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Virtuoso Variation Options User Guide

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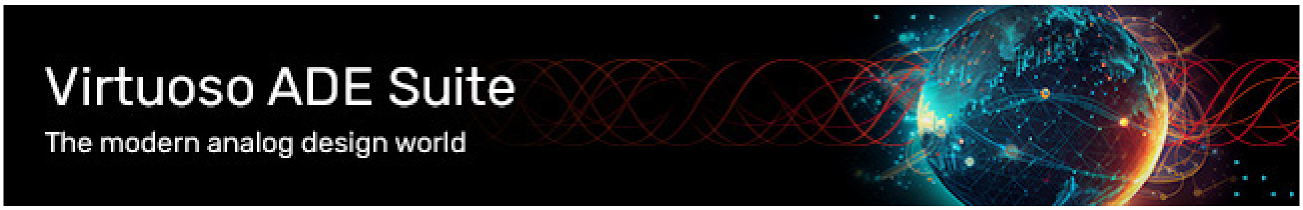
Introduction to Virtuoso Variation Option



Virtuoso® Variation Option extends the statistical variation capabilities of Virtuoso ADE Assembler and Virtuoso ADE Explorer to allow for more sophisticated statistical analyses to be performed on any design.

Following are the benefits of using Virtuoso Variation Option:

- Provides Fast Monte Carlo (FMC) method, which lets you extract useful statistical information without running the complete set of Monte Carlo samples, especially for high-sigma analysis. This reduces the simulation time.
- Provides mismatch contribution analysis and statistical sensitivity analysis to pinpoint most influential devices within a statistical simulation.
- Provides high-yield estimation capabilities for checking the outer boundaries of your design at the 4, 5, or 6-sigma level.
- Delivers advanced statistical sample reordering that improves the performance of the statistical simulation.
- Features easy, one-step creation of worst-case corners as derived by 3-sigma statistical sampling.
- Lets you integrate custom advanced optimization algorithm written in either C++ or Python into ADE Assembler.

Related Topics

License Requirements

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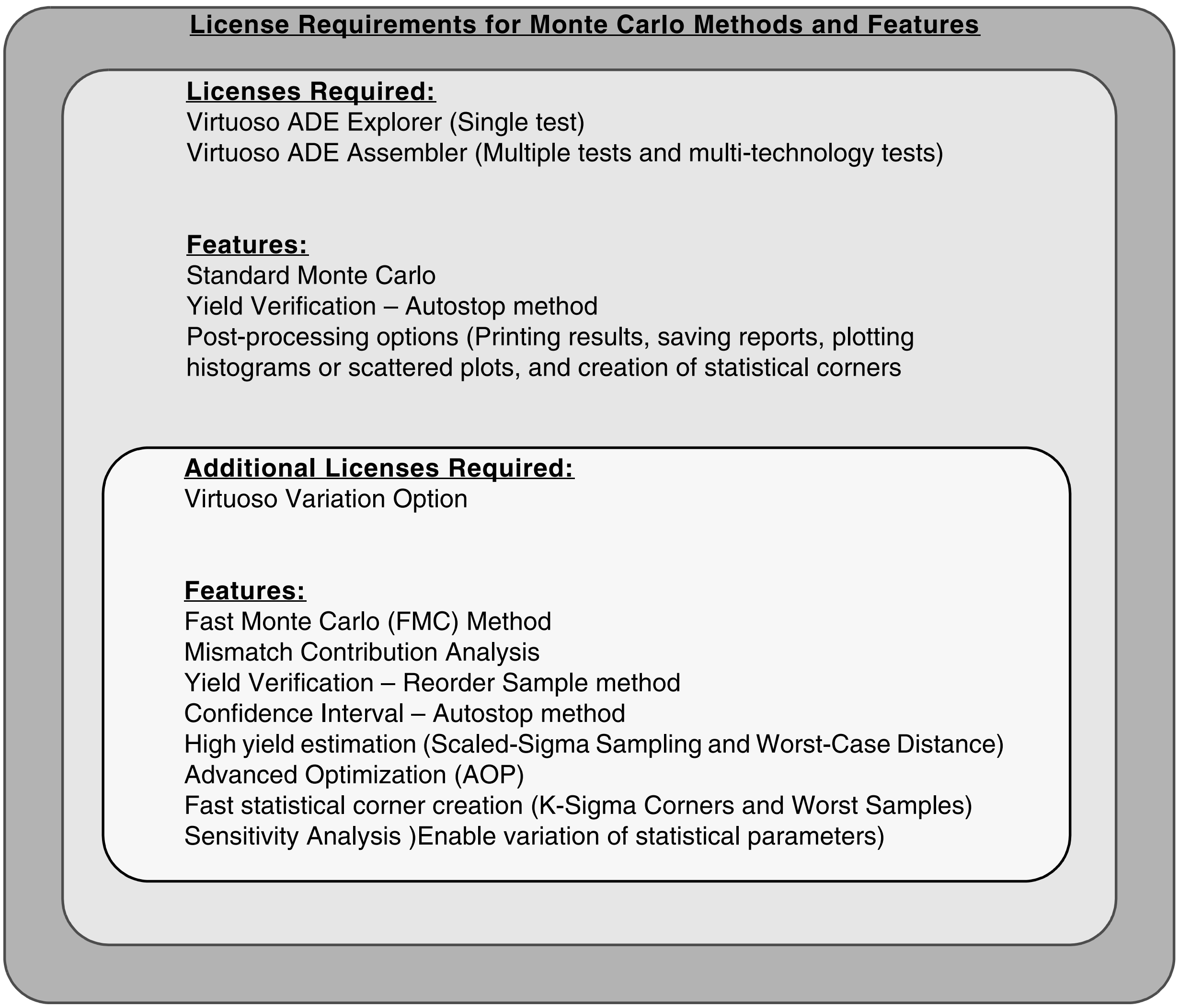
License Requirements

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.

The following figure shows the licenses required to run various Monte Carlo methods and features.



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Related Topics

Introduction to Virtuoso Variation Option

Fast Monte Carlo Method

Mismatch Contribution Analysis

Yield Verification

The Confidence Interval - Autostop Method

Statistical Corner Creation

High Yield Estimation

Advanced Optimization

Yield Improvement

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Statistical Sampling Methods

Spectre supports the following methods of sampling for Monte Carlo analysis:

- Random

  The Random sampling method takes the Brute Force approach of sequentially calling a random number generator without considering the samples generated previously. There is no sample selection or rejection. Therefore, it allows all samples to have an equal chance of getting selected from the population.

  The Random algorithm has a convergence accuracy of `1/sqrt(N)`.

- Latin Hypercube

  The Latin Hypercube method is a quasi-random sampling algorithm with sample selection and rejection. The sample space is evenly divided into probable subspaces. All sample points are then chosen simultaneously making sure that the total ensemble of sample points is a Latin Hypercube sample and that each subspace is sampled with the same density. This method requires fewer samples to get accurate results. This method is recommended when you know how many simulation points you need to run.

  The Latin Hypercube algorithm has a convergence accuracy of `1/pow(N,2/3)`.

- Low-Discrepancy Sequence

  The Low-Discrepancy Sequence (LDS) method uses a deterministic sequence to get a uniform coverage of the sampling space, which makes it better than the Random sampling method. In addition, LDS uses autostop features to generate samples, which is not supported by Latin Hypercube method. The convergence speed for LDS is faster than the Random sampling method and is comparable to the Latin Hypercube method. Therefore, overall, LDS method is better than both, Random and Latin Hypercube.

Related Topics

Monte Carlo Form

Fast Monte Carlo Method

Mismatch Contribution Analysis

Yield Verification

The Confidence Interval - Autostop Method

Statistical Corner Creation

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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 apply this method to existing standard Monte Carlo results or use the Sensitivity Accuracy method to automatically run the minimum required number of points.

The Sensitivity Accuracy method is used to post-process 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 select this method, the Monte Carlo run is stopped as soon as a model for variation contribution can be built for every output.

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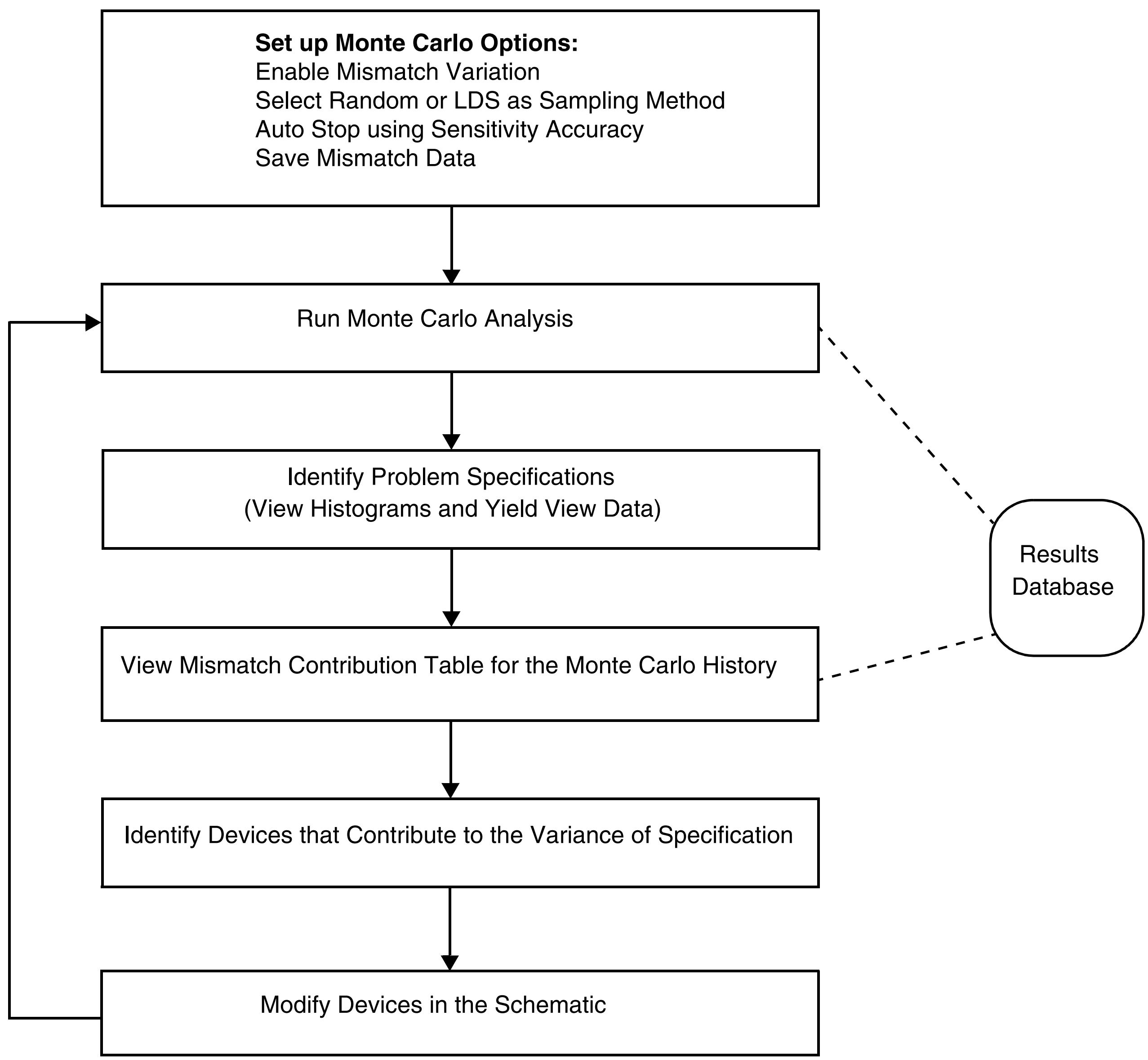
The following workflow shows how you can save and analyze the mismatch contribution data to improve your design.



Related Topics

Running Mismatch Contribution Analysis

Viewing Results of Mismatch Contribution Analysis

Running What-If Analysis

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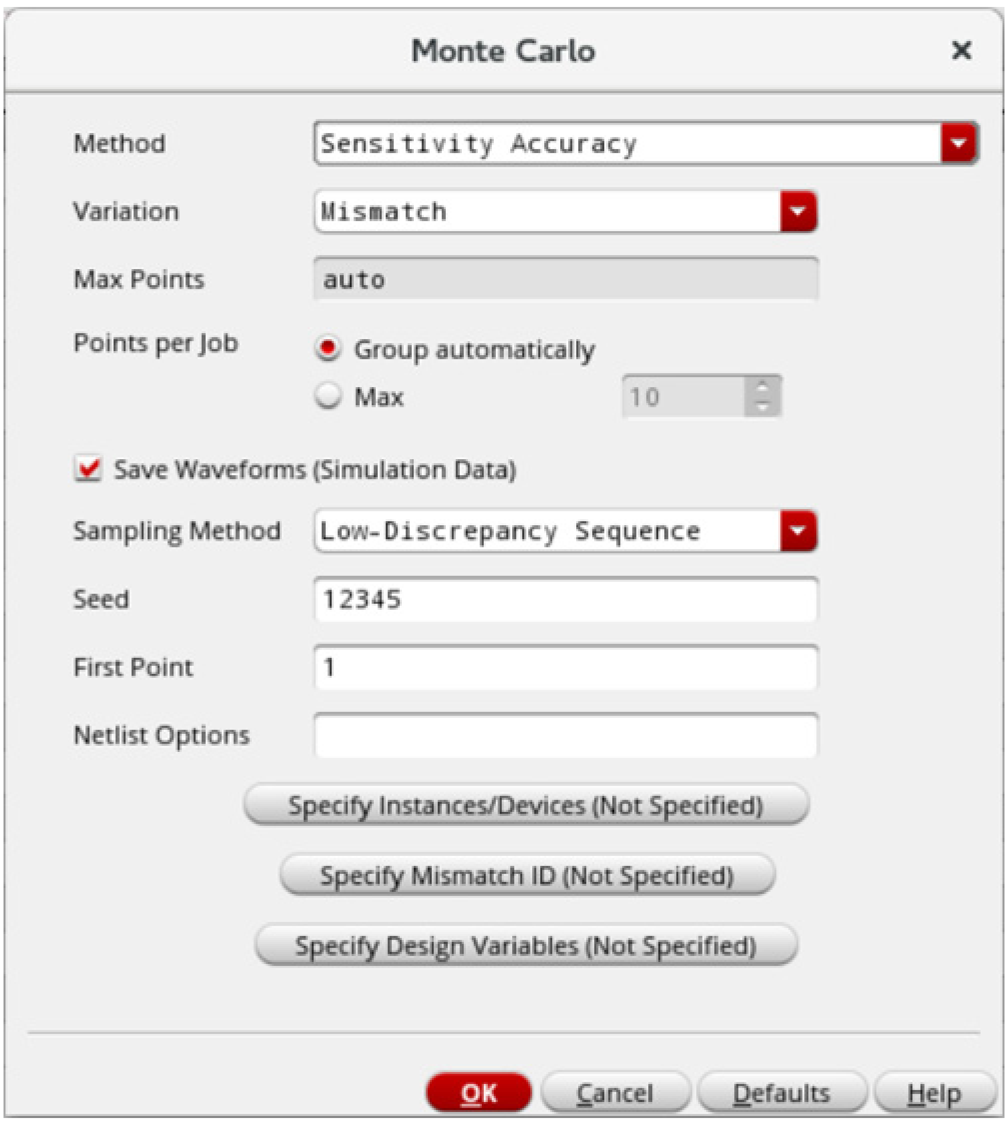
Running Mismatch Contribution Analysis

To run mismatch contribution analysis:

1. Open your design in ADE Assembler or ADE Explorer.
2. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
3. Click the *Simulation Options* command.

   The Monte Carlo form opens.



4. From the *Method* drop-down list, select *Sensitivity Accuracy*.

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5. From the *Variation* drop-down list, select *Mismatch*.
6. Select the *Save Waveform (Simulation Data)* check box to save the waveform data so that it can be used later for post-processing.

   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 select this check box to save the data for Monte Carlo analysis so that it can be later used for post-processing.
7. From the *Sampling Method* drop-down list, select *Low-Discrepancy Sequence*.
8. Click *OK* to close the Monte Carlo form.
9. Click *Run Simulation* to run the mismatch contribution analysis.

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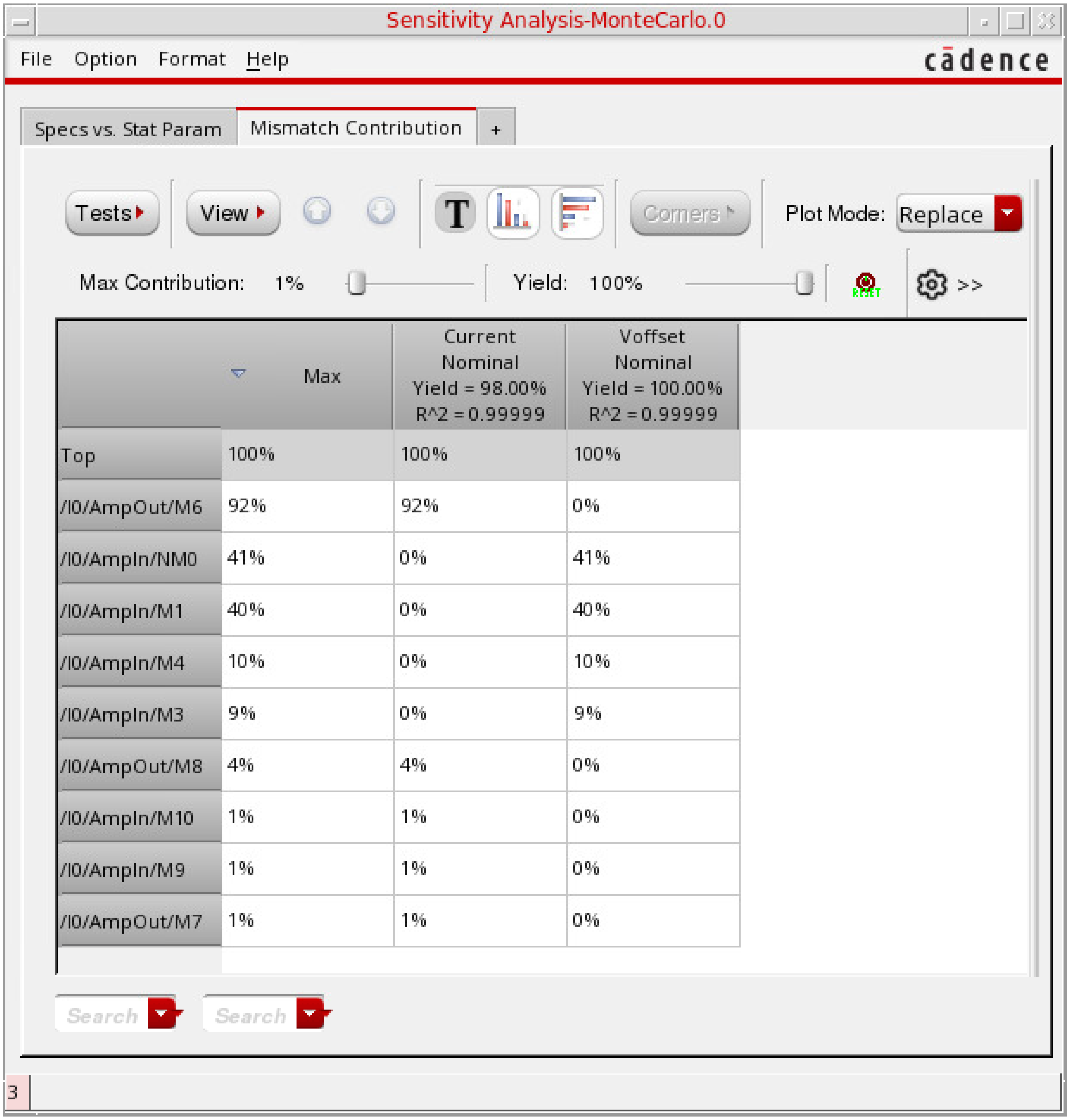
After the Monte Carlo run is complete, the Sensitivity Analysis-MonteCarlo.*N* form opens, displaying the results of mismatch contribution analysis in the *Mismatch Contribution* tab.



Related Topics

Monte Carlo Form

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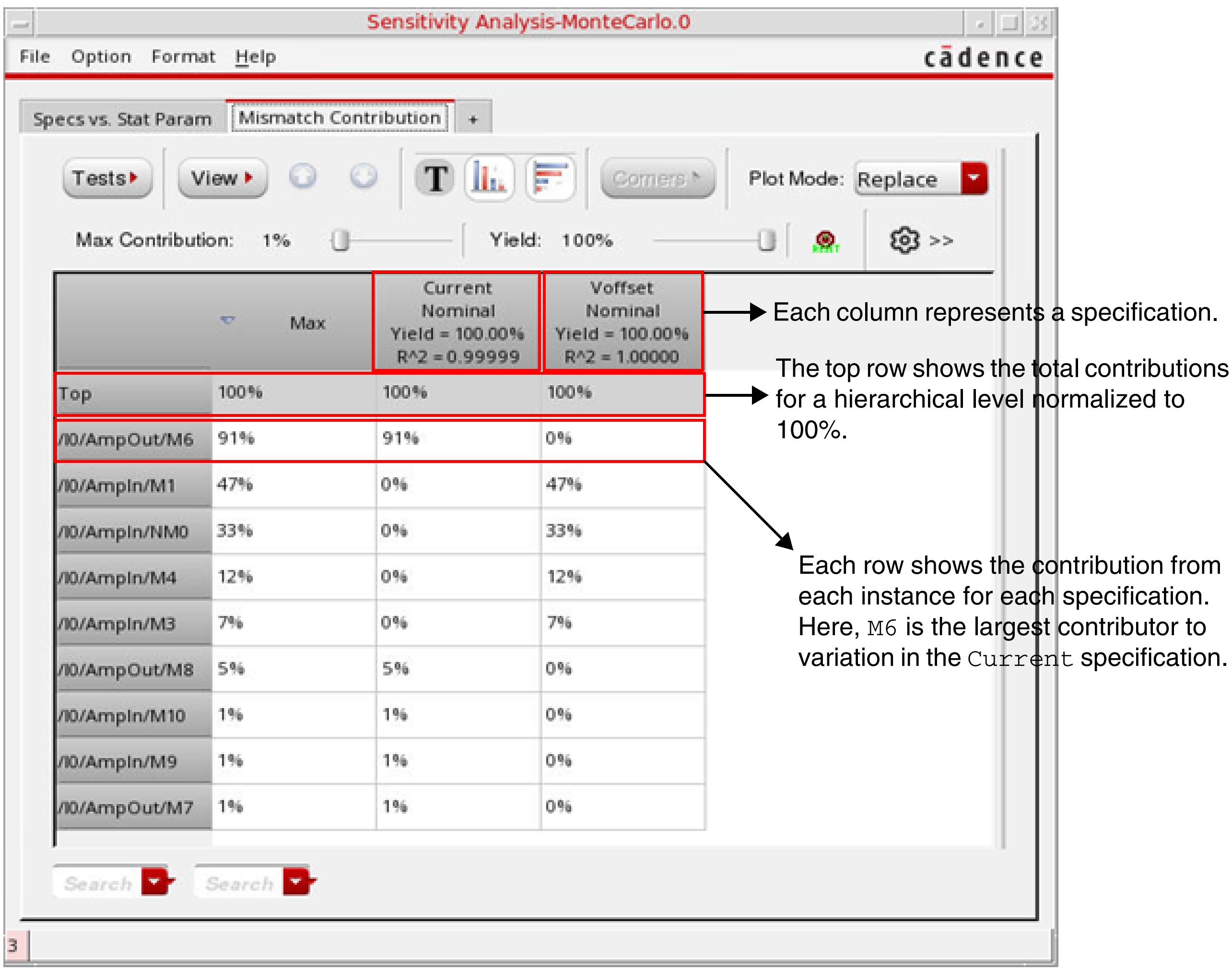
Viewing Results of Mismatch Contribution Analysis

To view the results of mismatch contribution analysis, do one of the following:

- Click *Mismatch Contribution* ()on the toolbar of the *Results* tab in ADE Assembler.
- In the *History* tab on the Data View assistant, right-click a history name and then choose *Mismatch Contribution*.

The Sensitivity Analysis-MonteCarlo.*N* form appears, displaying the results in the *Mismatch Contribution* tab.



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Related Topics

Mismatch Contribution Analysis

Running Mismatch Contribution Analysis

The Mismatch Contribution Table

Running What-If Analysis

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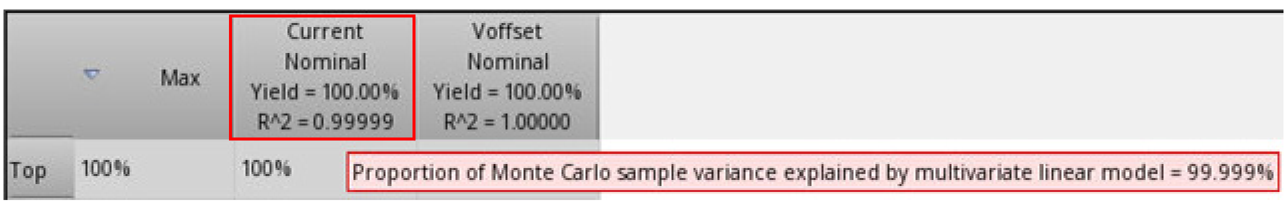
The Mismatch Contribution Table

The results of mismatch contribution analysis are displayed in a table on the *Mismatch Contribution* tab of the Sensitivity Analysis-MonteCarlo.*N* form.

In this table:

- Each row represents an instance of the design. For example, */I0/AmpOut/M6*.
- Each column represents an output specification.For example, *Current* and *Voffset*.
- Each cell shows the contribution (in percentage) of an instance towards the variance of the corresponding specification. All the contributions are normalized to 100%.

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.



`R^2` (Goodness of Fit) reports how much of the total variance is explained by the model. 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.

If you run the mismatch contribution analysis by selecting *All* as *Variation* on the Monte Carlo form, an additional *Process* row is displayed in the mismatch contribution results, as

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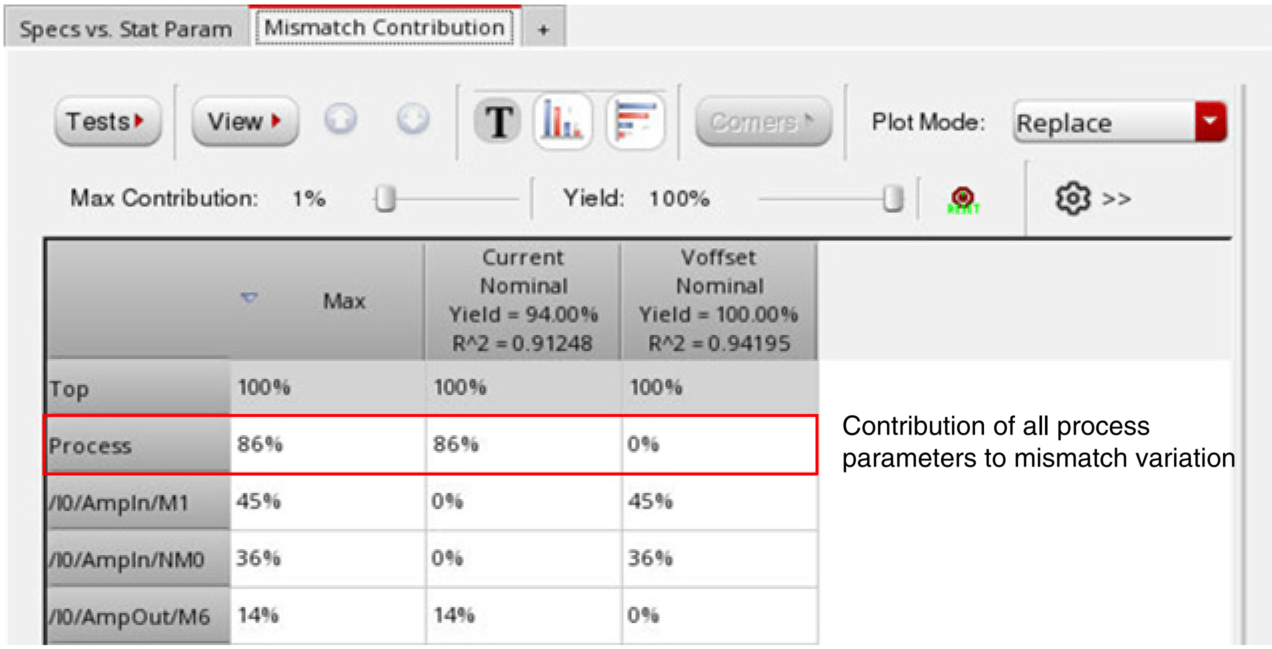
shown in the following figure. This row shows the contributions of all the process parameters to mismatch variation.



	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/AmpIn/M1	45%	0%	45%
/I0/AmpIn/NM0	36%	0%	36%
/I0/AmpOut/M6	14%	14%	0%

Related Topics

Mismatch Contribution Analysis

Viewing Results of Mismatch Contribution Analysis

Toolbar of the Mismatch Contribution Tab

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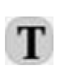
Toolbar of the Mismatch Contribution Tab

The toolbar of the *Mismatch Contribution* tab of the Sensitivity Analysis-MonteCarlo.*N* form contains the following commands.

Icon	Command Name	Description
N/A	*Tests*	Selects the test for which you want to view the mismatch contribution results. 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.
N/A	*View*	Selects one of the following views: ■ *Hierarchical*: Shows mismatch contribution results per instance. ■ *Flat*: Shows mismatch contribution results per parameter. This is the default view. ■ *Flat - Show Parameters*: Shows 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. ■ *Variance*: Shows the variance values for each instance or parameter. ■ *Percentage*: Shows the contribution of each instance or parameter to variance in percentage.
	*Ascend parameter hierarchy*	Ascends the design hierarchy one level.
	*Descend parameter hierarchy*	Descends the design hierarchy one level.
	*Display numerical values*	Displays the mismatch contribution results in numerical values.
	N/A	Displays vertical bar graphs to compare data in the rows.

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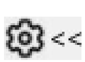
	N/A	Displays the horizontal bar graphs to compare data in the columns.
N/A	*Corners*	Selects the corner for which you want to view the mismatch contribution results.
N/A	*Plot Mode*	Selects one of the plotting modes to plot the mismatch contribution results: ■ *Replace*: Replaces the graph in the active window with a new graph. ■ *Append*: Appends the result in the active graph window or subwindow. ■ *New SubWin*: Plots the result in a new subwnidow within the existing graph window. ■ *New Win*: Plots the result in a new graph window.
N/A	*Max Contribution*	Hides the rows for the instance or parameters whose contribution to the variance is greater than or equal to the value specified by the *Max Contribution* filter. Use this filter to focus on the devices that have high contribution to the variance of the circuit.
N/A	*Yield*	Hides the columns for the specifications whose yield exceeds the value specified by the *Yield* filter. Use this filter when you need to focus on the outputs that are not achieving the required specification yield.
	*Reset*	Resets the *Max Contribution* and *Yield* filters to initial values.
	*Open the Mismatch Tuner*	Opens the Mismatch Tuner, which you can use to see how a change in the size of any device instance impacts the variation of circuit output.
	*Close the Mismatch Tuner*	Closes the Mismatch Tuner.

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Related Topics

Mismatch Contribution Analysis

Running Mismatch Contribution Analysis

Viewing Results of Mismatch Contribution Analysis

Running What-If Analysis

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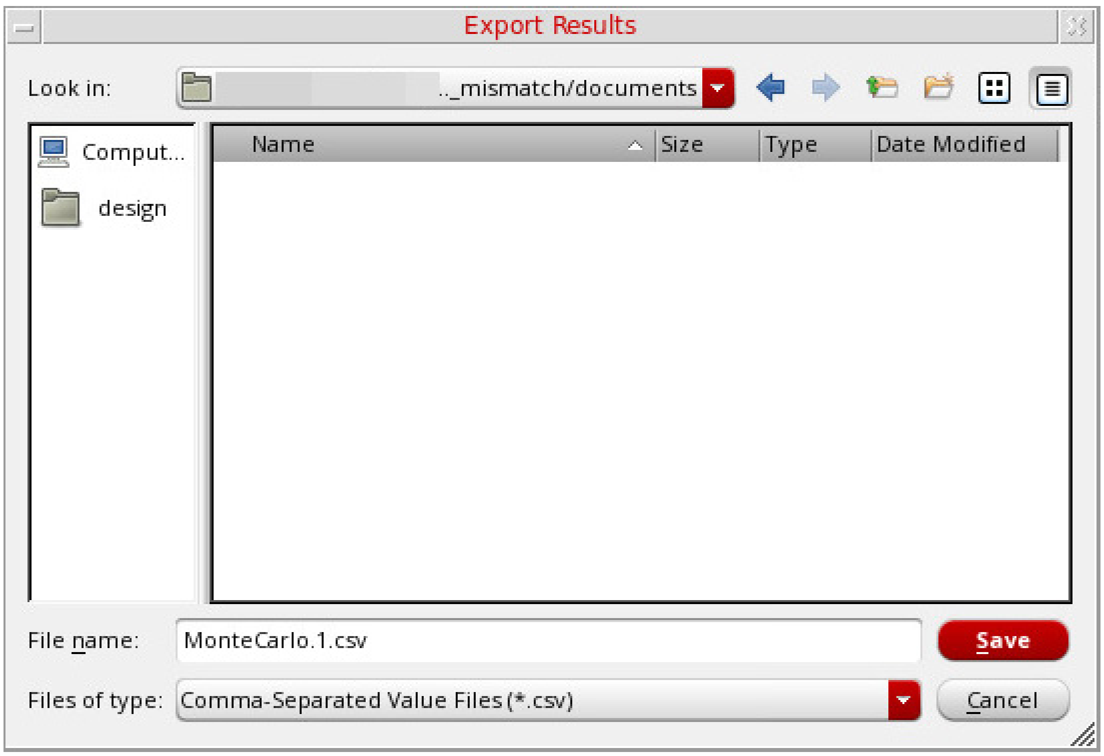
Exporting Mismatch Contribution Results

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

To export the results of mismatch contribution analysis to a CSV file:

1. On the *Mismatch Contribution* tab of the Sensitivity Analysis-MonteCarlo.*N* form, choose *File – Export Result to CSV – Current Tab*.

   The Export Results form opens.



2. In the *File Name* field, specify the name of the CSV file to which you want to export the results of mismatch contribution analysis.
3. Click *Save*.

For mismatch contribution results, data in the CSV file after exporting results is displayed exactly the same way as it is displayed in the Mismatch Contribution table.

For example, on the Mismatch Contribution table, if you have:

- selected instances to display hierarchically and descended to the level, `AmpIn`.

