Virtual Wafer Fab

SILVACO

VWF is software used for performing Design of Experiments (DOE) and Optimization Experiments. Split-lots can be used in various predefined analysis methods. Split parameters can be defined for any of Silvaco's process, device, parasitic extraction and circuit simulators. All simulations can be carried out in parallel either on a cluster of workstations or on a single SMP machine. VWF comes with a GUI, that also enables examination of experimental results.

Key Features

- VWF can represent an entire flow from process simulation to spice circuit performance, or just part of the flow
- Any mix of masks, process parameters, device parameters, circuit parameters or tuning coefficients can be defined as input variables
- Experiments can be defined by varying the input parameters automatically via a DOE such as Box Behnken, via an optimization algorithm like Levenberg-Marquardt, via a user-definable script or manually
- Powerful scripting interface allows to fully customize DOEs, to run experiments in the background and to compute complex optimization target functions
- Process characteristics such as oxide thickness, device characteristics such as a threshold voltage, or circuit characteristics such as rise time can be measured from the entire flow
- Each experimental variation can be run on a network of hosts to shorten simulation time
- Response models can be generated over the experimental spread and then input parameters can be rubber banded to see the effect on output responses
- A full worksheet of input and measured output responses can be exported to Spayn for additional statistical analysis, or to TonyPlot for viewing purposes
- Advanced security features allowing fine-grained access control

Database Manager

- Archive all experiments and results in a powerful SQL-92 compliant database
- Supports the Silvaco SRDB database to backup and restore databases easily
- Supports both database and file mode data storage environments
- VWF Tar Import/Export Smooth process to move an experiment from one database to another database
- Supports multiple databases
- Access to multiple databases through a user name and password
- External files used in the input deck are loaded in the database using the resources menu



Input decks can be loaded from files, or pasted from another directory in the same database or imported from another database.

Split-Lot Manager

- · Allows selection of variables where a design split will occur
- Design split points may occur at any stage of a complete process flow (i.e layout, process, device, parasitic extraction and spice)
- Resultant split tree is visually displayed
- Each leaf of the design tree may be selected to provide information on the simulation runtime output or to plot the current structure for that particular process flow



Split parameters are defined graphically for any type of simulator.

Access experiments through an explorer or tree view graphic.

Experimental Design Generator

- · Shows selectable list of available variables on which split-lots can be performed
- Each split may be chosen independently or based on DOE
- The DOE choices include
 - Full factorial and partial factorial orthogonal designs
 - Box Benkhen, Face Centered Cubic and Circumscribed Composite designs
 - Linear random and latin hypercube designs
 - Gaussian random design
- · Scalar and vector optimization can be done using multi-threaded GA and LM optimizer
- Sensitivity analysis where each selected variable is varied +/- a defined percentage
- Design generator fills in the split-lot tree with all selected variations after selection of the range for the DOE

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Design of Experiment Generator. The DoE is selected from the pull down menu.

Scripting Interface

- Extensions of DOE capability
- Allows to implement DOE strategies in JavaScript
- Supports execution of experiments in the background without the need to start the GUI (batch mode)
- · Allows to use shared libraries to interface functions of the underlying C and math libraries

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1 /* JavaScript implementation of a "Orthogonal Maximin Latin Hypercube" DOE algorithm. 2 3 *The code is an implementation of the algorithm described in: 5 * Orthogonal-Maximin Latin Hypercube Designs 6 * V. Roshan Joseph and Ying Hung	□ ·· □ vwf_js_setup.so	
7 * School of Industrial and Systems Engineering 8 * Georgia Institute of Technology 9 * Atlanta, GA 3033-2005, USA 10 * roshan@sys.egatech.edu 11 * 12 *		
 ¹³ ¹³ This script needs some functions from the C-library, which are not directly available in ¹⁵ * JavaScript, These functions are: ¹⁶ ¹⁷ * srand() ¹⁸ * rand() ¹⁸		
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JavaScript editor displaying an advanced Latin-Hypercube algorithm.

Network Job Controller

- VWF supports ORACLE grid engine and Open Grid Scheduler
- VWF supports LSF (Load Sharing Facility)
- Controls distribution of simulation jobs across the network
- Displays all machines on the network
- · Shows a complete list of all jobs in the simulation queue for all displayed machines
- · Shows the state of each machine to be controlled
- · Allows selected jobs to be canceled from the queue
- · Controls number of jobs sent to a single machine at any one time (for multi-cpu machines)



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Set up CPU numbers on multi-CPU machine when the local queue is used.

