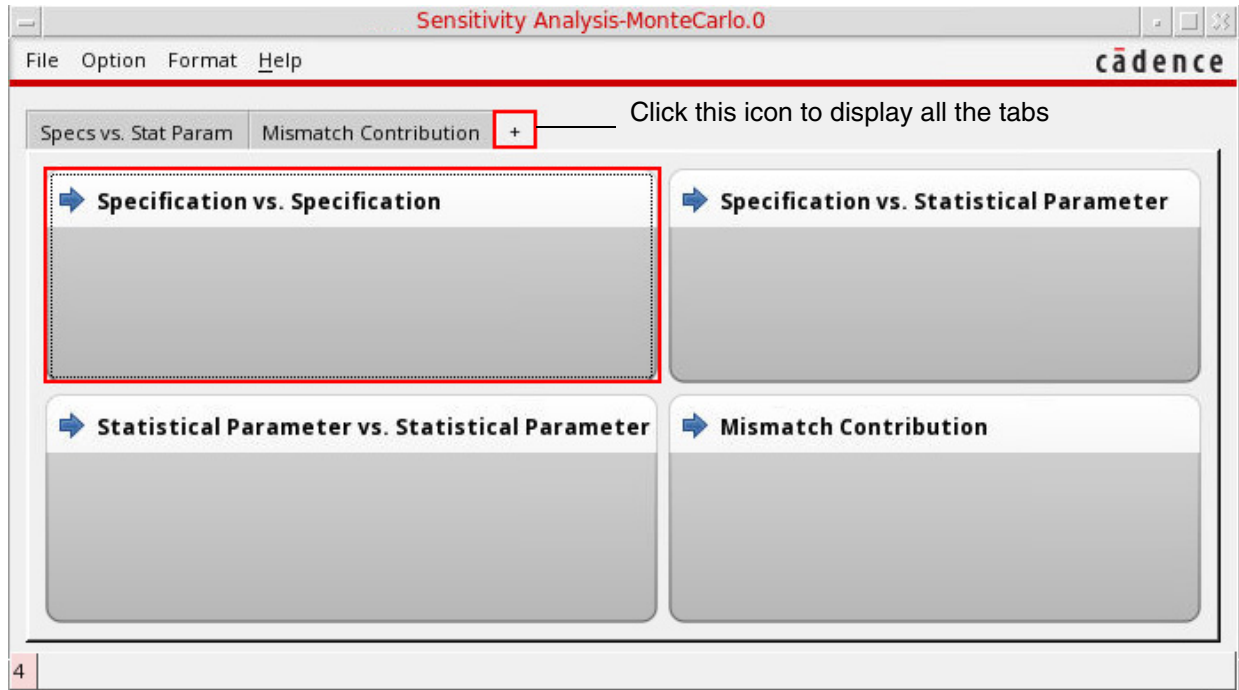
2. Specify the name of the file to which you want to export the results and click *Save*.

When you choose *All Tabs*, the *Export Results* form exports the sensitivity analysis results, displayed on the tabs that are currently visible in the Sensitivity Analysis window. If a tab is missing, you can add it by following these steps:

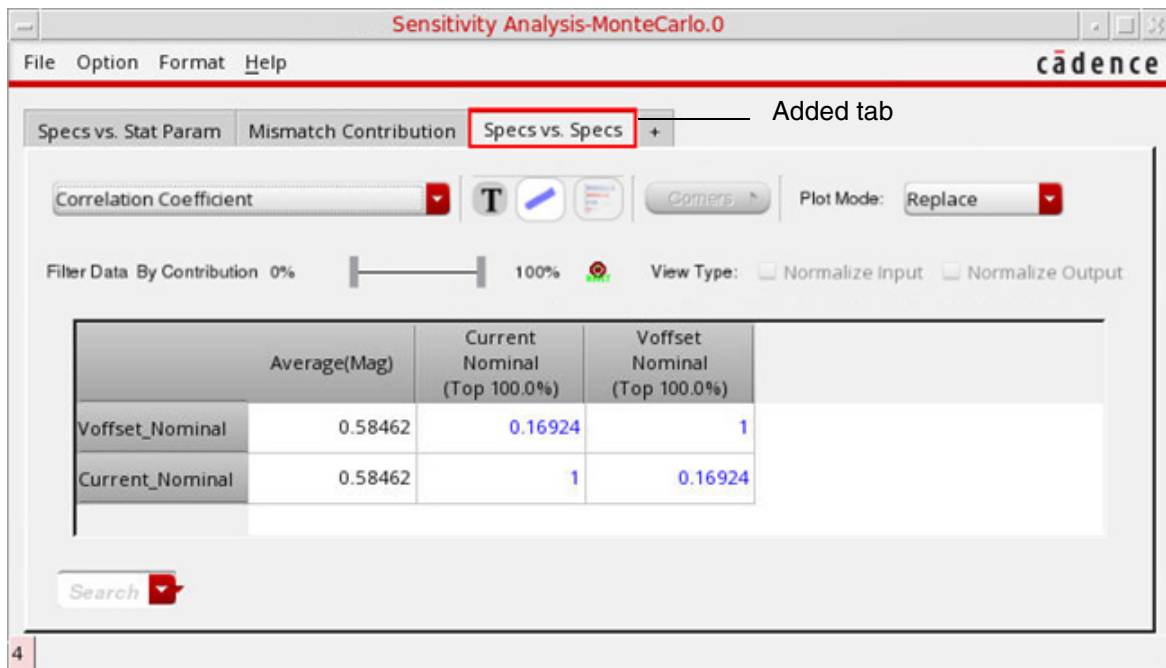
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1. On the Sensitivity Analysis window, click the '+' icon to display all the tabs, and then select the tab that you want to add.



2. The selected tab is added to the window.



**Note:** For mismatch contribution tab, you can control the contents and formatting of CSV

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file, based on the settings explained in [Controlling the CSV contents and Formatting](#), that is, data in the CSV file after exporting results is displayed exactly the same way as it is displayed in the mismatch contribution table. For other tabs, you cannot control the CSV contents and formatting.

### ***Controlling the CSV contents and Formatting***

When you export the results of mismatch contribution analysis to a CSV file, instances and variance data in the CSV file are displayed based on the following settings that you configure on the *Mismatch Contribution* tab:

---

Settings		Options and their Description
View	Instance	<i>Hierarchal, Flat, Flat – Show Parameters</i> Refer to <a href="#">Switching the Data View</a>
	Variance data	<i>Variance, Percentage</i> Refer to <a href="#">Switching the Data View</a>
Sort		Refer to <a href="#">Sorting Data</a>
Filter		<i>Max Contribution, Yield</i> Refer to <a href="#">Applying Filters to View Relevant Data</a>
Test		Refer to <a href="#">Changing the Test</a>

---

For example, on the mismatch contribution table, if you have:

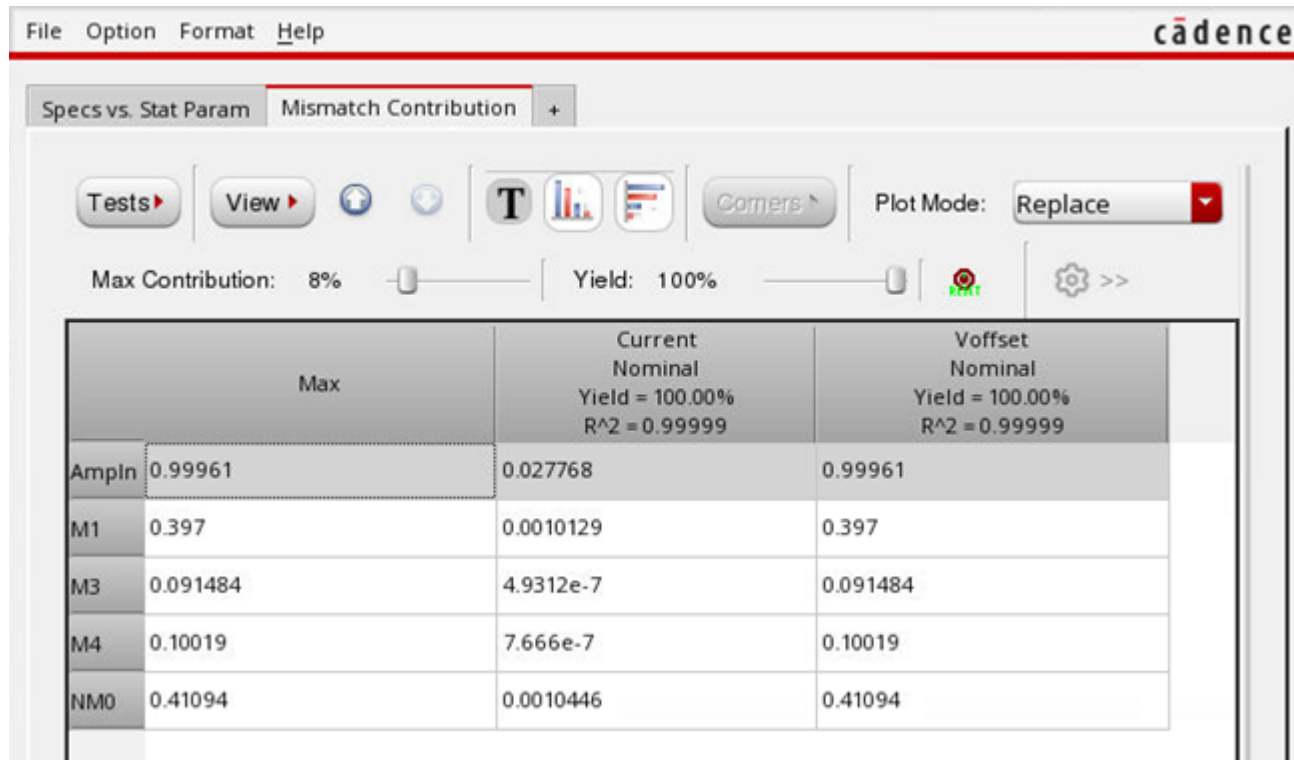
- selected instances to display hierarchically and descended to the level, `AmpIn`.
- filtered data to display only the instances that have a contribution value equal to or greater than 8%.
- selected data to display as variance.



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Data in the mismatch contribution table is displayed as shown in the following figure.



The following figure shows an example of the contents of the CSV file, when the results are exported to the CSV file.

The screenshot shows a CSV file with the following data:

	A	B	C	D
1	Mismatch Contribution Table :			
2		Max	Current Nominal Yield = 100.00% R^2 = 0.99999	Voffset Nominal Yield = 100.00% R^2 = 0.99999
3	Ampln	0.99961	0.027768	0.99961
4	M1	0.397	0.0010129	0.397
5	M3	0.091484	4.9312E-007	0.091484
6	M4	0.10019	7.666E-007	0.10019
7	NM0	0.41094	0.0010446	0.41094

You can observe that the CSV file contains data exactly as you see it in the mismatch contribution table.

## Highlighting a Device on Schematic

While analyzing data in the mismatch contribution table, you can highlight a device on the schematic to view its exact location. This can help in identifying and modifying a device in schematic to improve the variance data, if required.

To highlight a device on schematic, do this:

- ➔ Right-click a row and choose *Highlight on Schematic*.

Alternatively, you can press H.

## Yield Verification

You can use the Yield Verification - Basic AutoStop method of the Monte Carlo run mode to estimate the yield.

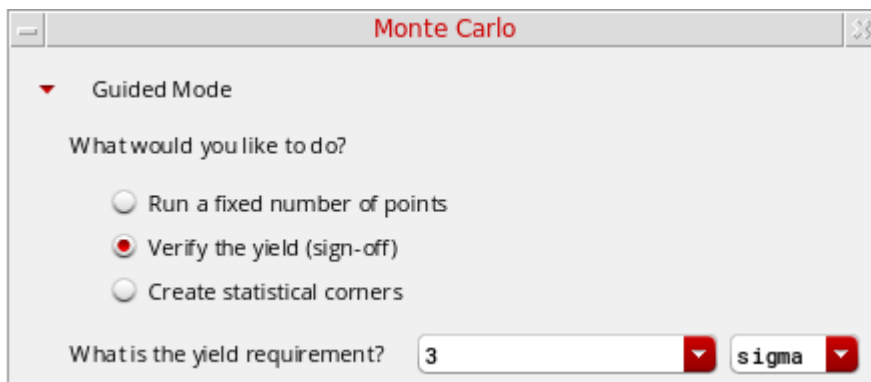
To verify the yield, you require a large number of samples when the actual yield is above or slightly below the target. For example, when verifying a 3-sigma target with confidence value of 90 percent, the run can be stopped if the first 1800 samples (approximately) pass the specification. The sample reordering method allows you to verify the yield without simulating such a large number of samples.

To perform yield verification using the Yield Verification - Reorder Samples method,

1. In the *Guided Mode*, select the *Verify the Yield (sign-off)* option.

When you select this option, the *What is the Yield requirement?* field appears in which you specify the sigma or percentage value. If you choose *sigma*, the default value is 3 and if you choose *%*, the default value is 99.865. The value you specify in this field is always in synchronization with the *Target Yield* field available in the *Advanced - Show All Options* section.

**Note:** These yield estimation methods are used only when the sigma value equal to 3. For higher sigma values, you can use scaled-sigma sampling or worst case distance methods.



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2. When the yield is 3, in the *Advanced - Show All Options* section, specify the following fields:

Monte Carlo

Guided Mode

What would you like to do?

☐ Run a fixed number of points

☒ Verify the yield (sign-off)

☐ Create statistical corners

What is the yield requirement? 3 sigma

Advanced - Show All Options

Variation All

Max Points 3427

Target Yield 3 sigma

Probability 99 %

Method Yield Verification - Reorder Samples

☐ Save Waveforms (Simulation Data)

Sampling Method Low-Discrepancy Sequence

Seed 12345

First Point 1

Netlist Options

Specify Instances/Devices (Not Specified)

OK Cancel Defaults Help

The target yield value is equal to **3 sigma**

Shows the maximum number of points to be simulated. This value changes with the change in probability and target yield.

Selected method is **Yield Verification - Reorder Samples**

Available Sampling methods are: **Low-Discrepancy Sequence** and **Random**.

- a. In the *Variation* drop-down, select variation as All, Mismatch, or Process.
- b. The *Max Points* field shows the maximum number of points that will be run. The value depends on both the target yield and probability. The number of simulations required is typically much smaller.
- c. In the *Target Yield* field, specify the yield value that you want to achieve for your design. The value of this field is same as the sigma field in the *Guided Mode* section.

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- d. In the *Probability* field, select a probability percentage value. Probability values closer to 100% will require more simulations before the yield estimate can be determined to be lower or higher than the target. Smaller probability values requires less simulations before auto stop is triggered. The default value is 95%.
3. In the *Method* drop-down, the *Yield Verification - Sample Reorder* method is already selected. This is the default value with the Virtuoso Variation Option license.
  4. Select the *Save Waveforms (Simulation Data)* option if you want to save output data (*psf* files) for every Monte Carlo iteration so that you can perform post-processing operations (like plotting, printing, annotation, and re-evaluation) on individual iterations.
  5. In the *Sampling Method* drop-down, select one of the following statistical sampling method to be used:
    - ☐ Random
    - ☐ Low-Discrepancy Sequence

For more information about these methods, see [Performing a Standard Monte Carlo Run](#) in *Virtuoso ADE Explorer User Guide*.
  6. In the *Seed* field, specify a seed for the Monte Carlo analysis. By always specifying the same seed, you can reproduce a previous experiment. If you do not specify a seed, the value 12345 is used.
  7. In the *First Point* field, specify a starting run number. The first point specifies the run that Monte Carlo begins with. By specifying this number, you can reproduce a particular run or sequence of runs from a previous experiment (for example, to examine an earlier case in more detail).
- To reproduce a run or sequence of runs, you need to specify the same value in the *Starting Run Number* and the *Monte Carlo Seed* fields.
8. In the *Netlist Options* field, specify additional analysis options that you want to add to the netlist.
- For example, "nullmfactorcorrelation=yes".
9. Click the *Specify Instances/Devices (Not Specified)* button to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see [Including or Excluding Instances and Devices for Applying Mismatch Variations](#).
  10. Click *OK*.

After the setup is complete, run the Monte Carlo simulation.

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As per this method, the Monte Carlo samples are ordered from worst to best based on failure probability modeling. First, a small number of samples are simulated to fit into the model of performance and statistical variation. Then, the remaining Monte Carlo samples are generated, but not simulated. The samples are then reordered based on the performance model. After that, simulation begins with the samples that have the highest probability to fail. The detailed steps are as follows:

1. The run begins with an initial Monte Carlo sampling, in which a small number of samples are simulated in the normal order (a minimum of 50 samples). The *Sensitivity Accuracy* method is applied that stops simulating new Monte Carlo samples after enough data is available for accurate modeling.
2. After the initial sampling and modeling is complete, the remaining samples are generated but not simulated. The total number of samples required for the run is determined automatically from the target yield and the probability requirements specified in the Monte Carlo form. For each of the remaining samples, the statistical parameter values are generated and the samples are ordered using failure probability modeling.
3. Now, the Monte Carlo samples are simulated in the highest probability to fail order. The Monte Carlo run stops automatically in both cases—target yield is met or not met.
  - ❑ When the yield is low, the failed samples are simulated first.
  - ❑ When the yield is high, the run stops early when the specifications pass for the samples with high probability to fail. The remaining samples have very low probability to fail.

If the design has low yield, the failed samples are identified early and the simulation run is stopped. On the other hand, if the design has high yield, it can be determined earlier that the yield target is met if the most probable to fail samples pass the specification. If these worst samples pass the specifications, the run stops early.

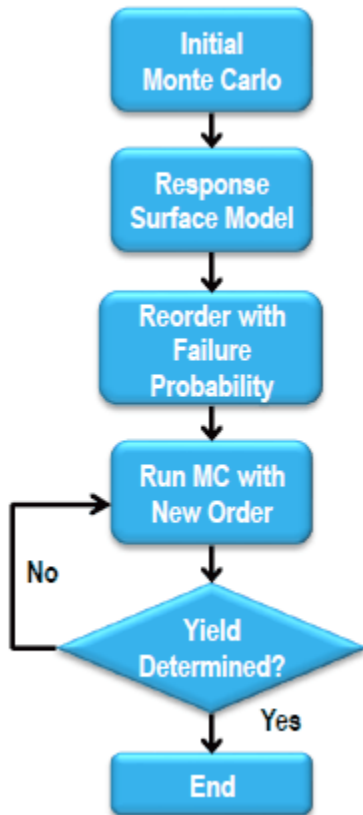
In both the cases, the run stops earlier than the traditional significance test method using a normal random sequence of samples. Significant time saving is observed in high yield cases, since the worst case samples are simulated much earlier in the run.