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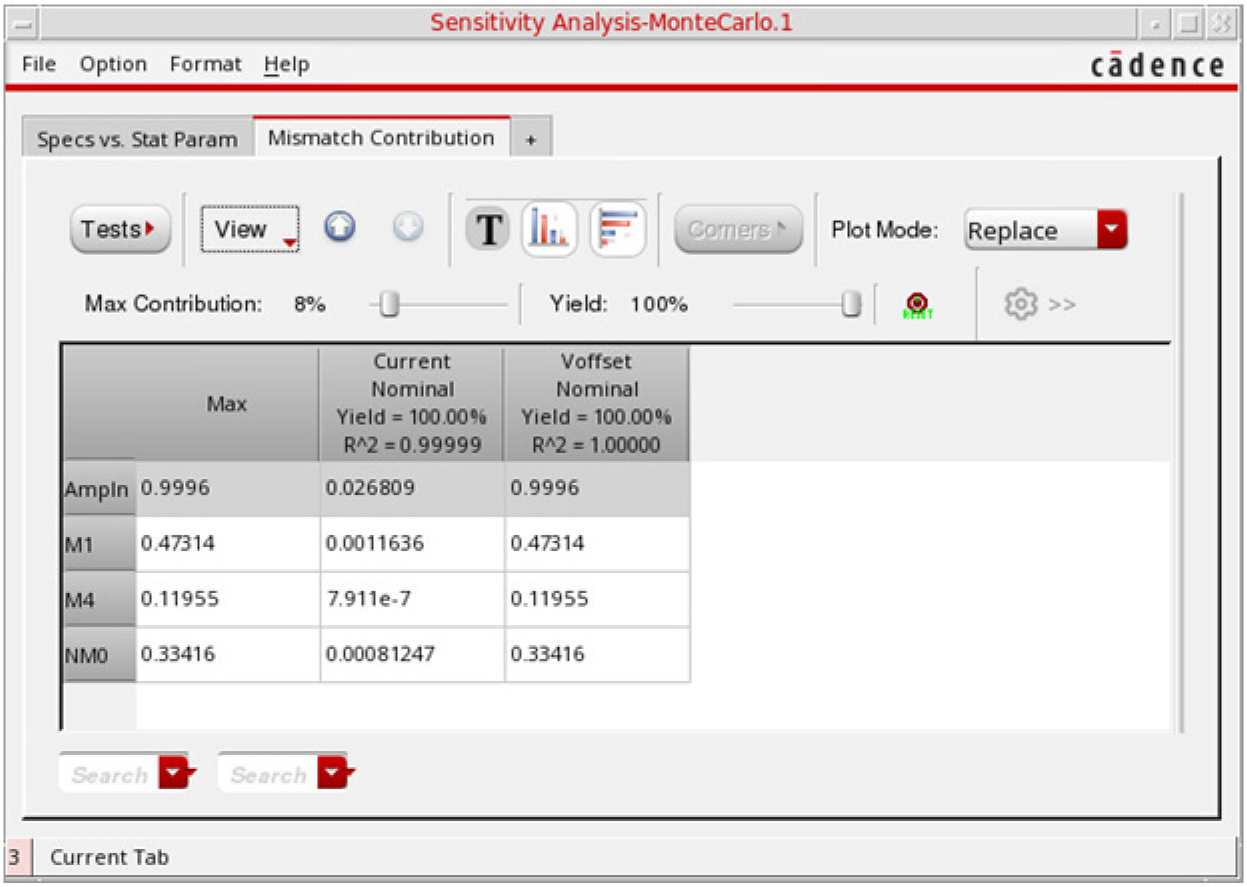
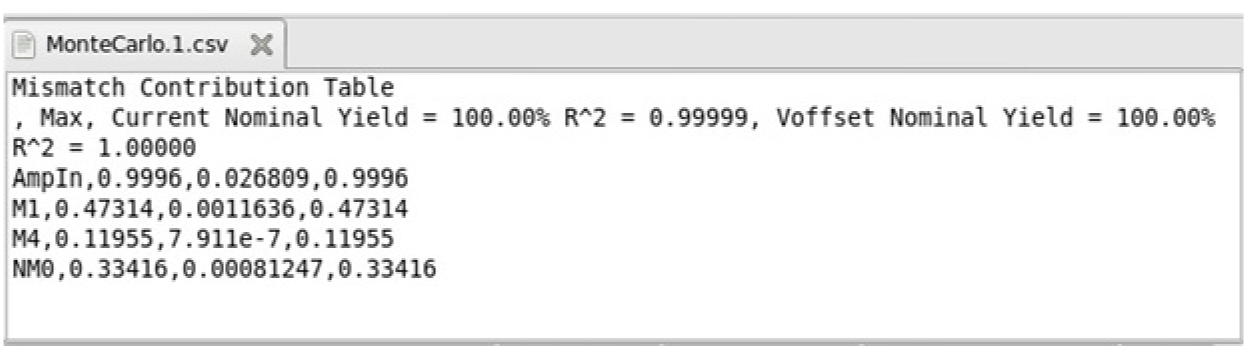
- filtered data to display only the instances that have a contribution value equal to or greater than 8%.
- selected data to display as variance.

Data in the mismatch contribution table is displayed as follows:



	Max	Current Nominal Yield = 100.00% R^2 = 0.99999	Voffset Nominal Yield = 100.00% R^2 = 1.00000
AmpIn	0.9996	0.026809	0.9996
M1	0.47314	0.0011636	0.47314
M4	0.11955	7.911e-7	0.11955
NM0	0.33416	0.00081247	0.33416

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




```
Mismatch Contribution Table
, Max, Current Nominal Yield = 100.00% R^2 = 0.99999, Voffset Nominal Yield = 100.00%
R^2 = 1.00000
AmpIn,0.9996,0.026809,0.9996
M1,0.47314,0.0011636,0.47314
M4,0.11955,7.911e-7,0.11955
NM0,0.33416,0.00081247,0.33416
```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You can observe that the CSV file contains data exactly as you see it in the mismatch contribution table.

Related Topics

Mismatch Contribution Analysis

Running Mismatch Contribution Analysis

Viewing Results of Mismatch Contribution Analysis

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Running What-If Analysis

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

Note: The *Open the Mismatch Tuner* command is disabled if the instances are displayed in the *Hierarchical* view. You need to change the view to the *Flat* view by using the *View* command in the toolbar of the *Mismatch Contribution* tab.

To identify the impact of a change in the size of a device on the variation of the circuit output:

1. On the *Mismatch Contribution* tab, click the *Open the Mismatch Tuner* command.

   For each instance, a row is added to the *Mismatch Tuner* pane. Each row has a slider to change the area multiplier of the corresponding instance. In addition, the *Std Dev* row

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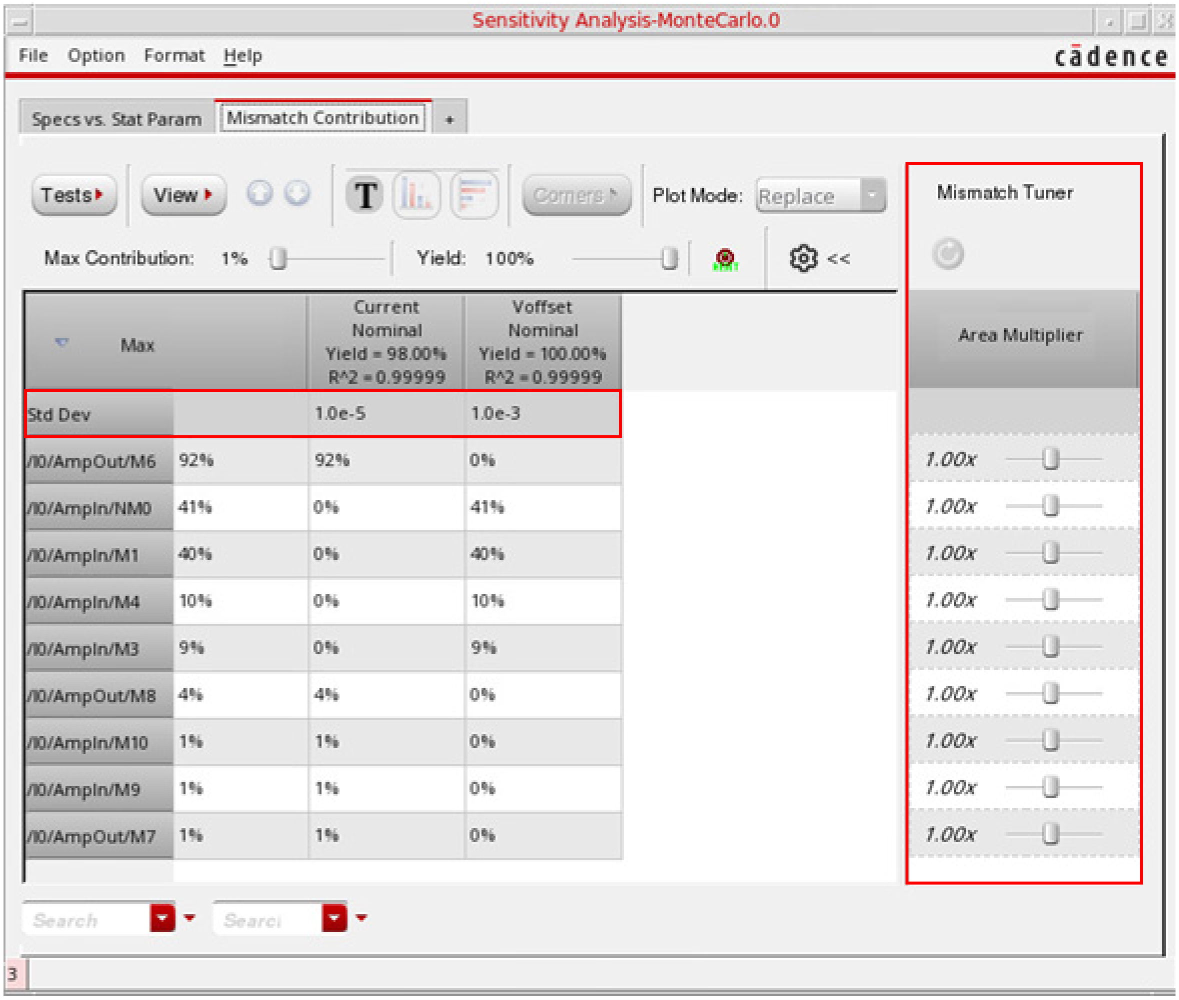
is displayed as the first row in the *Mismatch Contribution* table. This row displays the standard deviation for each output.



2. Drag the slider on the *Mismatch Tuner* to the left or to the right to decrease or increase the size of the corresponding instance. You can also change the size by typing a value in the range of `0.1-10` 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

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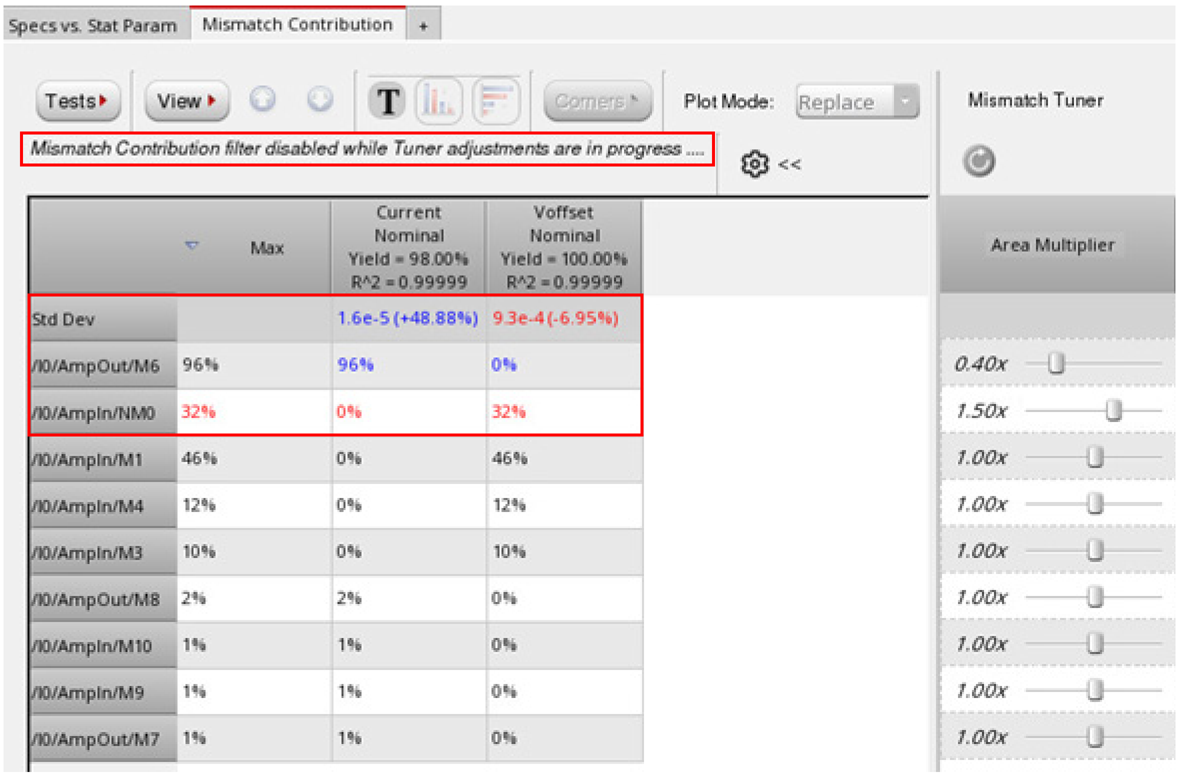
value is displayed in red or blue to indicate a negative or positive impact on the variation of that specification.



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

3. 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.

   The transistor area can be increased by maintaining the width-to-length ratio (`w/l`) and simultaneously increasing both the width (`w`) and length (`l`) of the transistor by a certain factor. For example, to increase the transistor area by `2x` while maintaining the `w/l` ratio, you can increase both `w` and `l` by the square root of `2`.

Note the following:

- You can clear all the multipliers by using the *Reset table to original contribution values* command on top-left corner of the *Mismatch Tuner*.

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- When the *Mismatch Tuner* is open, the variance contribution values are displayed only in the numerical format. If data is displayed in vertical or horizontal bar graphs, the data its format automatically changes to numerical when you open the *Mismatch Tuner*.
- The mismatch contribution and yield filters are hidden when the *Mismatch Tuner* is in progress.
- You cannot descend or ascend through the design hierarchy while the *Mismatch Tuner* is open.

Related Topics

Mismatch Contribution Analysis

Viewing Results of Mismatch Contribution Analysis

The Mismatch Contribution Table

Toolbar of the Mismatch Contribution Tab

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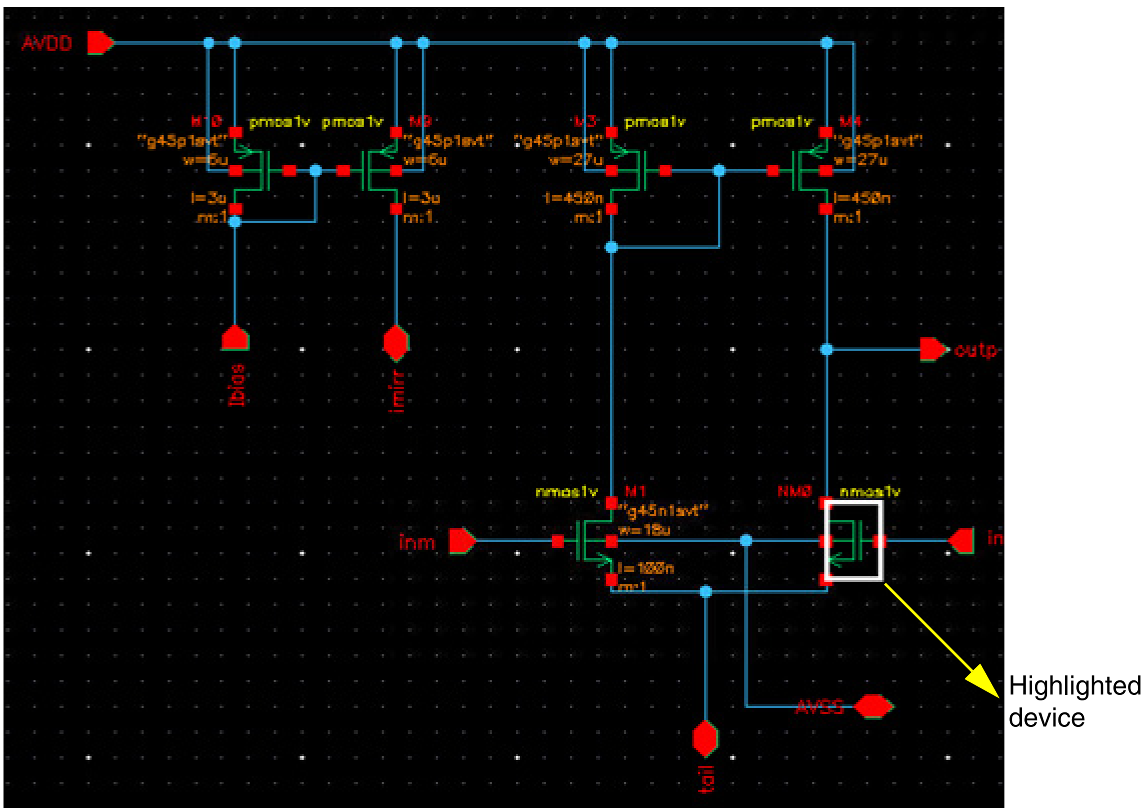
Highlighting a Device on Schematic

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 the schematic to improve the variance data, if required.

To highlight a device on the schematic:

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

Alternatively, you can press *H* on the keyboard.



Related Topics

[Mismatch Contribution Analysis]

[Running Mismatch Contribution Analysis]

[Viewing Results of Mismatch Contribution Analysis]

[Running What-If Analysis]

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3

Fast Monte Carlo Method

The Fast Monte Carlo (FMC) engine is implemented in the Spectre simulator. The FMC method lets you extract useful statistical information without running the complete set of Monte Carlo samples, especially for high-sigma analysis. This reduces the simulation time.

The FMC method identifies the tail samples out of total `N` Monte Carlo points without simulating all `N` points for the specified circuit measurement specification or set of measures. The number of sample points that is actually simulated is circuit dependent.

In FMC method, you must specify any two of the following parameters:

- *Total Samples* (`numruns`)
- *Target Yield* (`fmcsigma`)
- *Tail Samples* (`fmcnumtailsamples`)

For example, the following settings are equivalent, which indicates that for `1M` samples, the sample at `4.2` Sigma is the `14`th worst sample:

- *Total Samples* = `1M` and *Target Yield* = `4.2`
- *Target Yield* = `4.2` and *Tail Samples* = `14`
- *Total Samples* = `1M` and *Tail Samples* = `14`

The following table lists the relation between the fields, *Max Points*, *Target Yield*, and *Tail Samples* for FMC method.

Total Samples	Target Yield	Reported Samples	Sigma Range
20K	3	28	(2.99, 4.06)
100K	4	4	(3.98, 4.42)
1M	4.2	14	(4.2, 4.89)
100M	5.4	4	(5.39, 5.73)
500M	5.8	3	(5.73, 6)

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1B	5.8	4	(5.79, 6.11)

Outputs and Target Specifications

To reduce the run time, it is recommended that you enable only the minimum set of specifications of interest. If both min and max for the goal are not needed for a high-sigma analysis, you can use either of them based on what is the actual criterion for a failure of the specific measurement.

Related Topics

Workflow of Fast Monte Carlo Method

Running the Fast Monte Carlo Method

Spectre FMC Analysis

Workflow of Fast Monte Carlo Method

The Fast Monte Carlo (FMC) method first runs a group of samples and obtains measurements, then the algorithm builds a model and predicts the worst sample based on the user-specified results and specifications. It may take a few group iterations from model building, worst-sampling prediction, and verification to find out the tail of distribution. The FMC method thus improves performance and reduces memory cost when compared with the normal Monte Carlo method.

The FMC method also supports multi-process distribution to further improve the performance. The sample generation, model evaluation, and simulation are processed by worker processes running in parallel.

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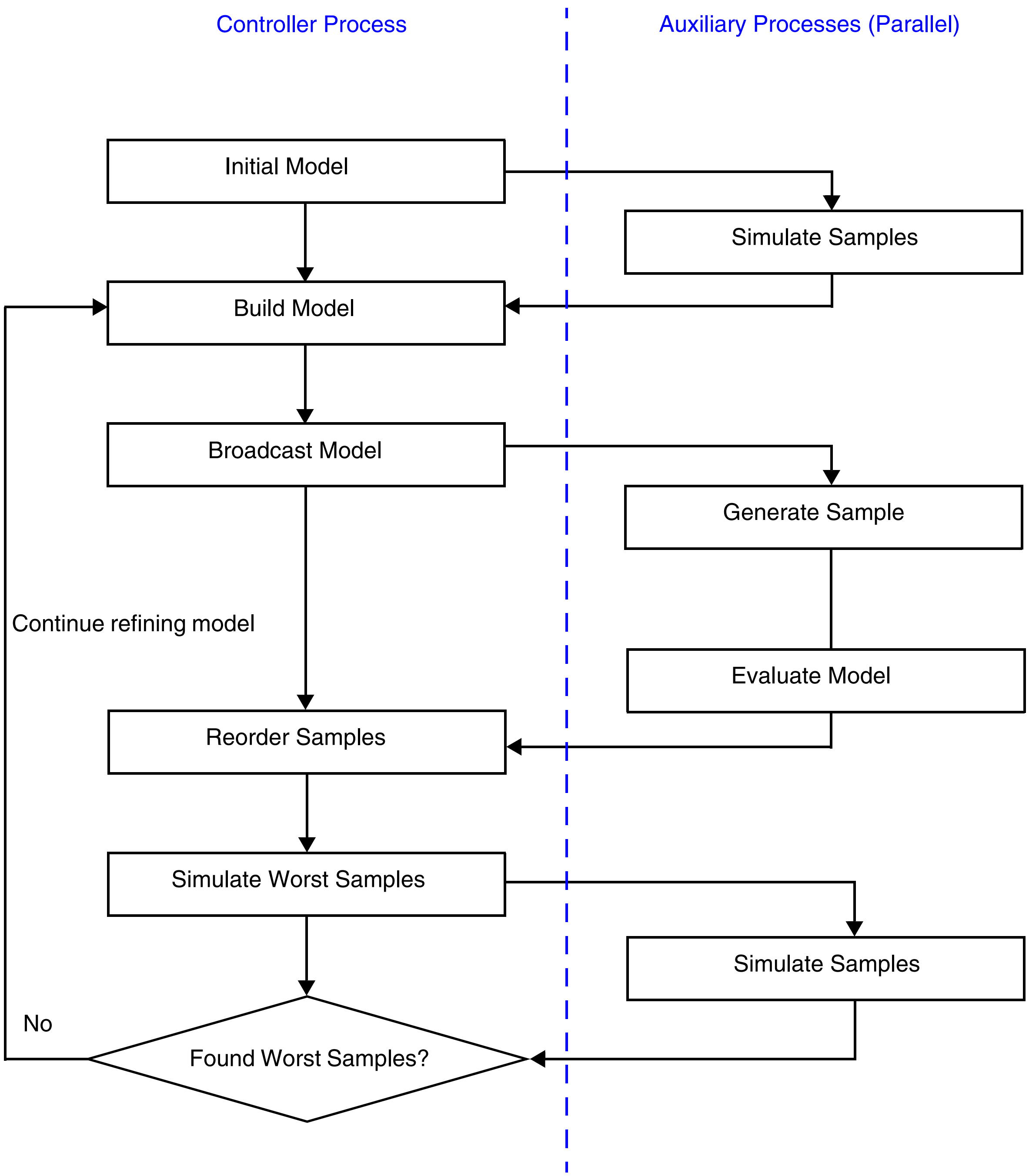
The following figure shows the workflow of the FMC method.



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Related Topics

Fast Monte Carlo Method

Running the Fast Monte Carlo Method

Spectre FMC Analysis

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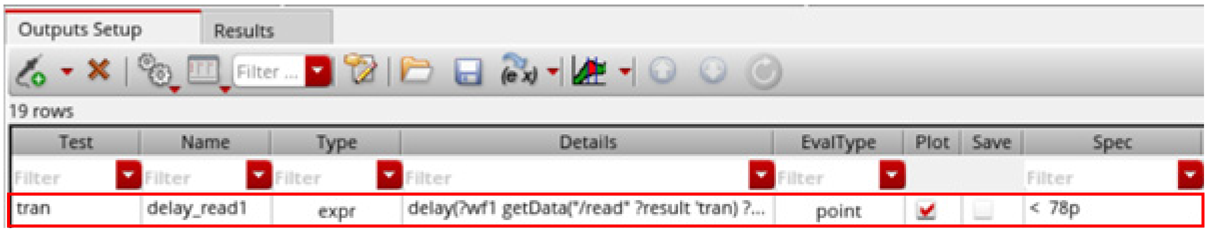
Running the Fast Monte Carlo Method

To run the FMC method:

1. Open your design in ADE Assembler.
2. In the *Outputs Setup* tab of ADE Assembler, define at least one specification.

   In the following example, the output `delay_read1` has a specification.

3. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
4. Click the *Simulation Options* command.

   The Monte Carlo form opens.
5. From the *Method* drop-down list, select *FMC Worst Samples*.
6. Specify any two of the following fields:

   a. In the *Total Samples* field, specify the maximum number of points to be simulated.

      The default value is `400`.

   b. In the *Target Yield* filed, specify the yield value that you want to achieve for your design. For example, `3 Sigma`.

   c. In the *Tail Samples* field, specify the number of tail samples. For example, `10`.
7. In the *Budget* field, specify the number of simulations to be run for FMC method. For example, if you set this field to `500`, no more than `500` points are simulated for FMC Worst Sample method. This is an optional field.
8. In the *Initial Points* field, specify the number of initial points based on which metrics, such as mean and standard deviations, are calculated and annotated in histograms. Specifying a higher number of initial points improves the accuracy of mean and standard deviation measurements.

   In FMC Worst Sample method, an initial model is built after the initial sampling group finishes. The initial model can be built with additional data points by increasing the number of initial points.

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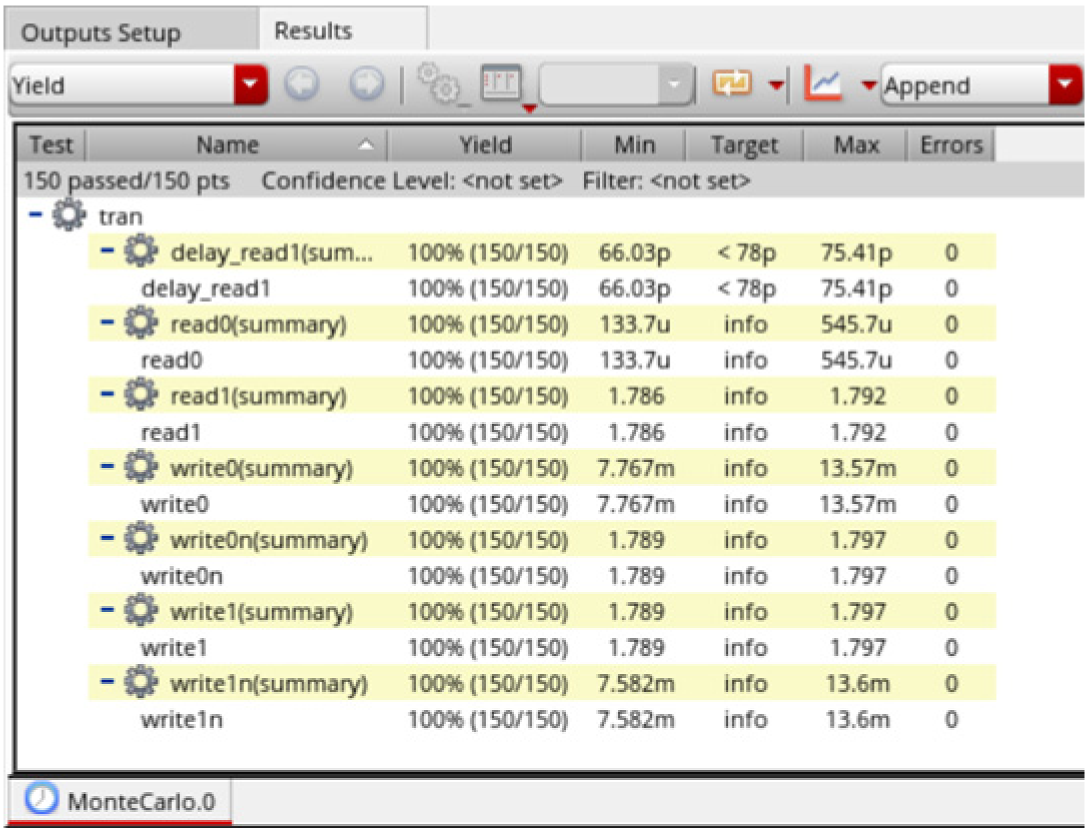
9. Select the *Save Waveform (Simulation Data)* check box to save the waveform data so that it can be used later for post-processing.
10. Click *OK* to close the Monte Carlo form.
11. In the *Run* toolbar of ADE Assembler, click *Run Simulation* to run the FMC method.

    The results are displayed in the *Results* tab, as shown in the following figure.



The number of passed points and total number of points are reported. Note that the yield estimate is not reported in the results. Metrics, such as *Mean*, *Std Dev*, that are normally reported for a standard Monte Carlo run are also omitted from the *Yield* results view.

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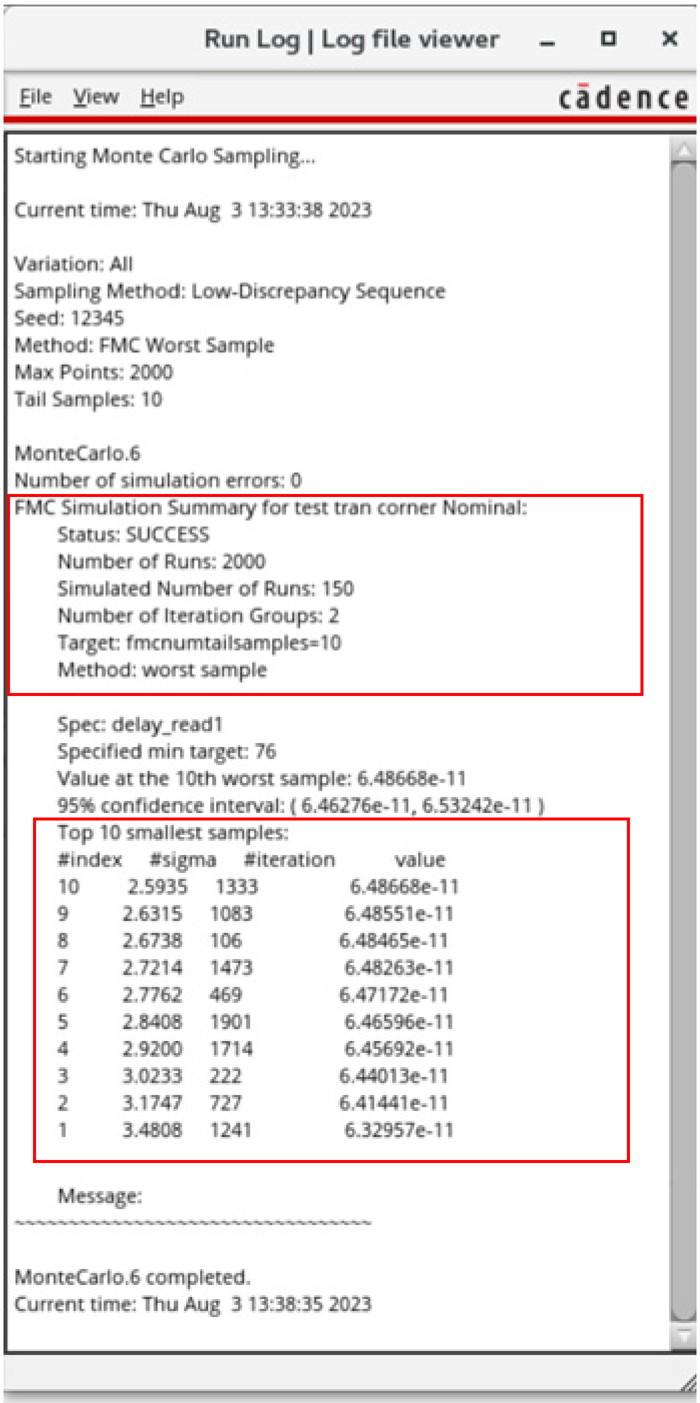
12. From the toolbar of the *Results* tab, click *Open Run Log* to open the run log.



Top 10 samllest samples

This FMC run identified the top worst samples out of `2000` total points, but only `150` sample points were actually simulated.

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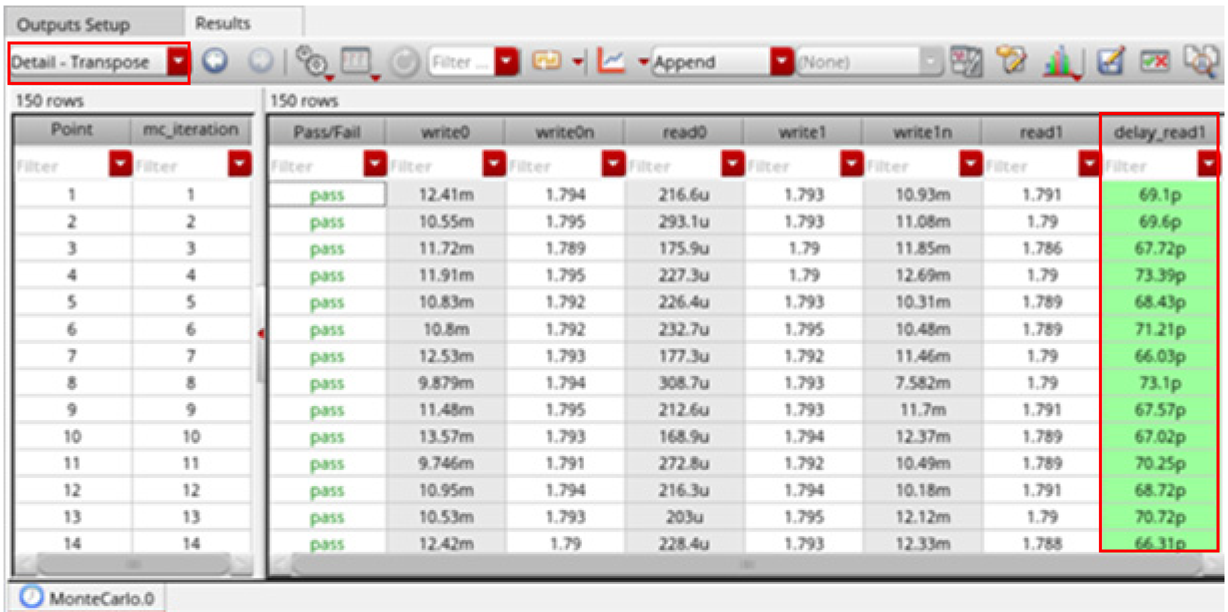
13. In the *Results* tab, from the *Select the results view* drop-down list, select the *Detail –Transpose* view.

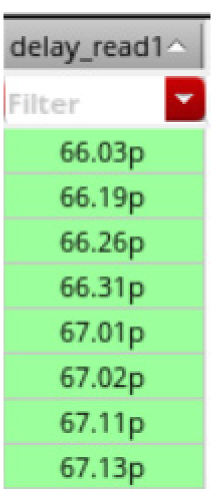
14. In the toolbar of the *Results* tab, click *Configure what is shown in the table* and deselect *Signals*.

The results are displayed in the *Detail – Transpose* view as follows.



15. Click the header of the output specification column to sort the values in the ascending order.

The values in the column are sorted,



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Related Topics

Fast Monte Carlo Method

Workflow of Fast Monte Carlo Method

Spectre FMC Analysis

Monte Carlo Form

Features Not Supported in the Fast Monte Carlo

The following features are not supported when you run the Fast Monte Carlo (FMC) method:

- ADE calibration features including pre-run scripts or `calcVal` expressions
- Reliability analysis
- Result reevaluation and rerun unfinished points
- History merging and reference history
- `MATLAB` output expressions
- The *Job Control Mode* field `ICRP`

  Note: The ADE job policy cannot be changed in the middle of an FMC run because the *Max Jobs* field is set at the start of the run.

Related Topics

Fast Monte Carlo Method

Workflow of Fast Monte Carlo Method

Running the Fast Monte Carlo Method

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4

Yield Verification

The accuracy of the yield estimate from a Monte Carlo run increases by simulating a large number of samples. However, running a large number of simulations can consume a lot of time and resources for large designs. You can perform one of the following yield verification methods to estimate the yield during the Monte Carlo analysis. These methods can be run when the target yield less than 4 sigma.

- Yield Verification - Autostop

  This method is used to automatically identify the appropriate number of samples for Monte Carlo analysis to simulate based on a target yield estimate. The Monte Carlo run will stop automatically without running additional simulations as soon as it can be determined that the yield is above or below the target.

  For more information about the Yield Verification - Autostop method, see Performing Yield Verification in *Virtuoso ADE Explorer User Guide*.

- Yield Verification - Reorder Samples

  This method is available only when you have the Virtuoso Variation Option (VVO) license. To verify the yield, you require a large number of samples when the yield is above or slightly below the target. For example, when verifying a 3-sigma target with confidence value 90 percent, the run can be stopped if the first 1800 samples (approximately) pass the specification. The sample reordering method helps you verify the yield without simulating such a large number of samples.

These yield estimation methods are used only when the sigma value is equal to 3. For higher sigma values, you can use either the Scaled-Sigma Sampling (SSS) method or the Worst-Case Distance (WCD) method.