## Virtuoso Variation Option User Guide

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The flowchart below represents the workflow used by this method:



### Example

Consider the example of a two-stage OpAmp in a 45nm process with analysis specified as: AC and TRAN.

Specifications are available for Gain, UGF, Current and Voffset.

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Now, run the Yield Verification with the *Reorder Samples to Speed Up Analysis* option enabled for target yield=99.87 and Probability=95.

The screenshot shows the 'Monte Carlo' dialog box with the following settings:

- Guided Mode:**
  - What would you like to do?
    - ☐ Run a fixed number of points
    - ☒ Verify the yield (sign-off)
    - ☐ Create statistical corners
  - What is the yield requirement?  %
- Advanced - Show All Options:**
  - Variation:
  - Max Points:
  - Target Yield:  %
  - Probability:  %
  - Method:
  - ☒ Save Waveforms (Simulation Data)
  - Sampling Method:
  - Seed:
  - First Point:
  - Netlist Options:
  -

Buttons at the bottom: **OK**, **Cancel**, **Defaults**, **Help**



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The log file generated during the simulation run is shown below:

---

Starting Monte Carlo Sampling...

Current time: Wed May 20 14:51:40 2015

Performing initial Monte Carlo to build response surface model...

Number of statistical parameters: 93

Maximum number of points needed to ensure model accuracy: 186

The actual number of points needed could be less, depending on the design and outputs.

MonteCarlo.1.InitialSampling stopped automatically because a response surface model can be accurately built for every spec.

Number of points completed: 50

Number of simulation errors: 0

Extracting statistical parameter values for all samples...

MonteCarlo.1.ParameterDump

Number of points completed: 1902

Number of simulation errors: 0

Evaluating remaining points ordered by probability to fail:...


MonteCarlo.1.Reorder stopped automatically because the yield is significantly higher than the target.

Number of points completed: 60

Number of simulation errors: 0

MonteCarlo.1 completed.

Current time: Wed May 20 14:56:01 2015



Yield was found to be significantly higher than the target.  
Though the number of points required are 1902, only 60  
samples were simulated using the Reorder method.

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The simulation results displayed on the *Results* tab are shown below:

Outputs Setup		Results							
Yield		<div> <div>Yield</div> <div>Replace</div> <div>(None)</div> </div>							
Test	Name	Yield	Min	Target	Max	Mean	Std Dev	Cpk	Errors
Yield Estimate: 93.3333 % (56 passed/60 pts)		Confidence Level: <not set> Filter: <not set>							
-	DC								
-	Current(summary)	93.3333% (56/60)	671.2u		1.09m	834.5u	16.27u	0.544	0
	Current	93.3333% (56/60)	991.4u	< 1.07m	1.09m	1.043m	16.27u	0.544	0
	Current_MC_0	100% (60/60)	671.2u	< 1.07m	803.5u	730u	22.13u	5.12	0
	Current_MC_01	100% (60/60)	671.2u	< 1.07m	803.5u	730u	22.13u	5.12	0
-	Voffset(summary)	100% (60/60)	-1.271m		4.459m	1.355m	477.2u	4.83	0
	Voffset	100% (60/60)	3.284m	< 7m	4.459m	3.89m	202.3u	5.12	0
	Voffset_MC_0	100% (60/60)	-1.271m	< 7m	1.573m	87.19u	477.2u	4.83	0
	Voffset_MC_01	100% (60/60)	-1.271m	< 7m	1.573m	87.19u	477.2u	4.83	0

Resulting yield for each specification and the number of points passed/number of points completed for each corner

**Note:** By default the Results table for the Yield Verification method with sample reordering enabled does not include standard deviation (*std dev*), *Mean*, and *Cpk* columns.

## Creating Statistical Corners

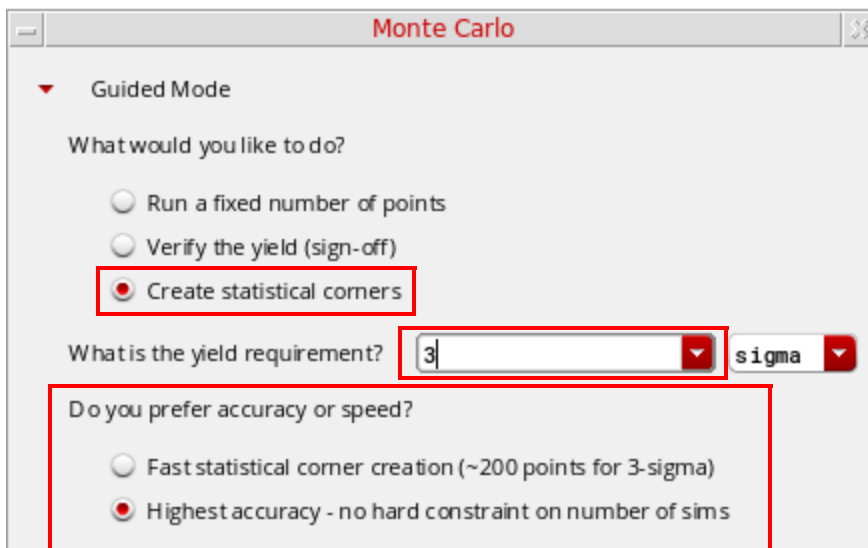
After running Monte Carlo simulations, you can analyze the yield and identify the specifications for which the results need improvement. You can then create statistical corners to be used in further analysis and design optimization. Several methods are available for creating statistical corners—basic and advanced methods. To know more about how to create statistical corners using basic methods, see the [Creating Statistical Corners](#) section in the *Virtuoso ADE Assembler User Guide*.

Virtuoso Variation Option provides the following two advanced methods to create statistical corners:

- [Worst Samples Using Sample Reordering](#)
- [K-Sigma Corners Method](#)

To create statistical corners using advanced methods,

- ➔ In the *Guided Mode* section, select the *Create Statistical Corners* check box and specify a target yield value.



Select one of the following options to specify your preference for speed or accuracy:

- ❑ *Fast statistical Corner creation (~200 points for 3-sigma)*—Select this option if you prefer speed over accuracy. When you select this option, the K-Sigma Corners method is performed to create statistical corners and the K-Sigma Corners is selected in the *Method* drop-down.

For information about how to use this method, see [K-Sigma Corners Method](#).

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- ❑ *Highest accuracy-no hard constraint on number of sims*—Select this option if you prefer accuracy over speed. When you select this option, the Worst Samples method is performed to create statistical corners and the Worst Samples is selected in the Method drop-down. When to Choose Worst Samples Versus K-Sigma Corners?

Both the Worst Samples and K-Sigma methods can be used to create statistical corners.

- A corner created by the Worst Samples method is from a sample generated by the simulator. It represents the condition that allows the yield verification sign-off to pass. If the design meets specifications at the corner from the Worst Samples method, yield verification is likely to pass with the same target yield and probability. The total number of samples considered by the Worst Sample method represent the sign-off condition for the given target yield and probability.

The Worst Samples method is recommended when high accuracy is needed and the number of statistical parameters is not large ( $< 1000$ ). For more details about this method, refer to [Worst Samples Using Sample Reordering](#).

- A corner created by the K-Sigma Corners method is based on modeling and extrapolation from the **Probability Density Function** (PDF) of the output. This corner is not one of the samples generated by the simulator and this method is typically faster than the Worst Samples method.

The K-Sigma Corners method is strongly recommended over the Worst Samples method when the number of statistical parameters is large ( $> 1000$ ). For more details about this method, refer to [K-Sigma Corners Method](#).

## **Worst Samples Using Sample Reordering**

In this method, the points are reordered based on the response surface modeling and sampling is stopped when the worst sample is found for each specification. The statistical corners are automatically created from the worst samples.

As a first step, sample reordering is performed using the failure probability modeling as explained in the [Yield Verification](#) auto stop method. Since the samples are already reordered from worst to best, the worst samples method requires comparatively smaller number of simulations to run. However, considering that the failure probability modeling can have some uncertainties, a minimum of 10 samples per spec is simulated to confidently identify the worst sample. Some specifications may require to run additional simulations before stopping.

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When you select the *Highest accuracy-no hard constraint on number of sims* option, the **Worst Samples** method is used to create statistical corners. The figure below shows the form fields for this method:

The screenshot shows the 'Monte Carlo' dialog box with the following settings:

- Guided Mode**
  - What would you like to do?
    - ☐ Run a fixed number of points
    - ☐ Verify the yield (sign-off)
    - ☒ Create statistical corners
  - What is the yield requirement?
  - Do you prefer accuracy or speed?
    - ☐ Fast statistical corner creation (~200 points for 3-sigma)
    - ☒ Highest accuracy - no hard constraint on number of sims
- Advanced - Show All Options**
  - Variation:
  - Max Points:
  - Target Yield:
  - Probability:
  - Method:
  - ☐ Save Waveforms (Simulation Data)
  - Sampling Method:
  - Seed:
  - First Point:
  - Netlist Options:
  -

Buttons at the bottom:

Accuracy is selected over speed.

For 3 sigma target yield, the maximum number of points is automatically set to **2289** for this method. This value changes when you change the probability.

Specify the probability (confidence level). The default probability is **95%**.

The method selected is **Worst Samples**.

For information about the common fields, see [Performing a Standard Monte Carlo Run in Virtuoso ADE Explorer User Guide](#).

Note the following additional field values available for the Worst Samples method:

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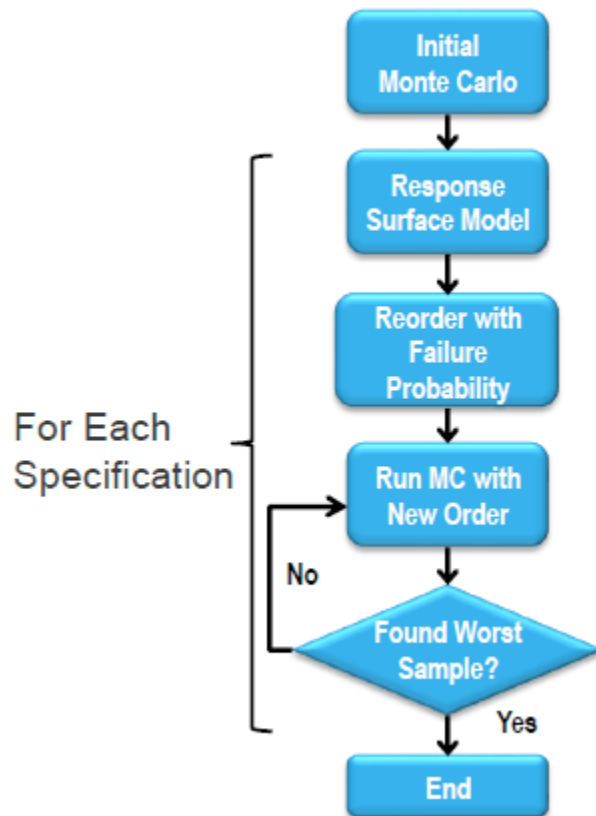
- The maximum number of points (samples) to be simulated are displayed in the *Max Points* field. Value for this field is automatically calculated based on the target yield or probability value. For example, it is set to 2289 when the probability is 95%. This value changes when you change the probability.
- In the *Probability* field, specify the probability value (confidence level). The default probability is 95%.
- The *Sampling Method* drop-down lists two methods, *Low-Discrepancy Sequence* (default) and *Random*.
- Click the *Specify Instances/Devices (Not Specified)* button to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see [Including or Excluding Instances and Devices for Applying Mismatch Variations](#).

After completing the setup, run the Monte Carlo simulation.

The *Worst Samples* method finds the worst sample based on the target yield and probability values, creates the statistical corners, and stops the Monte Carlo simulation when the worst sample has been found for every specification.

After the simulation run is complete, statistical corners are automatically generated for each specification from the worst samples and displayed in the *Data View* assistant and the *Corner Setup* form.

The flowchart below represents the workflow used by this method:



Alternatively, you can also use the worst samples method as a post-processing feature and create statistical corners from the simulation results. To do this, right-click the simulation results displayed on the *Results* tab and choose *Create Statistical Corner from Worst Sample*. For more information, see [Creating Statistical Corner from Worst Sample](#) in the *ADE Assembler User Guide*.

## Example


Consider the example of the Two-stage OpAmp design in 45nm process with analysis specified as: AC and TRAN.



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The specifications specified in this example are `Current` and `Voffset`. The figure below shows the specification values that are specified on the *Outputs Setup* tab.

Outputs Setup							
Results							
							
6 rows							
Test	Name	Type	Details	EvalType	Plot	Save	Spec
Filter	Filter	Filter	Filter	Filter			Filter
DC		signal	/V1/PLUS	point	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
DC		signal	/OUT	point	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
DC	Current	expr	abs(IDC("/V1/PLUS"))	point	<input checked="" type="checkbox"/>	<input type="checkbox"/>	< 1.07m
DC	Voffset	expr	(VDC("/inm") - VDC("/inp"))	point	<input checked="" type="checkbox"/>	<input type="checkbox"/>	< 7m
DC		signal	/inm	point	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
DC		signal	/inp	point	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

Now, run the Monte Carlo simulation with the method selected as *Worst Samples* for the following target yield and probability values:

- *Target Yield*—3 sigma
- *Probability (1-alpha)*—95%

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The simulation run first performs initial Monte Carlo to reorder samples and then runs the worst sample algorithm to generate the worst sample for each specification. The following run log is generated for this simulation run.

The screenshot displays the 'Run Log | Log file viewer' window from Cadence. The log contains the following text:

```
Starting Monte Carlo Sampling...
Current time: Fri Jan 18 15:40:00 2019
Performing initial Monte Carlo to build response surface model...

Variation: mismatch
Sampling Method: Random
Seed: 12345
Method: Worst Samples
Target Yield: 3 Sigma
Probability: 0.95

Number of statistical parameters: 52
Maximum number of points needed to ensure model accuracy: 104
The actual number of points needed could be less, depending on the design and outputs.

MonteCarlo.8.RO.InitialSampling stopped automatically because a response surface model can be accurately built for every spec.
Number of points completed: 50
Number of simulation errors: 0

Extracting statistical parameter values for all samples...
MonteCarlo.8.RO.ParameterDump
Number of points completed: 2289
Number of simulation errors: 0

Current specs:Current Voffset_L Gain UGF
Evaluating remaining points ordered by probability to fail:...
MonteCarlo.8.RO.AC stopped automatically because the worst Monte Carlo sample has been found for the current output.
Number of points completed: 131
Number of simulation errors: 0
Spec:Current, worst point number:65, point number in original Monte Carlo:461, value:0.00121394
Spec:Voffset_L, worst point number:76, point number in original Monte Carlo:726, value:0.00530537
Spec:Gain, worst point number:94, point number in original Monte Carlo:1128, value:44.5767
Spec:UGF, worst point number:107, point number in original Monte Carlo:1669, value:9.9905e+08
```

Annotations and arrows point to specific parts of the log:

- An arrow points from the text "Runs initial Monte Carlo to build a response surface model for every spec. In this example, 50 samples were simulated." to the "Performing initial Monte Carlo to build response surface model..." line.
- An arrow points from the text "For the same design, the number of completed points for a single job and the multiple jobs may vary because the initial surface model built by a single job and that built by multiple jobs may be different." to the "Number of points completed: 50" line.
- A red box highlights the section: "Number of statistical parameters: 52", "Maximum number of points needed to ensure model accuracy: 104", "The actual number of points needed could be less, depending on the design and outputs.", "MonteCarlo.8.RO.InitialSampling stopped automatically because a response surface model can be accurately built for every spec.", "Number of points completed: 50", "Number of simulation errors: 0".
- An arrow points from the text "The statistical parameters are extracted for 2289 points, which is the total number of Monte Carlo points based on the given target yield and probability" to the "Number of points completed: 2289" line.
- An arrow points from the text "Sample number of the sample identified as the worst sample for each spec" to the "Spec:Current, worst point number:65, point number in original Monte Carlo:461, value:0.00121394" line.
- An arrow points from the text "This value indicates that 81 additional points were simulated while identifying the worst samples for Voffset\_H, Gain, and UGF" to the "Spec:UGF, worst point number:107, point number in original Monte Carlo:1669, value:9.9905e+08" line.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

A comprehensive summary is added towards the end of the run log to show the worst samples for all the specifications together.

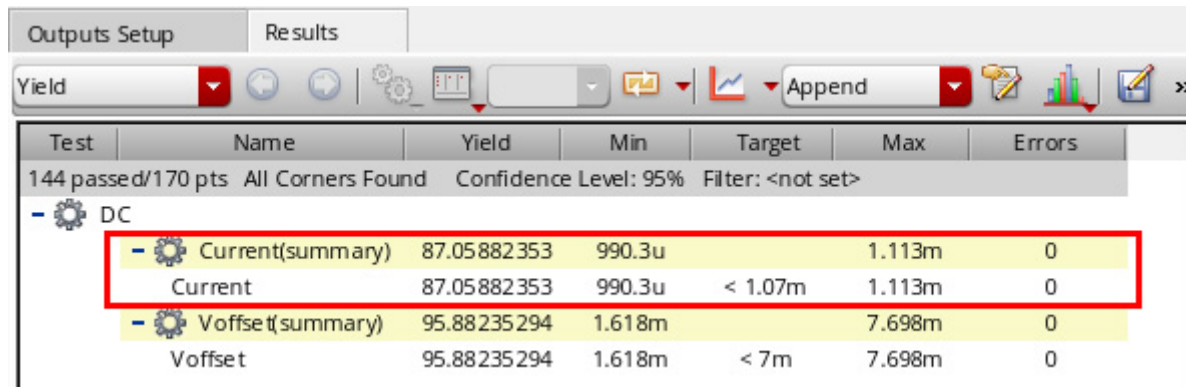
#### Summary:

Spec:Current, worst point number:65, point number in original Monte Carlo:461, value:0.00121394  
Spec:Gain, worst point number:94, point number in original Monte Carlo:1128, value:44.5767  
Spec:UGF, worst point number:107, point number in original Monte Carlo:1669, value:9.9905e+08  
Spec:Voffset\_L, worst point number:76, point number in original Monte Carlo:726, value:0.00530537  
Spec:Voffset\_H, worst point number:98, point number in original Monte Carlo:1294, value:0.0108198

MonteCarlo.8.RO completed.

Current time: Fri Jan 18 15:44:24 2019

The results are displayed on the *Results* tab, as shown below, which indicates that a total of 190 points were simulated while identifying the worst samples for all the four specifications.



Test	Name	Yield	Min	Target	Max	Errors
144 passed/170 pts All Corners Found Confidence Level: 95% Filter: <not set>						
- DC						
-	Current(summary)	87.05882353	990.3u		1.113m	0
	Current	87.05882353	990.3u	< 1.07m	1.113m	0
-	Voffset(summary)	95.88235294	1.618m		7.698m	0
	Voffset	95.88235294	1.618m	< 7m	7.698m	0

A statistical corner is generated for each spec in the setup (Current and Voffset). These corners can be viewed in the *Data View* assistant and *Corner Setup* form. The naming

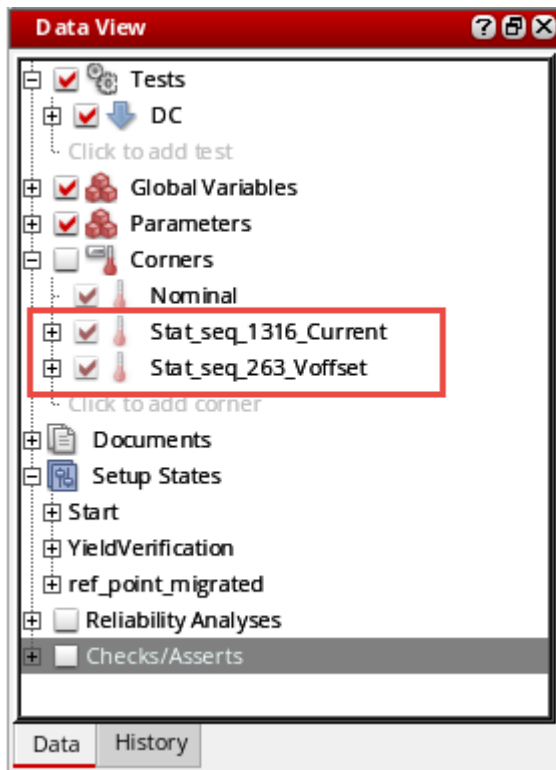
## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

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convention followed for these corners is

*Stat\_seq\_<worst\_corner\_number>\_<Spec\_name>*.



## K-Sigma Corners Method

This method creates the K-sigma statistical corner that meets the specified target yield value and applies the stopping criteria according to which the Monte Carlo simulation is stopped when the K-sigma statistical corner has been created for each specification.

It is possible that multiple corners meet the target specification criteria. Therefore, the K-sigma method finds the most representative corner by calculating the minimum distance to the nominal point. This representative corner has a greater probability to occur. The statistical corner can then be used for further analysis of the design.

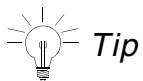
To prepare the setup for K-Sigma corner method:

1. Open the run options form for Monte Carlo.
2. In the *Guided Mode* section, select the *Create Statistical Corners* check box.
3. Specify a target yield value less than 4 sigma. For example, 3 sigma or 99.865%.

**Note:** The K-sigma Corners method is available only when the yield target is less than 4 sigma. By default, Monte Carlo uses single-sided sigma because the `useDoubleSidedSigma` variable is set to `nil`. Therefore, yield is represented as probability integration from `-infinity` to `+K sigma` in Gaussian distribution, and thus, 3 sigma is converted to 99.865%. When this variable is set to `t`, probability integration is done from `-K sigma` to `+K sigma`, and thus, 3 sigma is converted to 99.73%.

4. Select the *Fast statistical Corner creation (~200 points for 3-sigma)* option.

**Note:** The Method drop-down list is automatically set to K-Sigma Corners.



If you want to create a statistical corner with target sigma greater than 3, you can use high yield estimation to create the statistical corner. For more information, see [High Yield Verification and Corner Creation](#).

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

The figure below shows the form fields for this method:

The screenshot shows the 'Monte Carlo' dialog box with the following configuration:

- Guided Mode**
  - What would you like to do?
    - ☐ Run a fixed number of points
    - ☐ Verify the yield (sign-off)
    - ☒ Create statistical corners
  - What is the yield requirement? 3 sigma
  - Do you prefer accuracy or speed?
    - ☒ Fast statistical corner creation (~200 points for 3-sigma)
    - ☐ Highest accuracy - no hard constraint on number of sims
- Advanced - Show All Options**
  - Variation: All
  - Max Points: 200
  - Target Yield: 3 sigma
  - Method: K-Sigma Corners
  - ☐ Save Waveforms (Simulation Data)
  - Sampling Method: Low-Discrepancy Sequence
  - Seed: 12345
  - First Point: 1
  - Netlist Options: (empty)
  - Specify Instances/Devices (Not Specified)

Annotations on the right side of the dialog box:

- Speed is selected over accuracy
- Max Points field is set to **200** for K-Sigma Corners method
- The method is selected as **K-Sigma Corners**.
- Two sampling methods are available: **Low-Discrepancy Sequence** and **Random**

For information about the common fields, see [Performing a Standard Monte Carlo Run](#) in *Virtuoso ADE Explorer User Guide*.

Note the following additional field values available for the K-Sigma Corners method:

- ☐ The maximum number of points (samples) to be simulated are displayed in the *Max Points* field. This value is automatically set to 200 for this method.

## Virtuoso Variation Option User Guide

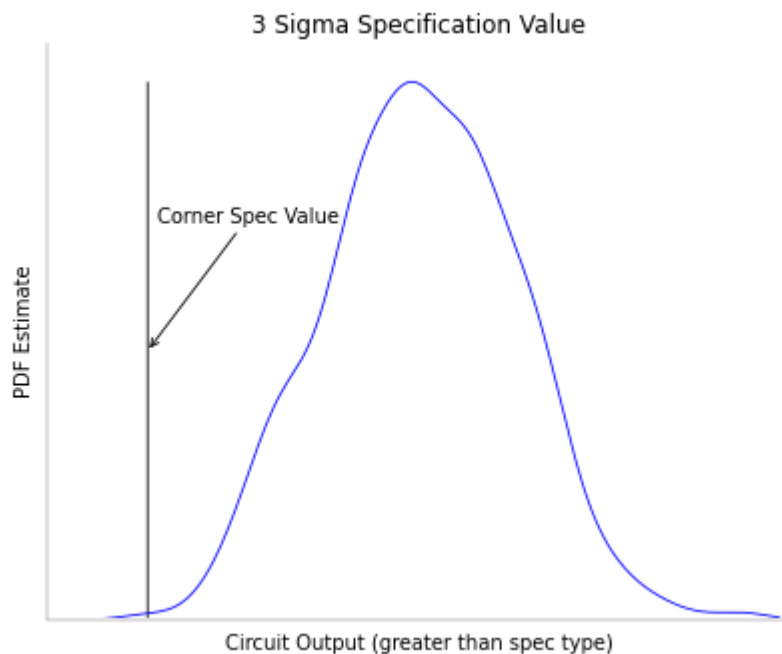
### Virtuoso Variation Option Advanced Features

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- ❑ The *Sampling Method* drop-down lists two methods, Low-Discrepancy Sequence (default) and Random.

5. Click the *Specify Instances/Devices (Not Specified)* button to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see [Including or Excluding Instances and Devices for Applying Mismatch Variations](#).
6. Click *OK*.
7. Run the Monte Carlo simulation.

The fast K-sigma corner algorithm estimates the **Probability Density Function (PDF)** of the performance distribution maintaining the accuracy of non-normal distributions. The specification target value is computed from the PDF estimate. Corners are generated based on the modeling and extrapolation from the PDF of the output.



The tool performs the following steps while running the K-Sigma Corners method:

1. Estimates the K-Sigma specification target. The specification target value is computed from the PDF estimate. The number of samples required to be run are based on the Monte Carlo sampling data. When the target sigma value is 3, a maximum of 200 samples are simulated.

2. Creates a representative statistical corner, which when simulated is close to the estimated value generated in step 1. This algorithm builds a model based on the statistical parameter data saved by the Monte Carlo run. At this point, a statistical corner can be generated without running any additional simulation.

To verify and improve the accuracy of this statistical corner, the Worst Case Corners simulations are run. The algorithm generates its best estimate of the K-sigma statistical corner in addition to scaled corners with scale values equal to 0.5 to 2 (total of 11 scaled corners).

The WCC simulation begins by first simulating the statistical corner with scale=1. If the actual simulated result is very close to the predicted value, this means the model is accurate and there is no need to simulate another scaled corners. Then, the WCC simulation stops and the K-sigma corner is created. The WCC simulation can also stop because the spec target is set to the value computed from the PDF estimate. The tolerance value is automatically specified small enough, where if the spec is met, it is unlikely that one of the scaled corners that is not simulated finds a better result.

3. Creates a separate K-sigma statistical corner for each spec.

## Example

Consider the same setup as used in the example for Worst Samples method.

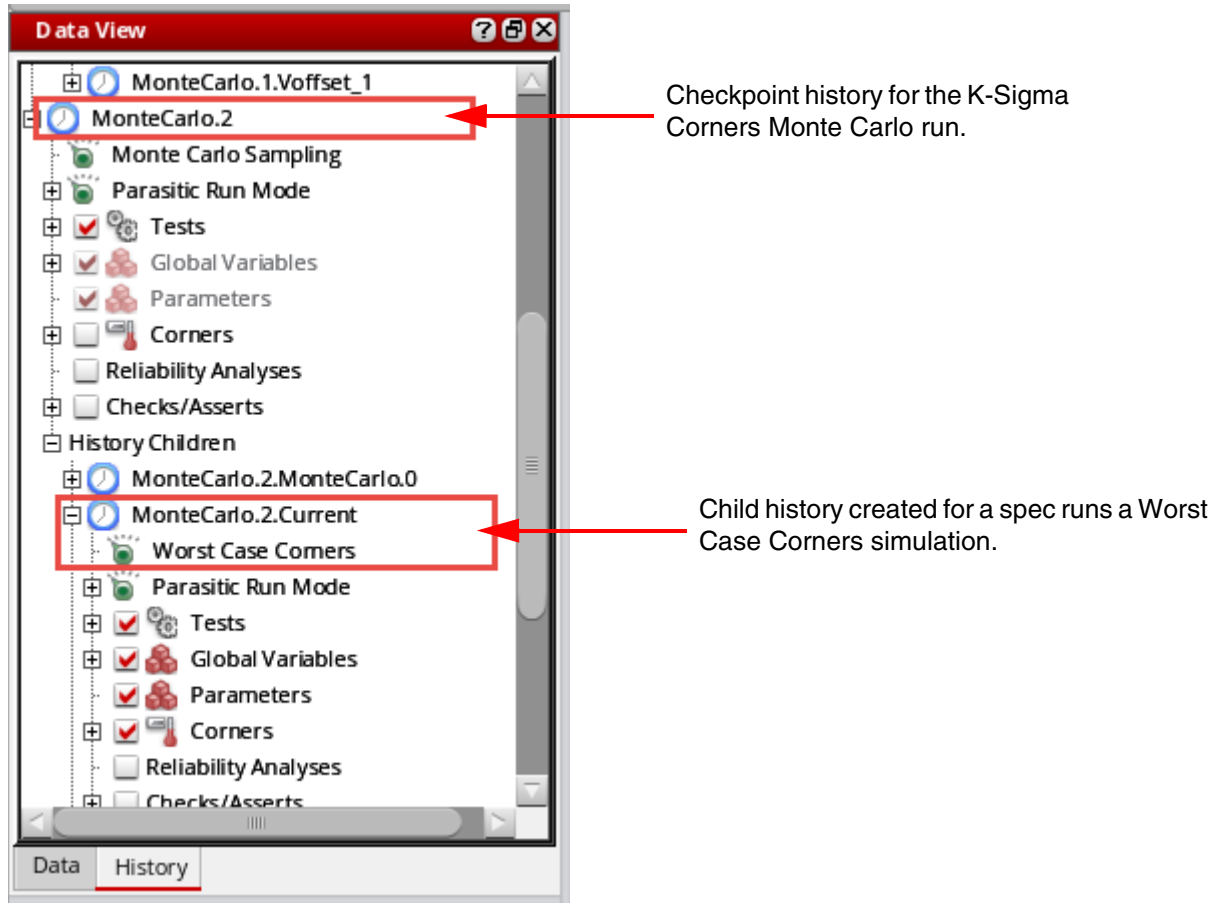
- Analyses: AC and TRAN
- Specs: Current and Voffset



## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

Now, run Monte Carlo with the method set to *K-Sigma Corners* and Target Sigma value set to 3. The `MonteCarlo.N` and its children histories are created as shown below.



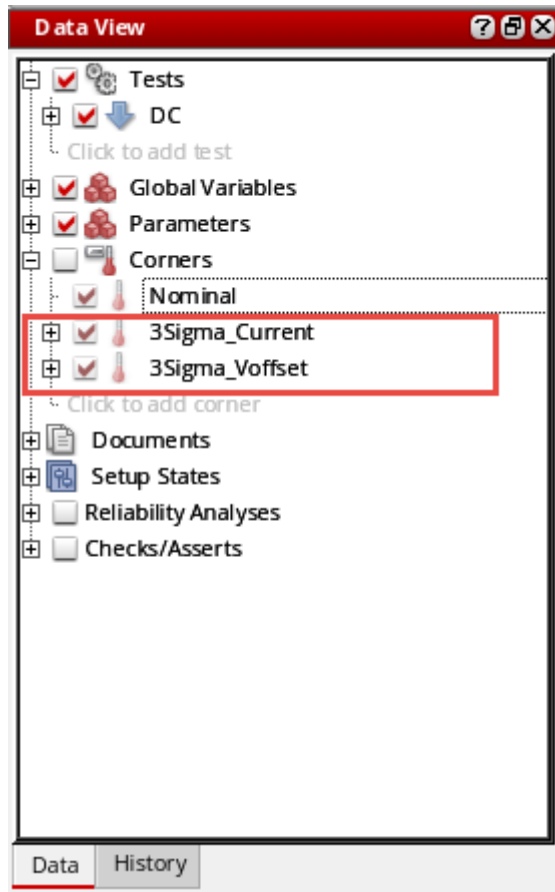
The `MonteCarlo.N` history is created first and shows the general simulation data set for the simulation. Next, the simulation run proceeds to extract the statistical corners and a child history is created for each spec with run mode set to Worst Case Corners.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

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After worst case corners are created for all the specifications, the simulation creates 3-sigma statistical corners for each specification. These corners are displayed in the Data View assistant and the Corners Setup form:

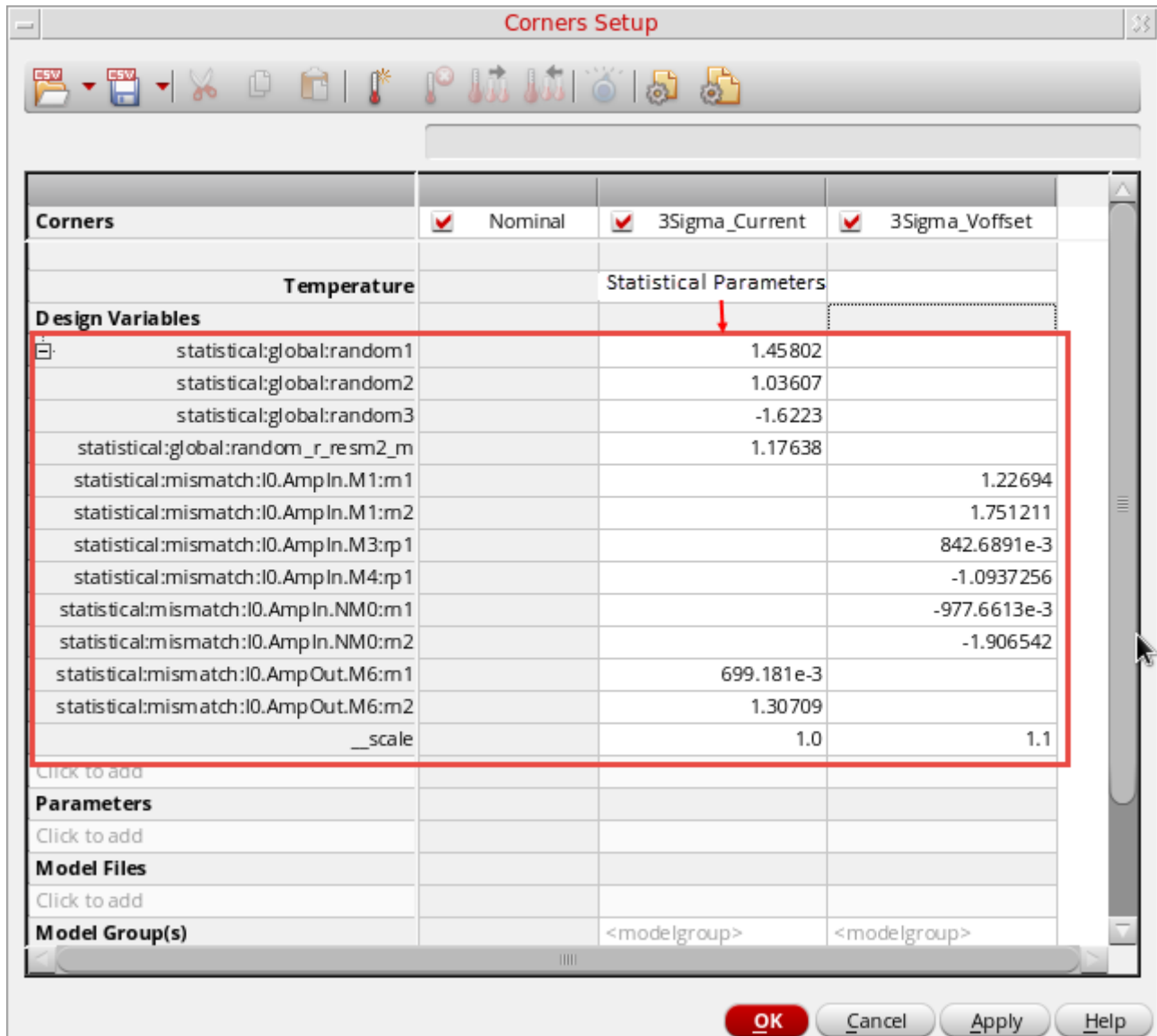


The K-sigma statistical corners are named as `KSigma_<spec_name>`, where `K` is the specified sigma value. For example, the sigma value in this example is 3; therefore, the K-sigma corner name is `3Sigma_<spec_name>`.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

In the corner details, you can see the statistical parameters used to create these corners.