Related Topics

Workflow of the Yield Verification - Reorder Samples Method

Running the Yield Verification - Reorder Sample Method

The Scaled-Sigma Sampling Method

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The Worst-Case Distance Method

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Workflow of the Yield Verification - Reorder Samples Method

In the Yield Verification - Reorder Samples 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.

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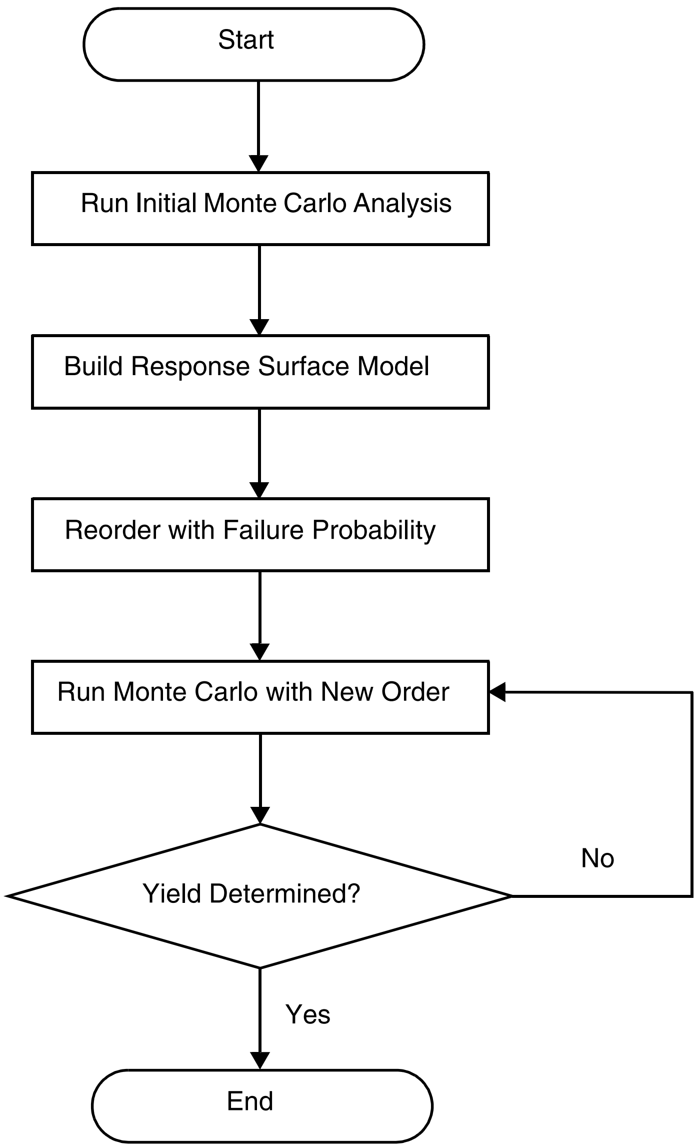
The following figure shows the workflow of this method.



Related Topics

Yield Verification

Running the Yield Verification - Reorder Sample Method

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Running the Yield Verification - Reorder Sample Method

Before you run the *Yield Verification -Reorder Sample* method, ensure that the following environment variable is set to `t`:

```
envSetVal("maestro.monte" "showMethodYieldVerificationReorderSamples" 'boolean t)
```

To verify yield using the Yield Verification - Reorder Sample method:

1. Open your design in ADE Assembler or ADE Explorer.
2. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
3. Click the *Simulation Options* command.

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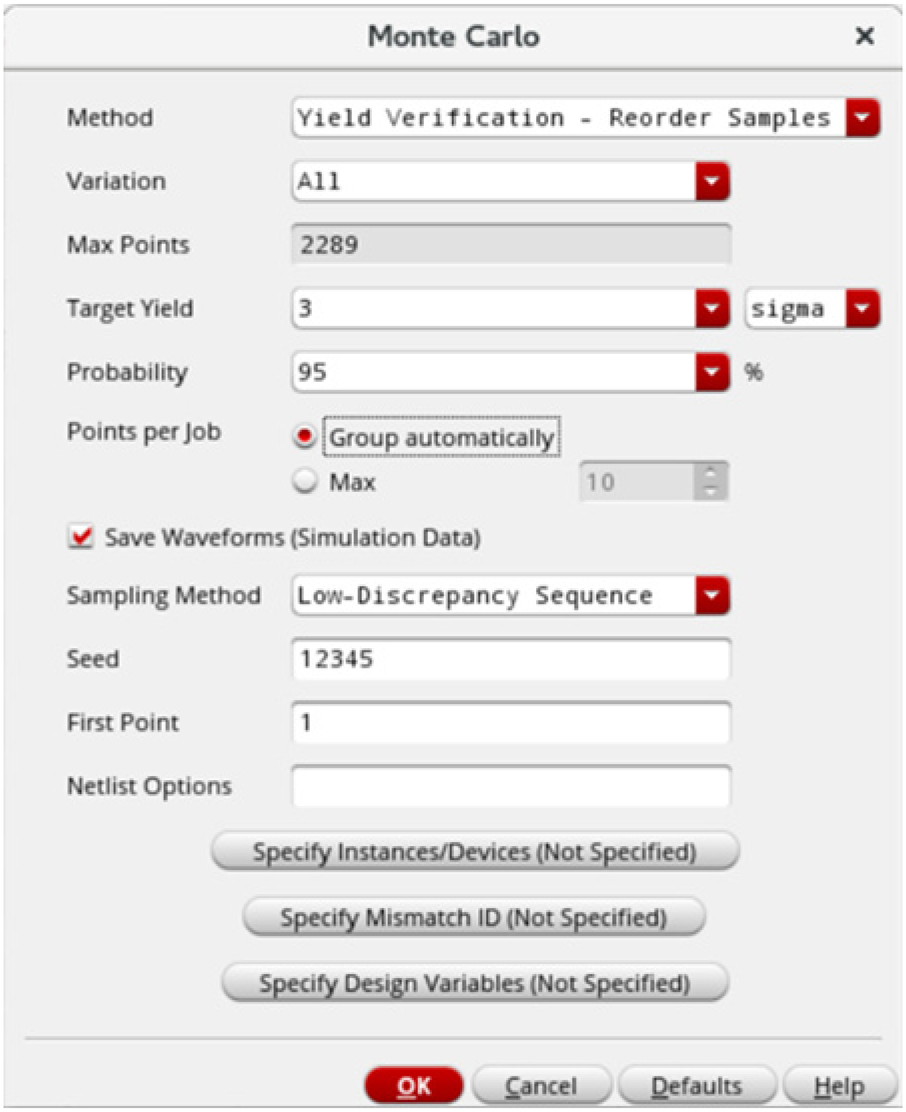
The Monte Carlo form opens.



4. From the Method drop-down list, select *Yield Verification - Reorder Sample*.
5. From the *Variation* drop-down list, select *Process*, *Mismatch*, or *All*.
6. The *Max Points* field shows the maximum number of points that will be run.

   This value depends on both the *Target Yield* and *Probability*. The number of simulations required is typically much smaller.
7. In the *Target Yield* field, specify the yield value that you want to achieve for your design. The target yield can be specified in either sigma or percentage
8. In the *Probability* field, select a probability percentage value.

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9. 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 require less simulations before autostop is triggered. The default value is 95%.

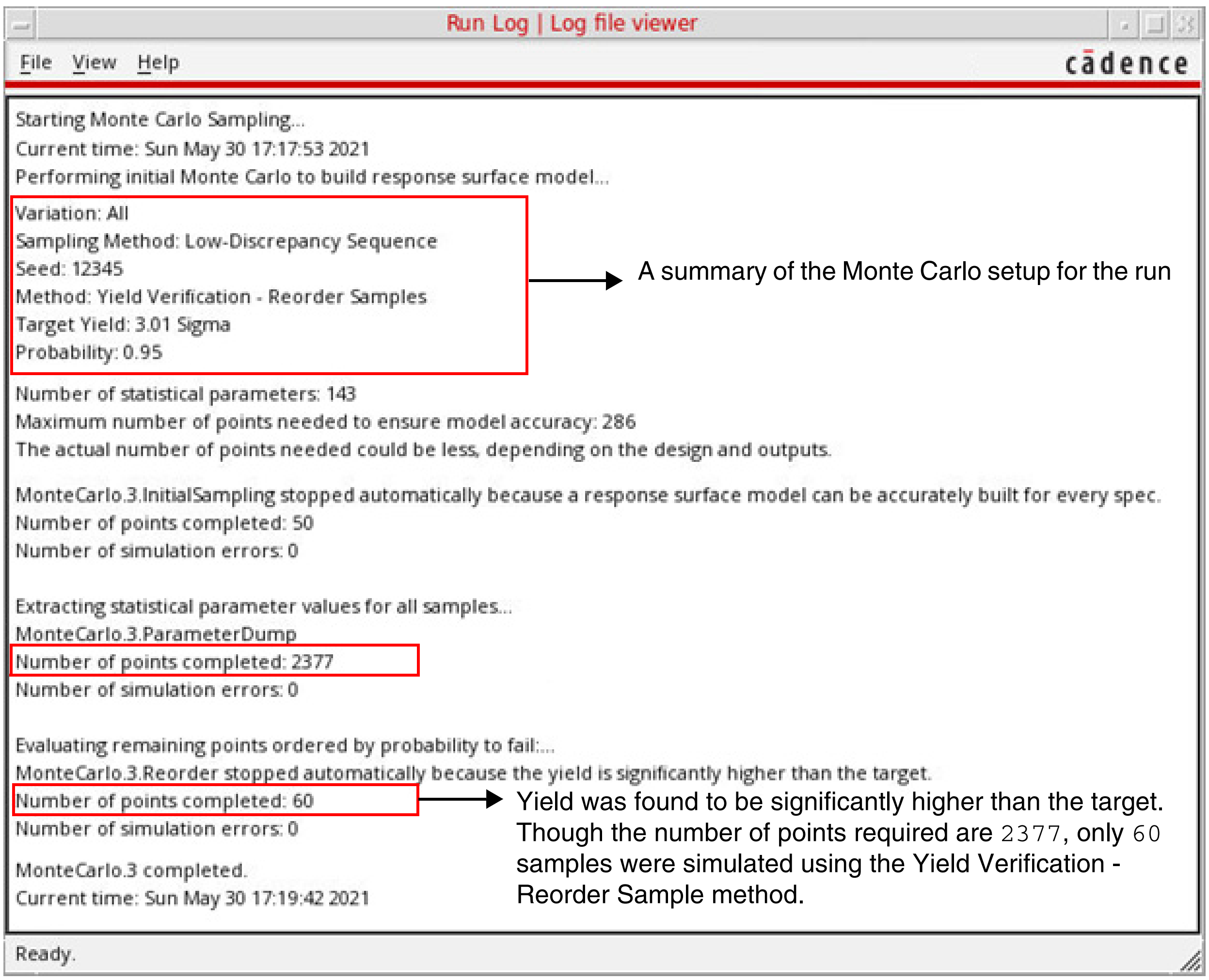
10. Select the *Save Waveform (Simulation Data)* check box to save the waveform data so that it can be used later for post-processing.

11. From the *Sampling Method* drop-down list, select *Random* or *Low-Discrepancy Sequence*.

12. Click *OK* to close the Monte Carlo form.

13. Click *Run Simulation* to run the *Yield Verification - Reorder Sample* method.

The Run Log reports the following information.



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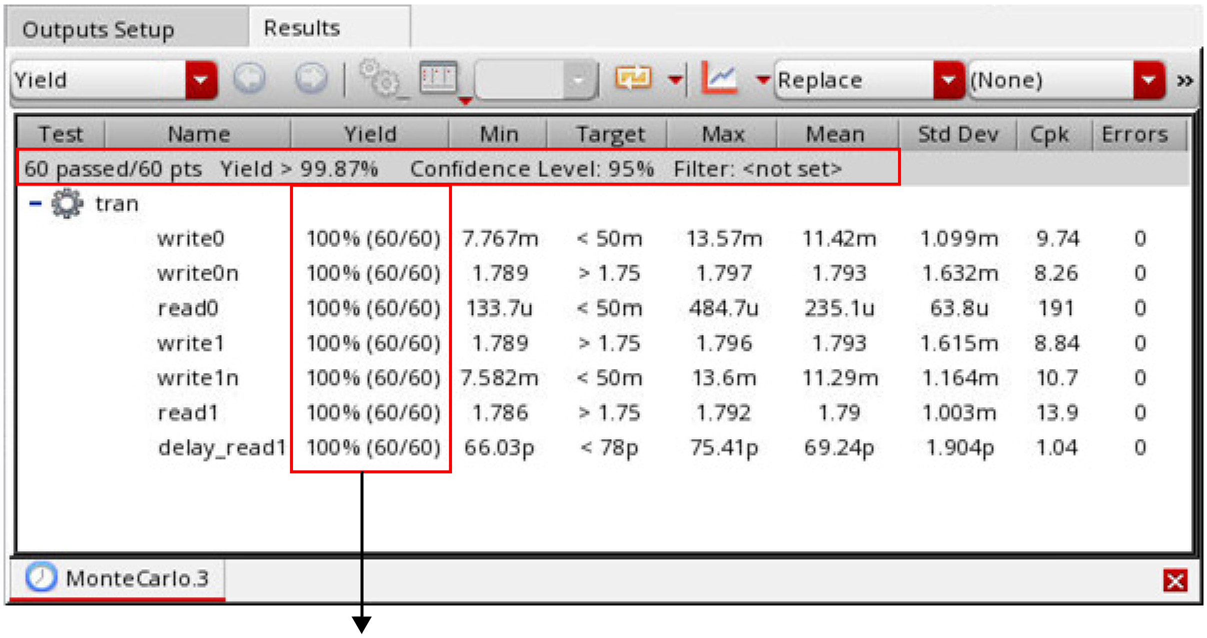
The *Yield* view of the *Results* tab displays the results of the Monte Carlo run for the Yield Verification - Reorder Sample method.



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

Related Topics

Monte Carlo Form

Statistical Sampling Methods

Yield Verification

Workflow of the Yield Verification - Reorder Samples Method

showMethodYieldVerificationReorderSamples

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5

Statistical Corner Creation

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 use them in further analysis and design optimization. Statistical corners contain the simulation settings needed to recreate the statistical variable values for a specific condition. Statistical corners apply to a particular measurement or specification.

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

- K-Sigma Corners

  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).

- Worst Samples

  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 Samples 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).

Related Topics

The K-Sigma Corners Method

The Worst Samples Method

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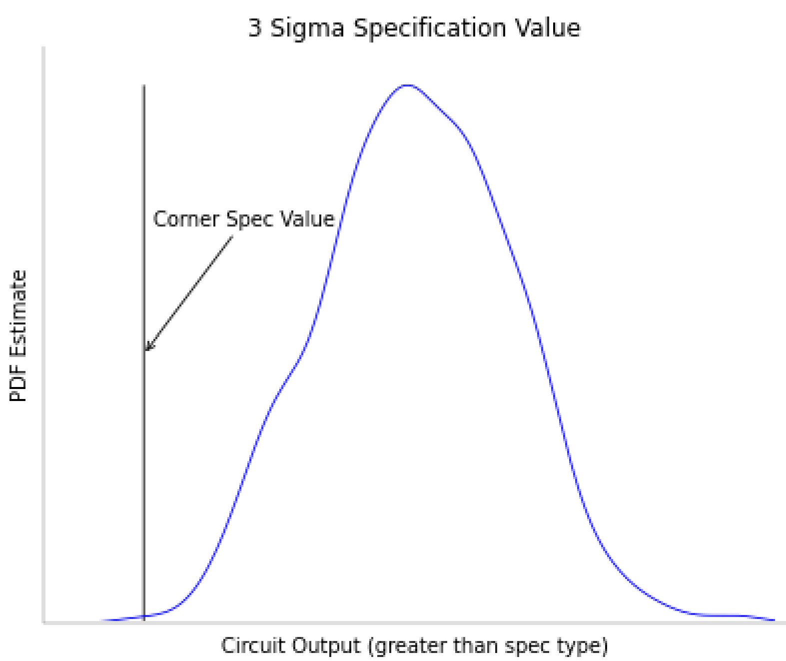
The K-Sigma Corners Method

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.

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.



This method is recommended if you prefer speed to accuracy.

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

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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%.

Related Topics

Workflow of the K-Sigma Corners Method

Running the K-Sigma Corners Method

Workflow of the K-Sigma Corners Method

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 (WCC) 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).

   A 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 a 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 specification.

Related Topics

The K-Sigma Corners Method

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Running the K-Sigma Corners Method

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Running the K-Sigma Corners Method

Before you run the *K-Sigma Corners* method, ensure that the following environment variable is set to `t`:

```
envSetVal("maestro.monte" "showMethodKSigmaCorners" 'boolean t)
```

To create statistical corners using the K-Sigma Corners method:

1. Open your design in ADE Assembler or ADE Explorer.
2. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
3. Click the *Simulation Options* command.

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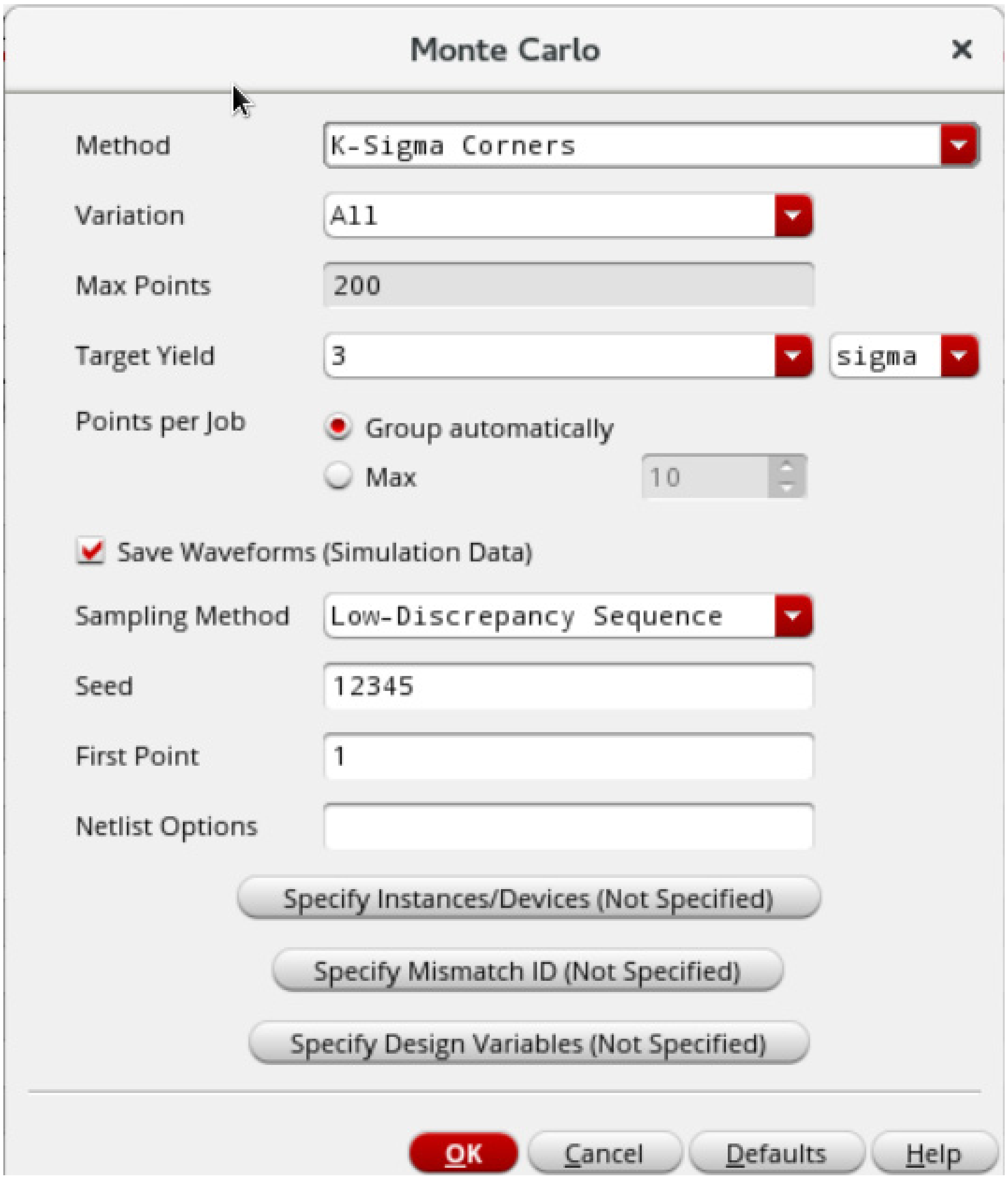
The Monte Carlo form opens.



4. From the *Method* drop-down list, select *K-Sigma Corners*.
5. From the *Variation* drop-down list, select *Mismatch*, *Process*, or *All*.
6. The *Max Points* field shows the maximum number of points to be simulated.

   This field is set to `200` points for the *K-Sigma Corners* method.

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7. Select the *Save Waveform (Simulation Data)* check box to save the waveform data so that it can be used later for post-processing.
8. From the *Sampling Method* drop-down list, select *Random* or *Low-Discrepancy Sequence*.
9. Click *OK* to close the Monte Carlo form.
10. Click *Run Simulation* to run the simulation.

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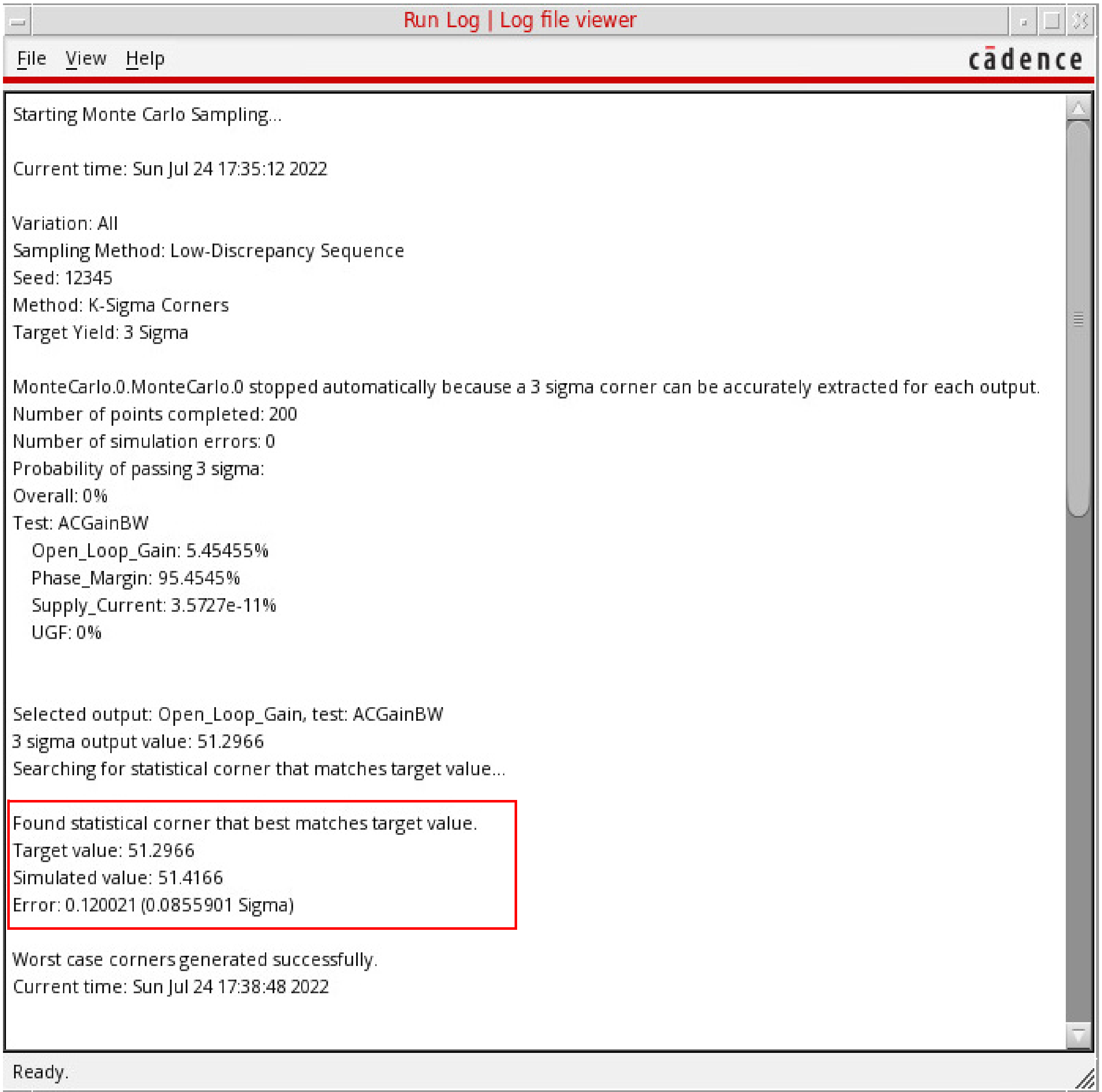
The Run Log reports both the estimated K-Sigma value of the specification (based on the PDF) and the simulated value of the corner.



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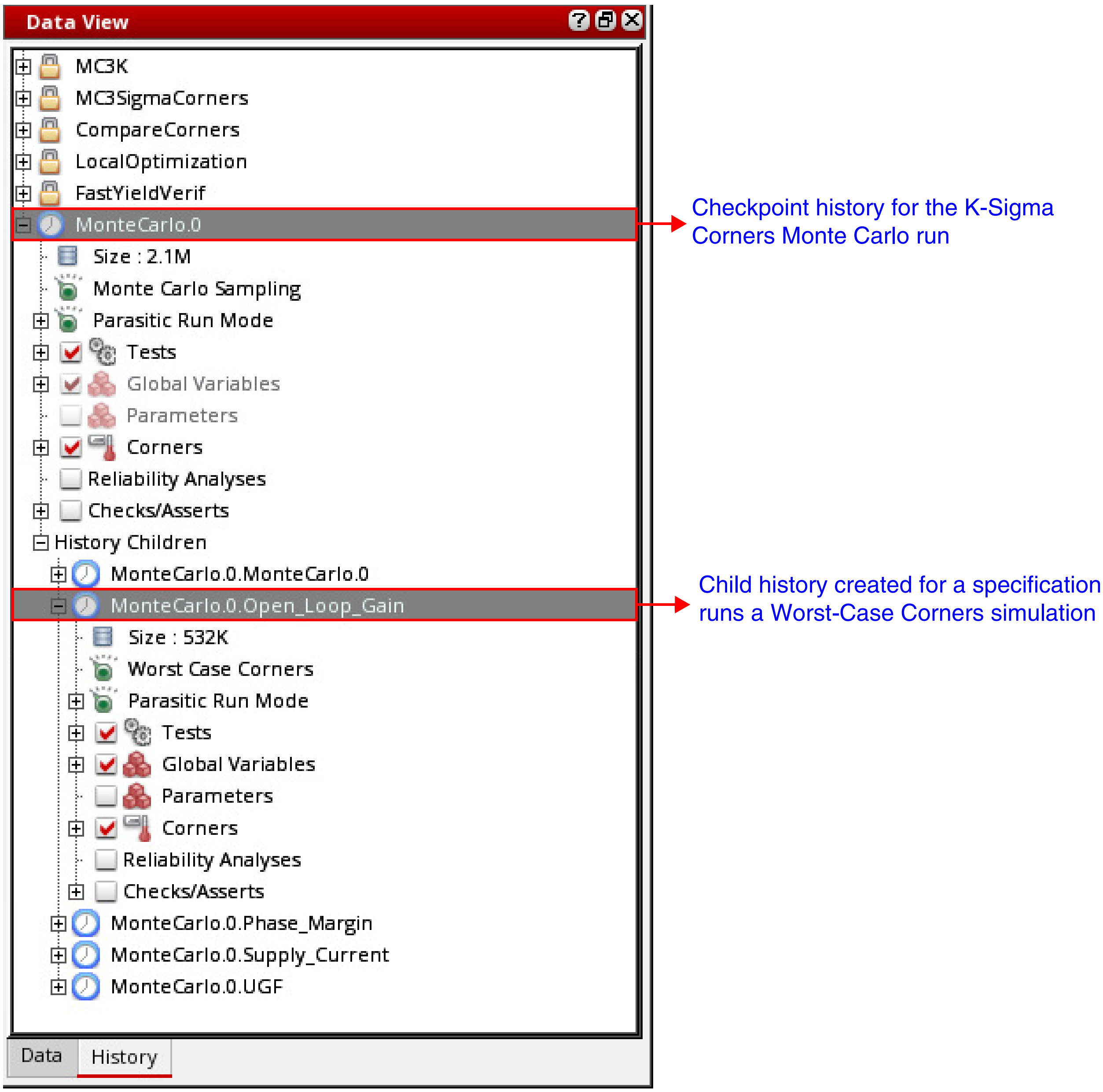
Example

When you run the K-Sigma Corners method with target yield set to *3 sigma*, the *MonteCarlo.N* and its child histories are created for each specification 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.

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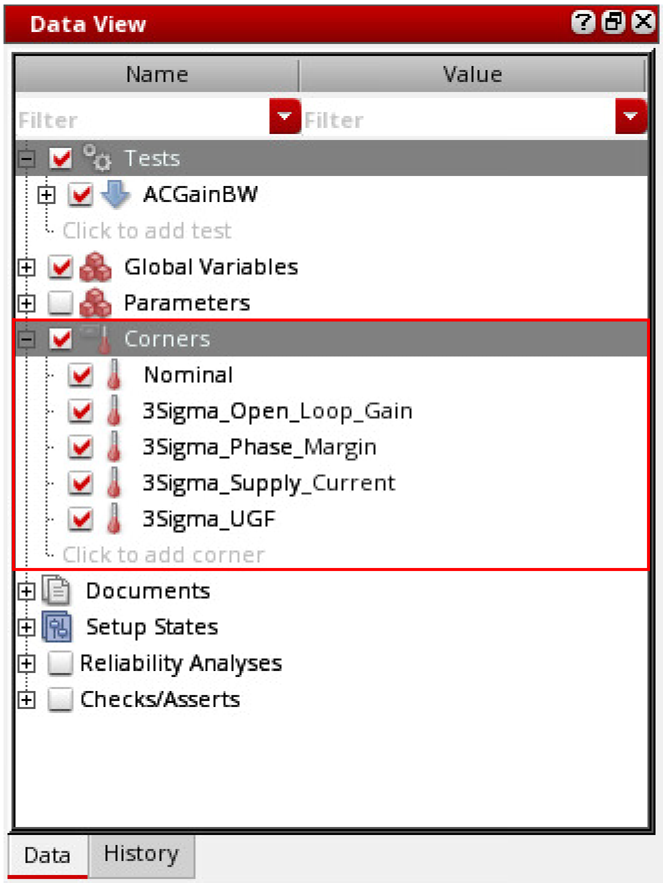
After worst-case corners are created for all the specifications, the simulation creates 3-sigma statistical corners for each specification. These corners are displayed in the Data View assistant and the Corners Setup form:



The K-Sigma statistical corners are named as `K`*Sigma_*`specification_Name`, where K is the specified sigma value. For example, the sigma value in this example is `3`; therefore, the K-Sigma corner names are *3Sigma_*`specification_name`.

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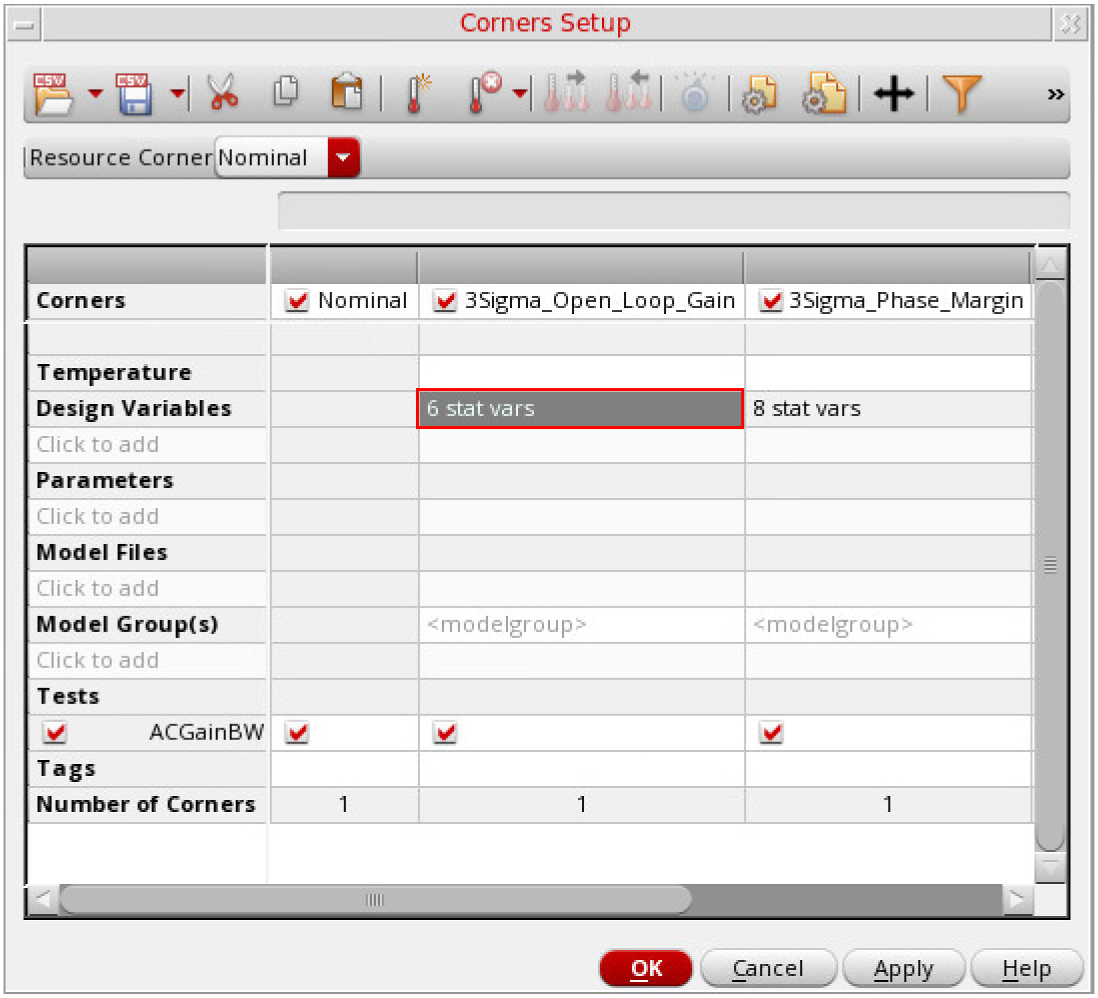
You can view the details of statistical parameters that are used to create a K-Sigma corner by double-clicking the cell in the *Design Variables* row under the column for that corner in the Corners Setup form.



On the *Results* tab, two tabs are displayed at the bottom for this Monte Carlo simulation run—*MonteCarlo*.*N* and *MonteCarlo*.*N*.*specification_name*, where *MonteCarlo*.*N*

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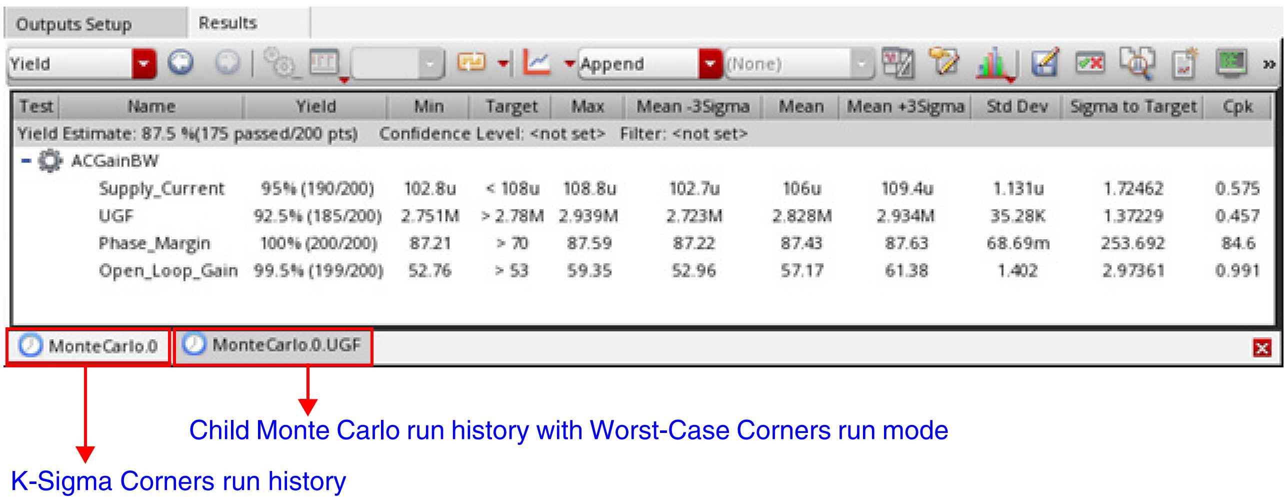
is the history for the K-Sigma Corners run and *MonteCarlo*.*N*.*specification_name* is the child history for the Worst-Case Corners run for the last specification in the setup.



You can simulate the design over the generated statistical corner for further analysis or design tuning.

Related Topics

Monte Carlo Form

Statistical Sampling Methods

The K-Sigma Corners Method

Workflow of the K-Sigma Corners Method

showMethodKSigmaCorners

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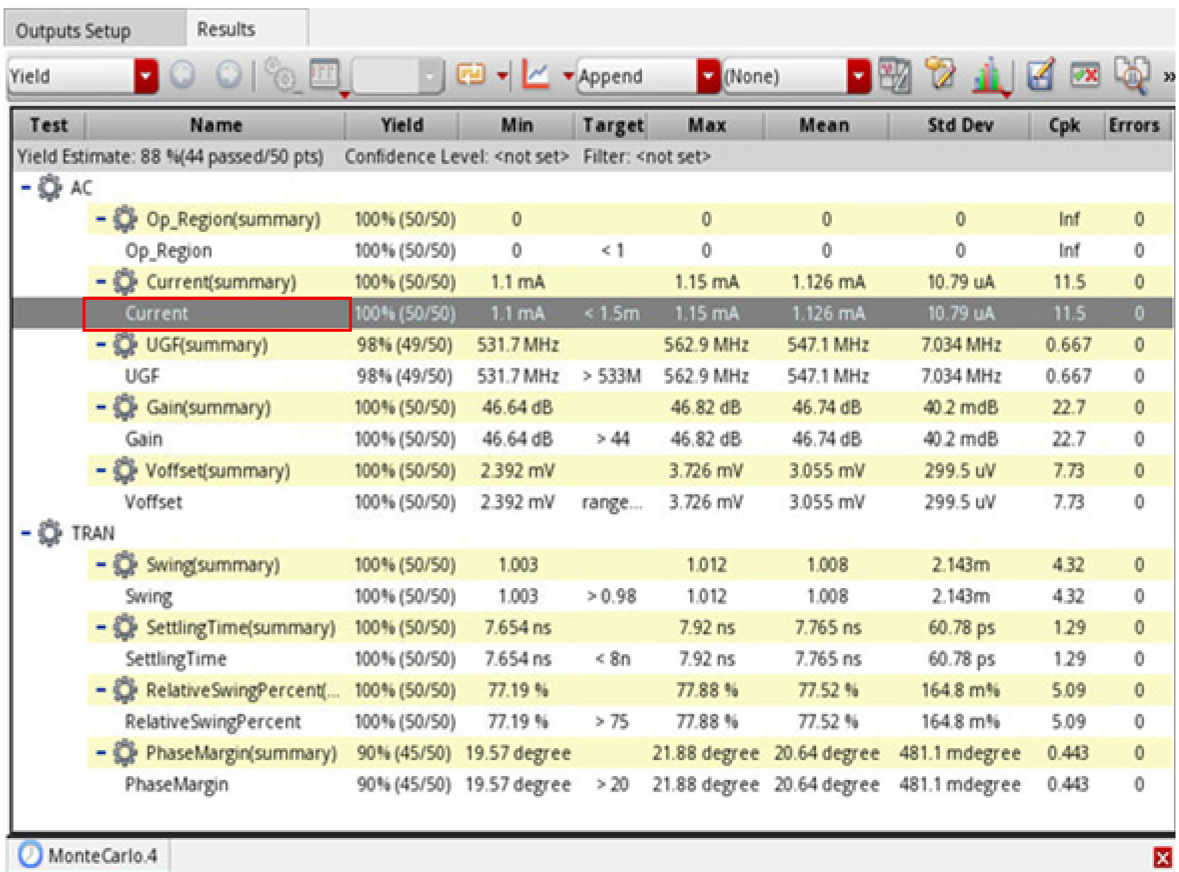
Creating K-Sigma Corners from a Standard Monte Carlo Run

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

To create K-Sigma statistical corners from a standard Monte Carlo simulation:

1. On the *History* tab of the Data View assistant, right-click the history for the Monte Carlo run for which you want to create K-Sigma corners, and then click *View Results*.

   The results of the Monte Carlo run are displayed in the *Yield* view of the *Results* tab.



2. Right-click a specification for which you want to create K-Sigma corners and then choose *Create Statistical Corner (Specify Yield in Sigma)*.

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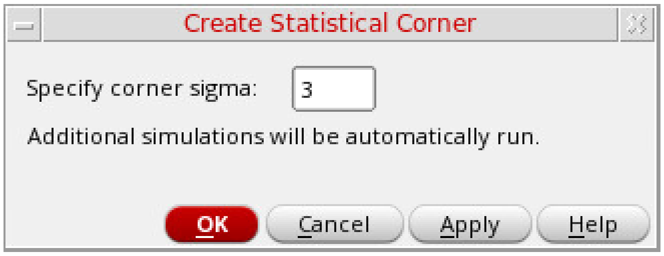
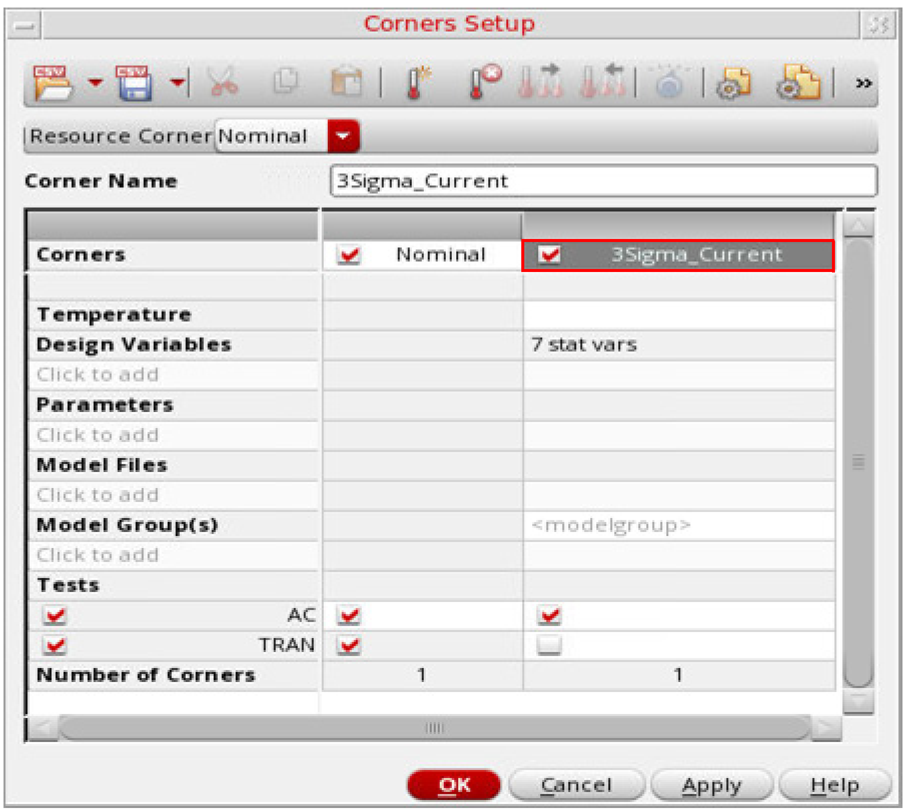
The Create Statistical Corner form opens.



3. In the *Specify corner sigma* field, enter a sigma value less than four. The default is *3*.
4. Click *OK* to close the form.

An additional simulation is run. After the simulation is complete, the K-Sigma corner created for the specification is displayed in the Corners Setup form.



The K-Sigma corner is named as `N`*Sigma_*`specification_name`, where `N` is the sigma value that you specified in the Create Statistical Corner form. For the sigma value `3` and the specification `Current`, the name of the corner is *3Sigma_Current*.

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Related Topics

The K-Sigma Corners Method

Workflow of the K-Sigma Corners Method

Running the K-Sigma Corners Method

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Displaying Mean K-Sigma and Median Columns in the Yield View

When you run a Monte Carlo simulation, the *Mean -3Sigma*, *Mean +3Sigma*, and *Median* columns are not displayed in the *Yield* view by default.

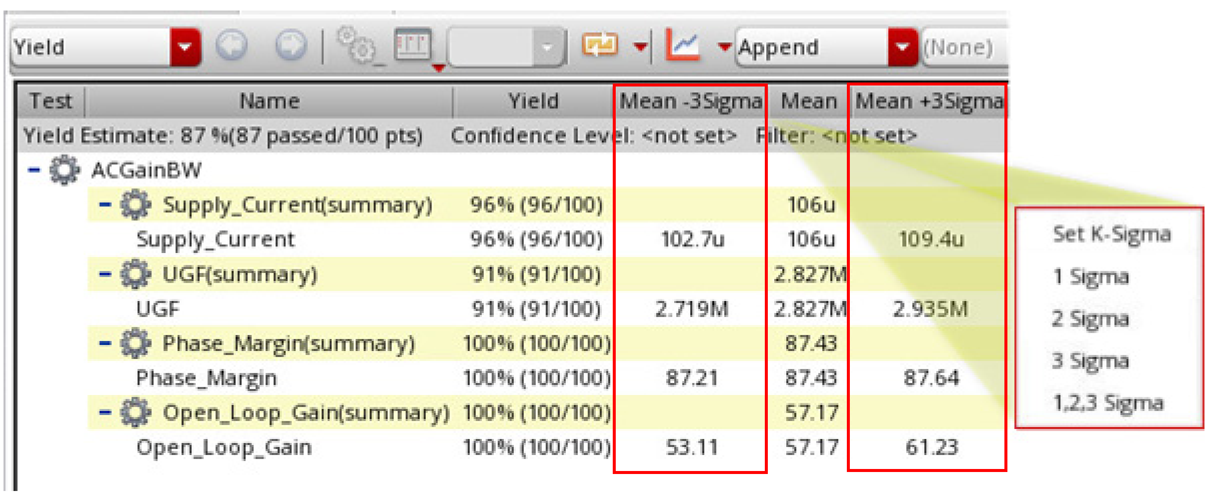
To display mean ±K-Sigma and *Median* columns in the *Yield* view:

1. In the *Yield* view of a Monte Carlo result, click *Configure what is shown in the table* and choose *Mean +- K-Sigma,* and *Median*.

   Alternatively, you can also set the following environment variable to display mean ±K-Sigma columns.

```
envSetVal("adexl.gui" "yieldViewShowDefault" 'string "\"Min\" \"Target\"
\"Max\" \"Mean\" \"Median\" \"Std Dev\" \"Cpk\" \"Errors\" \"User-Defined
Columns\" \"Mean +- K-Sigma\"")
```

   The *Mean -3Sigma* and *Mean +3Sigma* columns are displayed to the left and to the right of the *Mean* column.



2. Right-click either the *Mean -3Sigma* or the *Mean +3Sigma* column and choose one of the following options:

   - *1 Sigma*: Displays the *Mean -Sigma* and *Mean +Sigma* columns to the left and to the right of the *Mean* column.
   - *2 Sigma*: Displays the *Mean -2Sigma* and *Mean +2Sigma* columns to the left and to the right of the *Mean* column.
   - *3 Sigma*: Displays the *Mean -3Sigma* and *Mean +3Sigma* columns to the left and to the right of the *Mean* column.

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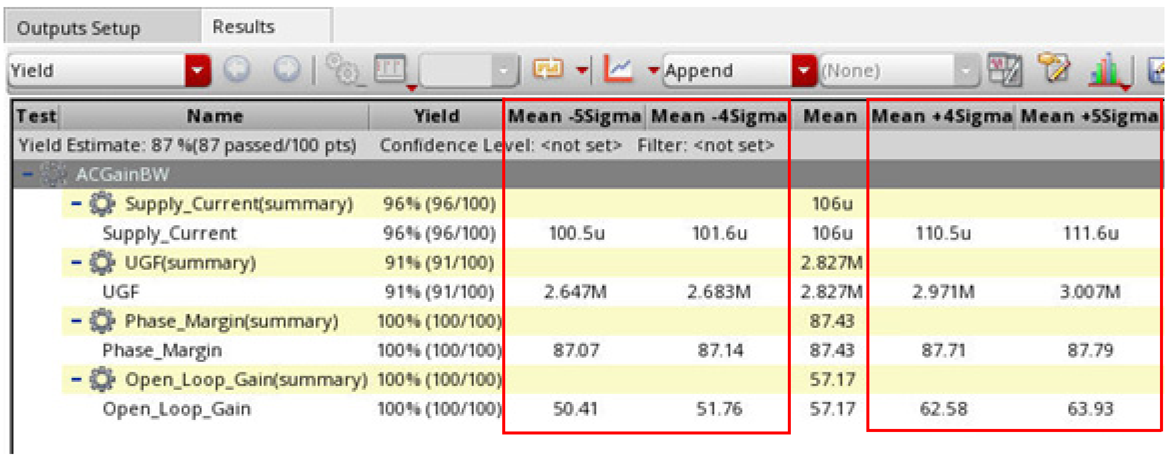
- ❑ *1,2,3 Sigma*: Displays the *Mean -3Sigma*, *Mean -2Sigma*, and *Mean -Sigma* columns to the left of the *Mean* column and *Mean +Sigma*, *Mean +2Sigma*, and *Mean +3Sigma* columns to the right of the *Mean* column.
- ❑ *Set K-Sigma*: Opens the Set K-Sigma form where you can specify the K-Sigma value or a list of K-Sigma values in the *K-Sigma* field.

  For example, if you specify `4,5` in this field, the *Mean -5Sigma* and *Mean -4Sigma* columns are displayed to the left of the *Mean* column and *Mean +4Sigma* and *Mean +5Sigma* columns are displayed to the right of the *Mean* column.



Test	Name	Yield	Mean -5Sigma	Mean -4Sigma	Mean	Mean +4Sigma	Mean +5Sigma
Yield Estimate: 87 %(87 passed/100 pts)		Confidence Level: <not set>		Filter: <not set>			
ACGainBW							
	Supply_Current(summary)	96% (96/100)			106u		
	Supply_Current	96% (96/100)	100.5u	101.6u	106u	110.5u	111.6u
	UGF(summary)	91% (91/100)			2.827M		
	UGF	91% (91/100)	2.647M	2.683M	2.827M	2.971M	3.007M
	Phase_Margin(summary)	100% (100/100)			87.43		
	Phase_Margin	100% (100/100)	87.07	87.14	87.43	87.71	87.79
	Open_Loop_Gain(summary)	100% (100/100)			57.17		
	Open_Loop_Gain	100% (100/100)	50.41	51.76	57.17	62.58	63.93

  You can also set the environment variable `yieldViewKSigma` to specify various K-Sigma values that you want to display as columns in the *Yield* view.

Related Topics

yieldViewKSigma

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The Worst Samples Method

In the Worst Samples 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. 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 running additional simulations before stopping. This method is recommended if you prefer accuracy to speed.

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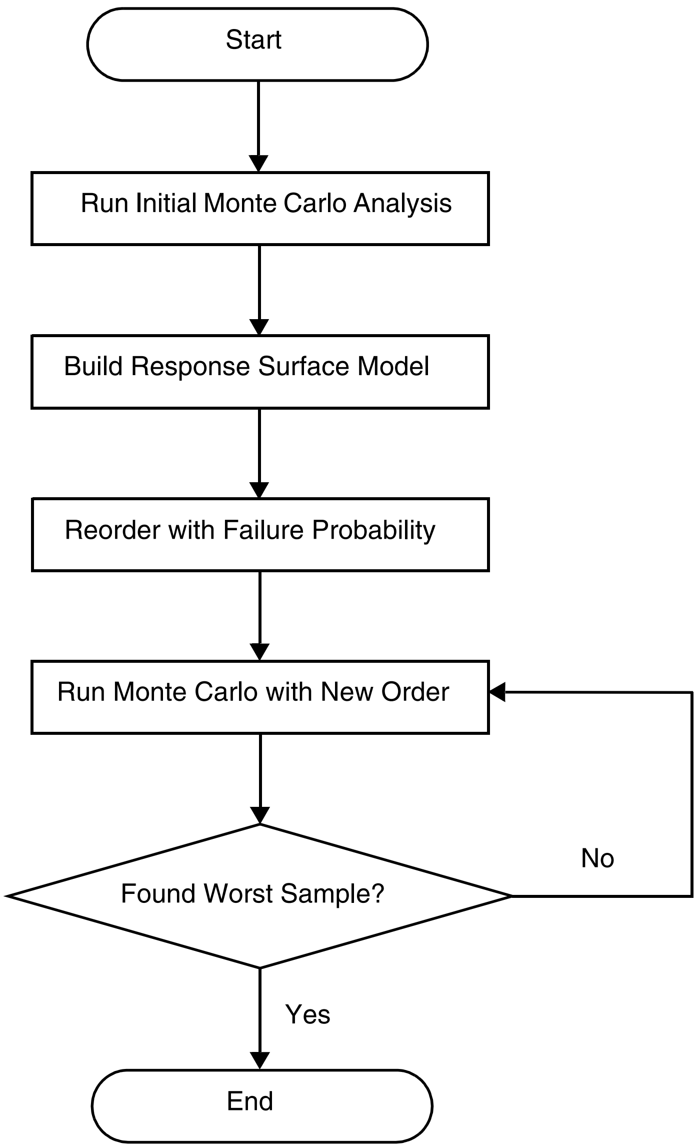
The following figure shows the workflow of the Worst Samples Method.



Related Topics

Running the Worst Sample Method

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Running the Worst Sample Method

Before you run the Worst Sample method, ensure that the following environment variable is set to `t`:

```
envSetVal("maestro.monte" "showMethodWorstSamples" 'boolean t)
```

To create statistical corners using the Worst Sample method:

1. Open your design in ADE Assembler or ADE Explorer.
2. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
3. Click the *Simulation Options* command.

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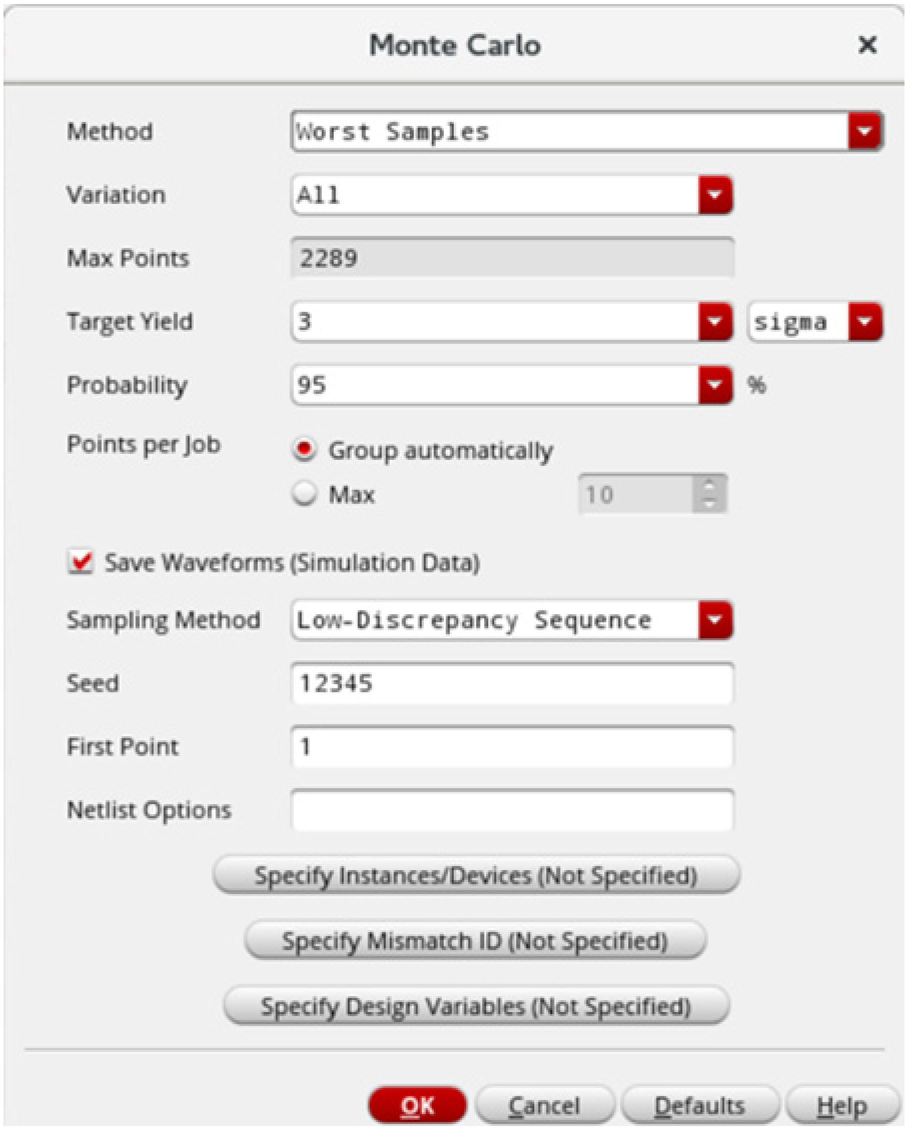
The Monte Carlo form opens.



4. From the *Method* drop-down list, select *Worst Samples*.

5. From the *Variation* drop-down list, select *Mismatch*, *Process*, or *All*.

6. The *Max Points* field shows the maximum number of points to be displayed.

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.

7. In the *Probability* field, specify the probability value (confidence level). The default probability is *95%*.

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8. Select the *Save Waveform (Simulation Data)* check box to save the waveform data so that it can be used later for post-processing.
9. From the *Sampling Method* drop-down list, select *Random* or *Low-Discrepancy Sequence*.
10. Click *OK* to close the Monte Carlo form.
11. Click *Run Simulation* to run the simulation.

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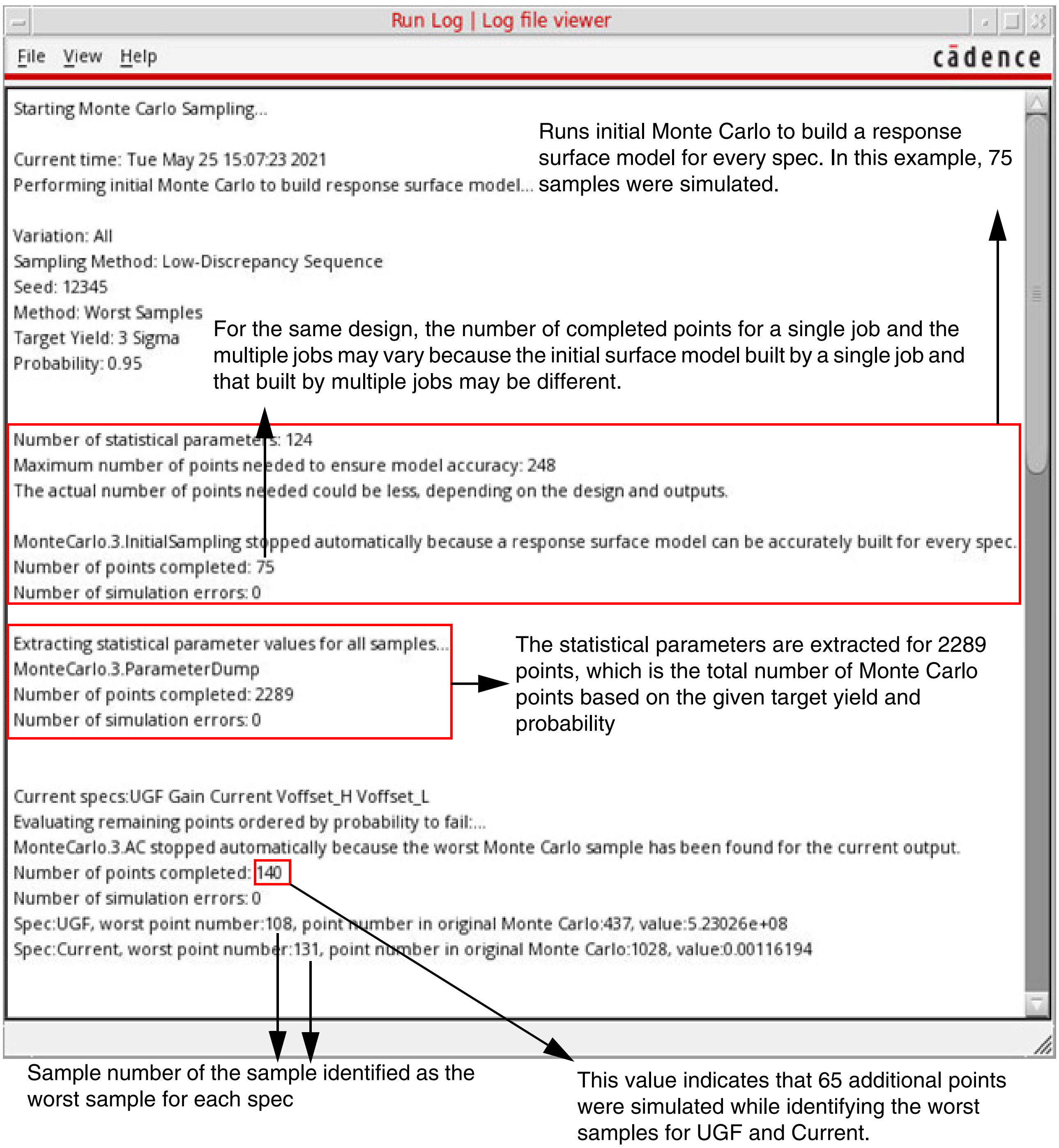
The simulation run first performs initial Monte Carlo to reorder samples and then runs the worst sample algorithm to generate the worst sample for each specification. The following run log is generated for this simulation run.



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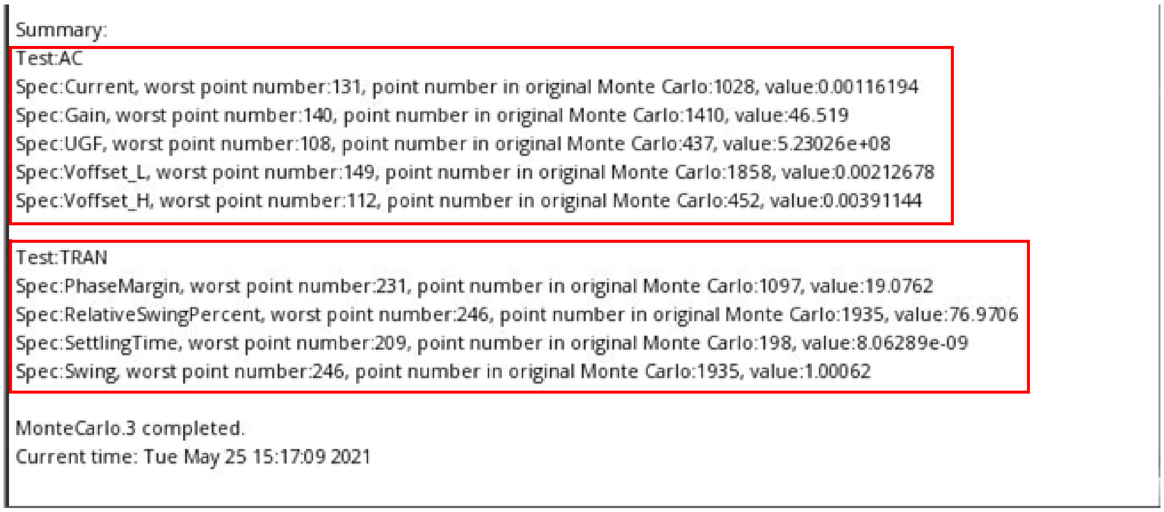
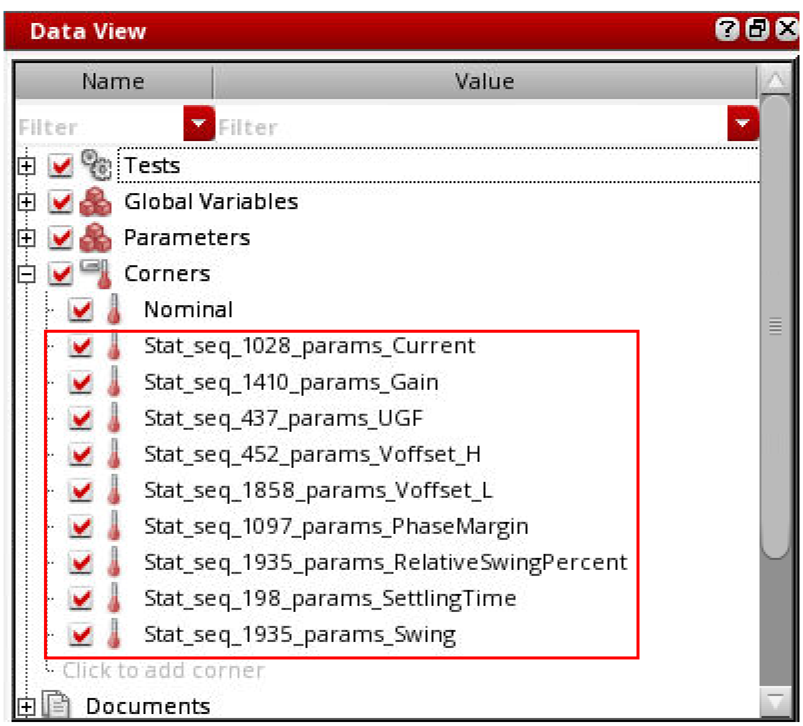
A comprehensive summary is added towards the end of the run log to show the worst samples for all the specifications together for each test.


Summary:
Test:AC
Spec:Current, worst point number:131, point number in original Monte Carlo:1028, value:0.00116194
Spec:Gain, worst point number:140, point number in original Monte Carlo:1410, value:46.519
Spec:UGF, worst point number:108, point number in original Monte Carlo:437, value:5.23026e+08
Spec:Voffset_L, worst point number:149, point number in original Monte Carlo:1858, value:0.00212678
Spec:Voffset_H, worst point number:112, point number in original Monte Carlo:452, value:0.00391144

Test:TRAN
Spec:PhaseMargin, worst point number:231, point number in original Monte Carlo:1097, value:19.0762
Spec:RelativeSwingPercent, worst point number:246, point number in original Monte Carlo:1935, value:76.9706
Spec:SettlingTime, worst point number:209, point number in original Monte Carlo:198, value:8.06289e-09
Spec:Swing, worst point number:246, point number in original Monte Carlo:1935, value:1.00062

MonteCarlo.3 completed.
Current time: Tue May 25 15:17:09 2021

A statistical corner is generated for each specification in the setup. These corners can be viewed in the Data View assistant and the Corner Setup form. The naming convention for these corners is *Stat_seq_`Worst_corner_number`_params_`Specification_name`*.



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Related Topics

Monte Carlo Form

Statistical Sampling Methods

The Worst Samples Method

showMethodWorstSamples

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6

The Confidence Interval - Autostop Method

The *Confidence Interval - Autostop* method automatically stops Monte Carlo analysis when the confidence interval for the output standard deviation divided by the output value range falls below the *Stop Percentage* value. The default *Stop Percentage* value is 5%.

In this method, you need not define number of sample points to run, target yield value, and specification targets because Monte Carlo run stops automatically when the stopping criteria is met, where stopping criteria is defined as follows:

$$\frac{(sigma_{\text{upper bound}} - sigma_{\text{lower bound}})}{(output_{\text{upper bound}} - output_{\text{lower bound}})} < \text{Stop Percentage}$$

The Monte Carlo run stops automatically after simulating all outputs satisfy the stopping criteria or after simulating the number of sample points specified in the *Max Points* field on the Monte Carlo form.

Decreasing *Stop Percentage* value results in increased number of points simulated.

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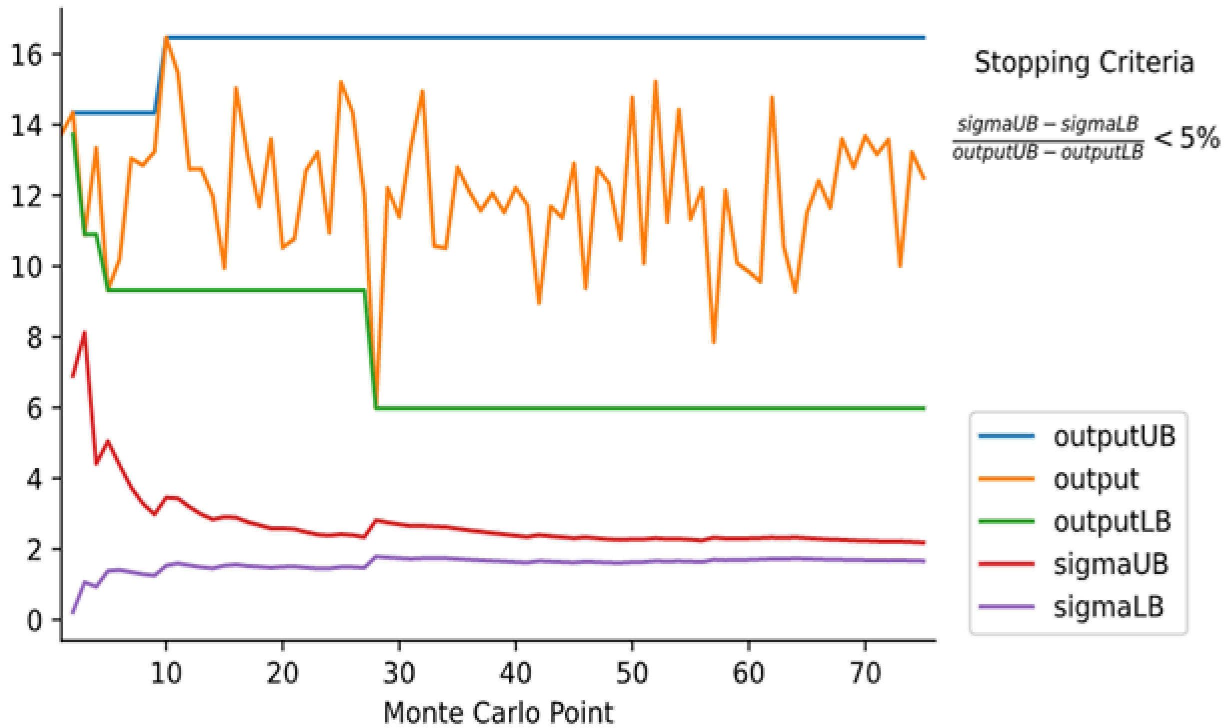
The following figure shows that for *Stop Percentage* = `5%`, the Monte Carlo run stops automatically after completing simulation of `75` sample points.



Note: This graphic is used only for reference to help you visualize how number of points completed vary with different values of *Stop Percentage*, *Confidence Leve*l, and *Confidence Sigma*. No such plot is actually generated in ADE Assembler or ADE Explorer.