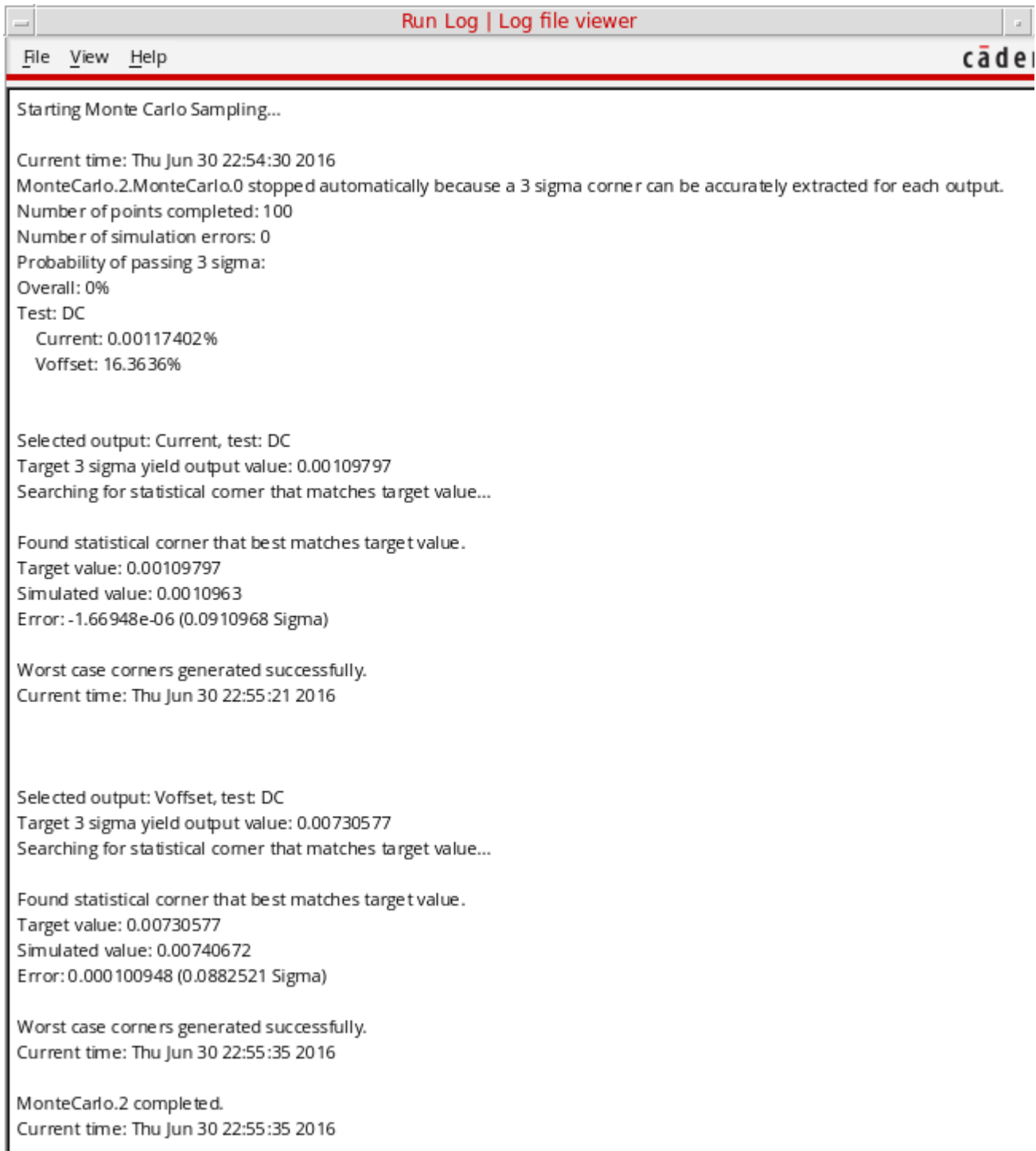


## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

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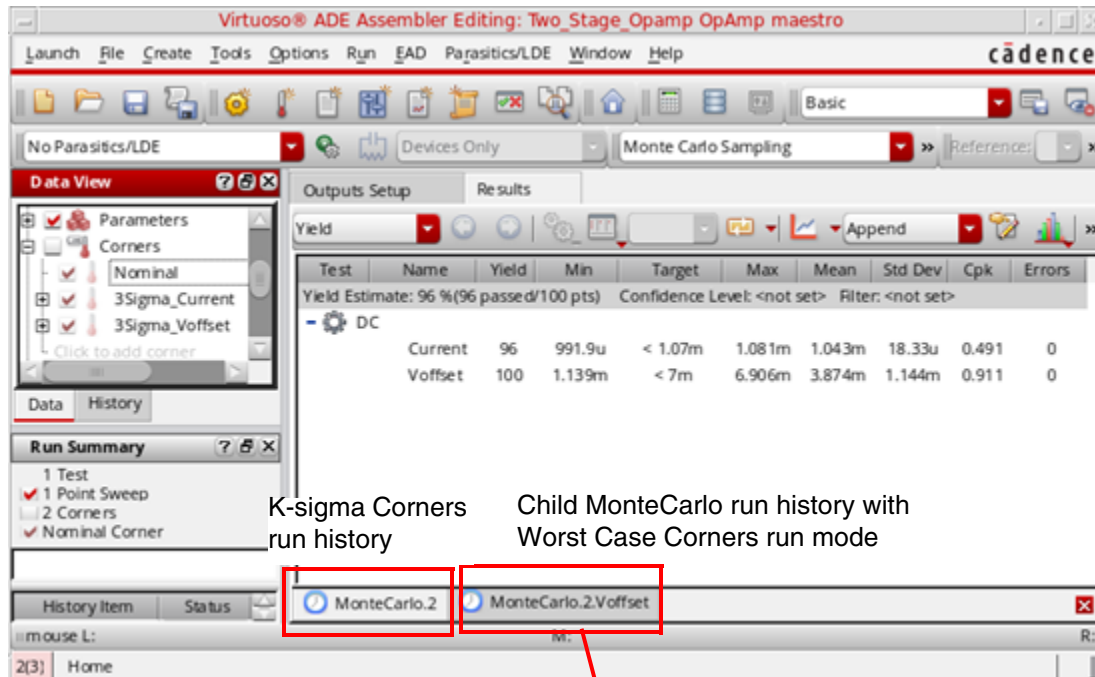
For more information, see the run log. This run log reports both the estimated K-sigma value of the spec based on the PDF and the simulated value of the corner.



# Virtuoso Variation Option User Guide

## Virtuoso Variation Option Advanced Features

When you open the Results tab, two tabs will be displayed at the bottom for this Monte Carlo simulation run—MonteCarlo.N and MonteCarlo.N.<spec-name>, where MonteCarlo.N is the history for the K-sigma Corners run and MonteCarlo.N.<spec-name> is the child history for the Worst Case Corners run for the last spec in the setup.



Outputs Setup Results

Detail Filter ... Append

60/66 rows

Point	Test	Output	Nominal	Spec	Weight	Pa
Parameters: statistical:mismatch:i0.AmpIn.M1:m1=1.227, statistical:mismatch:i0.AmpIn.M1:r2=1.751,						
7	DC	/V1/PLUS				
7	DC	/OUT				
7	DC	Current	1.045m			
7	DC	Voffset	7.407m	tol 0.00730577 ...		
7	DC	/inm				
7	DC	/inp				
Parameters: statistical:mismatch:i0.AmpIn.M1:m1=1.115, statistical:mismatch:i0.AmpIn.M1:r2=1.592,						
1	DC	/V1/PLUS				
1	DC	/OUT				
1	DC	Current	1.045m			
1	DC	Voffset	7.088m	tol 0.00730577 ...		
1	DC	/inm				
1	DC	/inp				
Parameters: statistical:mismatch:i0.AmpIn.M1:m1=1.004, statistical:mismatch:i0.AmpIn.M1:r2=1.433,						
6	DC	/V1/PLUS				

MonteCarlo.2 MonteCarlo.2.Voffset

Now, you can simulate the design over the generated statistical corner for further analysis or design tuning.

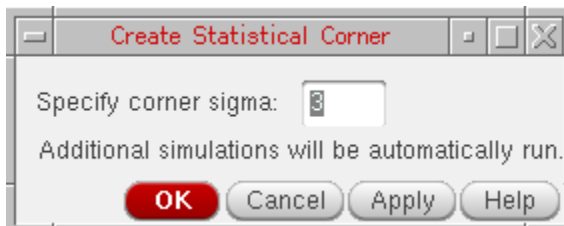
### Creating K-Sigma Corners After Running a Normal Monte Carlo Simulation

If you have already run a normal Monte Carlo analysis, you can create a K-Sigma corner from the results as a post-processing step.

Perform the following steps to create the K-sigma statistical corner:

1. Open the Monte Carlo results in the *Yield* view and identify the specification for which you need to improve the yield.
2. Right-click anywhere in the row for the identified specification and choose *Create Statistical Corner (Specify Yield in Sigma)*.

The *Create Statistical Corner* form appears.

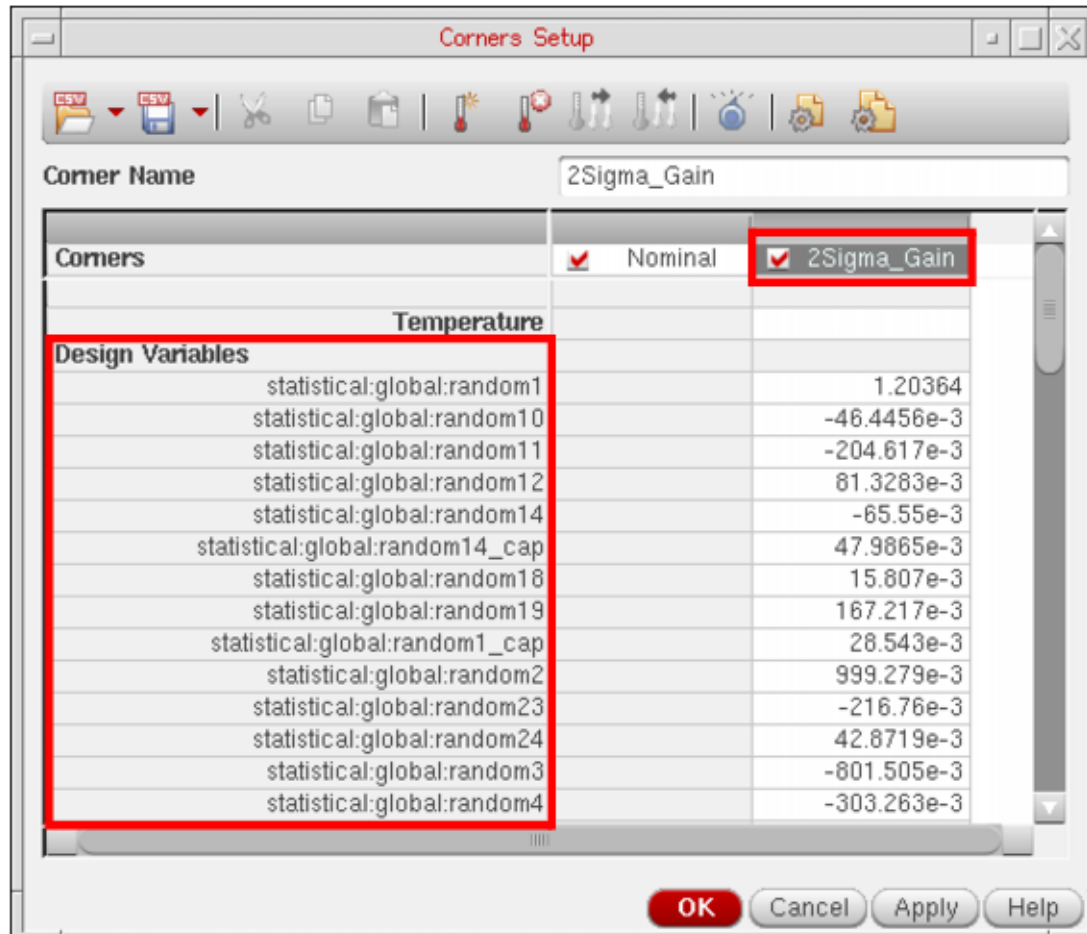


3. Specify a sigma value less than 4 in the *Specify corner sigma* field. The default value is 3.
4. Click *OK*.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

An additional simulation will be run and its corresponding run log will be displayed. After the simulation is complete, the K-sigma corner is displayed in the *Corners Setup* form, as shown in the figure below.



**Note:** The corner is named as `<sigma_value>Sigma_Gain`, where `<sigma_value>` is the corner sigma value you specify in the *Create Statistical Corner* form. For example, if you specify the sigma value as 2, the statistical corner name will be `2Sigma_Gain`.



#### Caution

**Starting from IC6.1.7 ISR4, the format in which Monte Carlo results are saved has changed. Therefore, if you use the results from IC6.1.7 ISR4 or later releases to create statistical corners in IC6.1.7 ISR3 or an earlier release, Virtuoso may stop abruptly. It is recommended not to use Monte Carlo results saved in the new format in any previous release.**

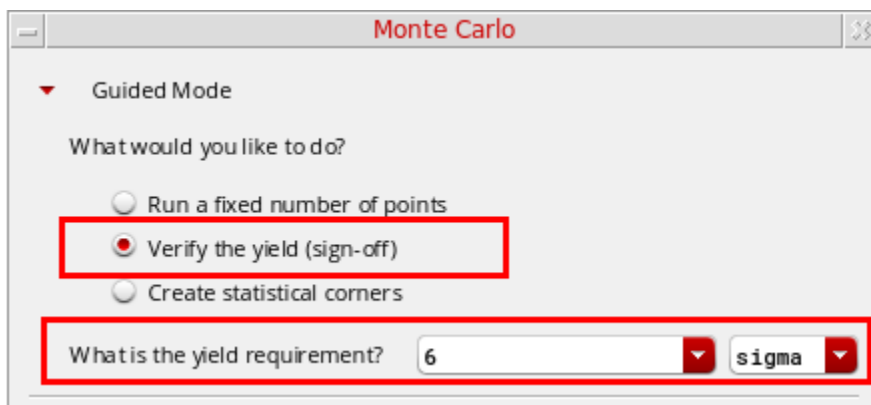
## High Yield Verification and Corner Creation

While running Monte Carlo run mode, you can perform high yield estimation by using the following two methods:

- Scaled-Sigma Sampling Method
- Worst Case Distance Method

You can run Monte Carlo with these methods by aiming for a yield higher than 3 sigma. That is, by using the following settings on the Monte Carlo options form:

- Selecting *Verify the yield (sign-off)* option under *What would you like to do?*
- Setting the *What is the yield requirement?* field to a value greater than 3



With the above settings the method in the *Advanced - Show All Options* section is changed to Scaled-Sigma Sampling. Another method that becomes available is Worst Case Distance. The sections given below provide details about these methods.



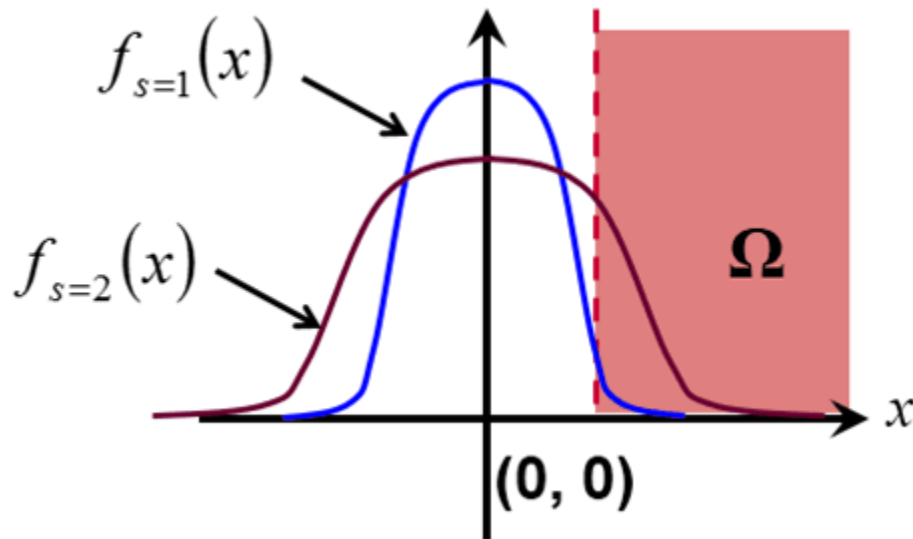
## Scaled-Sigma Sampling Method

The Scaled-Sigma Sampling method generates samples where the standard deviation has been scaled up. As a result, a larger number of samples fall into the failure region of the distorted distribution. The failure rate is then estimated from the scaled samples.

The Scaled-Sigma Sampling method is a resource-intensive method, but offers the following advantages:

- Efficiency for high dimensionality (very large numbers of devices and statistical parameters)
- Accuracy even for cases of high non-linearity
- Efficiency when the design is constrained by a large number of specifications

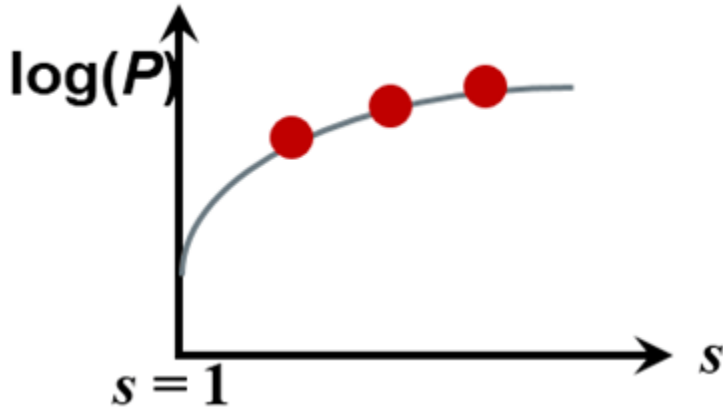
This figure shows the unscaled performance distribution (scaling factor  $s=1$ ) compared to the scaling factor  $s=2$ .