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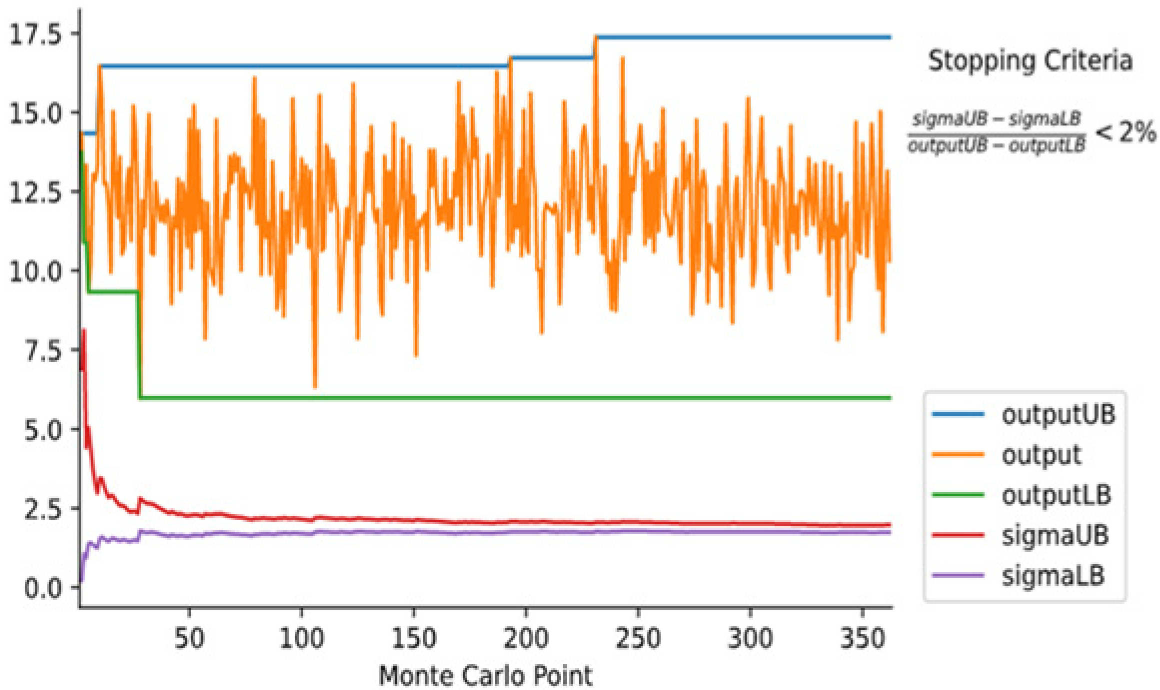
The following figure shows that for *Stop Percentage* = `2%`, the Monte Carlo run stops automatically after simulating `362` sample points.



Related Topics

Advanced Options of the Confidence Interval - Autostop Method

Outputs Supported by the Confidence Interval - Autostop Method

Running the Confidence Interval - Autostop Method

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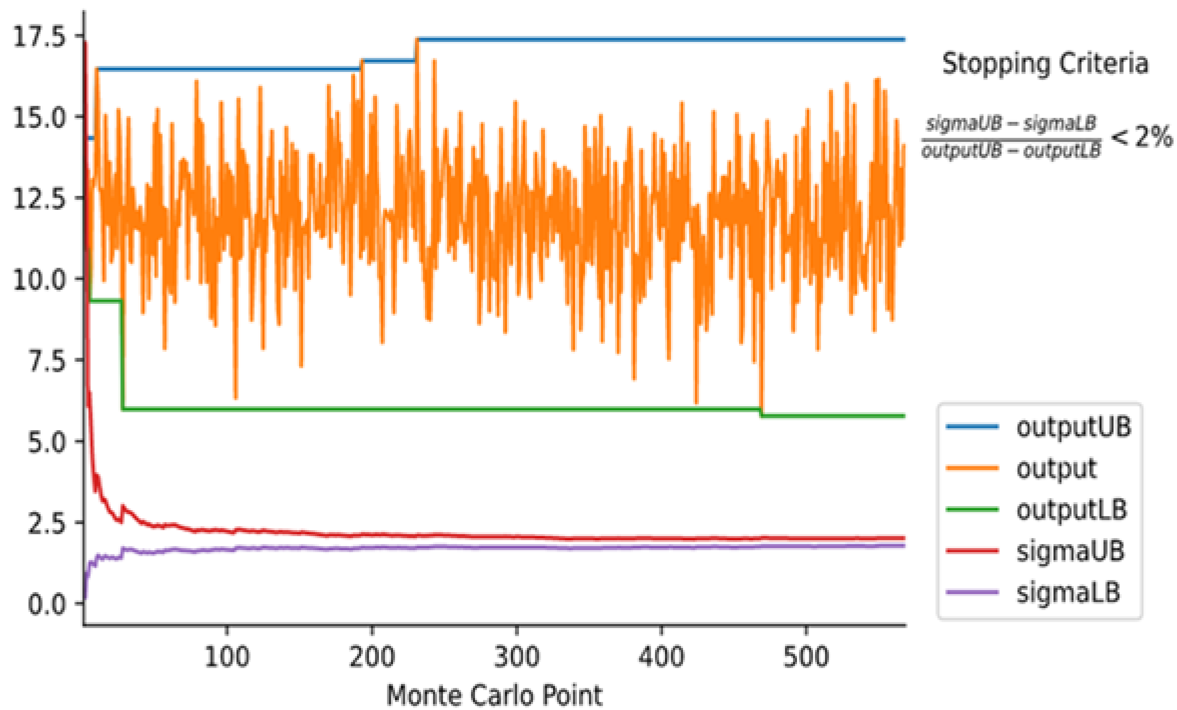
Advanced Options of the Confidence Interval - Autostop Method

Advanced options of the *Confidence Interval - Autostop* method are as follows:

- *Confidence Level*: Determines the confidence interval for the output standard deviation considered by the stopping criteria.

  Increasing *Confidence Level* results in increased number of points simulated.

  The following figure shows that the Monte Carlo run stops automatically after simulating `567` points for *Stop Percentage* `2%` and *Confidence Level* `98`.



- *Confidence Sigma*: Determines the range of output variations considered by the stopping criteria.

  Increasing *Confidence Sigma* results in decreased number of points, whereas decreasing *Confidence Sigma* results in increased number of points.

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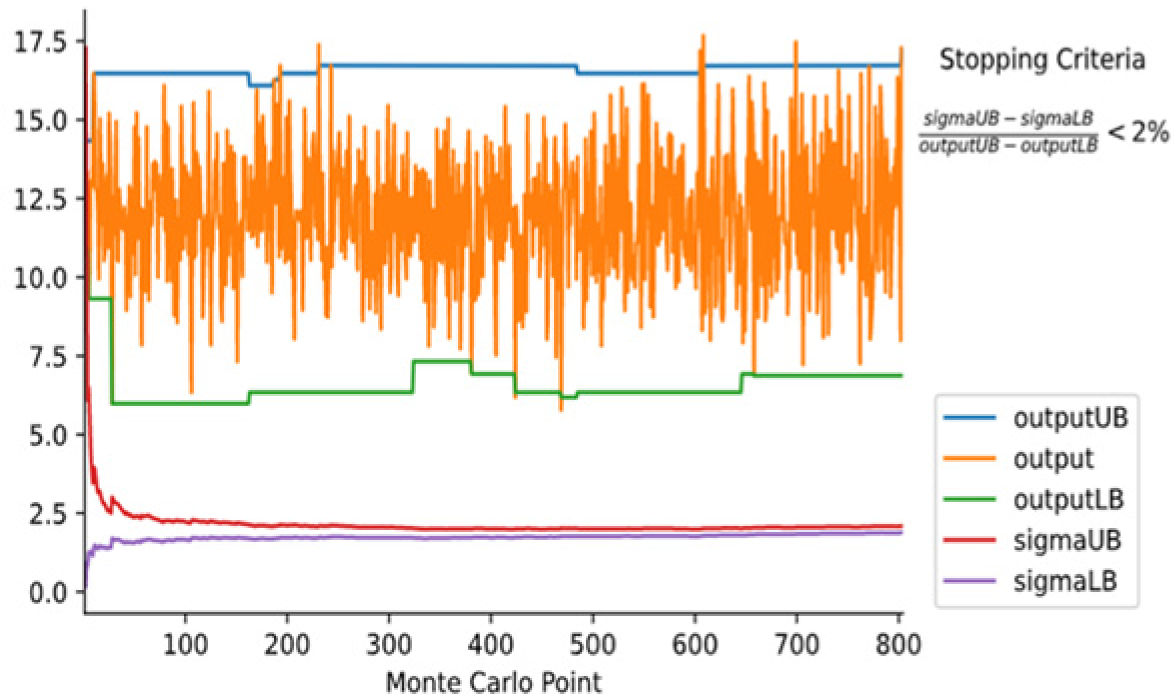
The following figure shows that the Monte Carlo run stops automatically after simulating `803` points for *Stop Percentage* = `2%`, *Confidence Level* = `98`, and Confidence Sigma = `2.5`.



Related Topics

[The Confidence Interval - Autostop Method]

[Outputs Supported by the Confidence Interval - Autostop Method]

[Running the Confidence Interval - Autostop Method]

[confidenceAutoStopLevel]

[confidenceAutoStopSigma]

[showConfidenceAutoStopLevel]

[showConfidenceAutoStopSigma]

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Outputs Supported by the Confidence Interval - Autostop Method

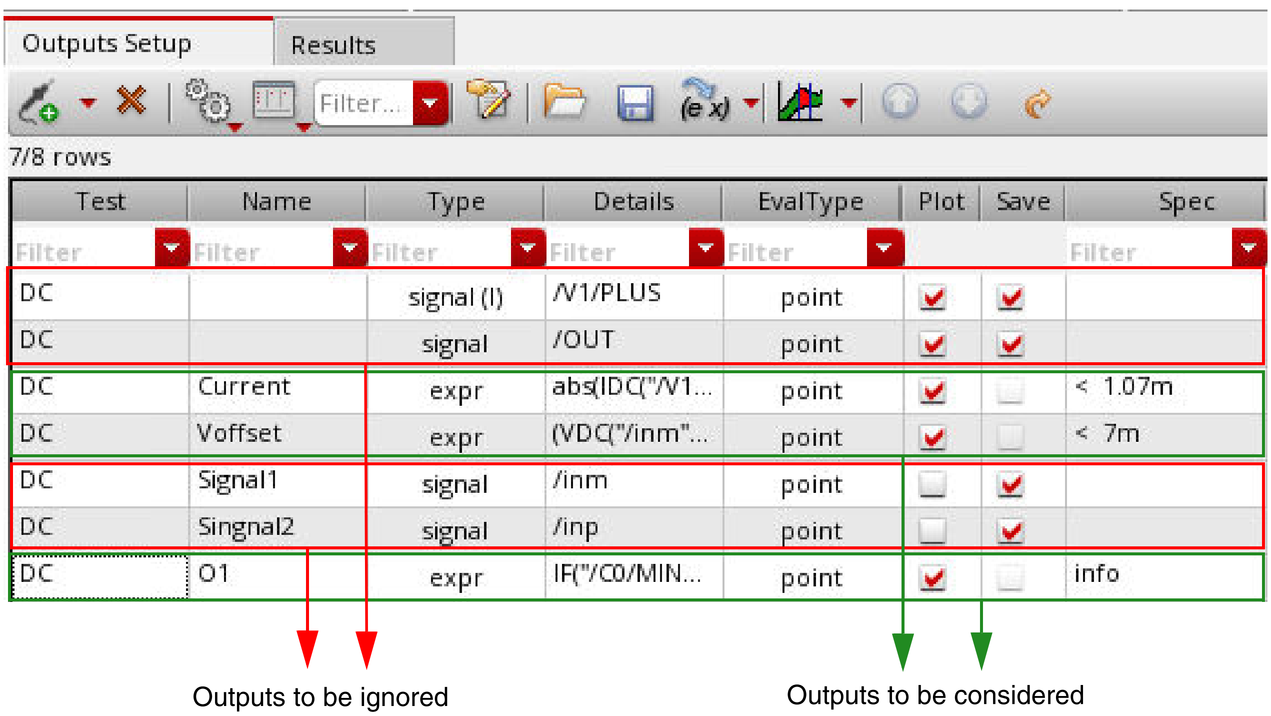
The following outputs are supported by the Confidence Interval - Autostop method:

- Outputs with specification type *info*. For such outputs, the specification target values are not required.
- Outputs with the following specification target values: *minimize*, *maximize*, <, >, *range*, and *tol*.

The following outputs are ignored by the Confidence Interval - Autostop method:

- Outputs with specification type *none*.
- Outputs that are disabled, that is, the outputs for which the *Plot* check box is not selected.

For example, outputs that are highlighted in green are considered and the outputs that are highlighted in red are ignored, as shown in the following outputs setup.



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Related Topics

The Confidence Interval - Autostop Method

Advanced Options of the Confidence Interval - Autostop Method

Running the Confidence Interval - Autostop Method

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Running the Confidence Interval - Autostop Method

Before you run the *Confidence Interval - Autostop* Method, ensure that the following environment variable is set to t:

```
envSetVal("maestro.monte" "showMethodCIAutoStop" 'boolean t)
```

To run the *Confidence Interval - Autostop* method:

1. Open your design in ADE Assembler or ADE Explorer.
2. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
3. Click the *Simulation Options* command.

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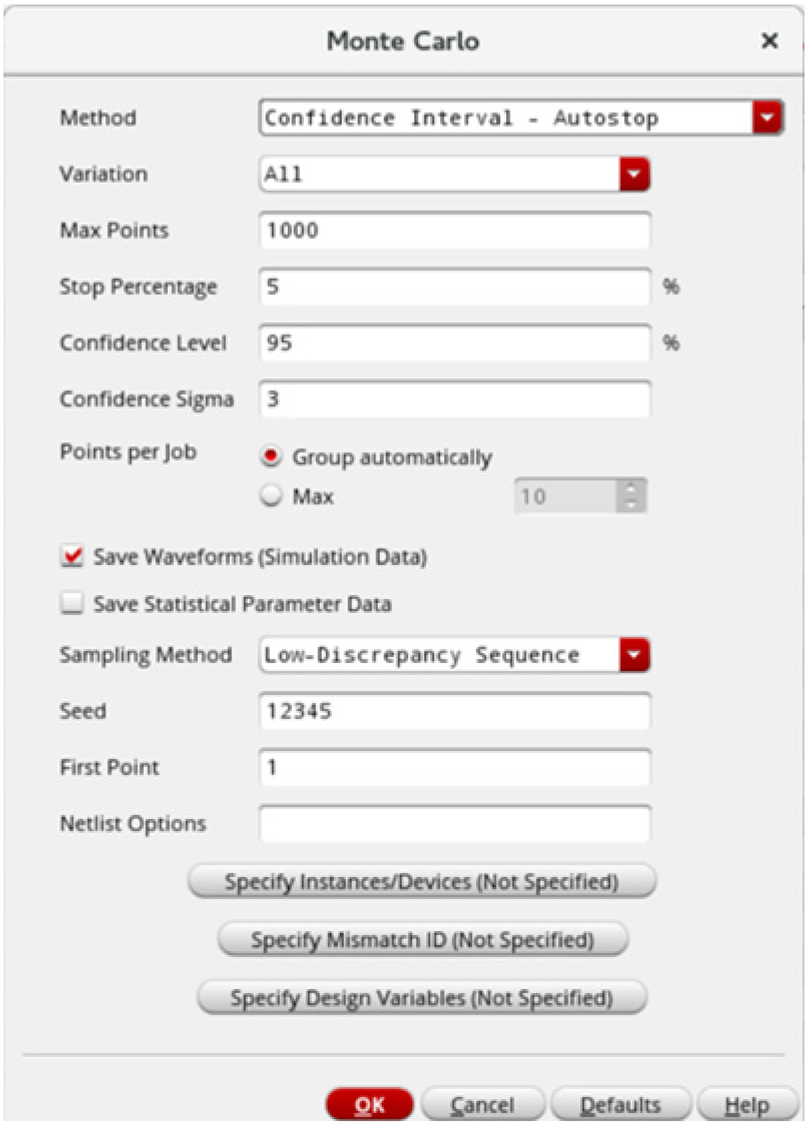
The Monte Carlo form opens.



4. From the *Method* drop-down list, select *Confidence Interval - Autostop*.
5. From the *Variation* drop-down list, select variation as *All*, *Mismatch*, or *Process*.
6. In the *Max Points* field, specify the maximum number of sample points to simulate.
7. In the *Stop Percentage* field, enter the percentage value of stopping criteria for the *Confidence Interval - Autostop* method. The default value is `5`.
8. In the *Confidence Level* field, specify confidence level for the output standard deviation considered by the stopping criteria.

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9. In the *Confidence Sigma* field, specify the confidence sigma value that controls the range of output variation considered by the stopping criteria.

   The *Confidence Level* and *Confidence Sigma* fields are hidden by default. You can set the showConfidenceAutoStopLevel and showConfidenceAutoStopSigmaenvironment variables to `t` to view them.

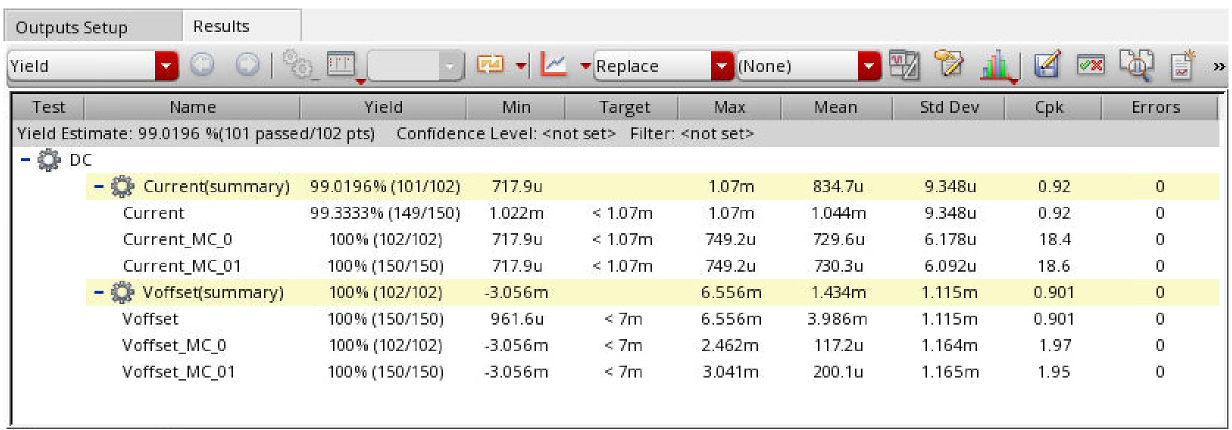
10. In the *Sampling Method* drop-down, select either *Random* or *Low-Discrepancy Sequence*.

11. Specify the other fields as required.

12. Click *OK* to close the Monte Carlo form.

13. Click *Run Simulation* to run the *Confidence Interval - Autostop* method.

The simulation results are displayed in the *Results* tab, as follows:



Test	Name	Yield	Min	Target	Max	Mean	Std Dev	Cpk	Errors
DC									
	Current(summary)	99.0196% (101/102)	717.9u		1.07m	834.7u	9.348u	0.92	0
	Current	99.3333% (149/150)	1.022m	< 1.07m	1.07m	1.044m	9.348u	0.92	0
	Current_MC_0	100% (102/102)	717.9u	< 1.07m	749.2u	729.6u	6.178u	18.4	0
	Current_MC_01	100% (150/150)	717.9u	< 1.07m	749.2u	730.3u	6.092u	18.6	0
	Voffset(summary)	100% (102/102)	-3.056m		6.556m	1.434m	1.115m	0.901	0
	Voffset	100% (150/150)	961.6u	< 7m	6.556m	3.986m	1.115m	0.901	0
	Voffset_MC_0	100% (102/102)	-3.056m	< 7m	2.462m	117.2u	1.164m	1.97	0
	Voffset_MC_01	100% (150/150)	-3.056m	< 7m	3.041m	200.1u	1.165m	1.95	0

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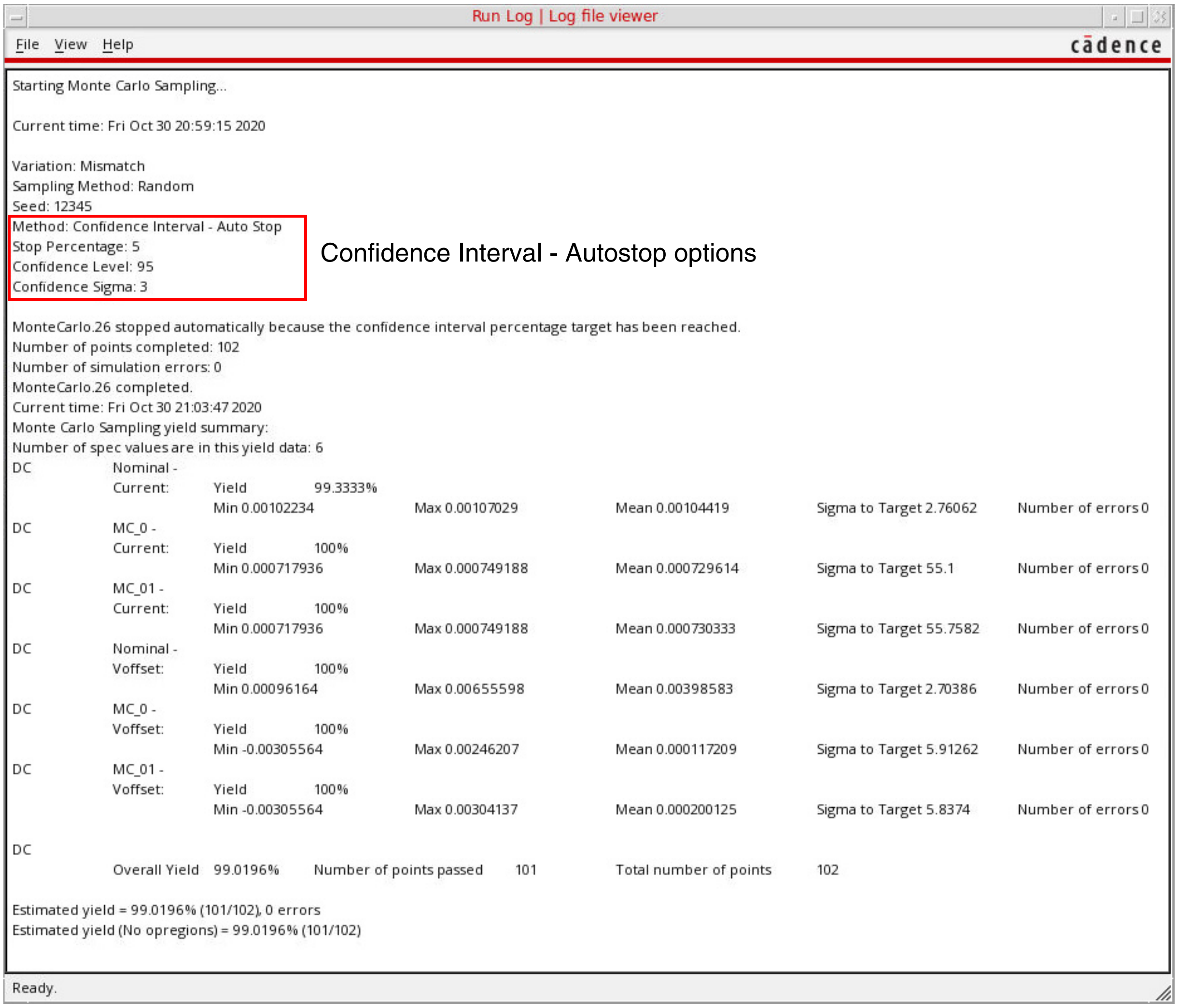
The run log is shown, as follows:



Related Topics

[Monte Carlo Form]

[showConfidenceAutoStopLevel]

[showConfidenceAutoStopSigma]

[Statistical Sampling Methods]

[The Confidence Interval - Autostop Method]

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[Advanced Options of the Confidence Interval - Autostop Method]

[Outputs Supported by the Confidence Interval - Autostop Method]

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7

High Yield Estimation

Parametric high yield estimation is required on devices that have extremely high volume, that is memory devices, or when testing the circuit limits is a must when failure of the part is not an option, for example, automotive safety or medical devices.

The Virtuoso Variation Option provides two methods of simulation to meet and match your needs and conditions:

- Scaled-Sigma Sampling (SSS)

  This method generates samples where the standard deviation has been scaled up.

- Worst-Case Distance (WCD)

  This method defines the shortest distance from the nominal point to the specification boundary in the process/mismatch parameter space.

Related Topics

The Scaled-Sigma Sampling Method

The Worst-Case Distance Method

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The Scaled-Sigma Sampling Method

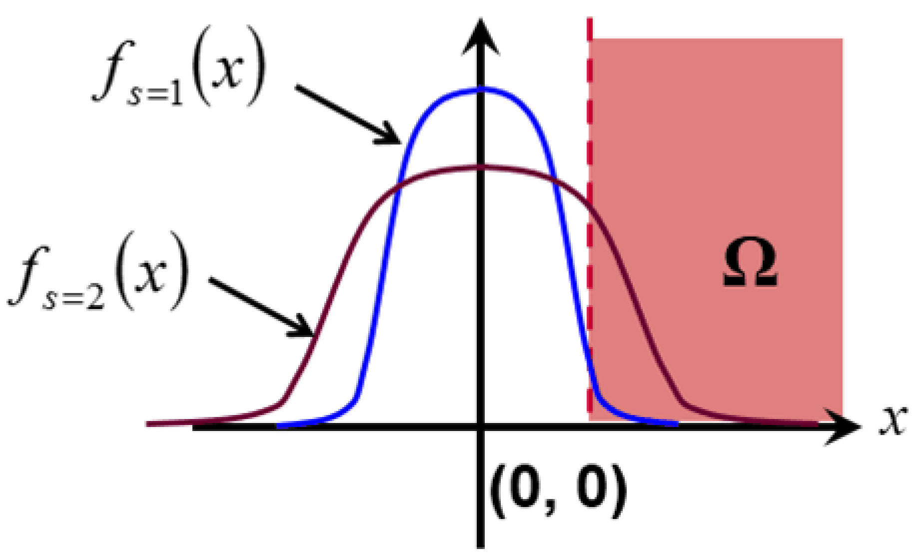
The Scaled-Sigma Sampling method generates samples where the standard deviation has been scaled up. This method is more accurate than the Worst-Case Distance method for nonlinear behavior and more efficient when there is a large number of statistical parameters and specifications. As a result, a larger number of samples fall into the failure region of the distorted distribution. The failure rate is then estimated from the scaled samples.

This method is selected by default when the yield is greater than 3 sigma.

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 Ω = failure region.

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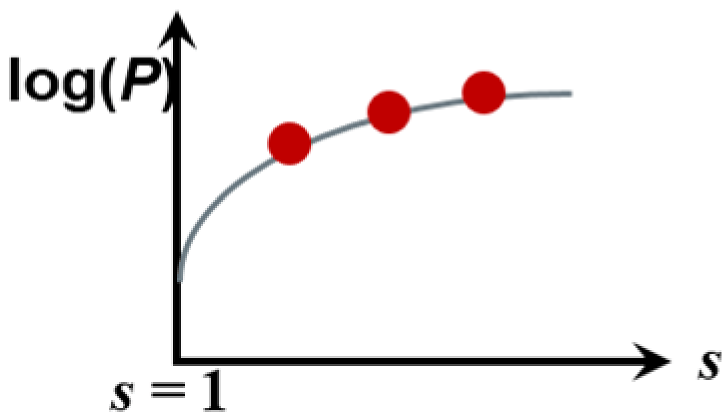
The failure rate can be calculated as:

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



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.

Related Topics

High Yield Estimation

Confidence Interval and Number of Samples

Running the Scaled-Sigma Sampling Method

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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.

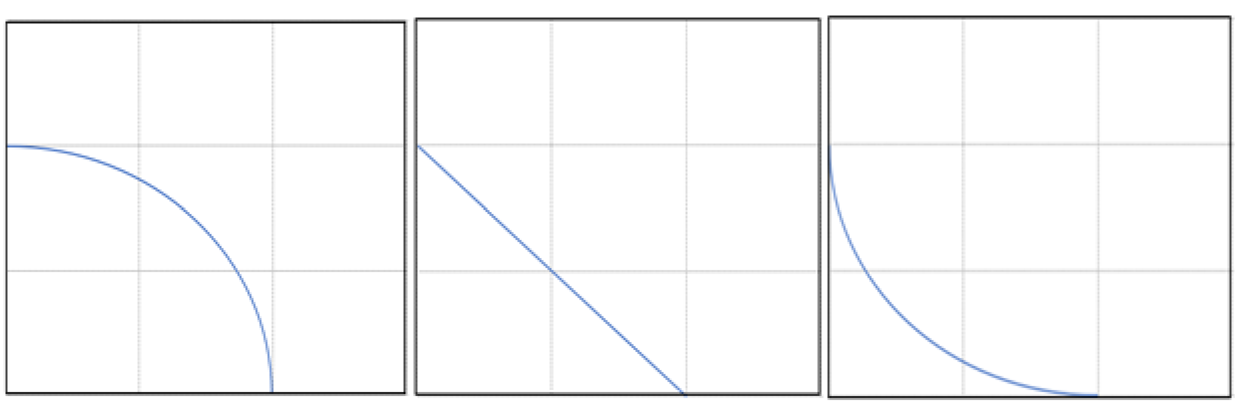
You can generate a quantitative example by running the Scales-Sigma Sampling method on a linear failure boundary case.

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.



Superlinear **Linear** **Sublinear**

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Related Topics

High Yield Estimation

The Scaled-Sigma Sampling Method

Running the Scaled-Sigma Sampling Method

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Running the Scaled-Sigma Sampling Method

Before you run the Scaled-Sigma Sampling (SSS) method, ensure that the following environment variable is set to `t`:

```
envSetVal("maestro.monte" "showMethodScaledSigmaSampling" 'boolean t)
```

To run the SSS method:

1. Open your design in ADE Assembler or ADE Explorer.
2. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
3. Click the *Simulation Options* command.

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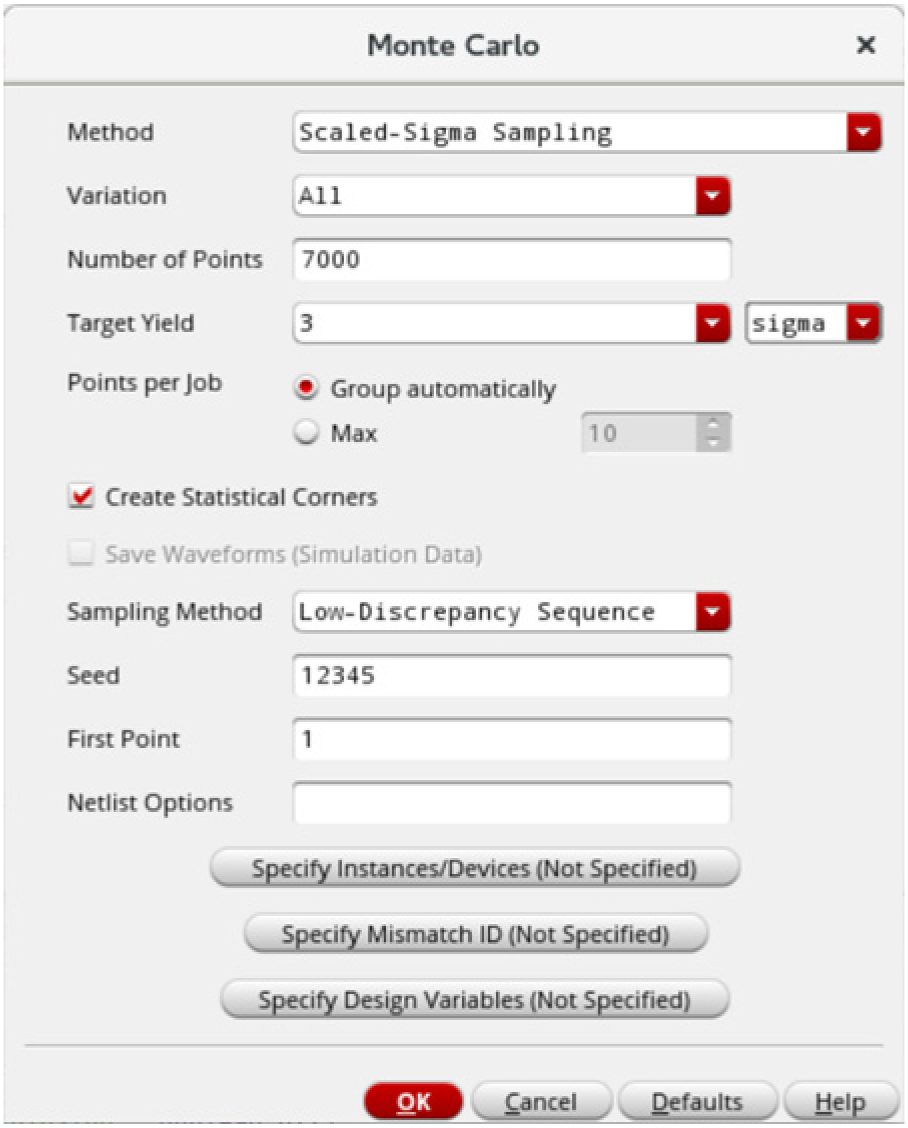
The Monte Carlo form opens.



4. In the *What is the yield requirement?* field, .
5. From the *Method* drop-down list, select *Scaled-Sigma Sampling*.
6. In the *Target Yield* field, select a value greater than *3 sigma*.
7. In the The *Number of Points* field, specify the number of points you want to run. The default value is `7000`.

   This total number of points are divided across all of the scaled runs. Increasing the number of points improves accuracy and reduces the confidence interval of the yield

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estimate. If there are `7` scaled Monte Carlo iterations, and number of points = `7000`, then each scaled iteration simulates `1000` points.

8. In the *Max Scaling Factor* field, specify the maximum scaling factor to be used for the Scaled-Sigma Sampling method. You can specify a value between 3–7. By default, this field is set to `7`, which means that seven child histories using seven different scaling factors will be generated.

   This field is hidden by default. You can set the enableMaxScalingFactorForSSS environment variable to `t` to view this field.

9. 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*.

10. From the *Sampling Method* drop-down list, select one of the following options: *Low-Discrepancy Sequence*, *Latin Hypercube*, or *Random*.

11. Click *OK* to close the Monte Carlo form.

12. Click *Run Simulation* to run the Monte Carlo simulation.

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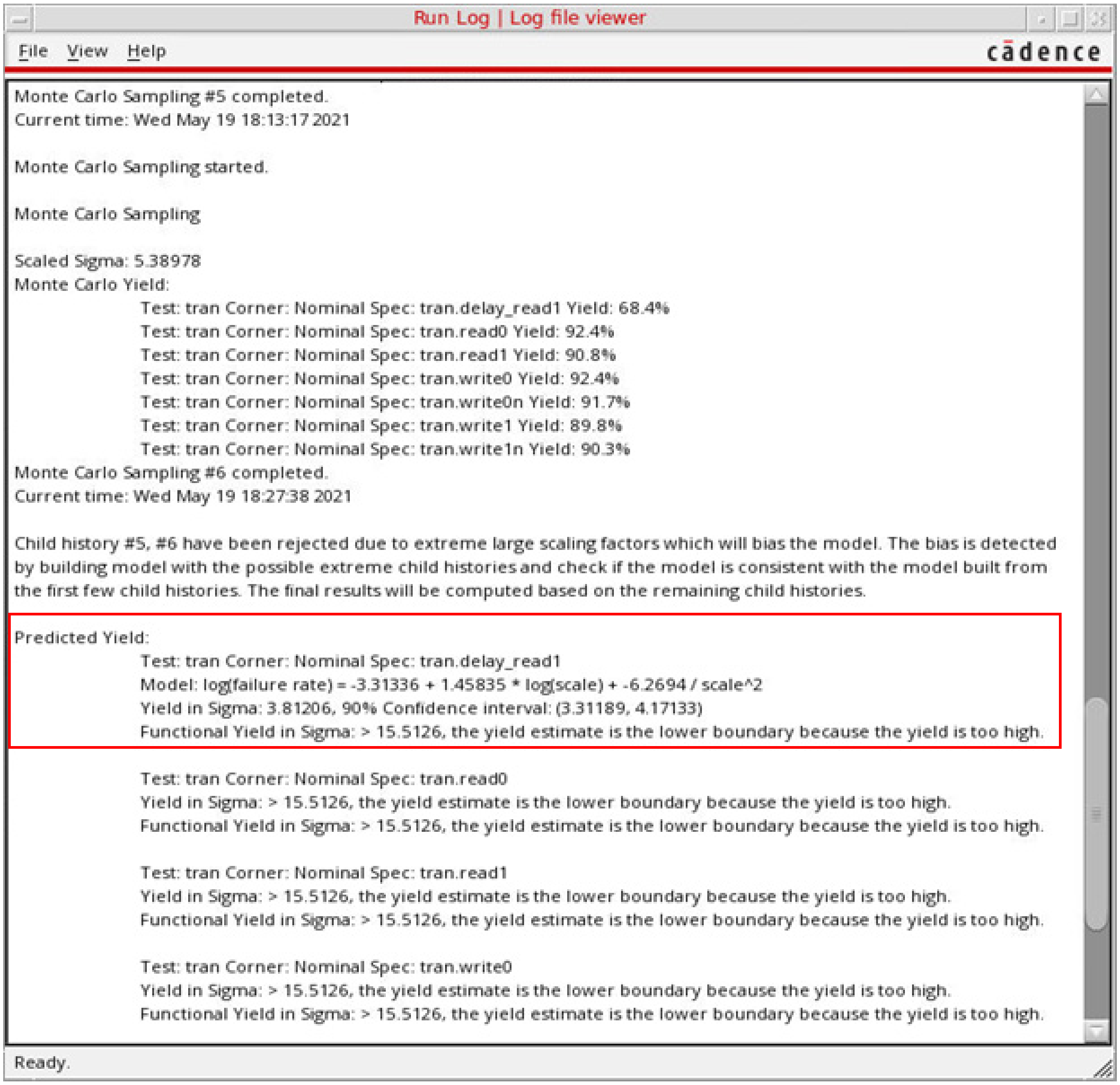
The Run Log opens, displaying the important information about the run.