Here,  $x$  = process parameter and  $\Omega$  = failure region.

The failure rate can be calculated as<sup>1</sup>:

$$\log(P) \approx \alpha + \beta \log(s) + \Upsilon/s^2$$



The above equation models the failure rate as a function of the scaling factor. The model has very few constraints on the failure region and can target multiple failure regions. The model is constructed based on a set of scaled Monte Carlo runs. Then, the unscaled yield estimate ( $s=1$ ) can be found.

---

1. Shupeng Sun, Xin Li, Hongzhou Liu, Kangsheng Luo, and Ben Gu, "Fast statistical analysis of rare circuit failure events via scaled-sigma sampling for high-dimensional variation space," IEEE/ACM International Conference on Computer-Aided Design (ICCAD), pp. 478-485, 2013.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

The figure below shows the advanced options that appear when you select this method on the Monte Carlo options form:

The screenshot shows the 'Monte Carlo' dialog box with the 'Advanced - Show All Options' section expanded. The 'Guided Mode' section has three radio buttons: 'Run a fixed number of points', 'Verify the yield (sign-off)' (selected), and 'Create statistical corners'. Below these, a red box highlights the 'What is the yield requirement?' field with the value '4' and a 'sigma' unit selector. An arrow points from this box to the text 'Target yield (sigma value) is greater than 3.'. In the 'Advanced' section, a red box highlights the 'Number of Points' field with the value '7000'. An arrow points from this box to the text 'The Number of Points is set to 7000 by default.'. Another red box highlights the 'Method' dropdown menu, which is set to 'Scaled-Sigma Sampling'. An arrow points from this box to the text 'The Method is changed to Scaled-Sigma Sampling'. A third red box highlights the 'Create Statistical Corners' checkbox, which is currently unchecked. An arrow points from this box to the text 'Select Create Statistical Corners check box if you want to create statistical corners. When this check box is selected, the task is changed to Create Statistical corners in the Guided Mode.'. Other fields in the 'Advanced' section include 'Variation' (set to 'All'), 'Target Yield' (set to '4' with a 'sigma' unit selector), 'Sampling Method' (set to 'Low-Discrepancy Sequence'), 'Seed' (set to '12345'), 'First Point' (set to '1'), and 'Netlist Options' (empty). At the bottom, there is a button 'Specify Instances/Devices (Not Specified)' and a row of buttons: 'OK', 'Cancel', 'Defaults', and 'Help'.

Target yield (sigma value) is greater than 3.

The **Number of Points** is set to 7000 by default.

The **Method** is changed to Scaled-Sigma Sampling

Select **Create Statistical Corners** check box if you want to create statistical corners. When this check box is selected, the task is changed to **Create Statistical corners** in the **Guided Mode**.

For details about general form fields on this form, see [Performing a Standard Monte Carlo Run](#) in *Virtuoso ADE Explorer User Guide*.

Note the following additional fields available for the Scaled-Sigma Sampling method:

- In the *Number of Points* field, specify the number of points you want to run. This field is set to 7000 by default.

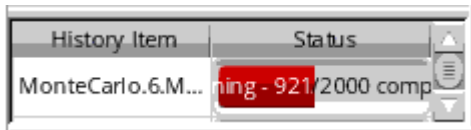
**Note:** The Scaled-Sigma sampling method includes multiple Monte Carlo runs with

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

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different scaling factors. Therefore, the total number of points required to run are calculated by adding points from all the Monte Carlo runs. This value is displayed in the status for the run history.



- Select the *Create Statistical Corners* check box if you want to create statistical corners.

**Note:** When this option is selected, the task selection in the *Guided Mode* is changed to *Create statistical corners*, but it continues to use the same settings for yield verification.

- The *Sampling Method* drop-down lists the following three methods: Low-Discrepancy Sequence (default), Latin Hypercube, and Random. For details about these sampling methods, see [Performing a Standard Monte Carlo Run in Virtuoso ADE Explorer User Guide](#).
- In the *Seed* field, specify a seed for the Monte Carlo analysis. By always specifying the same seed, you can reproduce a previous experiment. If you do not specify a seed, the value 12345 is used.
- In the *First Point* field, specify a starting run number. The first point specifies the run that Monte Carlo begins with. To reproduce a run or sequence of runs, you need to specify the same starting run number and seed value.
- In the *Netlist Options* field, specify the options that you want to generate in the netlist. For example, "nullmfactorcorrelation=yes".
- Click the *Specify Instances/Devices (Not Specified)* button to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see [Including or Excluding Instances and Devices for Applying Mismatch Variations](#).

After modifying the values on the form as required, click *OK* to start the Monte Carlo run.

The *Run Log / Log File Viewer* window appears displaying information regarding the progress of the Monte Carlo Sampling. The run starts with the scaled sigma value of 1, calculates yield for each corner at that sample, and then uses the next sample with a scaled sigma value for yield calculation. It continues to create samples till the target yield specified in the *Target Yield* field on the Monte Carlo run options form is achieved.

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### Virtuoso Variation Option Advanced Features

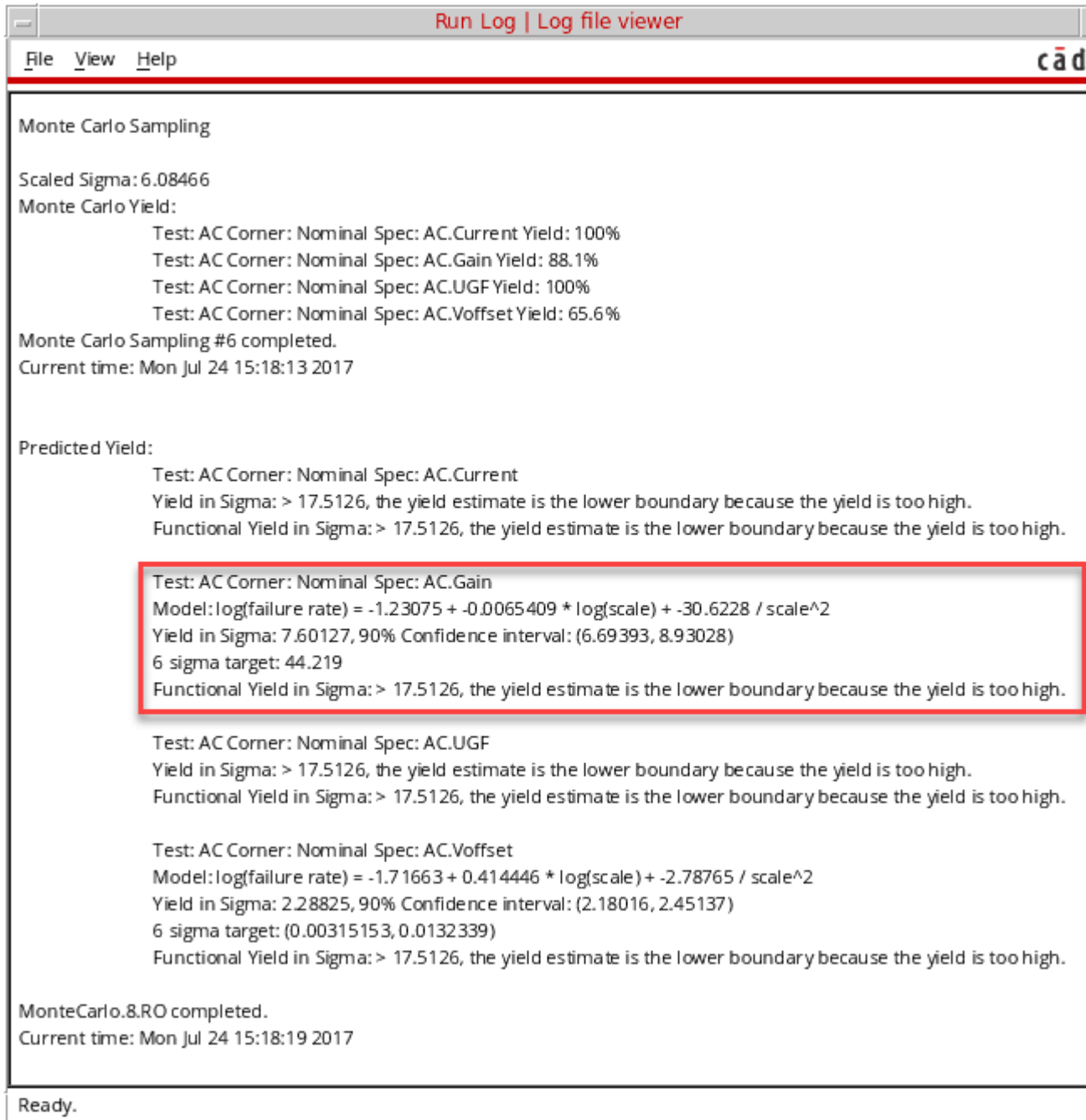
---

**Note:** Monte Carlo simulation with this method is stopped when simulation detects a uniform parameter distribution. This is because uniform statistical model parameters cannot be scaled. In this case, you can use the normal Monte Carlo Sampling method.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

The *Run Log/Log File Viewer* window appears displaying information about the progress of the Monte Carlo Sampling run, the scaled sigma value, the Monte Carlo yield and the predicted yield at each iteration, and the summary of the High Yield Estimation run.



For each output, the run log reports the following information:

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

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- The 90% confidence interval of the yield estimate in parenthesis, for example, (2.2028, 2.47348) is the 90% confidence interval for Voffset, as shown in the figure above.
- K sigma target value, where k is the target yield specified on the Monte Carlo run options form. You can consider this target for the outputs to get K sigma performance of this design.

**Note:** This value is reported in the run log only when *Create Statistical Corner* is selected on the run options form.

- The functional yield in sigma value, which is an estimate based on a functional pass or fail criteria. A failed point is counted only when the simulation or measurement evaluation fails.
- The model file (log failure) shows the internal model used to predict the failure rate. You can use this to inspect the model used for SSS algorithm.
- For the range and tolerance specifications, the output log prints the two confidence intervals in the following format:

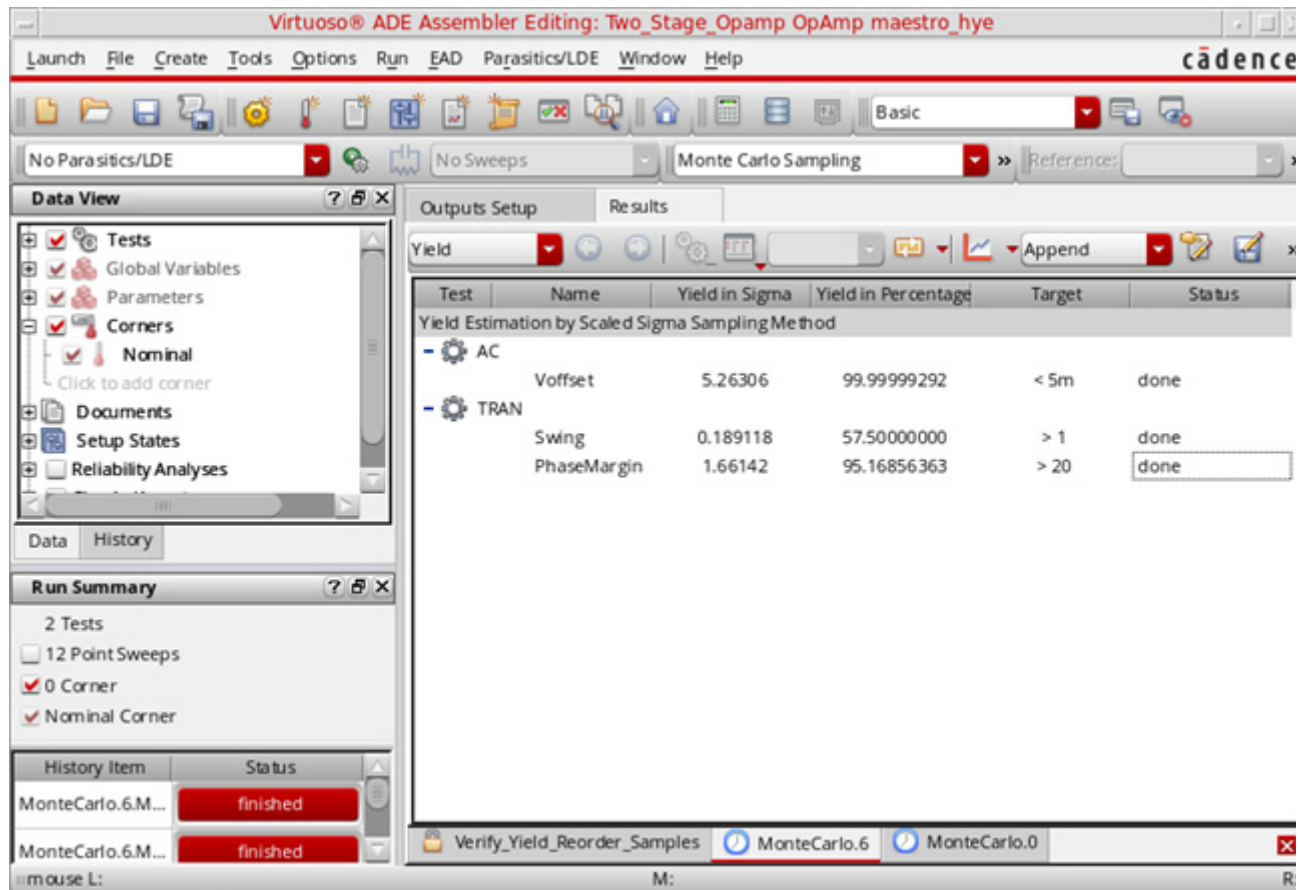
```
Test: opamp090:full_diff_opamp_AC:1 Corner: Nominal Spec:
opamp090:full_diff_opamp_AC:1.Current
Yield in Sigma: -367.446e-3, 90% Confidence interval: (-553.439e-3,
-181.885e-3)
4 sigma target: (0.00712165, 0.00713843), 90% Confidence intervals for low and
high targets: (0.00712051, 0.00712278) (0.00713749, 0.00713916)
```

**Note:** The model file (log failure) and K sigma target values are not reported for outputs when a model cannot be built either because the yield is too high or due to a failure in the model building process.

## Virtuoso Variation Option User Guide

### Virtuoso Variation Option Advanced Features

The results for the run are displayed on the *Results* tab, as shown below.



The *Results* tab includes the following fields:

- **Test**—Displays the name of the test.
- **Name**—Displays the name of the specification.
- **Yield in Sigma**—Displays the yield value. This value is calculated as shown below:  

$$\text{Yield in Sigma} = \sqrt{2} * \text{erfinv} (\text{Yield in Percentage}/100)$$
 where, *erfinv* is the inverse error function.  
 If the yield in sigma is greater than 8.2, the yield in percentage is displayed as 100%.
- **Yield in Percentage**—Displays the yield value in percentage.  
 The yield in percentage value is by default displayed with 10 digits. To change the number of digits to be displayed, set the value in the *digitsToShowForYieldInPercentage* environment variable. You can display a maximum of 53 digits.



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### Virtuoso Variation Option Advanced Features

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- **Target**—Displays the target to be achieved for the given specification.
- **Status**—Displays the convergence status for the given specification.

**Note:** When the initial Monte Carlo yield is poor, the yield verification run does not provide accurate results and is stopped to avoid running additional scaled Monte Carlo samples. Below is an example of run log that is generated in this case:

```
Scaled Sigma: 1

Monte Carlo Yield:
  Test: test1:1 Corner: Nominal Spec:
  test1:1.T1F2 Yield: 83.3333%
Monte Carlo Sampling #0 completed.
HighYieldEstimation.0 stopped because all specs have a low yield.
```

The **Status** column for a specification on the *Results* tab of the Scaled-Sigma Sampling results displays **done** even when the specification failures are very few. The *Yield in Sigma* column displays the minimum sigma value.

However, if the specification failures are very few, but the specification result is nonlinear and cannot determine whether the calculated yield is above a given number, the *Yield in Sigma* column for that specification displays **N.A.**

You can plot a spec verses sigma normal quantile graph to show the estimated result values. For more details, refer to [Plotting a Normal Quantile Graph for the Scaled-Sigma Sampling Method](#).

**Note:** If you selected the Create Statistical Corners check box in the advanced run options for Monte Carlo, statistical corners are created and added to the Corners tree in the Data View assistant. For more details, refer to [Creating a Statistical Corner with Statistical Parameter Values](#).

## About Confidence Interval and Number of Samples

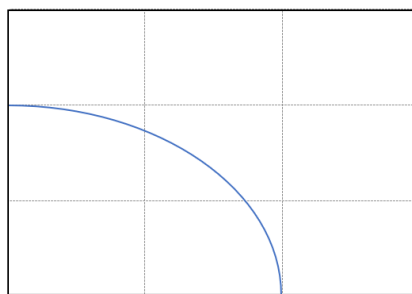
The change in confidence interval resulting from an increase or decrease in the total number of samples cannot be determined in advance, because it depends on the given circuit and failure boundary.

You can generate a quantitative example by running the Scales-Sigma Sampling method on a linear failure boundary case. The following table reports the 5% and 95% quantile values, generated based on 100 Scales-Sigma Sampling runs for each result (combination of number of samples and sigma target).