Run Log Information of the Scaled-Sigma Sampling Method

The Run Log of the in the Scaled-Sigma Sampling method reports the following information for each output:

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- The 90% confidence interval of the yield estimate in parenthesis. For example, (`3.31189`, `4.17133`) is the 90% confidence interval for `delay_read1`, 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 Monte Carlo 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)
```

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.

Related Topics

showMethodScaledSigmaSampling

Monte Carlo Form

Statistical Sampling Methods

The Scaled-Sigma Sampling Method

Yield View of the Scaled-Sigma Sampling Method

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

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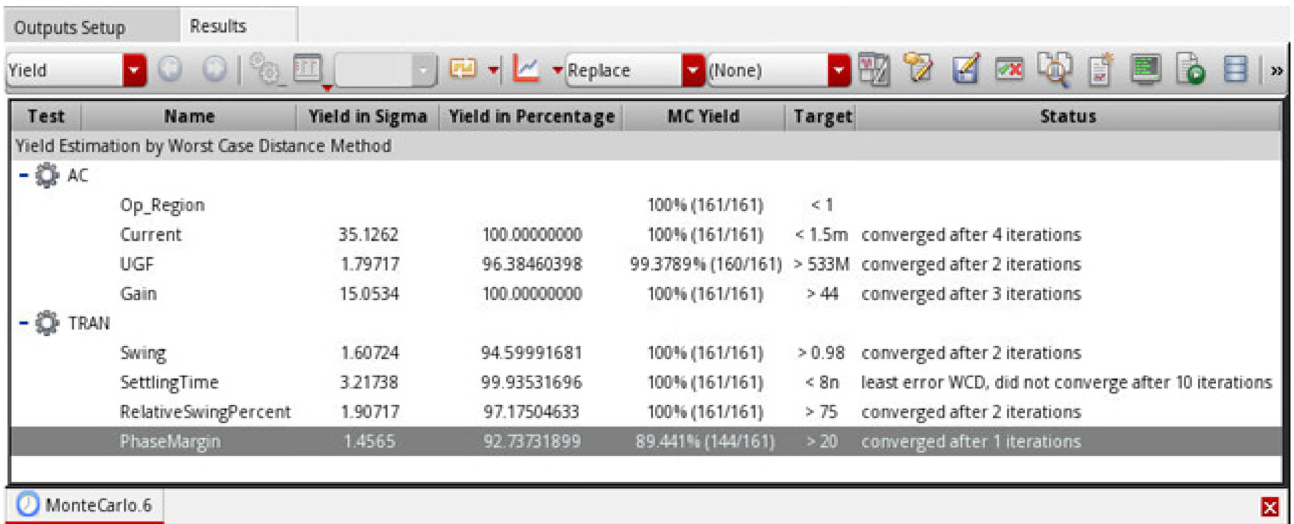
Yield View of the Scaled-Sigma Sampling Method

After the Monte Carlo run for the Scaled-Sigma Sampling method completes, the *Yield* view of the *Results* tab shows the yield estimation.



The following table describes the information displayed in different columns of the *Results* tab.

Column	Description
Test	Name of the test.
Name	Name of the specification.
Yield in Sigma	The yield value in sigma. This value is calculated using the following formula: $\text{Yield in Sigma} = \sqrt[2]{2} \times \text{erfinv}\left(\frac{\text{Yield in Percentage}}{100}\right)$ 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%`.

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Column	Description
Yield in Percentage	Displays the yield value in percentage. This value is calculated using the following formula: The yield in percentage value is displayed with 10 digits by default. To change the number of digits to be displayed for this value, set the value of the digitsToShowForYieldInPercentage environment variable. You can display a maximum of 53 digits for these values.
MC Yield	The yield value from the Monte Carlo run.
Target	The target to be achieved for the given specification.
Status	The convergence status for each specification.

Related Topics

The Scaled-Sigma Sampling Method

Running the Scaled-Sigma Sampling Method

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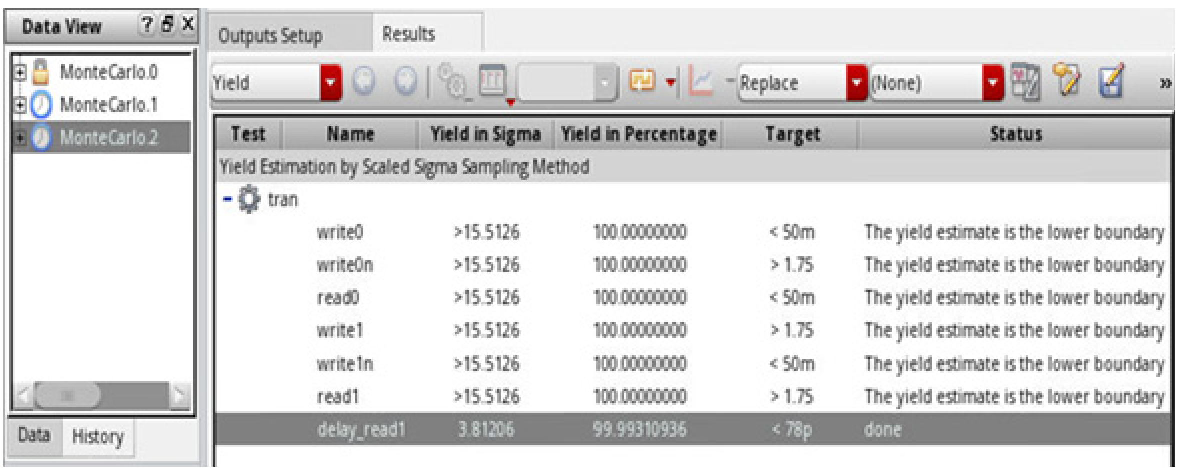
Plotting a Normal Quantile Graph for the Scaled-Sigma Sampling Method

After verifying yield using the Scaled-Sigma Sampling (SSS) method, you can plot a spec versus sigma normal quantile graph (QQ plot) to show the estimated result values at a number of normal quantiles. It also helps in comparing the result values for an output (delay_read1) with the values predicted for a standard normal distribution.

To plot a normal quantile plot for the SSS method:

1. In the *History* tab of the Data View assistant, right-click a Monte Carlo history for the SSS method, and then select *View Results*.

   The results of the Monte Carlo run for the SSS method are displayed in the *Results* tab.



2. In the *Yield* view of the *Results* tab, right-click a specification, and then select *QQ Plot*.

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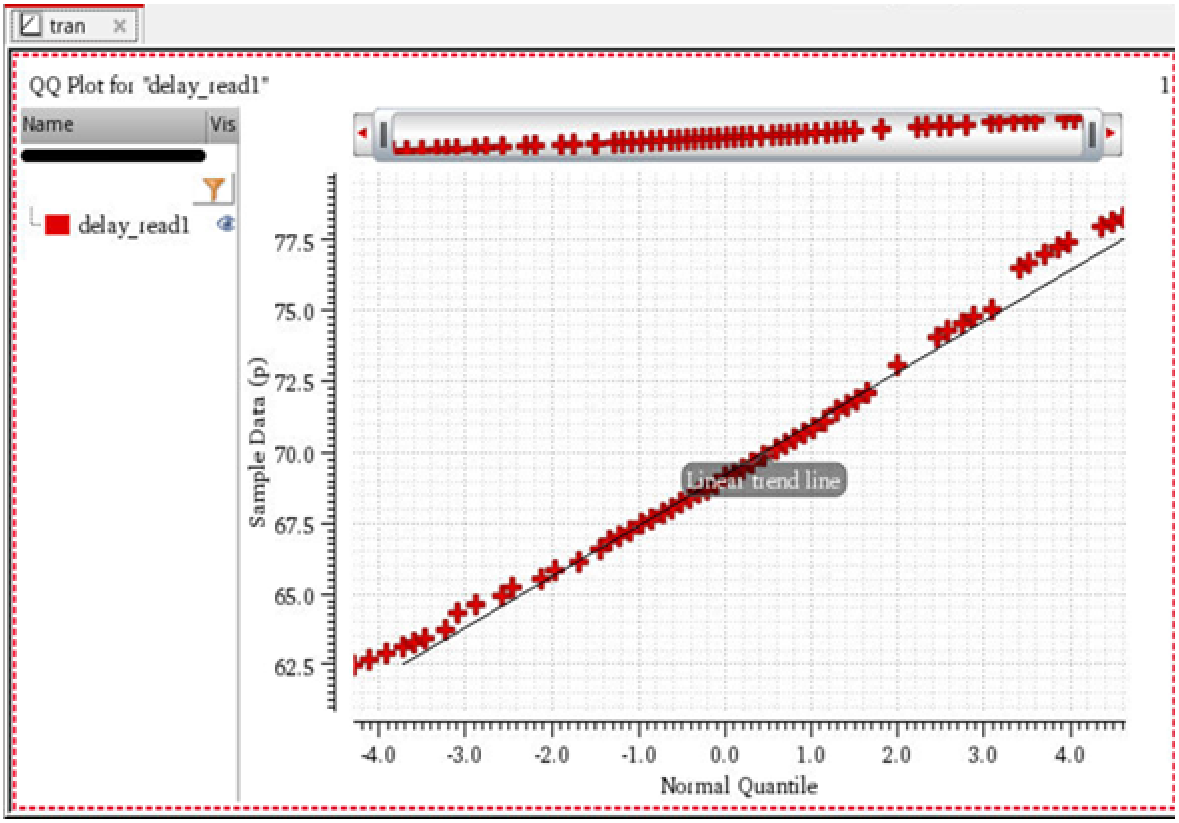
The graph window appears, showing the QQ plot.



In the graph, the y axis shows the estimated Monte Carlo results for output (`delay_read1`) and the x axis shows the normal quantiles of that sample data from `-4` sigma to `+4` 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.

Related Topics

The Scaled-Sigma Sampling Method

Running the Scaled-Sigma Sampling Method

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The Worst-Case Distance Method

The Worst-Case Distance (WCD) method defines the shortest distance from the nominal point to the specification boundary in the process/mismatch parameter space. WCD typically requires under 100 simulations for each spec and so is suitable for designs with a small number of specs/parameters that need to be monitored/changed.

When the target yield sigma value is greater than 4, you can select the WCD method to verify the yield of the design.

The worst case distance is a good indicator of circuit yield, where yield in percentage is approximately equal to:

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

where, `erf` is the error function.

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:

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

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 of ADE Assembler. 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.

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Related Topics

High Yield Estimation

Running the Worst-Case Distance Method

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Running the Worst-Case Distance Method

Before you run the Worst-Case Distance (WCD) method, ensure that the following environment variable is set to `t`:

```
envSetVal("maestro.monte" "showMethodWorstCaseDistance" 'boolean t)
```

To run the Worst-Case Distance method:

1. Open your design in ADE Assembler or ADE Explorer.
2. From the *Run Mode* drop-down list, select *Monte Carlo Sampling*.
3. Click the *Simulation Options* command.

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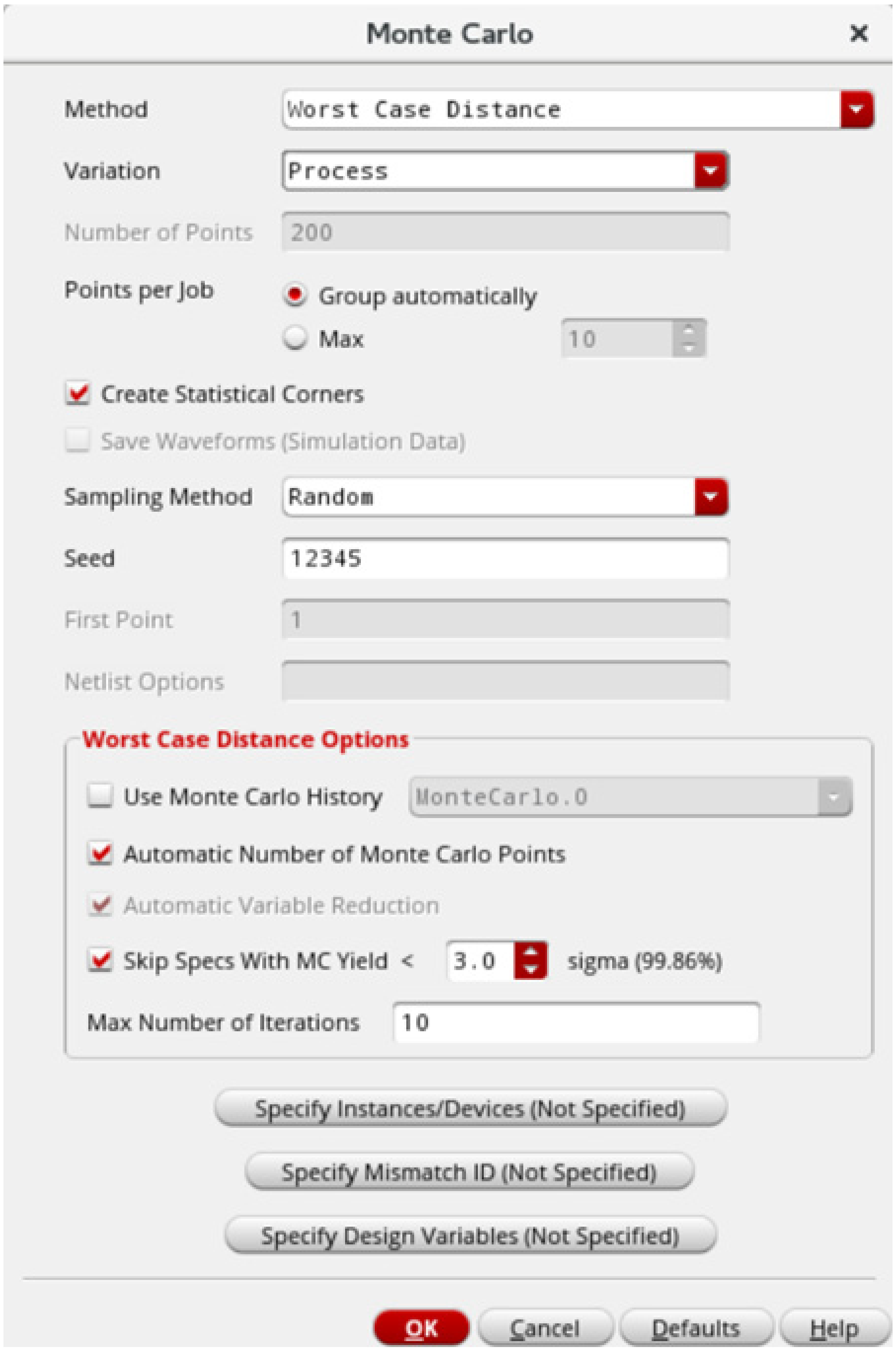
The Monte Carlo form opens.



4. From the *Method* drop-down list, select *Worst Case Distance*.
5. From the *Variation* drop-down list, select one of the following options: *Mismatch*, *Process*, or *All*.

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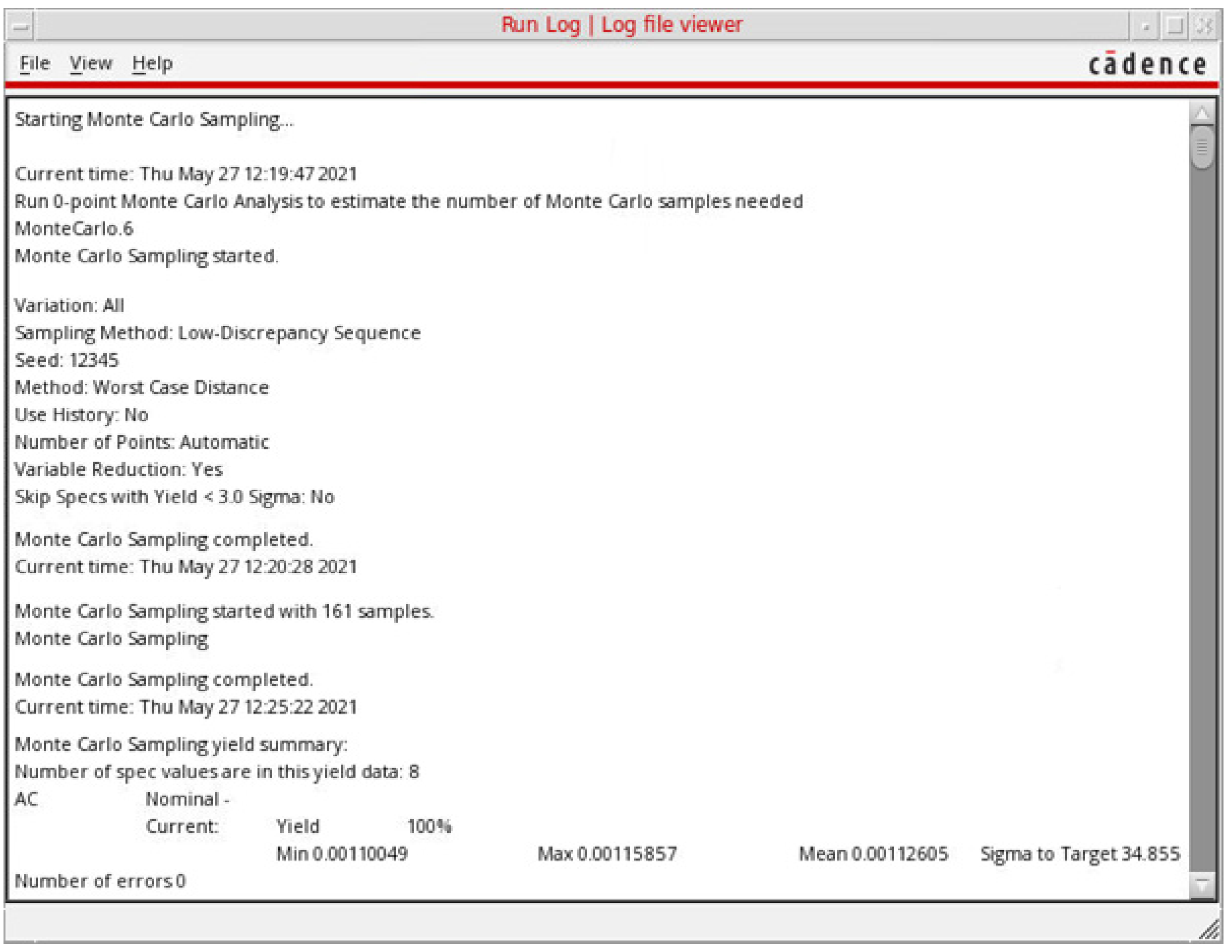
6. The *Number of Points* field is set to `200` by default. This field is disabled when the *Automatic Number of Monte Carlo Points* check box is selected.
7. Select the *Create Statistical Corners* check box if you want to create statistical corners. When this option is selected, the task selection in the *Guided Mode* is changed to *Create statistical corners*.
8. From the *Sampling Method* drop-down list, select one of the following options: *Low-Discrepancy Sequence*, *Latin Hypercube*, or *Random*.
9. In the *Worst Case Distance Options* section, specify the fields as required.
10. Click *OK* to close the Monte Carlo form.
11. Click *Run Simulation* to run the Monte Carlo simulation.

The Run Log | Log File viewer window appears, displaying information about the progress of the initial Monte Carlo Sampling run, the yield estimate at each iteration, and the summary of the Monte Carlo run.



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

Related Topics

showMethodWorstCaseDistance

Monte Carlo Form

Statistical Sampling Methods

High Yield Estimation

The Worst-Case Distance Method

Yield View of the Worst-Case Distance Method

Creating Statistical Corners from the Worst-Case Distance Method

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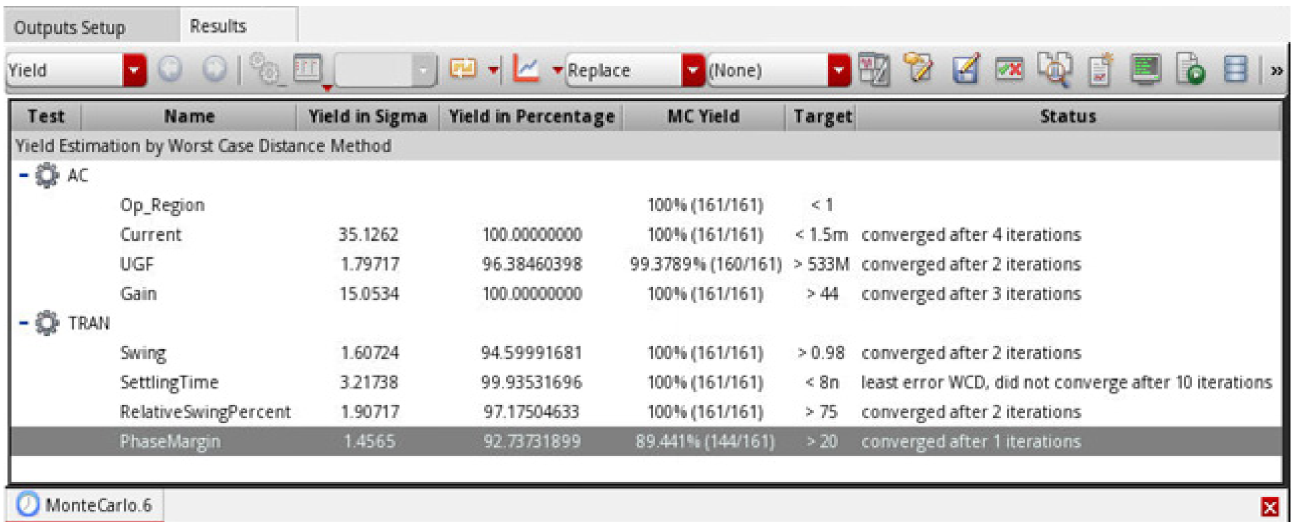
Yield View of the Worst-Case Distance Method

After the Monte Carlo run for the Worst-Case Distance (WCD) method completes, the *Yield* view of the *Results* tab shows the yield estimation.



The following table describes the information displayed in different columns of the *Results* tab.

Column	Description
Test	Name of the test.
Name	Name of the specification.
Yield in Sigma	The yield value in sigma. This value is calculated using the following formula: $\text{Yield in Sigma} = \sqrt[2]{2} \times \text{erfinv}\left(\frac{\text{Yield in Percentage}}{100}\right)$ 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%`.

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Column	Description
Yield in Percentage	Displays the yield value in percentage. This value is calculated using the following formula: $$\text{Yield in Percentage} = 0.5 + 0.5 \times \text{erf}\left(\frac{WCD}{2\sqrt{2}}\right)$$ where, `erf` is the error function. The yield in percentage value is displayed with 10 digits by default. To change the number of digits to be displayed for this value, set the value of the digitsToShowForYieldInPercentage environment variable. You can display a maximum of 53 digits for these values.
MC Yield	The yield value from the Monte Carlo run.
Target	The target to be achieved for the given specification.
Status	The convergence status for each specification.

Convergence Criteria and Convergence Statuses

The tool uses the following two convergence criteria in the WCD method:

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

  ```
  spec_value_error_ratio = abs(spec_value - spec_target)/
  max(abs(nominal_spec_value - spec_target), 6*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 following table describes the convergence statuses shown in the *Status* column of the *Yield* view in the *Results* tab.

Status	Description
converged after x iterations	The yield estimate converged after x iterations. For example, the yield estimate for the `Gain` specification converged after `3` iterations.

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Status	Description
skipped because the Monte Carlo yield is less than <value in percentage>	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 Monte Carlo form in the *Skip specs with MC Yield <* field, which is by default set to `3 sigma` or `99.86%`.
least error WCD, did not converge after x iterations	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. The yield estimate with the least error among iterations is reported.
lower boundary, did not converge after x iterations	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.
estimate based on MC data | lower boundary | least error WCD, stopped because evaluating of the WCD point sensitivity failed on iteration x	Yield estimation stopped before reaching the maximum number of iterations because of a simulation or measurement error in evaluating the WCD point sensitivity. The lower boundary is reported if it is identified, if not, the yield estimate with the least error among iterations is reported.
estimate based on MC data | lower boundary | least error WCD, stopped because evaluation of the WCD point failed on iteration x	Yield estimation stopped before reaching the maximum number of iterations because of a simulation or measurement error in evaluating the WCD point. The lower boundary is reported if it is identified, if not, the yield estimate with the least error among iterations is reported. If the run was stopped on the first iteration, the estimate based on the Monte Carlo result is reported.

Related Topics

The Worst-Case Distance Method

Running the Worst-Case Distance Method

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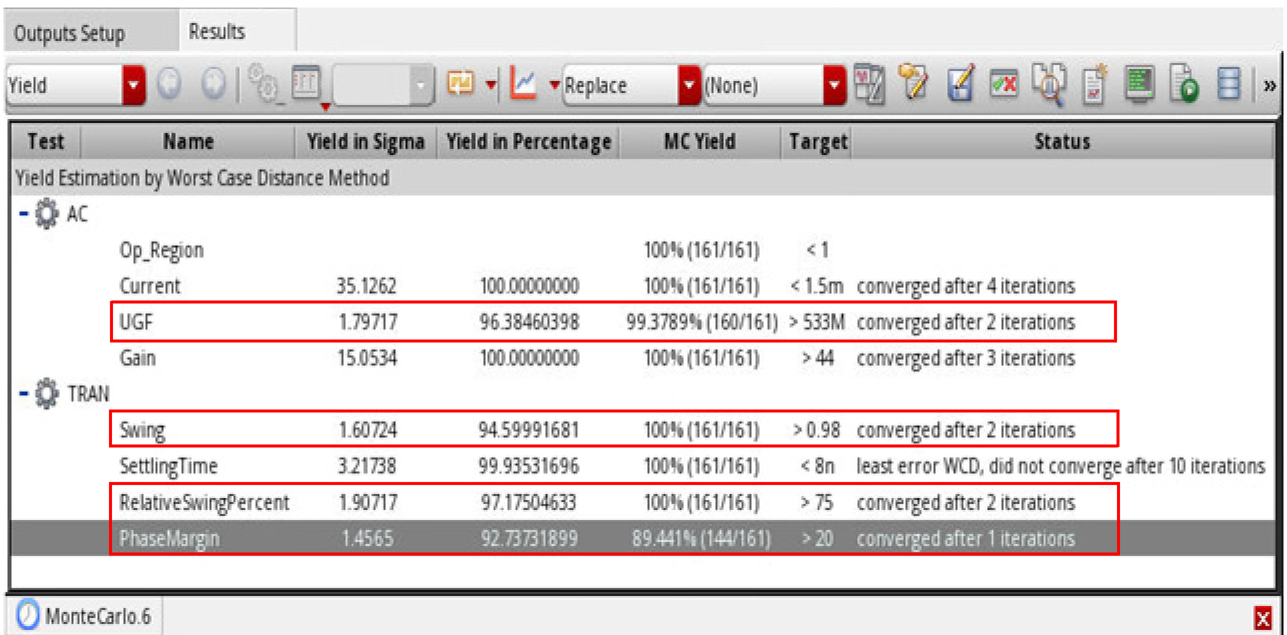
Creating Statistical Corners from the Worst-Case Distance Method

If you run Monte Carlo for a design without skipping the specifications that have yield of less than 3 sigma or 99.86%, the results may show specifications that have yield value less that 3 sigma.

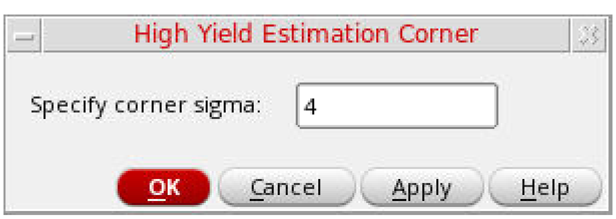
In the following example, the Monte Carlo yield for the specifications *UGF*, *Swing*, *RelativeSwingPercent*, and *PhaseMargin* is less than 3 sigma.



To improve the yield for a specification, you can create a statistical corner based on the Worst-Case Distance (WCD) point of the specification.

1. In the *Yield* view of the Worst-Case Distance results, right-click a specification, and then select either *Create Corner (Specify Yield in Sigma)* or *Create Corner (Specify Yield in Percentage)*.

   The High Yield Estimation Corner form opens.



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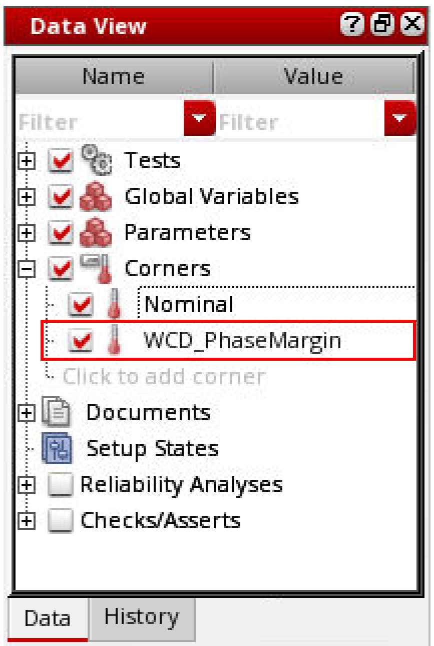
2. In the *Specify corner sigma* field, specify the sigma value to which you want to extend the WCD point. If you selected *Create Corner (Specify Yield in Percentage)* in step 1, specify the target yield value to be achieved in percentage.

   Note: 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.

3. Click *OK* to create the statistical corner.

   The statistical corner is created with the name *WCD_`specification_name`*.



4. Enable this corner and run global optimization on the design.

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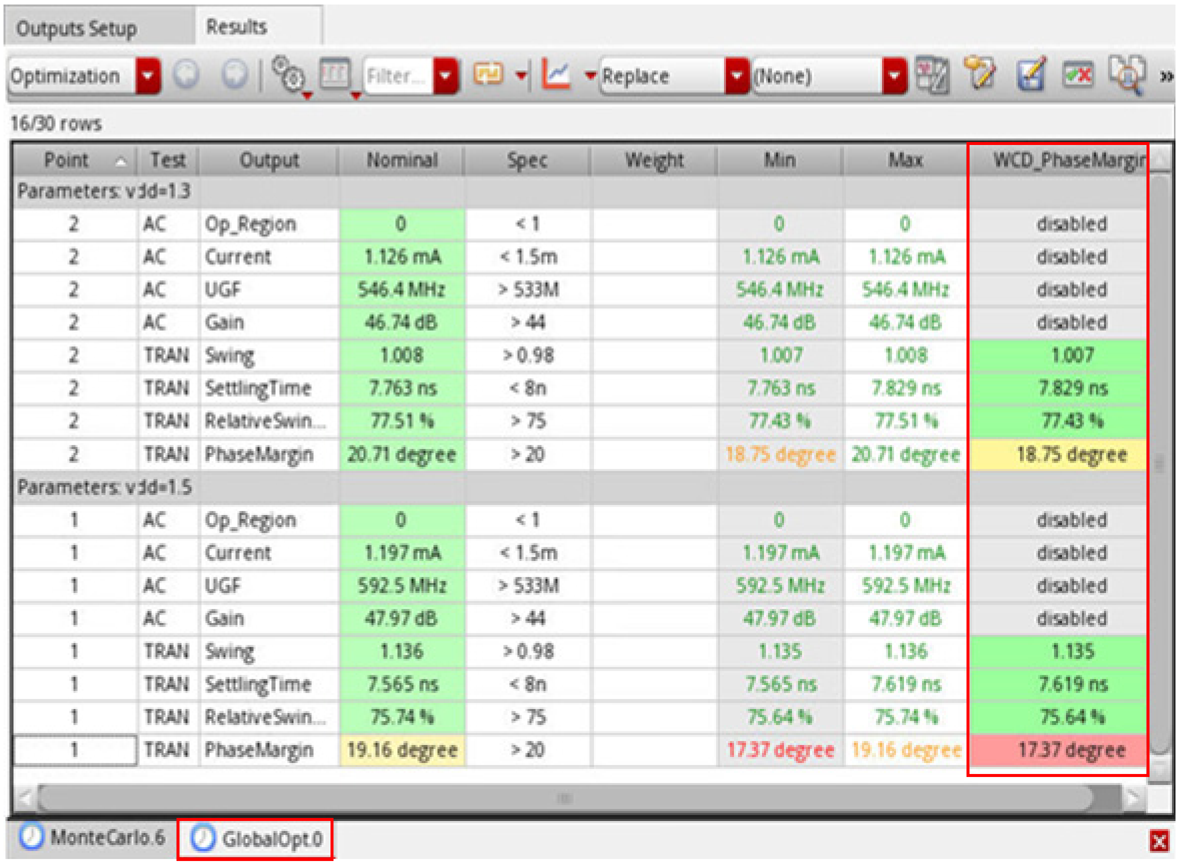
The results for the new statistical corners are displayed.



Point	Test	Output	Nominal	Spec	Weight	Min	Max	WCD_PhaseMargin
Parameters: vdd=1.3								
2	AC	Op_Region	0	< 1		0	0	disabled
2	AC	Current	1.126 mA	< 1.5m		1.126 mA	1.126 mA	disabled
2	AC	UGF	546.4 MHz	> 533M		546.4 MHz	546.4 MHz	disabled
2	AC	Gain	46.74 dB	> 44		46.74 dB	46.74 dB	disabled
2	TRAN	Swing	1.008	> 0.98		1.007	1.008	1.007
2	TRAN	SettlingTime	7.763 ns	< 8n		7.763 ns	7.829 ns	7.829 ns
2	TRAN	RelativeSwin...	77.51 %	> 75		77.43 %	77.51 %	77.43 %
2	TRAN	PhaseMargin	20.71 degree	> 20		18.75 degree	20.71 degree	18.75 degree
Parameters: vdd=1.5								
1	AC	Op_Region	0	< 1		0	0	disabled
1	AC	Current	1.197 mA	< 1.5m		1.197 mA	1.197 mA	disabled
1	AC	UGF	592.5 MHz	> 533M		592.5 MHz	592.5 MHz	disabled
1	AC	Gain	47.97 dB	> 44		47.97 dB	47.97 dB	disabled
1	TRAN	Swing	1.136	> 0.98		1.135	1.136	1.135
1	TRAN	SettlingTime	7.565 ns	< 8n		7.565 ns	7.619 ns	7.619 ns
1	TRAN	RelativeSwin...	75.74 %	> 75		75.64 %	75.74 %	75.64 %
1	TRAN	PhaseMargin	19.16 degree	> 20		17.37 degree	19.16 degree	17.37 degree

5. From the results of the optimization run, right-click a design point, and select *Save variable and parameter values to Setup State* to save the values of variables and parameters from that point into a setup state.

   The values of all the variables and parameters for this design point are saved as a state named as `history_name`.*PointID*.`pointID`. For example, *GlobalOpt.0.PointID.1*.

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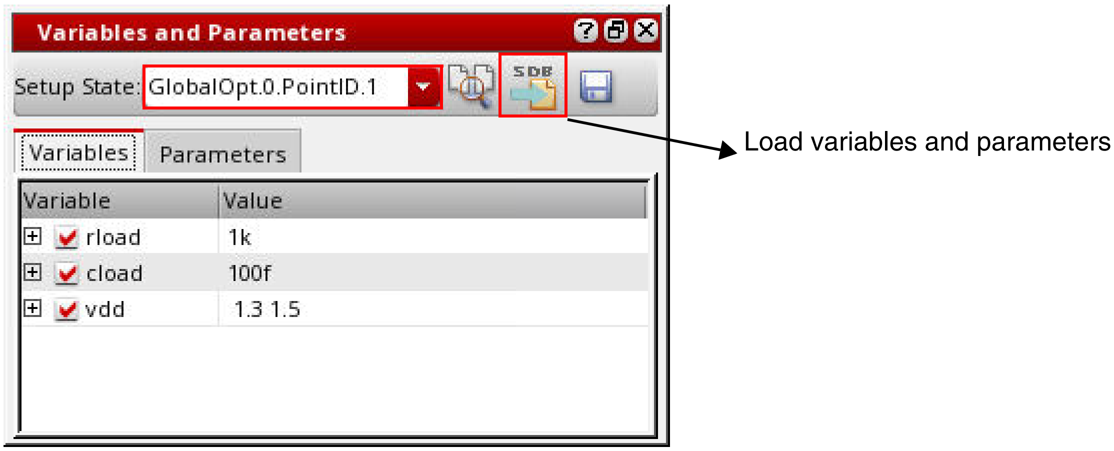
6. Open the Variables and Parameters assistant and select this setup state from the *Setup State* drop-down list.



7. Click *Load variables and parameters*.
8. Run the Monte Carlo simulation again using the same setup.

   The results show significant improvement in the yield and the worst case distance values.

Related Topics

High Yield Estimation

The Worst-Case Distance Method

Yield View of the Worst-Case Distance Method

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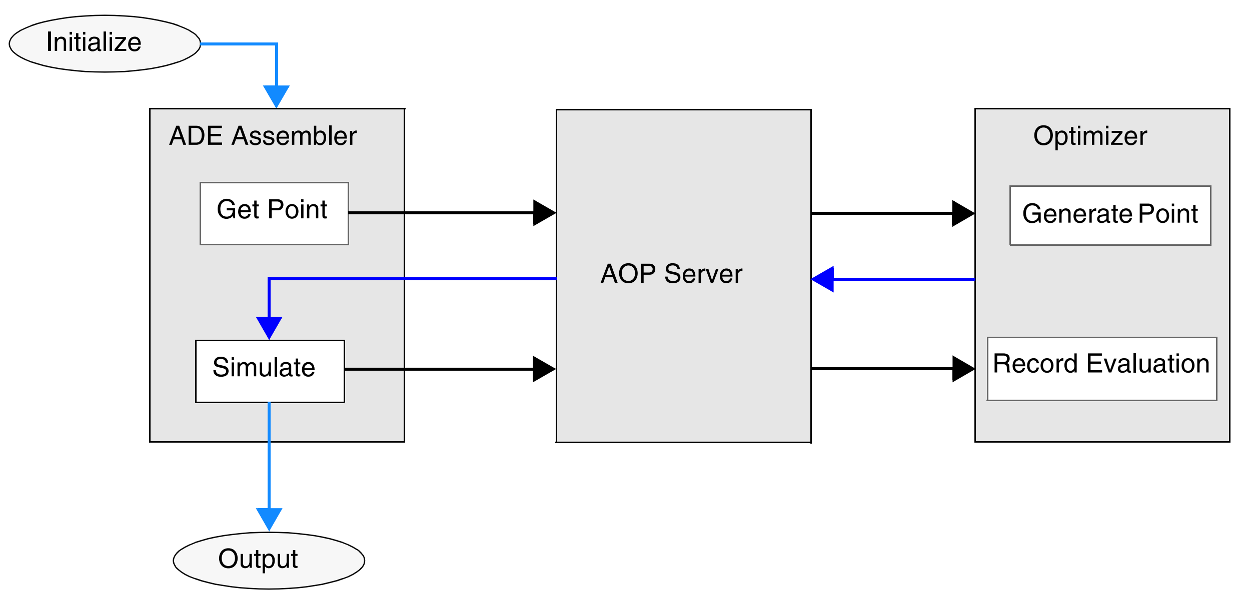
8

Advanced Optimization

You can use Virtuoso ADE Assembler and Advanced Optimization Platform (AOP) to optimize your circuit designs. You can also write your custom optimization algorithm in C++ or Python, and integrate it into ADE Assembler using AOP.

The following figure shows the workflow of advanced optimization in ADE Assembler.



There are three key components in this workflow: ADE Assembler, AOP Servers, and Optimizer.

1. ADE Assembler initiates the process by providing a design space to the AOP Server. This design space represents the range of parameters or configurations for a particular system or problem.
2. The AOP Server employs an algorithm to sample this design space. The algorithm then sends the sampled points back to ADE Assembler for further evaluation.

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3. ADE Assembler takes these sampled points and performs simulations. It evaluates these points by applying specific mathematical expressions and computes a value for the cost function (or merit) based on predefined specifications and their corresponding weights.
4. AOP Server invokes a record evaluation method. This method is utilized by the optimization algorithm to determine the next steps in the optimization process.
5. The workflow iterates continuously until any of the stopping criteria are met. These criteria could include reaching a desired level of performance, minimizing costs, or achieving other optimization goals.

This workflow facilitates an iterative optimization process where ADE Assembler, AOP Server, and the Optimizer work together to explore and refine the design space until the desired objectives are achieved.

Related Topics

Advantages of Advanced Optimization

Running Advanced Optimization

AOP Options Form

Example of Custom Optimization Algorithm

Integrating a Custom Optimizer into ADE Assembler

Hyperparameters of Valhalla Optimizer

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Advantages of Advanced Optimization

Advantages of using advanced optimization in ADE Assembler are as follows:

- Lets you use different optimizers as per the need.
  - Comes with various algorithms, such as particle swarm optimization (PSO), Dakota, Optuna, and other surrogate model-based optimizers.
  - Supports custom optimization algorithms that you can write on your own.
  - Allows further tuning of hyperparameters of global optimizers (legacy optimizers).
- Provides multi-language support, C++ and Python.
- Provides better data management to share results using web server.

Related Topics

Advanced Optimization

Running Advanced Optimization

AOP Options Form

Example of Custom Optimization Algorithm

Integrating a Custom Optimizer into ADE Assembler

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Advanced Optimizers in ADE Assembler

The Advanced Optimization form in ADE Assembler lets you select the following optimizers:

- GRPR

  GPRP optimizer is a combination of genetic algorithm (GA) and Simulated Annealing (SA) with a surrogate model.

- Valhalla

  Valhalla is a combination of particle swarm optimization (PSO) and genetic algorithm (GA).

- Dakota

  Dakota provides advanced parametric analyses that enable design exploration, model calibration, risk analysis, and quantification of margins and uncertainty with computational models.

- Optuna

  Optuna is an open source hyperparameter optimization framework to automate hyperparameter search using Python. It searches large spaces and prune unpromising trials for faster results.

- Particle swarm optimization (PSO)

  PSO is a swarm or population-based algorithm. It optimizes a problem by iteratively trying to improve a candidate solution.

In addition, you can also write your custom optimization algorithm in C++ or Python.

The factor that determines how fast an optimization algorithm converges is the cost function, which depends on the circuit, measurements, specifications, and design space.

Related Topics

Hyperparameters of Valhalla Optimizer

Hyperparameters of Optuna Optimizer

Hyperparameters of Dakota Optimizer

Hyperparameters of Particle Swarm Optimizer

Example of Custom Optimization Algorithm

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AOP Options Form

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Example of Custom Optimization Algorithm

You can create a custom optimization algorithm either in C++ or Python.

The following piece of code shows an example of the custom optimization algorithm written in Python.

```
# ***************************************************************************
#                Copyright 2023 Cadence Design Systems, Inc.
#                           All Rights Reserved.
#
# This work cannot be republished or copied in its original form
# without prior written permission from Cadence Design Systems, Inc.
#
# Permission is granted to modify this code for the purpose of
# developing new optimizers to run within Virtuoso Studio.
# ***************************************************************************

import dso
import numpy as np
import random

random.seed(1)


class RakOptimizer(dso.BaseOptimizer):
    def __init__(self):
        super().__init__()
        self.optimizer_info.set_optimizer_name(name='RAK Optimizer')
        self.optimizer_info.set_hyperparameter_property_range(
            hp='batchSize',
            hp_default=2,
            hp_min=2,
            hp_step=1,
            hp_max=1000,
            hp_description='Controls Batch Size')

    # def pre_processing(self):
    #     pass

    def get_points(self):
```


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```
        point_dic = self.domain.sample(size=self.hyper_params['batchSize'])
        point_array = point_dic.parse_into_object(out_type=np.ndarray)
        ret = dso.GetPointsReturnType()
        ret.parse_from_object(domain=self.domain, samples=point_array)
        return ret

    def record_evaluations(self, evaluation_result):
        pass


if __name__ == '__main__':
    RakOptimizer().run()
```

Methods Used in the Custom Optimization Algorithm Example

In the example of custom optimization algorithm, following methods are used:

- `__init__()`

  It is a Python constructor that is loaded with the AOP framework. It contains essential information about the optimization algorithm, such as name, description, and details of hyperparameters. Note that specific design space information is not accessible at this stage because simulation run in ADE Assembler has not started yet.

  The details of optimizer hyperparameters can be defined as follows.

```
self.optimizer_info.set_hyperparameter_property_range(
            hp='Batch Size',
            hp_default=100,
            hp_min=10,
            hp_step=1,
            hp_max=1000,
           hp_description='Specifies the maximum number of points that can be 
submitted by optimizer during one iteration')
```

  In this example, a hyperparameter named *Batch Size* is defined. The default value of this parameter is `100`. The minimum and maximum values for this hyperparameters is `10` and `1000`, respectively. The tooltip for this hyperparameters reads: *Specifies the maximum number of points that can be submitted by optimizer during one iteration.*

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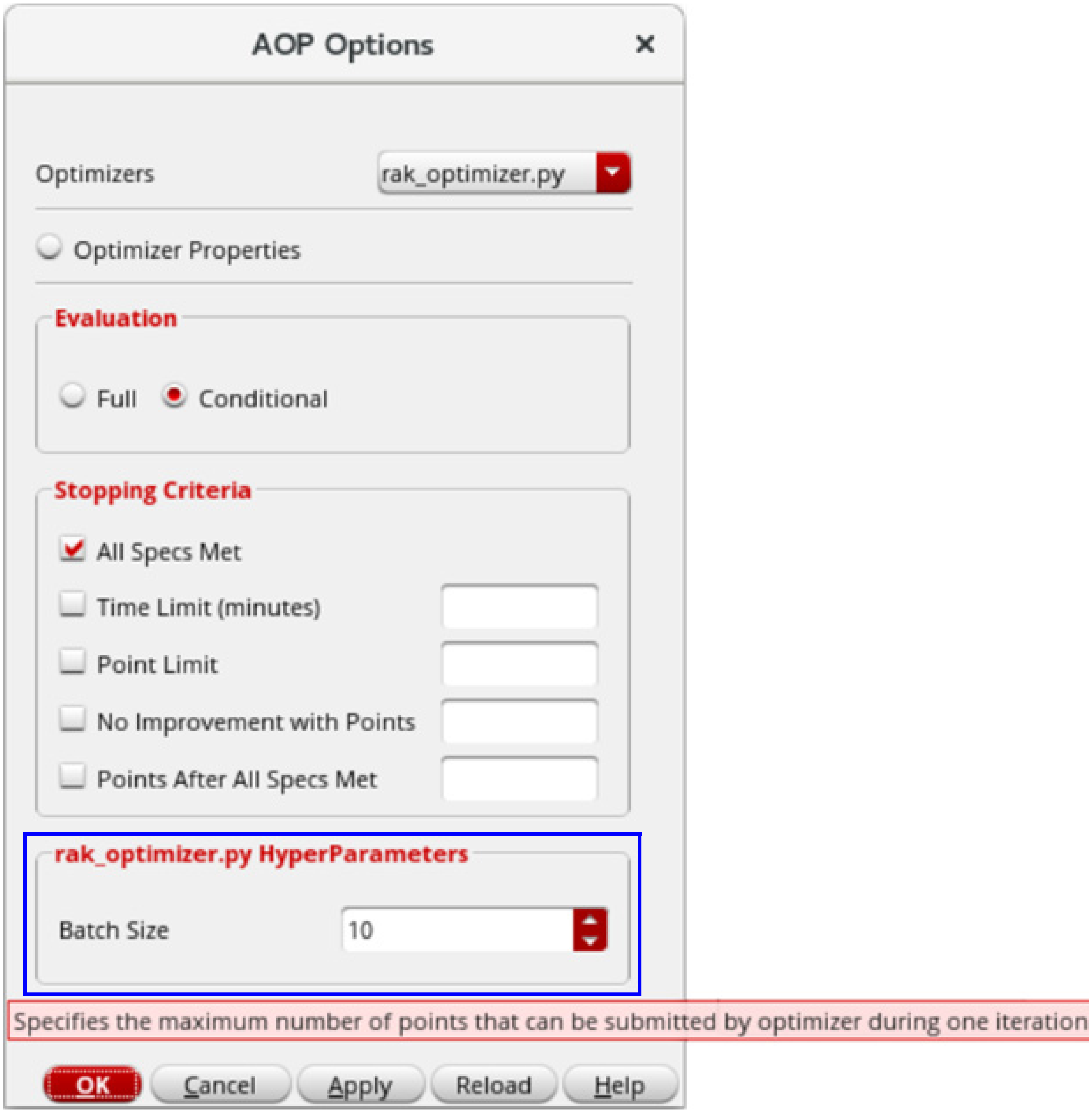
This hyperparameter option is displayed in the *rak_optimizer.py HyperParameters* section of the AOP Options form, as follows:



Where, `rak_optimizer.py` is the name of the custom optimization algorithm currently selected in the *Optimizers* drop-down list.

- `pre_processing()`

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This method is used to initialize settings that are necessary for the optimization run. Information about design space is available at this stage because optimization run is started in ADE Assembler.

- `get_points()`

  This method is used by the AOP framework to request the optimization algorithm for the points to simulate.

- `record_evaluations()`

  This method is used by AOP framework to return the merit values associated with the simulated points. In this example, the optimizer performs random sampling and does not use any information returned from ADE Assembler.

Related Topics

Advanced Optimization

Advantages of Advanced Optimization

AOP Options Form

Running Advanced Optimization

Integrating a Custom Optimizer into ADE Assembler

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Integrating a Custom Optimizer into ADE Assembler

After creating your custom optimization algorithm, you must integrate it into ADE Assembler. You can then select this algorithm from the Optimizers drop-down list in the AOP Options form when running the Advanced Optimization run.

To integrate the custom optimization algorithm into ADE Assembler:

1. Set the following Shell environment variable to specify the colon-separated directories where you want to save the custom optimization algorithms:

   ```
   setenv DSO_HOME_OPTIMIZERS $CDSHOME/tools/DSO/optimizer/system/target:$PWD/
   custom_optimizers
   ```

   Where, $CDSHOME is the Cadence installation directory, and $PWD is the current working directory.

   You can specify another directory separated by a colon (:).

2. Save your custom optimization algorithms in either of the following directories:

   ```
   setenv AOP_OPTIMIZERPATH
   $CDSHOME/tools/DSO/optimizer/system/target:$PWD/custom_optimizers
   ```

   The algorithms saved in these directories are available to be selected from the *Optimizers* drop-down list in the AOP Options form.

Related Topics

Advanced Optimization

Example of Custom Optimization Algorithm

Advantages of Advanced Optimization

AOP Options Form

Running Advanced Optimization

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Hyperparameters of Valhalla Optimizer

The following table describes the hyperparameters of Valhalla optimizer.

Hyperparameter	Description
Budget	Number of iterations to be run before optimizer stops.
Elitist Percentage	The percentage of top particles or individuals to be propagated to next iteration of optimization.
No of Particles	The number of particles or individuals in a population.
No of DOE Points	The number of points required before the initial surrogate model is created.
Random Seed	Seeds to initialize random number generators.
Surrogate Iterations	The number of iterations to be performed by internal optimizers using the generated surrogate model.

Related Topics

Advanced Optimization

Advanced Optimizers in ADE Assembler

Example of Custom Optimization Algorithm

Integrating a Custom Optimizer into ADE Assembler

AOP Options Form

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Hyperparameters of Optuna Optimizer

The following table describes the hyperparameters of Optuna optimizer.

Hyperparameter	Description
Batch Size	Maximum number of jobs to be run.
Budget	Number of points to be run before the optimizer stops.
Random Seed	Seeds to initialize pseudo-random number generators.
Sampler	Sampling algorithm
Stopping Threshold	Percent of budget which if consumed without a change in best point, causes optimization to exit.

Related Topics

Advanced Optimization

Advanced Optimizers in ADE Assembler

Example of Custom Optimization Algorithm

Integrating a Custom Optimizer into ADE Assembler

AOP Options Form

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Hyperparameters of Dakota Optimizer

The following table describes the hyperparameters of Dakota optimizer.

Hyperparameter	Description
Batch Size	Maximum number of jobs to be run
LHS Sampling Size	Sampling size for the Latin Hypercube method
Max Iterations	Number of batches
Population Size	Number of candidates in each iterations
Seed	Seeds to initialize pseudo-random number generators
Sub Optimizer Choice	Algorithm to be selected

Related Topics

Advanced Optimization

Advanced Optimizers in ADE Assembler

Example of Custom Optimization Algorithm

Integrating a Custom Optimizer into ADE Assembler

AOP Options Form

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Hyperparameters of Particle Swarm Optimizer

The following table describes the hyperparameters of Particle Swarm Optimizer (PSO).

Hyperparameter	Description
Batch Size	Maximum number of jobs to be run.
Budget	Maximum number of points that can be simulated.
Number of Particles	Number of candidates in each iterations.
Seed	Seeds to initialize pseudo-random number generators.
W	Inertia weight
C1	Cognitive constant
C2	Social constant

Related Topics

Advanced Optimization

Advanced Optimizers in ADE Assembler

Example of Custom Optimization Algorithm

Integrating a Custom Optimizer into ADE Assembler

AOP Options Form

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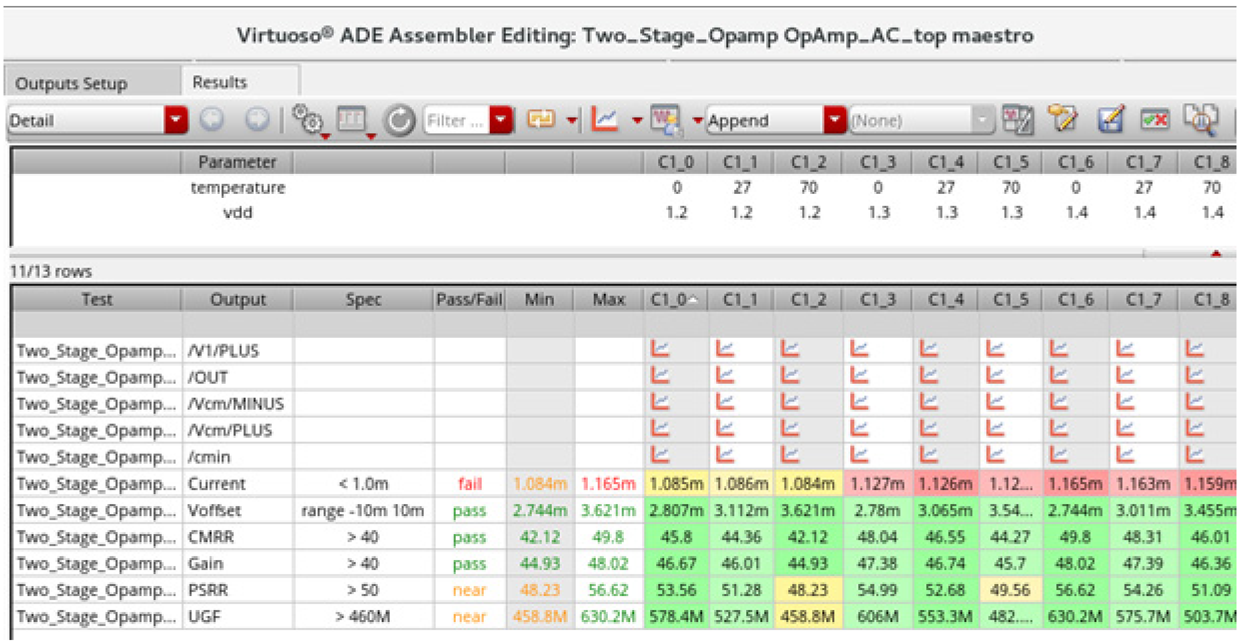
Running Advanced Optimization

To run advanced optimization:

1. Run a simulation for the design that you want to optimize. Ensure that the specifications have been defined for the outputs in the *Outputs Setup* tab in ADE Assembler.

2. The simulation results are displayed in the *Results* tab.



	Parameter					C1_0	C1_1	C1_2	C1_3	C1_4	C1_5	C1_6	C1_7	C1_8
	temperature					0	27	70	0	27	70	0	27	70
	vdd					1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4

Test	Output	Spec	Pass/Fail	Min	Max	C1_0	C1_1	C1_2	C1_3	C1_4	C1_5	C1_6	C1_7	C1_8
Two_Stage_Opamp...	/V1/PLUS													
Two_Stage_Opamp...	/OUT													
Two_Stage_Opamp...	/Vcm/MINUS													
Two_Stage_Opamp...	/Vcm/PLUS													
Two_Stage_Opamp...	/cmin													
Two_Stage_Opamp...	Current	< 1.0m	fail	1.084m	1.165m	1.085m	1.086m	1.084m	1.127m	1.126m	1.12...	1.165m	1.163m	1.159m
Two_Stage_Opamp...	Voffset	range -10m 10m	pass	2.744m	3.621m	2.807m	3.112m	3.621m	2.78m	3.065m	3.54...	2.744m	3.011m	3.455m
Two_Stage_Opamp...	CMRR	> 40	pass	42.12	49.8	45.8	44.36	42.12	48.04	46.55	44.27	49.8	48.31	46.01
Two_Stage_Opamp...	Gain	> 40	pass	44.93	48.02	46.67	46.01	44.93	47.38	46.74	45.7	48.02	47.39	46.36
Two_Stage_Opamp...	PSRR	> 50	near	48.23	56.62	53.56	51.28	48.23	54.99	52.68	49.56	56.62	54.26	51.09
Two_Stage_Opamp...	UGF	> 460M	near	458.8M	630.2M	578.4M	527.5M	458.8M	606M	553.3M	482....	630.2M	575.7M	503.7M

   The cells in the results are highlighted in green, yellow, and red colors, which indicate that the measurements meet specification, almost meet specification, and do not meet specification, respectively.

3. In the *Data View* assistant, right-click the name of the test, and choose *Open Design in Tab*.

   The schematic design opens in a new tab.

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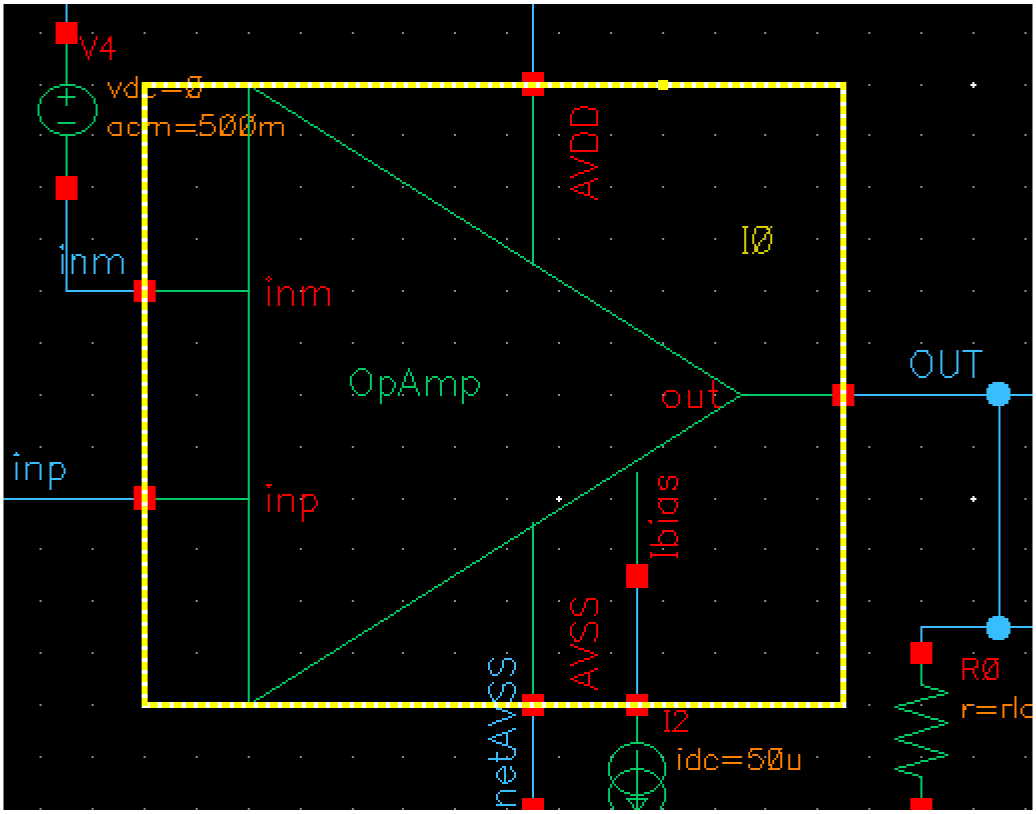
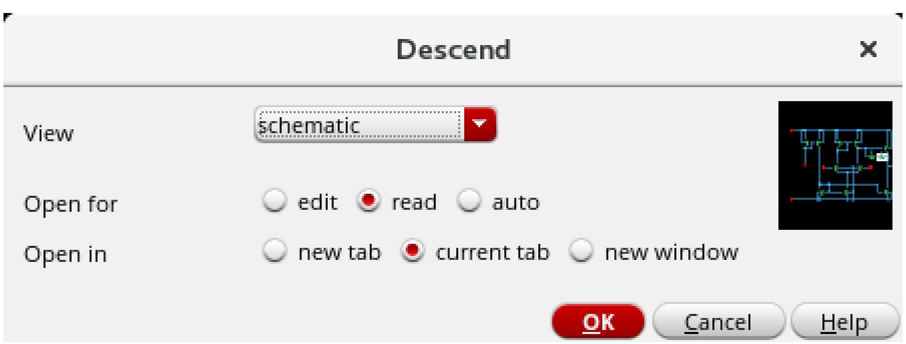
4. Select an OpAmp instance, for example, `I0`.



5. Right-click the selected instance, and choose *Descend Read* to descend into the schematic of the selected design.

The Descend form opens.



6. Keep the default selection in the form and click *OK*.

The schematic of the selected instance opens in read-only mode in the current tab.

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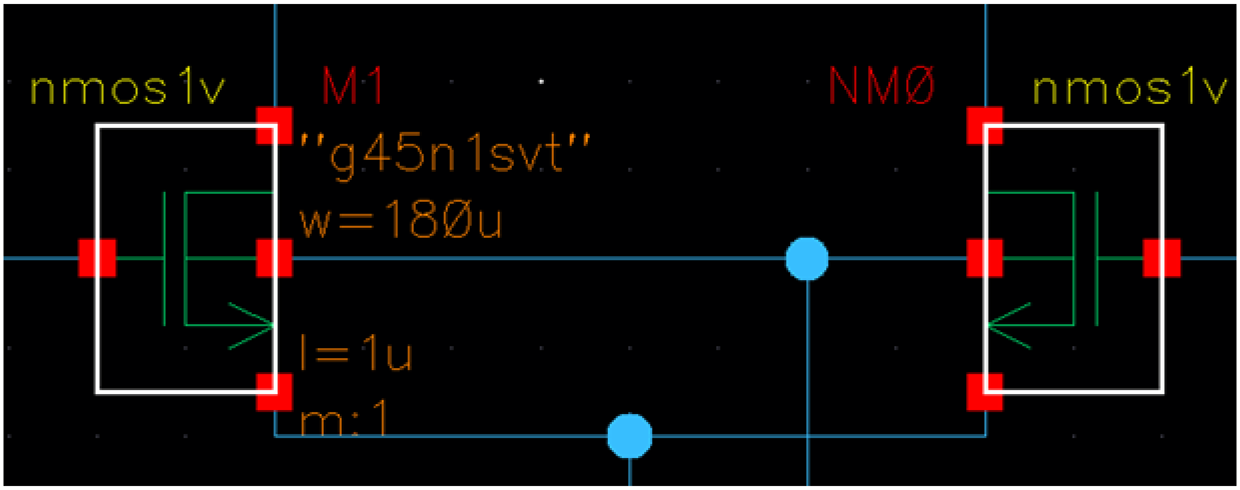
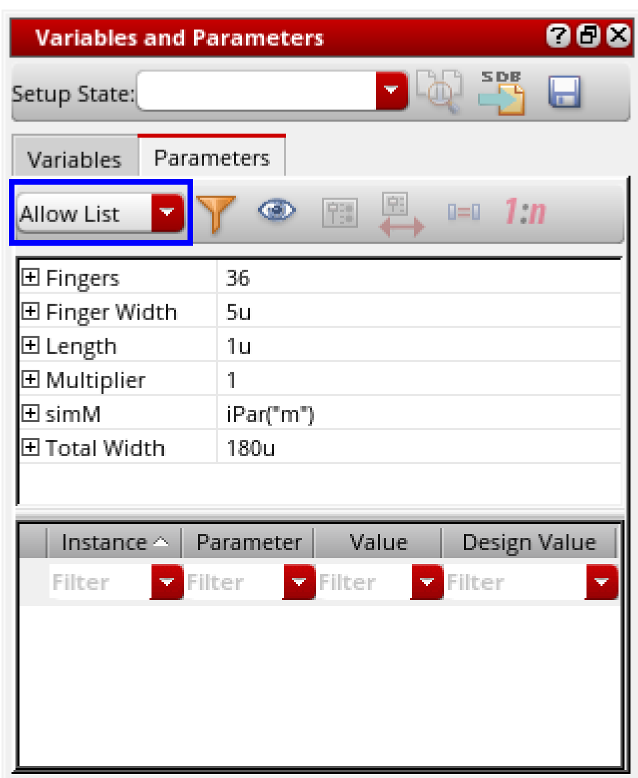
7. Select multiple instances while holding down the `Shift` key on the keyboard. For example, `M1` and `NM0`.



8. From the menu bar of ADE Assembler, choose *Window – Assistants – Variables and Parameters*.

   The Variables and Parameters assistant opens.



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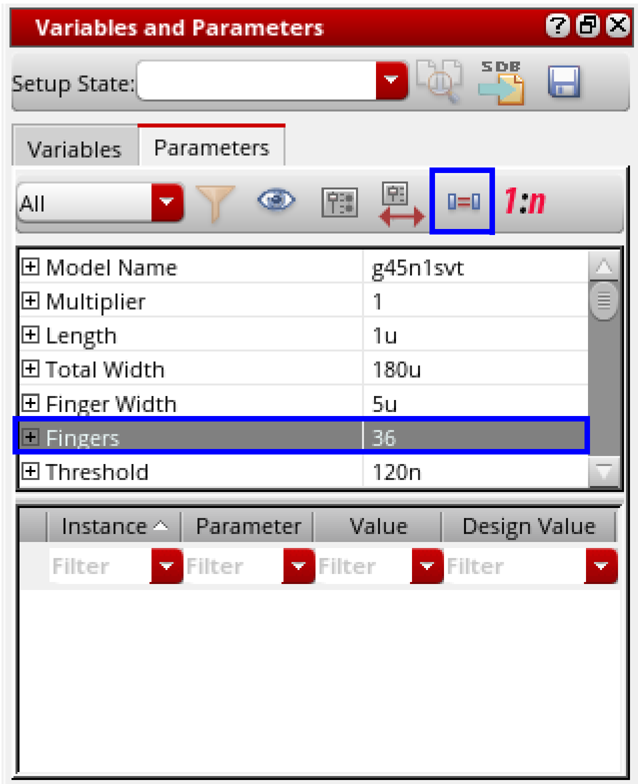
9. In the *Parameters* tab of the Variables and Parameters form, select *All* from the highlighted drop-down list.



10. Click a parameter, for example, *Fingers,* and then click the *Match Parameters* icon.

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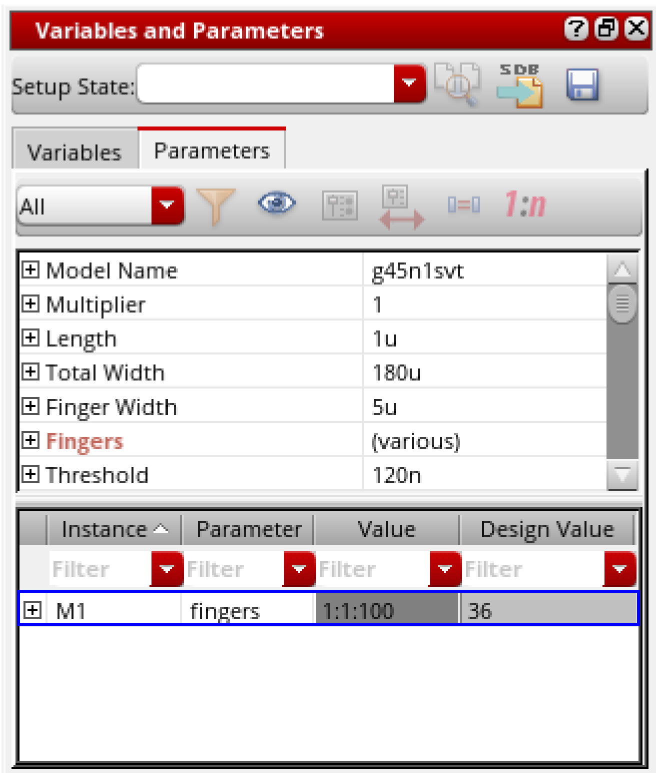
11. In the *Value* column, define the parametric sweep values for the instance `M`. For example, `1:1:100`.



12. To load rest of parameters saved in a setup state:

- ❑ Click the *maestro* tab of ADE Assembler.
- ❑ In the *Data View* assistant, expand *Setup States*.
- ❑ Right-click a setup state, and then click *Load* to load the setup state. For example: *optimization_parameter.*

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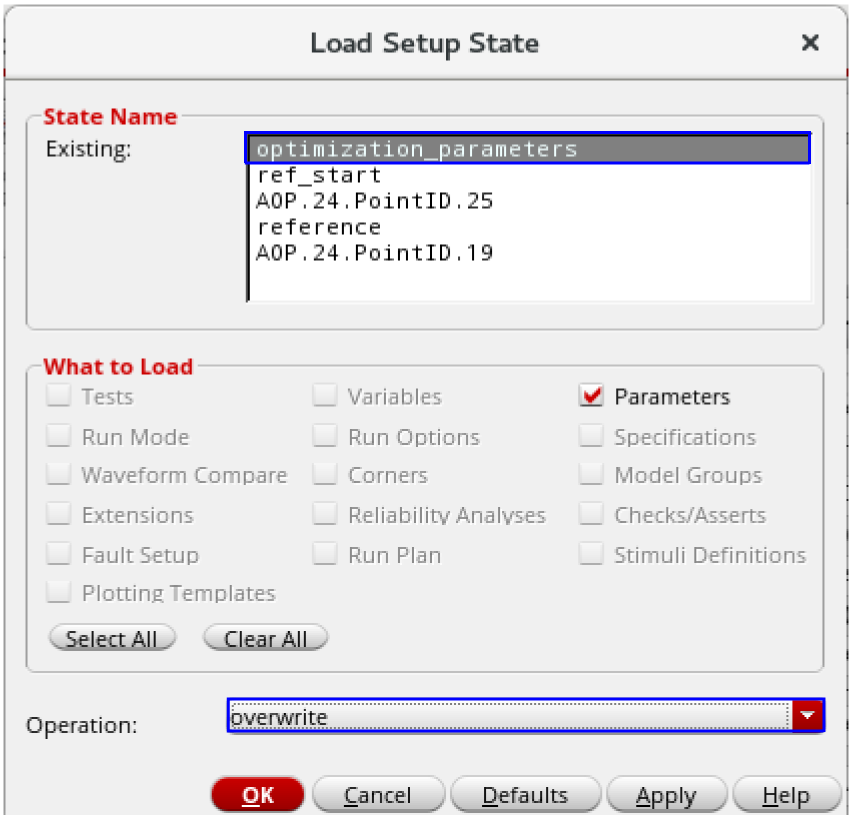
The Load Setup State form opens.



13. Click OK to load the setup state.

    All the parameters saved in the setup state are loaded.

14. From the *Run Mode* drop-down list in the *Run* toolbar of ADE Assembler, select *Advanced Optimization*. The history name is changed to *AOP*.

15. Click *Simulation Options*.

    The AOP Options form is displayed.

16. From the *Optimizers* drop-down list, select a custom optimization algorithm you have created. For example, *PSO*.

17. Specify other options. You can also edit the values of hyperparameters defined for the custom optimization algorithm you selected from the *Optimizers* drop-down list.

18. Click *OK* to close the AOP Options form.

19. Click *Run Simulation*.

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The optimizer converges on a solution that meets all specification, as shown in the following figure.

The default history name for the Advanced Optimization run is *AOP*.*n*, where *n* is the number of advanced optimization run.

Related Topics

[Advanced Optimization]()

[Advantages of Advanced Optimization]()

[AOP Options Form]()

[Example of Custom Optimization Algorithm]()

[Integrating a Custom Optimizer into ADE Assembler]()

[Loading a Setup State]()

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9

Yield Improvement

Virtuoso Variation Option provides the Improve Yield run mode that returns a design to a state where it meets all of the design criteria and has the highest possible yield. If no such point is reached, it runs iterative analyses on the current criteria and determines the conditions for highest possible yield for that design.

The Improve Yield run mode runs iterations of sizing and Monte Carlo analysis to arrive at a solution. When you start the Improve Yield run, 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.

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.

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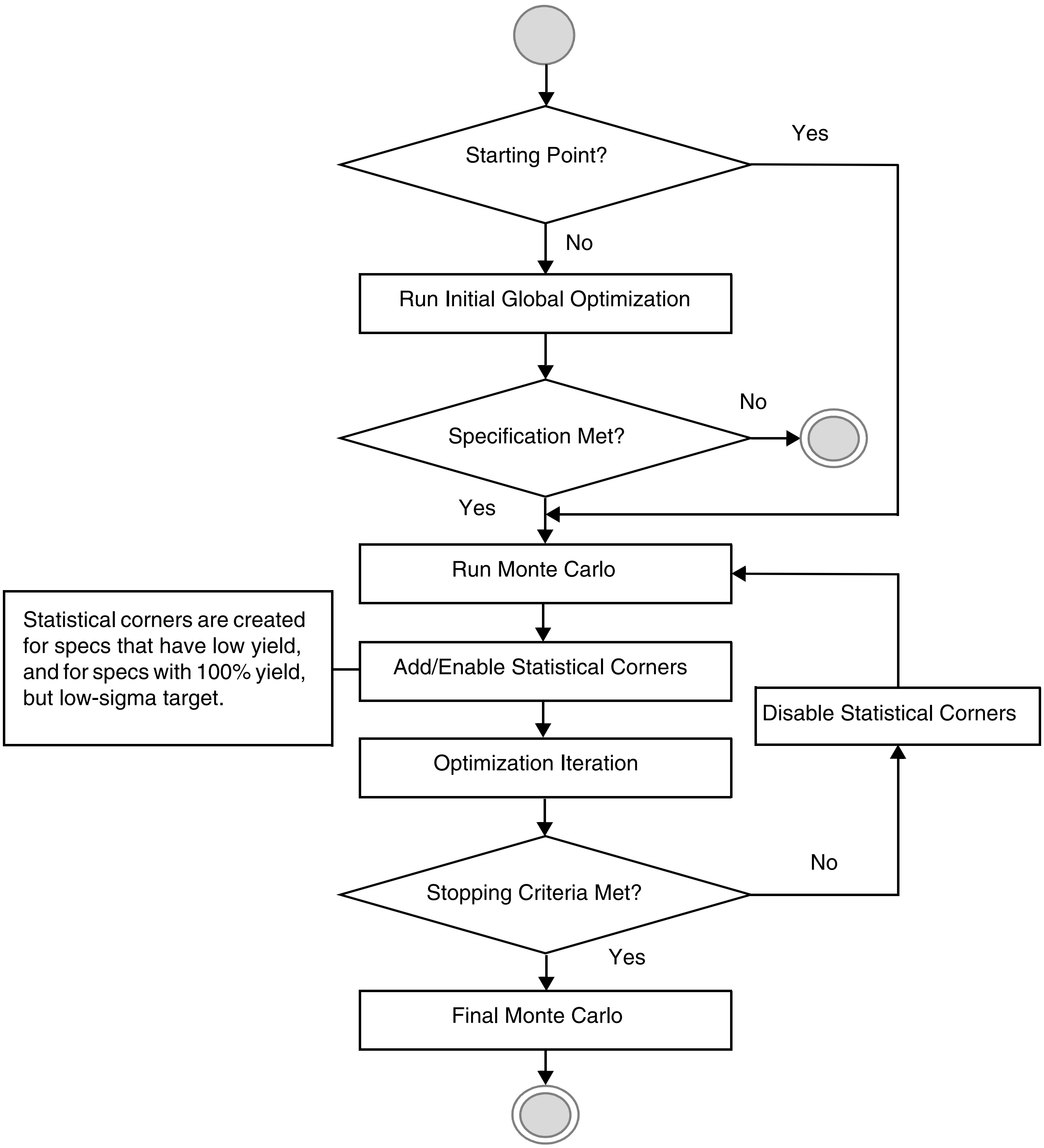
The following figure shows the workflow of the *Improve Yield* run mode.



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Related Topics

Improving Yield of a Design

Full Evaluation and Conditional Evaluation

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Full Evaluation and Conditional Evaluation

The optimization options in the Improve Yield mode provides the following evaluation types:

- Full Evaluation

  Full evaluation runs all tests for each new design point to compare against the current lowest-cost point (best point).

- Conditional Evaluation

  Conditional evaluation first simulates only the tests or corners that failed at the previous point. If the results of those tests and corners are worse than they were at the previous point, the remaining tests and corners are skipped for that design point. This evaluation saves time for optimization over many tests and corners.

Related Topics

Improve Yield Form

Improving Yield of a Design

Advanced Optimization

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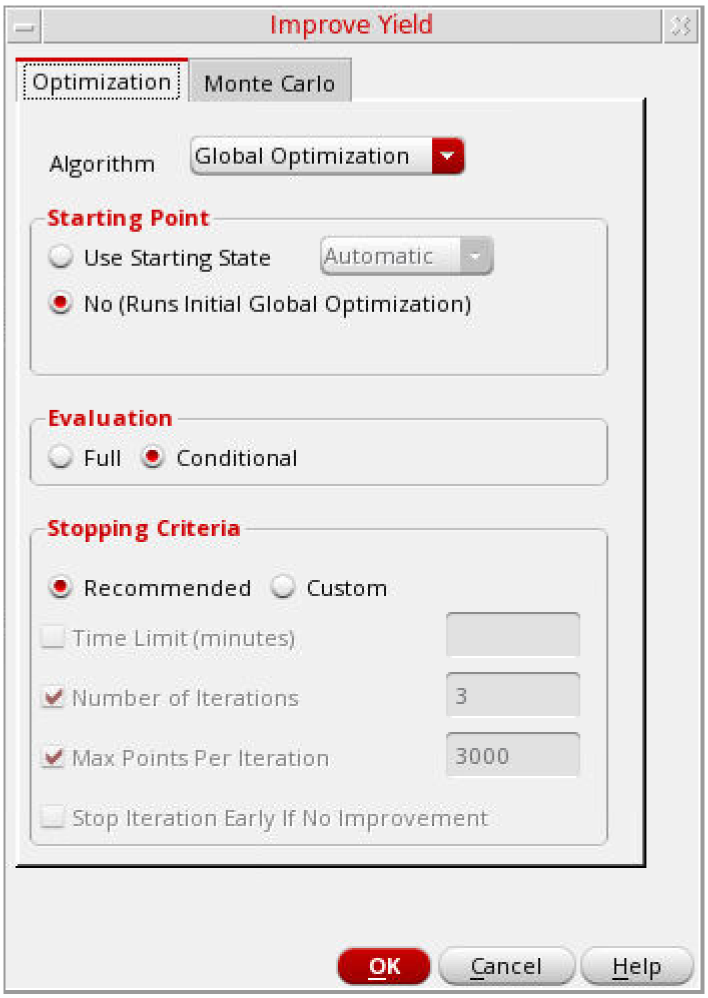
Improving Yield of a Design

To improve the yield of a design:

1. From the *Select a Run Mode* drop-down list, choose *Improve Yield*.
2. Click *Simulation Options*.

   The Improve Yield form opens.



3. On the *Optimization* tab, from the *Algorithm* drop-down list, select an optimization algorithm.
4. From the *Starting Point* options, select a starting point for the simulation run.
5. From the *Evaluation* options, select one of the following evaluation types:

   ❑ *Full*

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- *Conditional*

6. In the *Stopping Criteria* section, select the *Recommended* check box to use the following recommendations for stopping criterion:
   - Three sizing/Monte Carlo iterations
   - 3000 points run per iteration

   If you want to modify the recommended options, select the *Custom* check box, and then select one or more of the following stopping criteria:
   - To set a time limit for the run, select the *Time Limit (minutes)* check box and enter a value.
   - To specify the number of sizing/Monte Carlo iterations, select the *Number of Iterations* check box and enter the number in the field.
   - 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.
   - 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.
7. Click the *Monte Carlo* tab to specify the options for Monte Carlo run.
8. From the *Statistical Variation* options, select *Process*, *Mismatch*, or *All*.
9. From the *Sampling Method* drop-down list, select *Random*, *Latin Hypercube*, or *Low-Discrepancy Sequence*.
10. In the Number of Points field, specify the number of Monte Carlo points to simulate.
11. If the *Sampling Method* is selected as *Latin Hypercube*, specify the number of bins (subdivisions) in the *Number of Bins* field.
12. (Optional) In the *Monte Carlo Seed* field, enter the seed number. If you do not specify any value the default 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.
14. Click *Specify Tests for Monte Carlo* to select the tests for which you want to run the Monte Carlo simulation.
15. Click *OK* to close the form.
16. Click *Run Simulation*.

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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.

Related Topics

Improve Yield Form

Full Evaluation and Conditional Evaluation

Yield Improvement

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10

Virtuoso Variation Option Forms

This section describes the forms used in Virtuoso Variation Option.

- The Monte Carlo form:

  The Monte Carlo form lets you set up options to run various Monte Carlo methods.

- The Improve Yield form:

  The Improve Yield form lets you specify the options for running Improve Yield mode.

- The AOP Options form:

  The AOP Options form lets you specify the options to run advanced optimization.

Related Topics

Monte Carlo Form

Improve Yield Form

AOP Options Form

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Monte Carlo Form

The Monte Carlo form lets you set up options to run various Monte Carlo methods.

Field	Description
Method	Lets you select one of the following methods to run Monte Carlo sampling: ■ *Standard Monte Carlo* ■ *FMC Worst Samples* ■ *Sensitivity Accuracy* ■ *Yield Verification - Autostop* In addition, you can also select the following options provided that the corresponding environment variables are set to `t`. ■ *Confidence Interval - Autostop* showMethodCIAutoStop ■ *K-Sigma Corners* showMethodKSigmaCorners ■ *Yield Verification - Reorder Samples* showMethodYieldVerificationReorderSamples ■ *Worst Samples* showMethodWorstSamples ■ *Scaled-Sigma Sampling* showMethodScaledSigmaSampling ■ *Worst Case Distance* showMethodWorstCaseDistance
Variation	Selects one of the following statistical variation options: ■ *Mismatch*: For per-instance statistical variations. ■ *Process*: For process statistical variations. ■ *All*: For both process and per-instance statistical variations.

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Field	Description
Max Points	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 Monte Carlo run is stopped.
Number of Points	Specifies the number of sample points to simulate. You can use scientific notation to specify values in this field. For example, you can use either `1e3` or `1k` to specify `1000` points.
Max Scaling Factor	Specifies the maximum scaling factor to be used for the Scaled-Sigma Sampling method. You can specify a value between 3–7. By default, this field is set to 7, which means that seven child histories using seven different scaling factors will be generated. Environment variable: enableMaxScalingFactorForSSS
Total Samples	Specifies the maximum number of points to be simulated for FMC Worst Sample method.
Target Yield	Specifies the yield value that you want to achieve for your design. It can be expressed either as a sigma value or as a percentage value. The target yield can be any value between *3–6 sigma* or *99.865%*.
Tail Samples	Specifies the number of tail samples. If you do not specify the number of tail samples, it is calculated automatically using *Total Samples* and *Target Yield* values.
Budget	Specifies the number of simulations to be run for FMC method. For example, `500`, which indicates that no more than `500` points are simulated for the FMC method. This is an optional field.

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Field	Description
Initial Points	Specifies the number of initial points based on which metrics, such as mean and standard deviations are calculated and annotated in histograms. Specifying higher number of initial points improves the accuracy of the mean and standard deviation measurements. In FMC method, an initial model is built after the initial sampling group finishes. The initial model can be built with additional data points by increasing the number of initial points. This is an optional field.
Points per Job	Lets you control the grouping of Monte Carlo points (Spectre `montecarlo numruns`): ■ *Group automatically*: Select this option if you want the tool to determine the grouping and to automatically set the `numruns` value based on the number of *Max Jobs*. ■ *Max*: Lets you specify the number of Monte Carlo points. For example, if you specify `1`, a separate Spectre netlist is created with `numruns=1` for each Monte Carlo point.
Create Statistical Corners	Lets you create statistical corners that can further be used in optimizing and debugging the design. This option is available only for *Scaled-Sigma Sampling* and *Worst-Case Distance* methods.
Save Waveforms (Simulation Data)	Saves output data (psf files) for every Monte Carlo iteration so that you can perform post-processing operations, such as plotting, printing, annotation, and re-evaluation on individual iterations. This option is not available for *Scaled-Sigma Sampling* and *Worst-Case Distance* methods.
Distribution Type and Scaling	Lets you specify the distribution types for Monte Carlo process and mismatch variations. Environment variable: showOptionDistributionTypeAndScaling

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Field	Description
Process	Specifies the distribution type for Monte Carlo process variations. The valid values are *Gaussian* and *Uniform*. ■ For *Gaussian*, specify the value by which you want to scale the standard deviation of process variation parameters in the *Std Scale* field. ■ For *Uniform*, specify the n-scale value for process variation parameters in the *N Scale* field.
Mismatch	Specifies the distribution type for Monte Carlo mismatch variations. The valid values are *Gaussian* and *Uniform*. ■ For *Gaussian*, specify the value by which you want to scale the standard deviation of mismatch variation parameters in the *Std Scale* field. ■ For *Uniform*, specify the n-scale value for mismatch variation parameters in the *N Scale* field.
Probability	Specifies the probability value in percentage. 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 require fewer simulations before autostop is triggered. The default probability is `95%`. Environment variable: yieldProbability
Stop Percentage	Specifies the percentage value of stopping criteria for the Confidence Interval - Autostop method. Environment variable: confidenceAutoStopPercentage
Confidence Level	Determines the confidence interval for the output standard deviation considered by the stopping criteria. Environment variables: confidenceAutoStopLevel and showConfidenceAutoStopLevel.
Confidence Sigma	Determines the range of output variations considered by the stopping criteria. Environment variables: confidenceAutoStopSigma and showConfidenceAutoStopSigma.

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Field	Description
Sampling Method	Selects one of the following statistical sampling methods: ■ *Random* ■ *Latin Hypercube* ■ *Low-Discrepancy Sequence* For more information, see Statistical Sampling Methods.
Seed	Specifies a seed for the Monte Carlo analysis. You can reproduce a previous experiment by specifying the same seed. If you do not specify a seed, the default value `12345` is used.
First Point	Specifies 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).
Netlist Options	Specifies additional analysis options that you want to generate in the netlist. You cannot specify the `numruns`, `firstrun`, and `seed` options in this field. For example: `"nullmfactorcorrelation=yes"`
Specify Instances/ Devices	Click to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see Specifying Instances for Monte Carlo Mismatch and Process Variation in *Virtuoso ADE Explorer User Guide*.
Specify Mismatch ID	Click to specify the mismatch ID. For more information see, Introduction to Mismatch ID in *Virtuoso ADE Assembler User Guide*.
Specify Design Variables	Click to specify design variables that you want to vary with statistical distribution in Monte Carlo analysis. For more information see, Varying Design Variables with Statistical Distribution in *Virtuoso ADE Assembler User Guide*.

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Field	Description
Worst Case Distance Options	Provides additional options that are related to the Worst-Case Distance method.
Use Monte Carlo History	Selects 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. 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.
Automatic Number of Monte Carlo Points	Enables 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 specify the number of Monte Carlo points to be simulated, disable this check box.
Automatic Variable Reduction	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. By default, the *Automatic Variable Reduction* check box is disabled. To enable this check box, first deselect the *Automatic Number of Monte Carlo Points* check box.
Skip Specs With MC Yield <	Ignores the specifications for which Monte Carlo yield is less than a specified percentage. 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 estimation on all the specifications, deselect the *Skip Specs With MC Yield <* check box.
Max Number of Iterations	Specifies the maximum number of iterations to be run for each specification. The default number of iterations is `10`.

Related Topics

Running the Fast Monte Carlo Method

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Running the Confidence Interval - Autostop Method

Statistical Sampling Methods

Running Mismatch Contribution Analysis

Running the Yield Verification - Reorder Sample Method

Running the K-Sigma Corners Method

Running the Worst Sample Method

Running the Scaled-Sigma Sampling Method

Running the Worst-Case Distance Method

Creating Statistical Corners

Performing a Standard Monte Carlo Run

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Improve Yield Form

The Improve Yield form lets you specify the options for running the *Improve Yield* mode. The form contains the following tabs:

Tab	Description
Optimization Tab	Lets you specify the optimization algorithm, starting point of the simulation run, evaluation type, and stopping criteria.
Monte Carlo Tab	Lets you specify the Monte Carlo run options for the Improve Yield mode.

Optimization Tab

The following table describes the fields available on the *Optimization* tab of the Improve Yield form.

Field	Description
Algorithm	Selects one of the following optimization algorithms: ■ *Global Optimization* ■ *BFGS* ■ *Conjugate Gradient* ■ *Brent-Powell* ■ *Hooke-Jeeves*

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Field	Description
Starting Point	Selects one of the following options to specify a starting point for the simulation run: ■ *Use Starting State*: 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 *Use Starting State* drop-down list on the form. ■ *No (Runs Initial Global Optimization)*: To perform an initial global optimization on the nominal corner and to use its best point as the starting point for the run. If you select this option, 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.
Evaluation	Lets you select one of the following evaluation methods: ■ Full ■ Conditional For more information, see Full Evaluation and Conditional Evaluation.
Stopping Criteria	Lets you use either the recommended options or custom options for stopping criteria.
Time Limit (minutes)	Sets a tile limit for the run.
Number of Iterations	Specifies the number of sizing/Monte Carlo iterations. The default is `3`.

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Field	Description
Max Points Per Iteration	Specifies the maximum number of points processed per iteration. The default is `3000`.
Stop Iteration Early If No Improvement	Stops the process early if the sizing results in no improvement. 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 *Max Points Per Iteration* / `3`.

Monte Carlo Tab

The following table describes the fields available on the *Optimization* tab of the Improve Yield form.

Field	Description
Statistical Variation	Selects one of the following statistical variation options: ■ *Mismatch*: For per-instance statistical variations. ■ *Process*: For process statistical variations. ■ *All*: For both process and per-instance statistical variations.
Sampling Method	Selects one of the following statistical sampling methods supported by Spectre: ■ *Random* ■ *Latin Hypercube* ■ *Low-Discrepancy Sequence* For more information, see Statistical Sampling Methods.
Number of Points	Specifies the number of Monte Carlo points to be simulate.

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Field	Description
Number of Bins	Specifies the number of bins (subdivisions) for the Latin Hypercube method. ■ 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.
Run Normal Simulation	Runs normal simulation.
Monte Carlo Seed	Specifies 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 by default.
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 detail. **Note:** 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.
Specify Instances/ Devices	Click to specify the sensitive instances and devices you want to either include or exclude for applying mismatch variations. For more information, see Specifying Instances for Monte Carlo Mismatch and Process Variation in *Virtuoso ADE Explorer User Guide*.

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Field	Description
Specify Tests for Monte Carlo	Click to select the tests for which you want to run Monte Carlo simulation.

Related Topics

Improving Yield of a Design

Full Evaluation and Conditional Evaluation

Statistical Sampling Methods

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AOP Options Form

The AOP Options form lets you specify the options to run advanced optimization method.

Field	Description
Method	Lets you select the optimization algorithm. You can create your custom optimization algorithm in either C++ or Python.
Starting State	Lets you select the setup state you want to use as the starting state. ADE Assembler allows you to create setup states that contain complete or part of the simulation setup. You can later restore the simulation setup from the setup state by loading all or part of the settings in the setup state.
Optimizer Properties	Lets you view the properties of the selected optimization algorithm.
Evaluation	Lets you select one of the following evaluation methods: ■ Full ■ Conditional For more information, see Full Evaluation and Conditional Evaluation.
Stopping Criteria	Lets you specify criteria of duration of time for which advanced optimization must run. ■ *All Specs Met*: Runs until all goals are met ■ *Time Limit (minutes)*: Sets a time limit for the run ■ *Point Limit*: Sets a limit for the number of points to run ■ *No Improvement with Points*: Stops sizing when no improvement is seen for a specified number of points You cannot select both the *Point Limit* and *No Improvement with Points* check boxes simultaneously. ■ *Points After All Specs Met*: Continues exploring the design space for a better solution even all specifications are met. You cannot select both the *All Specs Met* and *Points After All Specs Met* check boxes simultaneously.

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Field	Description
`Optimizer` HyperParameters	Groups hyperparameters defined in the selected custom optimization algorithm.

Related Topics

Advanced Optimization

Advantages of Advanced Optimization

Running Advanced Optimization

Example of Custom Optimization Algorithm

Integrating a Custom Optimizer into ADE Assembler

Loading a Setup State

Hyperparameters of Valhalla Optimizer

Hyperparameters of Optuna Optimizer

Hyperparameters of Dakota Optimizer

Hyperparameters of Particle Swarm Optimizer

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11

Environment Variables

This section provides information on the names, descriptions, and graphical user interface equivalents of the environment variables used in Virtuoso Variation Option.

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confidenceAutoStopLevel