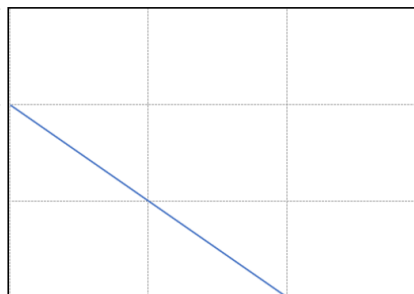
Number of Samples	4 Sigma	6 Sigma
1000	3.30 4.75	4.56 7.49
7000	3.62 4.32	5.31 6.75
50000	3.80 4.12	5.70 6.36

Depending on the failure boundary shape, the confidence interval may differ. The linear boundary results can be used as a reference because of the following reasons:

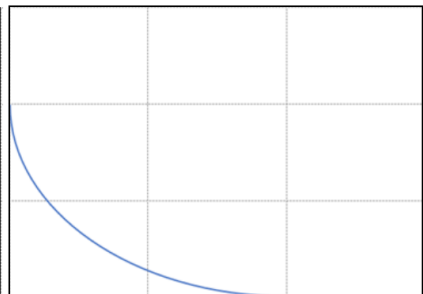
- Many failure boundaries are not very strongly nonlinear.
- The confidence interval tends to be:
  - ☐ Small: If the failure rate scales faster than linear boundary
  - ☐ Large: If failure rate scales slower than linear boundary



**Super-linear**



**Linear**



**Sub-Linear**

## Creating Corners from Scaled-Sigma Sampling Method

The statistical corner generated from the Scaled-Sigma Sampling method is a sequence-based corner. A corner is generated for each selected specification. Based on the sigma value that you specify, the target value of the spec is estimated. Then, using one of the

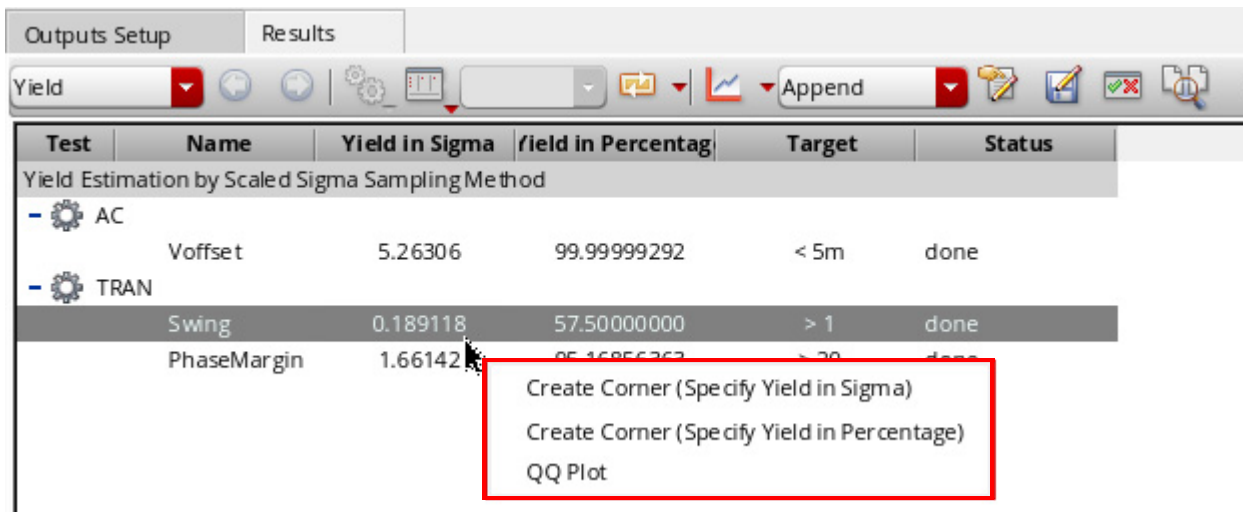
## Virtuoso Variation Option User Guide

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simulated points, a sample is identified that most closely matches this value. This identified sample is used to create the statistical corner.

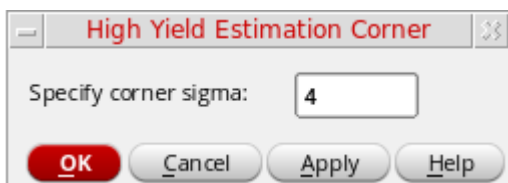
Perform the following steps to create statistical corner from Scaled-Sigma Sampling method:

1. After running a Monte Carlo simulation with *Method* as *Scaled-Sigma Sampling* and *Target Yield* > 3, open the *Results* tab as described in the previous section.
2. Right-click the selection and choose one of the create corner options as shown in the figure below:



You can select multiple specifications using the **Ctrl** key.

When you click these options, the *High Yield Estimation Corner* form appears.



**Note:** The corner sigma value displayed on this form is same as *Target Yield* on the Monte Carlo setup form. If *Target Yield* is not set, by default, the corner sigma is set to 4.

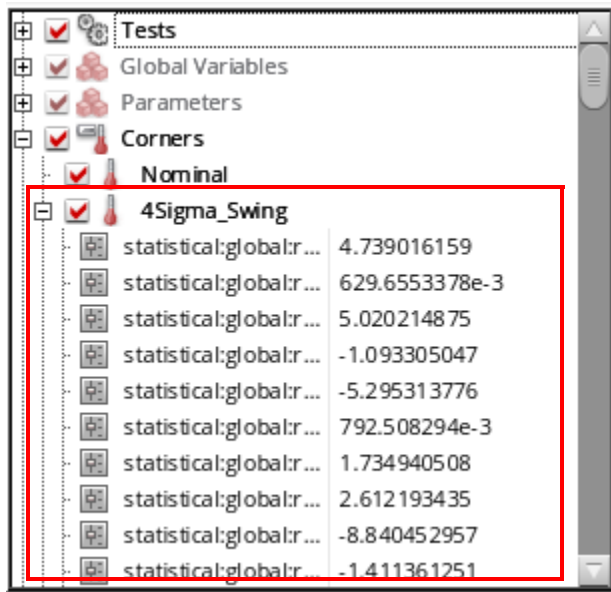
3. Specify the corner sigma or percentage value equal to or greater than 4.
4. Click **OK**.

## Virtuoso Variation Option User Guide

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The statistical corner for the specified value is created and displayed in the Data View assistant and Corner Setup form. For example, if you specify the sigma value=4, the statistical corner created is 4Sigma\_<SpecName> as shown in the figures below.



Notice the corner is created using the statistical values of the variables for the point that matches the target value of the spec most closely.

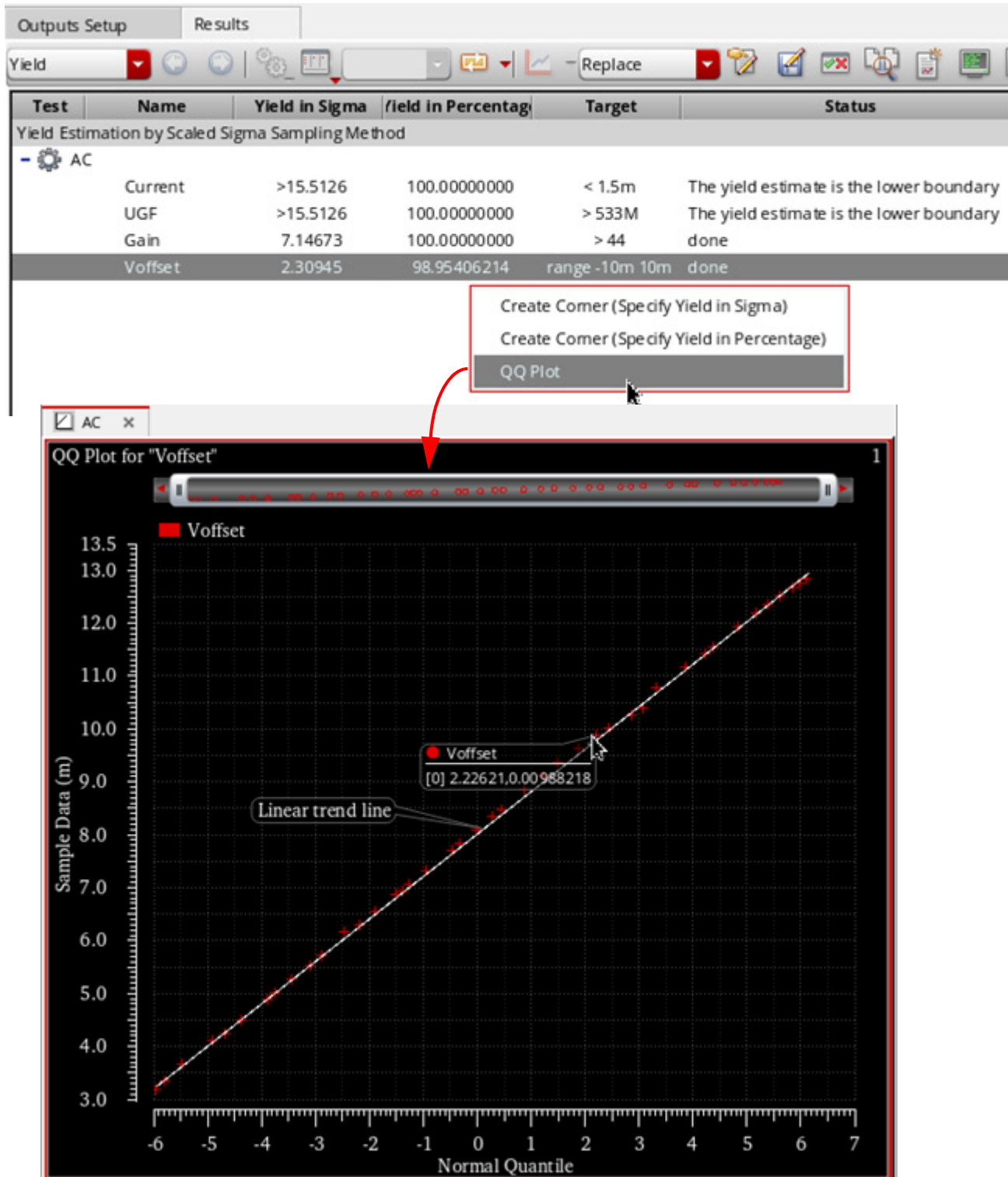
### Plotting a Normal Quantile Graph for the Scaled-Sigma Sampling Method

After verifying yield using the scaled-sigma sampling method, you can plot a spec verses sigma normal quantile graph (QQ Plot) to show the estimated result values at a number of

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normal quantiles. It also helps in comparing the result values for an output (`Voffset` in the example shown below) with the values predicted for a standard normal distribution.



In the graph shown above, Y-axis shows the estimated Monte Carlo results for output `Voffset` and the X-axis shows the normal quantiles of that sample data from -6 sigma to +6 sigma.

You can compare the normal quantile graph (shown in red) with the linear trend line, which is a reference line that signifies how the data is plotted if it is perfectly normally distributed. Points close to this line indicate that the data is close to normal distribution and the points far from this line indicate that the data is not close to normal distribution.

## Worst Case Distance Method

When the target yield sigma value is greater than 3, you can also select the Worst Case Distance method to verify the yield of the design. In this method, the high yield estimation finds the shortest distance—referred to as Worst Case Distance or WCD—from the nominal point to the specification boundary in the process/mismatch parameter space. The worst case distance is a good indicator of circuit yield, where yield in percentage is approximately equal to

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{wcd} e^{-t^2/2} dt = \frac{1}{2} \left[ 1 + \operatorname{erf} \left( \frac{wcd}{\sqrt{2}} \right) \right]$$

where, `erf` is the error function.

**Note:** WCD provides accurate yield estimation when the specification boundary is linear in the process or mismatch parameter space. Strong non-linearity of the specification boundary can cause difficulty in finding the WCD points. A non-linear specification however may not result in a non-linear specification boundary in statistical space.

The Worst Case Corners method supports only statistical parameters that follow a normal distribution. It begins with a Monte Carlo Sampling run, uses the Monte Carlo results to filter non-high yield specifications (for which the Monte Carlo run gives accurate yield estimates), and then applies the WCD method on each high yield specification by doing the following:

- Reads the process and mismatch parameter information from the Monte Carlo results
- Performs parameter reduction based on the Monte Carlo results
- Runs multiple sensitivity analysis iterations to find the WCD

You can improve the circuit yield by creating a statistical corner from the worst case distance point. For more details, refer to [Creating Statistical Corners From a Worst Case Distance Analysis](#).

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**Note:** Before you run Monte Carlo with this method, ensure that the Range and tolerance (tol) type specifications are disabled or deleted in the Outputs Setup tab. This is because these two specifications are not supported for Worst Case Distance. You can also convert the range and tolerance (tol) type specifications into two separate specifications for the min and max boundaries.

The figure below shows the advanced options that appear when Worst Case Distance is selected in the *Method* drop-down.

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The screenshot shows the 'Monte Carlo' dialog box with several sections and fields. Red boxes and arrows highlight specific features:

- Guided Mode:** Includes radio buttons for 'Run a fixed number of points', 'Verify the yield (sign-off)' (selected), and 'Create statistical corners'.
- Yield Requirement:** A field labeled 'What is the yield requirement?' with the value '4' and a unit dropdown set to 'sigma'.
- Advanced - Show All Options:**
  - 'Variation' dropdown set to 'All'.
  - 'Number of Points' field set to '200'.
  - 'Target Yield' field set to '4' and unit dropdown set to 'sigma'.
  - 'Method' dropdown set to 'Worst Case Distance'.
  - 'Create Statistical Corners' checkbox (highlighted with a red box and arrow).
  - 'Save Waveforms (Simulation Data)' checkbox.
  - 'Sampling Method' dropdown set to 'Low-Discrepancy Sequence' (highlighted with a red box and arrow).
  - 'Seed' field set to '12345'.
  - 'First Point' field set to '1'.
  - 'Netlist Options' field.
- Worst Case Distance Options:** A sub-section containing:
  - 'Use Monte Carlo History' dropdown.
  - 'Automatic Number of Monte Carlo Points' checkbox (checked).
  - 'Automatic Variable Reduction' checkbox (checked).
  - 'Skip Specs With MC Yield <' field set to '3.0' and unit dropdown set to 'sigma (99.86%)' (checked).
  - 'Max Number of Iterations' field set to '10'.
- Buttons:** 'OK', 'Cancel', 'Defaults', and 'Help' at the bottom.

Target yield (sigma value) is greater than 3.

The default **Number of Points** is set to **200**. This field is available only when the **Automatic Number of Monte Carlo Points** check box in WCD Options is not selected.

Select **Create Statistical Corners** check box if you want to create statistical corners. When this check box is selected, the task is changed to **Create Statistical corners** in the **Guided Mode**.

Three sampling methods available: Low-Discrepancy Sequence, Random, and Latin Hypercube

Additional Worst Case Distance options appear on the form.



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### Virtuoso Variation Option Advanced Features

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For information about the common fields in all the Monte Carlo run methods, see [Performing a Standard Monte Carlo Run](#) in *Virtuoso ADE Explorer User Guide*.

Note the following additional field values available for this method:

1. The *Number of Points* field is by default set to 200. This field is disabled when the *Automatic Number of Monte Carlo Points* check box is selected.
2. Select the *Create Statistical Corners* check box if you want to create statistical corners. When this option is selected, the task selection in the *Guided Mode* is changed to *Create statistical corners*.
3. The *Sampling Method* drop-down lists the following three methods:  
Low-Discrepancy Sequence (default), Latin Hypercube, and Random.
4. In the *Worst Case Distance Options* section, specify the following fields:

a. The *Use Monte Carlo History* option is enabled if you have already run a Monte Carlo simulation. You can use the process and mismatch data from the history of that run. In this drop-down list, you can select a reference Monte Carlo run history from the list of available histories. It is essential that the simulation data of the selected history contains the process and mismatch data. If any one of these data is not available, an error message is displayed.

**Note:** When you use the Monte Carlo run history, number of points are not printed in the run log.

b. The *Automatic Number of Monte Carlo Points* check box is selected by default. This is used to enable the automatic selection of number of Monte Carlo points. When you select this check box, the *Number of Points* and *Automatic Variable Reduction* fields become unavailable. To manually provide the number of Monte Carlo points to be simulated, disable this check box.

c. By default, the *Automatic Variable Reduction* check box is disabled. To enable this check box, deselect the *Automatically Select Number of Monte Carlo Points* check box. The *Automatic Variable Reduction* option reduces the set of statistical variables by eliminating insignificant variables (variables that have no variation or have no influence on the WCD point). Insignificant variables bring noise and require more simulations for sensitivity analysis. Therefore, it is recommended to enable variable reduction.

d. To ignore the specifications for which Monte Carlo yield is less than a specified percentage, select the *Skip Specs With MC Yield <* checkbox and specify a sigma value. The default value of this field is 3 sigma; therefore, specifications for which the Monte Carlo yield is less than 99.86% are ignored. If you want to run high yield

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estimation on all the specifications, disable the *Skip Specs With MC Yield <* check box.

**e.** In the *Max Number of Iterations* field, specify the maximum number of iterations to be run for each specification. The default number of iterations is 10.