```
maestro.monte confidenceAutoStopLevel float confidenceLevel
```

Description

Specifies the default value of *Confidence Level* to be used in the Confidence Interval - Autostop method. You can specify any floating point value between `0.0`–`100000.0`.

The default value is `95.0`.

GUI Equivalent

Form	The *Advanced - Show All Options* section on the Monte Carlo form.
Field	*Confidence Level*

Examples

```
envGetVal("maestro.monte" "confidenceAutoStopLevel")
envSetVal("maestro.monte" "confidenceAutoStopLevel" 'float 100.0)
```

Related Topics

The Confidence Interval - Autostop Method

Advanced Options of the Confidence Interval - Autostop Method

Monte Carlo Form

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confidenceAutoStopPercentage

`maestro.monte confidenceAutoStopPercentage float` *`stopPercentage`*

Description

Specifies the default value of *Stop Percentage* to be used in the Confidence Interval - Autostop method. You can specify any floating point value between `0.0`–`100000.0`.

The default value is `5.0`.

GUI Equivalent

Form	The *Advanced - Show All Options* section on the Monte Carlo form.
Field	*Stop Percentage*

Examples

```
envGetVal("maestro.monte" "confidenceAutoStopPercentage")
envSetVal("maestro.monte" "confidenceAutoStopPercentage" 'float 100.0)
```

Related Topics

The Confidence Interval - Autostop Method

Advanced Options of the Confidence Interval - Autostop Method

Monte Carlo Form

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confidenceAutoStopSigma

```
maestro.monte confidenceAutoStopSigma float confidenceSigma
```

Description

Specifies the default value of *Confidence Sigma* to be used in the Confidence Interval - Autostop method. You can specify any floating point value between `0.0`–`100000.0`.

The default value is `3.0`.

GUI Equivalent

Form	The *Advanced - Show All Options* section on the Monte Carlo form.
Field	*Confidence Sigma*

Examples

```
envGetVal("maestro.monte" "confidenceAutoStopSigma")
envSetVal("maestro.monte" "confidenceAutoStopSigma" 'float 5.0)
```

Related Topics

The Confidence Interval - Autostop Method

Advanced Options of the Confidence Interval - Autostop Method

Monte Carlo Form

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digitsToShowForYieldInPercentage

```
adexl.gui digitsToShowForYieldInPercentage int digitsInYieldPercentage
```

Description

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. You can specify any integer value between `10`–`53`.

The default value is `10`.

GUI Equivalent

None

Examples

```
envGetVal("adexl.gui" "digitsToShowForYieldInPercentage")
envSetVal("adexl.gui" "digitsToShowForYieldInPercentage" 'int 12)
```

Related Topics

High Yield Estimation

Yield View of the Scaled-Sigma Sampling Method

Yield View of the Worst-Case Distance Method

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enableMaxScalingFactorForSSS

```
maestro.monte enableMaxScalingFactorForSSS boolean { t | nil }
```

Description

Specifies whether to show the *Max Scaling Factor* field in the *Advanced - Show All Options* section of the Monte Carlo form when the *Method* is *Scaled-Sigma Sampling*.

The default value is `nil`, which indicates that the *Max Scaling Factor* field is hidden.

GUI Equivalent

Form	The *Advanced - Show All Options* section on the Monte Carlo form.
Field	*Max Scaling Factor*

Examples

```
envGetVal("maestro.monte" "enableMaxScalingFactorForSSS")
envSetVal("maestro.monte" "enableMaxScalingFactorForSSS" 'boolean t)
```

Related Topics

The Scaled-Sigma Sampling Method

Monte Carlo Form

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maxPointsForSensitivityAccuracy

`maestro.monte maxPointsForSensitivityAccuracy int` *`maxPointsToSimulate`*

Description

Specifies the maximum number of sample points to be simulated for the Sensitivity Accuracy method. You can specify any integer value between `1`–`100000`.

The default value is `100000`.

GUI Equivalent

None

Examples

```
envGetVal("maestro.monte" "maxPointsForSensitivityAccuracy")
envSetVal("maestro.monte" "maxPointsForSensitivityAccuracy" 'int 50000)
```


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showConfidenceAutoStopLevel

```
maestro.monte showConfidenceAutoStopLevel boolean { t | nil }
```

Description

Specifies whether to show the *Confidence Level* field in the Monte Carlo form when the *Method* is selected as *Confidence Interval - Autostop*.

The default value is `nil`, which indicates that the *Confidence Level* field is hidden.

The *Confidence Interval - Autostop* method is hidden from the *Method* drop-down list by default. Set the following environment variable to `t` to display it.

```
envSetVal("maestro.monte" "showMethodCIAutoStop" 'boolean t)
```

GUI Equivalent

The *Confidence Level* field in the Monte Carlo form.

Examples

```
envGetVal("maestro.monte" "showConfidenceAutoStopLevel")
envSetVal("maestro.monte" "showConfidenceAutoStopLevel" 'boolean t)
```

Related Topics

The Confidence Interval - Autostop Method

Advanced Options of the Confidence Interval - Autostop Method

Monte Carlo Form

showMethodCIAutoStop

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showConfidenceAutoStopSigma

```
maestro.monte showConfidenceAutoStopSigma boolean { t | nil }
```

Description

Specifies whether to show the *Confidence Sigma* field in the Monte Carlo form when the *Method* is selected as *Confidence Interval - Autostop*.

The default is `nil`, which indicates that the *Confidence Sigma* field is hidden.

The *Confidence Interval - Autostop* method is hidden from the *Method* drop-down list by default. Set the following environment variable to `t` to display it.

```
envSetVal("maestro.monte" "showMethodCIAutoStop" 'boolean t)
```

GUI Equivalent

The *Confidence Sigma* field in the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showConfidenceAutoStopSigma")
envSetVal("maestro.monte" "showConfidenceAutoStopSigma" 'boolean t)
```

Related Topics

The Confidence Interval - Autostop Method

Advanced Options of the Confidence Interval - Autostop Method

Monte Carlo Form

showMethodCIAutoStop

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showMethodCIAutoStop

```
maestro.monte showMethodCIAutoStop boolean { t | nil }
```

Description

Specifies whether to show the *Confidence Interval - Autostop* option in the *Method* drop-down list of the Monte Carlo form.

The default is `nil`, which indicates that the *Confidence Interval - Autostop* option is hidden.

GUI Equivalent

The *Confidence Interval - Autostop* option in the *Method* drop-down list of the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showMethodCIAutoStop")
envSetVal("maestro.monte" "showMethodCIAutoStop" 'boolean t)
```

Related Topics

The Confidence Interval - Autostop Method

Advanced Options of the Confidence Interval - Autostop Method

Monte Carlo Form

showConfidenceAutoStopLevel

showConfidenceAutoStopSigma

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showMethodKSigmaCorners

```
maestro.monte showMethodKSigmaCorners boolean { t | nil }
```

Description

Specifies whether to show the *K-Sigma Corners* option in the *Method* drop-down list of the Monte Carlo form.

The default is `nil`, which indicates that the *K-Sigma Corners* option is hidden.

GUI Equivalent

The *K-Sigma Corners* option in the *Method* drop-down list of the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showMethodKSigmaCorners")
envSetVal("maestro.monte" "showMethodKSigmaCorners" 'boolean t)
```

Related Topics

The K-Sigma Corners Method

Running the K-Sigma Corners Method

Monte Carlo Form

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showMethodScaledSigmaSampling

```
maestro.monte showMethodScaledSigmaSampling boolean { t | nil }
```

Description

Specifies whether to show the *Scaled-Sigma Sampling* option in the *Method* drop-down list of the Monte Carlo form.

The default is `nil`, which indicates that the *Scaled-Sigma Sampling* option is hidden.

GUI Equivalent

The *Scaled-Sigma Sampling* option in the *Method* drop-down list of the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showMethodScaledSigmaSampling")
envSetVal("maestro.monte" "showMethodScaledSigmaSampling" 'boolean t)
```

Related Topics

The Scaled-Sigma Sampling Method

Running the Scaled-Sigma Sampling Method

Monte Carlo Form

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showMethodWorstCaseDistance

```
maestro.monte showMethodWorstCaseDistance boolean { t | nil }
```

Description

Specifies whether to show the *Worst Case Distance* option in the *Method* drop-down list of the Monte Carlo form.

The default is `nil`, which indicates that the *Worst Case Distance* option is hidden.

GUI Equivalent

The *Worst Case Distance* option in the *Method* drop-down list of the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showMethodWorstCaseDistance")
envSetVal("maestro.monte" "showMethodWorstCaseDistance" 'boolean t)
```

Related Topics

The Worst-Case Distance Method

Running the Worst-Case Distance Method

Monte Carlo Form

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showMethodWorstSamples

```
maestro.monte showMethodWorstSamples boolean { t | nil }
```

Description

Specifies whether to show the *Worst Samples* option in the *Method* drop-down list of the Monte Carlo form.

The default is `nil`, which indicates that the *Worst Samples* option is hidden.

GUI Equivalent

The *Worst Samples* option in the *Method* drop-down list of the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showMethodWorstSamples")
envSetVal("maestro.monte" "showMethodWorstSamples" 'boolean t)
```

Related Topics

The Worst Samples Method

Running the Worst Sample Method

Monte Carlo Form

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showMethodYieldVerificationAutoStop

```
maestro.monte showMethodYieldVerificationAutoStop boolean { t | nil }
```

Description

Specifies whether to show the *Yield Verification - Autostop* option in the *Method* drop-down list of the Monte Carlo form.

The default is `nil`, which indicates that the *Yield Verification - Autostop* option is hidden.

GUI Equivalent

The *Yield Verification - Autostop* option in the *Method* drop-down list of the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showMethodYieldVerificationAutoStop")
envSetVal("maestro.monte" "showMethodYieldVerificationAutoStop" 'boolean t)
```

Related Topics

Yield Verification

Monte Carlo Form

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showMethodYieldVerificationReorderSamples

```
maestro.monte showMethodYieldVerificationReorderSamples boolean { t | nil }
```

Description

Specifies whether to show the *Yield Verification - Reorder Samples* option in the *Method* drop-down list of the Monte Carlo form.

The default is `nil`, which indicates that the *Yield Verification - Reorder Samples* option is hidden.

GUI Equivalent

The *Yield Verification - Reorder Samples* option in the *Method* drop-down list of the Monte Carlo form

Examples

```
envGetVal("maestro.monte" "showMethodYieldVerificationReorderSamples")
envSetVal("maestro.monte" "showMethodYieldVerificationReorderSamples" 'boolean t)
```

Related Topics

Yield Verification

Workflow of the Yield Verification - Reorder Samples Method

Running the Yield Verification - Reorder Sample Method

Monte Carlo Form

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showOptionDistributionTypeAndScaling

```
maestro.monte showOptionDistributionTypeAndScaling boolean { t | nil }
```

Description

Specifies whether to show *Distribution Type and Scaling* options in the Monte Carlo form.

The default is `nil`, which indicates that the *Distribution Type and Scaling* options are hidden.

GUI Equivalent

None

Examples

```
envGetVal("maestro.monte" "showOptionDistributionTypeAndScaling")
envSetVal("maestro.monte" "showOptionDistributionTypeAndScaling" 'boolean t)
```

Related Topics

Monte Carlo Form

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sortVariablesOpt

```
adexl.algorithm sortVariablesOpt boolean { t | nil }
```

Description

Specifies whether the variables and parameters are sorted before generating random samples for an optimization run.

The default value is `nil`, which indicates that the variables are not sorted before the run is started. However, you can sort them by setting this variable to `t` to ensure that the results of different optimization runs are the same irrespective of the order of variables and parameters.

GUI Equivalent

None

Examples

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


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useDoubleSidedSigma

`adexl.algorithm useDoubleSidedSigma boolean { t | nil }`

Description

Specifies whether to create single-sided or double-sided K-Sigma statistical corners.

The default is `nil`, which indicates that single-sided K-Sigma corners are created.

GUI Equivalent

None

Examples

```
envGetVal("adexl.algorithm" "useDoubleSidedSigma")
envSetVal("adexl.algorithm" "useDoubleSidedSigma" 'boolean t)
```

Related Topics

The K-Sigma Corners Method

Running the K-Sigma Corners Method

Creating K-Sigma Corners from a Standard Monte Carlo Run

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WCCEnableNewlyCreatedCorners

```
adexl.gui WCCEnableNewlyCreatedCorners boolean { t | nil }
```

Description

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

The default is `t`, which indicates that the worst-case corners are enabled.

GUI Equivalent

None

Examples

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


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yieldProbability

`adexl.monte yieldProbability float` *`percentageValue`*

Description

Specifies the yield probability (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 fewer simulations before the auto-stop is triggered.

You can specify any floating point value between `0.0`–`100.0`. The default is `95.0`.

GUI Equivalent

None

Examples

```
envGetVal("adexl.monte" "yieldProbability")
envSetVal("adexl.monte" "yieldProbability" 'float 100.0)
```

Related Topics

Monte Carlo Form

Running the Yield Verification - Reorder Sample Method

Running the Worst Sample Method

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yieldViewKSigma

`maestro.gui yieldViewKSigma string` *`listOfKSigmaValues`*

Description

Specifies the value or a list of values of K-Sigma that you want to display as columns in the *Yield* view of a Monte Carlo result. You can specify a list of either comma-separated values or space-separated values.

The default value is `3`.

GUI Equivalent

The *K-Sigma* field in the Set K-Sigma form.

Examples

```
envGetVal("maestro.gui" "yieldViewKSigma")
envSetVal("maestro.gui" "yieldViewKSigma" 'string "1,3,4.5")
envSetVal("maestro.gui" "yieldViewKSigma" 'string "1 3 4.5")
```

Related Topics

Displaying Mean K-Sigma and Median Columns in the Yield View

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