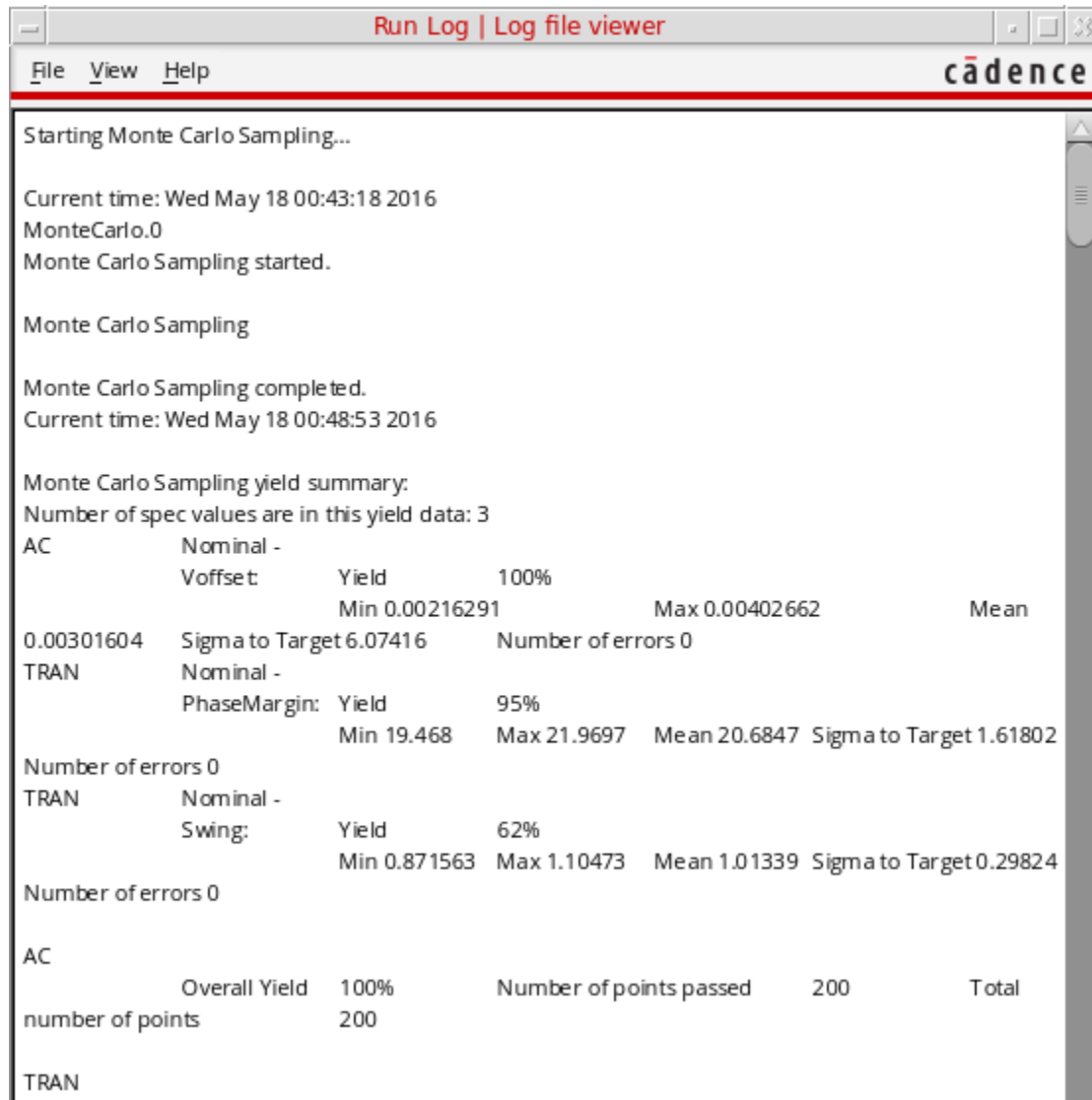
5. Click the *Specify Instances/Devices (Not Specified)* button to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see [Including or Excluding Instances and Devices for Applying Mismatch Variations](#).
6. Click *OK* to start the Monte Carlo run.

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The *Run Log / Log File Viewer* window appears displaying information regarding the progress of the initial Monte Carlo Sampling run, the yield estimate at each iteration, and the summary of the Monte Carlo run.

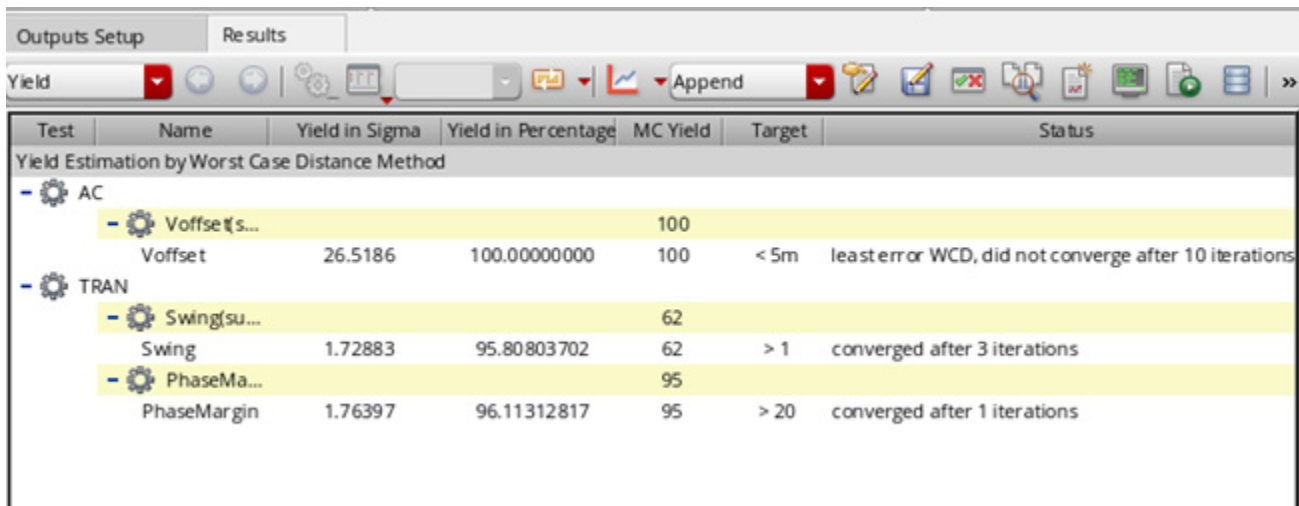


The log file also displays the sigma of the statistical variable, which helps in understanding the results when you work with different units. The log file also displays the statistical

## Virtuoso Variation Option User Guide

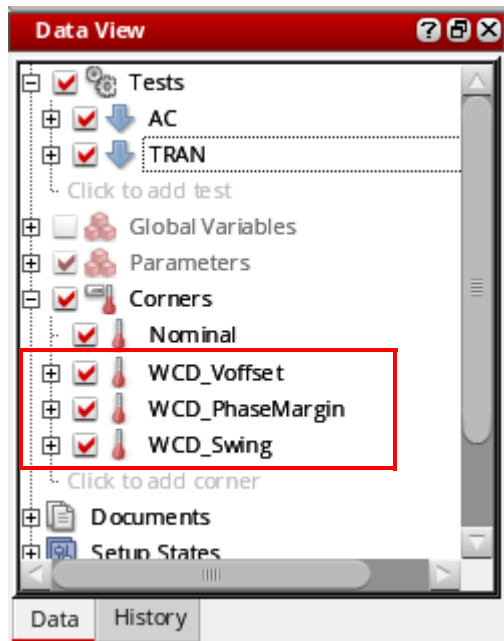
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parameter contribution values for the WCD point and device contribution values for the squared WCD values.



Test	Name	Yield in Sigma	Yield in Percentage	MC Yield	Target	Status
Yield Estimation by Worst Case Distance Method						
- AC	- Voffsets...			100		
	Voffset	26.5186	100.0000000	100	< 5m	least error WCD, did not converge after 10 iterations
- TRAN	- Swing(su...			62		
	Swing	1.72883	95.80803702	62	> 1	converged after 3 iterations
- PhaseMa...				95		
	PhaseMargin	1.76397	96.11312817	95	> 20	converged after 1 iterations

If the *Create Statistical Corners* check box was selected, this method creates corners for specification that meets the target yield. If the Monte Carlo yield is very low for a given specification, the Worst Case Distance method skips that specification and does not create corners. In addition, an error message is displayed that suggests to decrease the sigma value in the *Skip Specs with MC Yield* field.



The Results tab shows the following columns:

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- **Name:** Displays the name of specification.
- **Yield in Sigma:** Displays the yield value in sigma. This value is calculated as shown below:

$$\text{Yield in Sigma} = \text{sqrt}(2) * \text{erfinv}(\text{Yield in Percentage}/100)$$

where, `erfinv` is the inverse error function.

If the yield in sigma is greater than 8.2, the yield in percentage is displayed as 100%.

- **Yield in Percentage:** Displays the yield value in percentage. This value is calculated as shown below:

$$\text{Yield in Percentage} = 0.5 + 0.5 * \text{erf}(\text{WCD}/\text{sqrt}(2))$$

where, `erf` is the error function.

**Note:** The yield in percentage value is by default displayed with 10 digits. To change the number of digits to be displayed for this value, set the value of variable `digitsToShowForYieldInPercentage` environment variable. You can display a maximum of 53 digits for these values.

- **MC Yield:** Displays the yield value from the Monte Carlo run.
- **Target:** Displays the target to be achieved for the given specification.
- **Sigma to Target:** Displays the sigma to target value.
- **Status:** Displays the convergence status for each specification.

The tool uses the following two convergence criteria:

- ❑ The predicted WCD point is on the specification boundary (within tolerance < 0.02). The log file reports the 'Spec value error' at each iteration.

$$\text{spec\_value\_error\_ratio} = \frac{\text{abs}(\text{spec\_value} - \text{spec\_target})}{\text{max}(\text{abs}(\text{nominal\_spec\_value} - \text{spec\_target}), 6 * \text{spec\_sigma})}$$

- ❑ The angle between the gradient vector and the statistical variable vector is < 8 deg. The log file reports the 'Gradient direction error' at each iteration.

The convergence status can be any of the following:

---

Status	Description
<i>converged after x iterations</i>	The yield estimate converged after x iterations.  For example, the yield estimate for the <code>Slew_rate</code> specification converged after 2 iterations.

---

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Status	Description
<i>skipped because the Monte Carlo yield is less than &lt;value in percent&gt;</i>	Yield estimation was skipped for the specification because the Monte Carlo yield estimate was too low. The low yield threshold value is specified in the run option form in the <i>Skip specs with MC Yield &lt; value</i> field, which is by default set to 3 sigma or 99.73%.
<i>least error WCD, did not converge after x iterations</i>	<p>Yield estimation did not converge after the maximum number of iterations has completed. The specification failure boundary is strongly non-linear or the maximum number of iterations is too small.</p> <p>The yield estimate with the least error among iterations is reported.</p> <p>For details on the high yield verification criteria, see <a href="#">convergence criteria</a>.</p>
<i>lower boundary, did not converge after x iterations</i>	<p>Yield estimation did not converge because the specification has an unrealistic yield estimate which is larger than 12 sigma in yield after the maximum number of iterations. The yield estimate increased at each iteration, but never converged.</p> <p>For details on the high yield verification criteria, see <a href="#">convergence criteria</a>.</p>
<i>estimate based on MC data / lower boundary / least error WCD, stopped because evaluating of the WCD point sensitivity failed on iteration x</i>	<p>Yield estimation stopped before reaching the maximum number of iterations because of a simulation or measurement error in evaluating the WCD point sensitivity.</p> <p>The lower boundary is reported if it is identified, if not, the yield estimate with the least error among iterations is reported.</p>
<i>estimate based on MC data / lower boundary / least error WCD, stopped because evaluation of the WCD point failed on iteration x</i>	<p>Yield estimation stopped before reaching the maximum number of iterations because of a simulation or measurement error in evaluating the WCD point.</p> <p>The lower boundary is reported if it is identified, if not, the yield estimate with the least error among iterations is reported.</p> <p>If the run was stopped on the first iteration, the estimate based on the Monte Carlo result is reported.</p>

### Creating Statistical Corners From a Worst Case Distance Analysis

After running the Monte Carlo run, if you find that the required yield value is not achieved for any specification, you can create statistical corner based on the worst case distance point for that specification. You can use these new corners to run optimization or manually tune the design accordingly.

For example, if you run Monte Carlo for a design without skipping the specs that have monte carlo yield of less than 3 sigma, the results might show specifications that have yield value less than 3 sigma, as shown below:

Test	Name	Yield in Sigma	Yield in Percentage	MC Yield	Target	Status
Yield Estimation by Worst Case Distance Method						
AC	Voffset	26.5186	100.00000000	100	< 5m	least error or WCD, did not converge after 10 iterations
TRAN	Swing	1.72883	95.803702	62	> 1	converged after 3 iterations
TRAN	PhaseMargin	1.76397	96.11312817	95	> 20	converged after 1 iterations

**Note:** In the above results, the monte carlo yield for Swing and PhaseMargin is less than 3 sigma. To improve the performance for these specifications, you can create a statistical corner based on the Worst Case Distance (WCD) point of these specifications. For this, you can specify a target yield value greater than three sigma, either in terms of sigma or in terms of percentage value.

To create a WCD corner based on yield in sigma, right-click a specification and choose *Create Corner (Specify Yield In Sigma)*.

The High Yield Estimation Corner form appears, as shown below.

In the High Yield Estimation Corner form, do the following:

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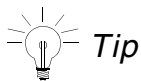
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1. In the *Specify corner sigma* field, specify a target sigma value to which you want to extend the WCD point.
2. Click *OK*.

A statistical corner is created by using the specification values that can improve the circuit yield to the target sigma value. The name of the statistical corner is prefixed with *WCD\_*.

The new corner is added to the Data View and the Corners Setup form.

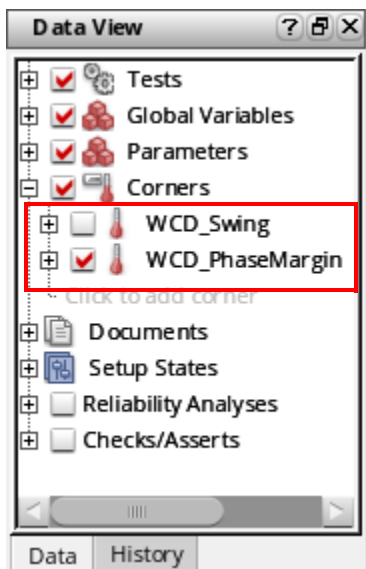
Alternatively, you can choose *Create Corner (Specify Yield In Percentage)* and specify the target yield value to be achieved in terms of percentage.



#### Tip

For a normal design, you can set for a corner sigma value equal to 3.0. However, for a high yield design, you can set a corner sigma value equal to 6.0. A good practice is to increase the sigma value by 0.5 to 1.0 in each iteration instead of increasing it by large amount.

In the example shown above, let us create two statistical corners by setting the corner sigma for Swing and PhaseMargin equal to 4 and 3, respectively. In this case, the corners are created as shown below.



The statistical corners created display the target sigma value in tooltip.

Now, if you enable corners and run global optimization on the design, the results for the new statistical corners appear. From the results of an optimization run, you can identify a best



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design point and save the values of variables and parameters from that point into a setup state. For this, right-click the design point and choose *Save variables and parameters to Setup State*, as shown below.

The screenshot shows the 'Results' tab of the Virtuoso Variation Option interface. A table displays 30/90 rows of design points. A context menu is open over the table, showing options: 'Backannotate', 'Save variable and parameter values to Setup State' (highlighted), 'Submit Point...', and 'Troubleshoot Point'.

Point	Test	Output	Nominal	Spec	Weight	Min	Max
Parameters: dload=100f, rload=1K							
2	AC	Voffse				3.073 mV	3.073 mV
2	TRAN	Swing				1.008	1.012
2	TRAN	PhaseM				1.67 degree	22.97 degree
Parameters: dload=110f, rload=1K							
10	AC	Voffse				3.073 mV	3.073 mV
10	TRAN	Swing	1.012	> 1		1.008	1.012
10	TRAN	PhaseMargin	22.85 degree	> 20		21.55 degree	22.85 degree
Parameters: dload=120f, rload=1K							
18	AC	Voffset	3.073 mV	< 5m		3.073 mV	3.073 mV
18	TRAN	Swing	1.012	> 1		1.008	1.012
18	TRAN	PhaseMargin	22.73 degree	> 20		21.44 degree	22.73 degree
Parameters: dload=130f, rload=1K							
26	AC	Voffset	3.073 mV	< 5m		3.073 mV	3.073 mV
26	TRAN	Swing	1.012	> 1		1.008	1.012
26	TRAN	PhaseMargin	22.61 degree	> 20		21.32 degree	22.61 degree
Parameters: dload=140f, rload=1K							
34	AC	Voffset	3.073 mV	< 5m		3.073 mV	3.073 mV
34	TRAN	Swing	1.012	> 1		1.008	1.012

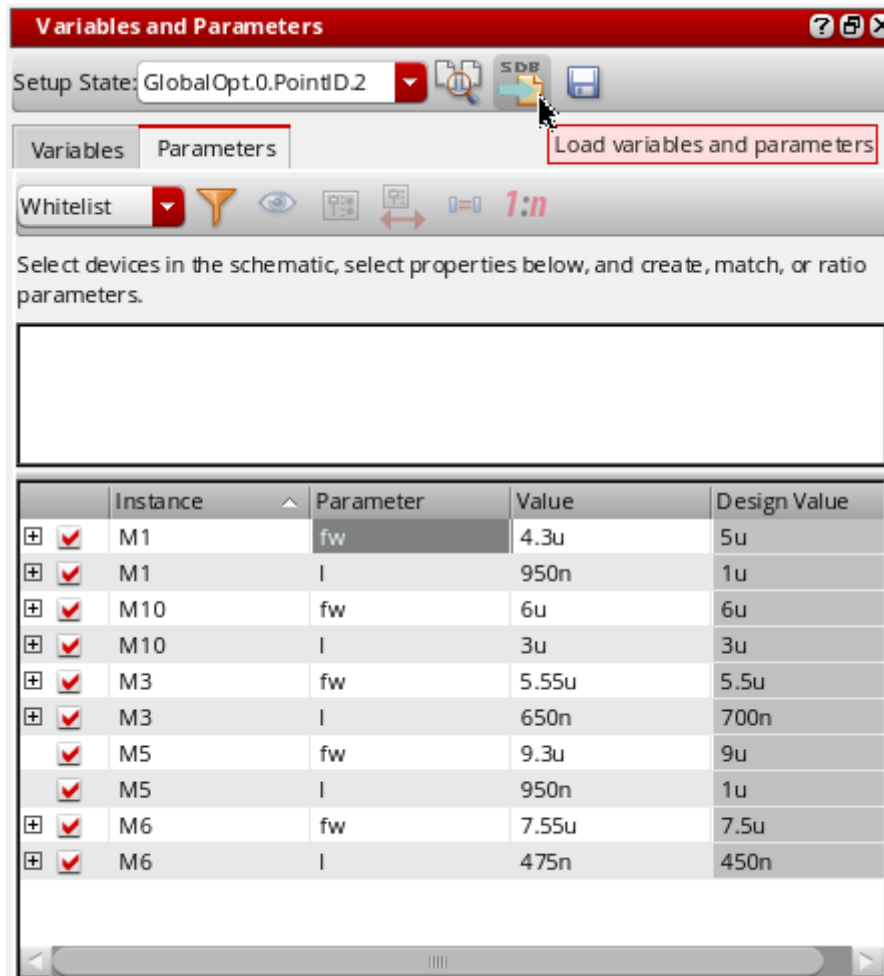
At the bottom, there are tabs for 'Verify\_Yield\_Reorder\_Samples', 'MonteCarlo.6', 'MonteCarlo.0', and 'GlobalOpt.0'.

The values of all the variables and parameters for this design point are saved as a state named as `<history-name>.PointID.<point-ID>`.

## Virtuoso Variation Option User Guide

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To verify if there is any improvement in the yield for the selected specifications, run a Monte Carlo simulation again by using the saved values are used for the variables and parameters. For this, load the state in the Variables and Parameters assistant, as shown below.

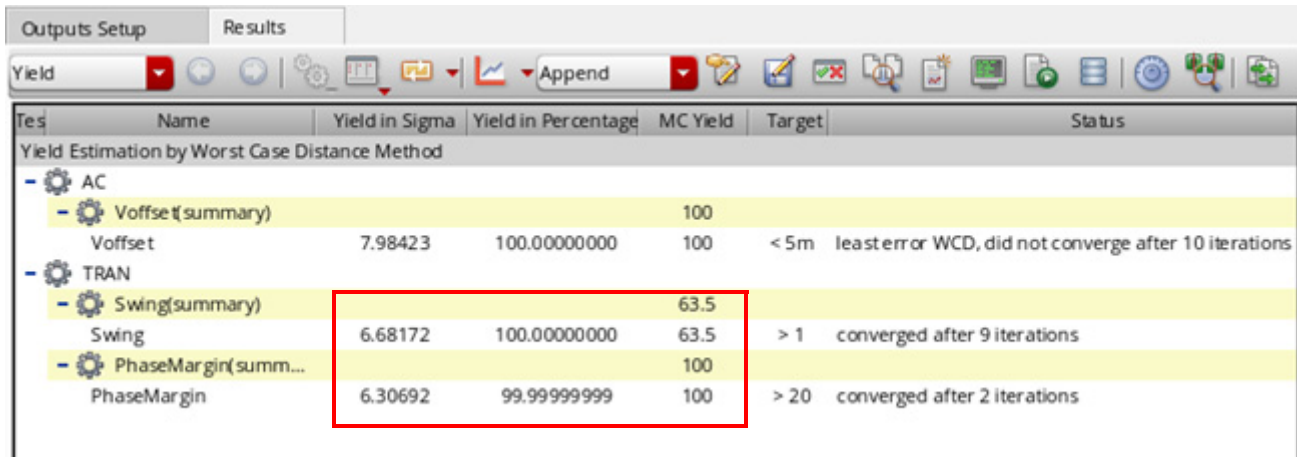


Using the same Monte Carlo setup as used earlier, run a simulation.

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For the example given above, the results show significant improvement in the yield and the worst case distance values, as shown below:



The screenshot shows the 'Results' tab of the 'Outputs Setup' window. The 'Yield' dropdown is selected. The table displays 'Yield Estimation by Worst Case Distance Method' with columns: Test, Name, Yield in Sigma, Yield in Percentage, MC Yield, Target, and Status. The results are grouped by analysis type: AC and TRAN. Under AC, 'Voffset(summary)' has a yield of 100. Under TRAN, 'Swing(summary)' has a yield of 63.5, and 'PhaseMargin(summary)' has a yield of 100. A red box highlights the 'Yield in Sigma' and 'Yield in Percentage' columns for the TRAN analysis type.

Test	Name	Yield in Sigma	Yield in Percentage	MC Yield	Target	Status
Yield Estimation by Worst Case Distance Method						
AC	Voffset(summary)			100		
	Voffset	7.98423	100.0000000	100	< 5m	least error WCD, did not converge after 10 iterations
TRAN	Swing(summary)			63.5		
	Swing	6.68172	100.0000000	63.5	> 1	converged after 9 iterations
	PhaseMargin(summary)			100		
	PhaseMargin	6.30692	99.9999999	100	> 20	converged after 2 iterations

You can see that the yield in sigma value has increased for Swing and PhaseMargin as compared to the results of the previous high yield estimation run.

## **Virtuoso Variation Option User Guide**

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## Improving Yield for a Design

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Virtuoso Variation Option provides the *Improve Yield* run mode that you can use to return a design point that meets all corners and has the highest possible yield.

This chapter describes this run mode in detail.

## The Improve Yield Run Mode

The Improve Yield run mode runs iterations of sizing and Monte Carlo analysis to arrive at a solution. When you start Improve Yield, Virtuoso Variation Option first generates the statistical corners, then, as the run progresses, evaluates points on a subset of those corners. Promising points are then evaluated on a larger set of corners. Eventually the tool arrives at the best point—one that has been evaluated at all statistical corners and has the highest possible yield.

Also available are a number of stopping criteria, including time and points limits. Once the tool hits any of the specified options, it will end the improvement process.




*Improve Yield*, like *Monte Carlo Sampling*, is available only for the Spectre circuit simulator.

Your design must include devices or device models for which you have specified statistically varying parameter values. You must have one or more specs defined and enabled. You must specify either global (process) or mismatch (per-instance) variations or both. You can also specify correlation information. After simulating, you can select the yield view to view mean and standard deviation information. For more information, see Performing Monte Carlo Analysis in the Virtuoso ADE Assembler User Guide.

**Note:** For information about specifying parameter distributions for Spectre circuit simulation, see Specifying Parameter Distributions Using Statistics Blocks in the Analyses chapter of the *Spectre Circuit Simulator and Accelerated Parallel Simulator User Guide*.

To improve the yield:

1. From the *Select a Run Mode* drop-down list on the Run toolbar, choose *Improve Yield*.
2. Click  to specify improve yield options.

## Virtuoso Variation Option User Guide

### Improving Yield for a Design

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The Improve Yield options form appears.

The screenshot shows the 'Improve Yield' dialog box with the following settings:

- Optimization** tab selected.
- Algorithm:** Global Optimization (dropdown menu).
- Starting Point:**
  - ☐ Use Starting State (dropdown menu set to StartingPoint)
  - ☒ No (Runs Initial Global Optimization)
- Evaluation:**
  - ☐ Full
  - ☒ Conditional
- Stopping Criteria:**
  - ☒ Recommended
  - ☐ Custom
  - ☐ Time Limit (minutes) [empty text box]
  - ☒ Number of Iterations [3]
  - ☒ Max Points Per Iteration [3000]
  - ☐ Stop Iteration Early If No Improvement

Buttons at the bottom: **OK** (highlighted in red), Cancel, Help.

3. On the *Optimization* tab, select the optimization algorithm from the *Algorithm* drop-down list.
4. In the *Starting Point* panel, select one of the following options to specify a starting point for the simulation run:
  - ☐ *Use Starting State*—Select this option if you have created a setup state and want to use that as the starting point for the run. To use the setup state as the starting point for the optimization, select a setup state that defines a set of fixed values for every global variable or parameter that defines a range of values in the active setup.

You must have a setup state available to use this option.

**Note:** If the setup of your cellview earlier used a reference point as a starting point, the details of the starting point have been saved in a setup state named `ref_point_migrated`. Name of this state is automatically selected in the *Starting State* drop-down list on the run options form.

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- ❑ *No (Runs Initial Global Optimization)*—Select this option if you do not have a reference point, or do not want to use the reference point as the starting point for sizing. When this option is selected, the tool performs an initial global optimization on the nominal corner and uses its best point as the starting point for the run. If you select *No (Runs Initial Global Optimization)*, ensure that:
  - The nominal corner is not disabled in the Run Summary pane.
  - For tests that are enabled in the Data View pane, the nominal corner is not disabled in the Corners Setup form.

You can also set these run mode options using SKILL and can view the data.sdb file inside the maestro view to find the names of the run options. The options are set when you open the maestro view. For example, by default the Algorithm is set to Global Optimization and if you want to change the algorithm to BFGS, you can follow the below steps:

- a. Open the `maestro` view. The default value for *Algorithm* is displayed in the SKILL file.
- b. In the SKILL file, change the algorithm to BFGS.
- c. Save the maestro cellview.
- d. Open the maestro view again. The BFGS algorithm is set.

You can either set the default run options one time (at the time of ADE Assembler launch) or force the run options to not allow you to change them during the session. Now we connect to two triggers.

`postInstall` to set the default options when the maestro view is opened.

`runOptionsUpdated` to reset the run options in case

you want to force some options and make the user unable to change them.

```
(axlSessionConnect session_name "postInstall"
'CCRaxlLaunchADEXL_setDefaultIYrunOptions)
(axlSessionConnect session_name "runOptionsUpdated"
'CCRaxlRunOptionsUpdated_forceIYrunOptions)
```

The Improve Yield algorithm default is set once on ADE Assembler launch. You can change the algorithm during the session. It will be reset to the default the next time the maestro view is opened. If you uncomment the `axlSessionConnect` line for the `runOptionsUpdated`, the new file will have the same behavior as before by setting the default options only at the time of ADE Assembler launch.



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5. Select an evaluation type by selecting one of the following radio buttons under *Evaluation*:

- ☐ Full
- ☐ Conditional

For more information on conditional evaluation, see [Understanding Conditional Evaluation](#).

6. Select the *Recommended* check box under *Stopping Criteria* to use the recommended options. The recommended options are:

- ☐ Three sizing/Monte Carlo iterations
- ☐ 3000 points run per iteration

If you want to modify these defaults, select the *Custom* check box, then one or more of the following stopping criteria:

- a. To set a time limit for the run, select the *Time Limit (minutes)* check box and enter a value in hours.
- b. To specify the number of sizing/Monte Carlo iterations, select the *No. of Iterations* check box and enter the number in the field.
- c. If you want to specify the maximum number of points processed per iteration, select the *Max Points per Iteration* check box and enter the number of points in the field.
- d. If you want to stop the process early if the sizing results in no improvement, select the *Stop Iteration Early if No Improvement* check box. This option is applied to each optimization iteration. This stopping criteria is similar to the *No Improvement with Points* stopping criteria for the global or local optimization run modes for which the user also specifies the number of points. In the case of iterative run modes, the number of points is calculated as  $\text{Max Points per Iteration} / 3$ .

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7. Select the Monte Carlo tab to specify options for Monte Carlo.

The screenshot shows the 'Improve Yield' dialog box with the 'Monte Carlo' tab selected. The 'Statistical Variation' section has three radio buttons: 'Process', 'Mismatch', and 'All', with 'All' selected. The 'Sampling Method' section has a dropdown menu set to 'Random'. Below this, there are input fields for 'Number of Points' (set to 200) and 'Number of Bins'. There is a checked checkbox for 'Run Nominal Simulation'. Below that are input fields for 'Monte Carlo Seed' and 'Starting Run Number'. At the bottom of the dialog are two buttons: 'Specify Instances/Devices (Not Specified)' and 'Specify Tests for Monte Carlo'. The standard 'OK', 'Cancel', and 'Help' buttons are at the very bottom.

8. When you run Improve Yield, you have a choice of varying the process statistical variables, mismatch statistical variables, or both. If you run only one type of statistical variable, the other variables are set to fixed values.

In the *Method* group box, select one of the following statistical variations:

<i>Process</i>	for process statistical variations
<i>Mismatch</i>	for per-instance statistical variations
<i>All</i>	for both process and per-instance statistical variations

#### **Important**

You must define your models so that they respond to the statistical variations you choose. You must specify the file containing your models on the Model Library Setup form. For a Spectre circuit simulator example of how to define your models, see “Specifying Parameter Distributions Using Statistics Blocks” in the *Virtuoso Spectre Circuit Simulator User Guide*.

9. In the *Number of Points* field, type the number of Monte Carlo points you want to simulate.
10. In the *Sampling Method* group box, select the statistical sampling method to be used—*Random*, *Latin Hypercube*, or *Low-Discrepancy Sequence*.
11. If the selected sampling method is *Latin Hypercube*, specify the number of bins (subdivisions) for the *Latin Hypercube* method in the *Number of Bins* field.

Note the following:

- ☐ If a number is specified, the number of bins will be the specified number, or *Number of Points + Starting Run Number - 1*, whichever is greater. For example, if the specified number of bins is 90, the number of points specified in the *Number of Points* field is 100 and the starting run number specified in the *Starting Run Number* field is 6, the value 105 (100+6-1) is used.
  - ☐ If no number is specified, a default value of *Number of Points + Starting Run Number - 1* is used. For example, if the number of points specified in the *Number of Points* field is 100 and the starting run number specified in the *Starting Run Number* field is 6, the default value of 105 (100+6-1) is used.
12. (Optional) If you want to specify a different seed for the Monte Carlo analysis, select the *Monte Carlo Seed* check box and enter the seed number.
- By always specifying the same seed, you can reproduce a previous experiment. If you do not specify a seed, the value 12345 is used.
13. (Optional) If you want to specify a starting run number, select the *Starting Run Number* check box and enter the starting run number.

The starting run number specifies the run that Monte Carlo begins with. By specifying this number, you can reproduce a particular run or sequence of runs from a previous experiment (for example, to examine an earlier case in more detail).

#### **Tip**

To reproduce a run or sequence of runs, you need to specify the same value in the *Starting Run #* and the *Monte Carlo Seed* fields.

14. By default, mismatch variations are applied to all subcircuit instances in the design. Click the *Specify Instances/Devices* button to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see the [Including or Excluding Instances and Devices for Applying Mismatch Variations](#) section in the *Virtuoso ADE Assembler User Guide*.

15. Click *Specify Tests for Monte Carlo* and select the check box next to the test name for which you want to run Monte Carlo.

**Note:** The N-Sigma tab is not available on the Improve Yield options form now. You can run High Yield Estimation and create statistical corners to optimize your design and to achieve a yield of less than the desired sigma value for the selected specifications. For more details, refer to [Creating Statistical Corners From a Worst Case Distance Analysis](#).

16. In the Run workspace, click the *Run simulation* icon to improve the yield.

The tool begins synthesizing with Monte Carlo analysis.

**Note:** There is no change in the simulation results if the *Run Nominal Simulation* check box is selected. You can ignore this setting on the Monte Carlo tab of the Improve Yield form.

When the Improve Yield run is finished, the Data View lists the Improve Yield check point. Expanding this check point displays the different runs that make up a full Improve Yield run, including iterations of Optimization and Monte Carlo. You can view the results of any of these runs by right-clicking and choosing *View Results*.

Several factors are considered in generating statistical corners, which includes overall yield estimate, individual yield of each specification, and sigma to target value of each specification. Statistical corners are created for specs that have low yield as well as for specs that have yield estimate=100%, but low sigma to target value. When the overall yield is high, statistical corners are created at the worst sample. When the yield is low, the Improve Yield method is less effective in creating statistical corners.

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## Environment Variables

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This appendix describes public environment variables that control characteristics of Virtuoso Variation Option. You can customize the operation and behavior of the features by changing the values of these environment variables.

Also see:

“Environment Variables” in the *Virtuoso ADE Assembler User Guide*

## Virtuoso Variation Option Environment Variables

You can set the following environment variables in your `.cdsenv` or `.cdsinit` files to customize the settings for simulations or results:

- `digitsToShowForYieldInPercentage`
- `sortVariablesOpt`
- `useDoubleSidedSigma`
- `toleranceComparionRatiorForRSM`
- `WCCEnableNewlyCreatedCorners`
- `yieldProbability`

### **digitsToShowForYieldInPercentage**

Specifies the number of digits to be displayed for values in the *Yield In Percentage* column on the Results tab for High Yield Estimation run.

In `.cdsenv`:

```
adexl.gui digitsToShowForYieldInPercentage int 6
```

In `.cdsinit` or the CIW:

```
envSetVal("adexl.gui" "digitsToShowForYieldInPercentage" 'int t)
```

Valid Values:

A positive integer value

Default Value: 10

### **sortVariablesOpt**

Specifies if the variables and parameters should be sorted before generating random samples for an optimization run. By default, the variables are not sorted before the run is started. However, you can sort them by setting this variable to `t` so as to ensure that the result of different optimization runs is same irrespective of the order of variables and parameters.

In `.cdsenv`:

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```
adexl.algorithm sortVariablesOpt boolean nil
```

In `.cdsinit` or the CIW:

```
envSetVal("adexl.algorithm" "sortVariablesOpt" 'boolean t)
```

Valid Values:

<code>t</code>	Sorts the variables and parameters before generating random samples.
<code>nil</code>	Does not sort the variables and parameters before generating random samples. This is the default value.

### useDoubleSidedSigma

Specifies whether the K-sigma statistical corner is single-sided or double-sided. You can set this variable while creating K-sigma statistical corner from the following methods:

- K-sigma corner from Monte Carlo
- K-sigma corner from High Yield Estimation

In `.cdsenv`:

```
adexl.algorithm useDoubleSidedSigma boolean nil nil
```

In `.cdsinit` or the CIW:

```
envSetVal("adexl.algorithm" "useDoubleSidedSigma" 'boolean nil)
```

Valid Values:

<code>t</code>	When this variable is set to <code>t</code> , the double-sided K-sigma statistical corner is created.
<code>nil</code>	When this variable is set to <code>nil</code> , the single-sided K-sigma statistical corner is created.  This is the default value.

## **toleranceComparionRatiorForRSM**

Ignores the RSM model coefficient if its ratio to the maximum coefficient value is less than the specified limit.

In `.cdsenv`:

```
adexl.gui toleranceComparionRatiorForRSM float 1e-6
```

In `.cdsinit` or the CIW:

```
envSetVal("adexl.gui" "toleranceComparionRatiorForRSM" 'float 1e-6)
```

Valid Values:

Any floating point number

Default:      `1e-6`

## **WCCEnableNewlyCreatedCorners**

Specifies whether to enable or disable the corners that are created after the worst case corner simulation run.

In `.cdsenv`:

```
adexl.gui WCCEnableNewlyCreatedCorners boolean nil
```

In `.cdsinit` or the CIW:

```
envSetVal("adexl.gui" "WCCEnableNewlyCreatedCorners" 'boolean nil)
```

Valid Values:

<code>t</code>	When this variable is set to <code>t</code> , the corners are enabled.
<code>nil</code>	When this variable is set to <code>nil</code> , the corners are disabled.
	This is the default value.



### yieldProbability

Defines the significance level in percentage. Probability values closer to 100% require more simulations before the yield estimate is determined to be lower or higher than the target. Smaller probability values require less simulations before the auto-stop is triggered.

In `.cdsenv`:

```
adexl.monte yieldProbability float 90
```

In `.cdsinit` or the CIW:

```
envSetVal("adexl.monte" "yieldProbability" 'float 90)
```

Valid Values:

An integer value between 0 and 100

Default: 95.0