Defining a shared library to load.

Grid-Engine Cluster Configuration.

Split Plot Worksheet

- Extension of Interactive Worksheet Editor
- Different view at worksheet allowing to filter by file-type
- Multiple selection of several files to plot
- Data can either be plotted in a single TonyPlot window or several TonyPlot windows can be opened one per file



Drain Current vs. Gate Voltage shown for 4 different process parameter combinations. Curves correspond to the selected cells 8.2, 8.5, 8.6, and 8.9 (red, green, dark blue, light blue).

Interactive Worksheet Editor

- · Display in the worksheet the variations of input parameters
- · Additional splits may be added into the worksheet for simulation
- · Selection of splits may be enabled or disabled before being simulated
- Results can be selected to be exported to TonyPlot for visualization purpose
- · Results can be selected to be exported to Spayn for further statistical analysis

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The worksheet can be directly sent either to TonyPlot or Spayn for subsequent statistical analysis and RSM generation.

Security Features

- · VWF allows to define read/write and execute permissions for every directory and experiment in the system
- · Experiments can be shared between several users in the database
- · User groups can be used to define the same permissions for several users
- · One pre-defined superuser allows to change ownerships and permissions for all users and groups

Name	Read	Write	Execute	Info	
🎬 Design	ম	Γ	Γ	manager, designer, project_leader	
🎬 Analyze	V			manager, reporter, statistician, project_leader	
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Powerful Import/Export Capabilities

- VWF allows to export a whole experiment from the database into an external TAR representation for inter-site exchange or to open the experiment in VWF filemode
- · TAR files can be imported into the database as experiments
- CSV files can be imported to define a DOE
- · Worksheet can be exported into CSV
- Simulation decks can be imported from an existing CVS repository

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Edit Expeni		
escription	Resources Deck Tree Worksheet	Export
Name Type Status Author Base Dir Creation Date Last Change Description :	tutorial_01 DOE Finished demo /tmp/Tutorial/tutorial_01_10001 /tmp/Tutorial/tutorial_01_10001 Thu Jun 23 10:31:35 2011 Thu Jun 23 10:48:29 2011	Data : Option : IF [Experiment] IF Create Archive IF Resources IF Results IF Results Files If Create Archive IF Resul
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Experiment tutorial_01 is exported to a zipped TAR file. The result can directly be opened in VWF filemode or the file can be imported into another database.

		VWF Explorer		- • ×
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Import single file		VWF 2.8.0.	R Copyright © 1984 - 2011 SILVACO	, Inc.

Importing a single TAR file.



Importing several TAR files in batch mode.

Importing CSV file to define a DOE.



Importing deck from a CVS repository.

Result Analyzer

- RSM model generation
- Interactive model visualization
- Sensitivity analysis
- Process synthesis
- Yield analysis
- Optimization results visualization



Statistical summary as well as histograms are available in Spayn for of all variables (i.e process parameter) and corresponding extracted parameter (i.e Ring Oscillator frequency).



✓ Export...

RSM generation done in Spayn and then visualized in TonyPlot. The ring oscillator frequency is shown as a function of process parameter (gate oxidation time and Vt implant dose).

OK

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/tadjust	gateoxtime	0.9998	-0.0618	0.7948	-0.8923	0.9998	-0.1543	-0.0495	-0.6844	-0.1
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N–lin AVGer 🛛 🗖										

Correlation between user selectable parameter is available directly from Spayn.



Yield analysis with user selectable statistical distribution. Yield of ring oscillator frequency is shown as a function of different process parameter distribution (i.e. gate oxidation time).

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20 30

0.25 5

Tonyplot: VWF Production Mode: Distribution

Mean: 25

Std Dev: 2.5

🔽 Update Graph

Ready

Graphical view of an optimization experiment. In Green the best result that minimize the target.

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3	88414068.878	0.56536515057	0.0506802	0.0406802	10.6816	8.50348	6.41423	10526800000	9.390
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7	48166215.837	0.97179675102	0.0592408	0.0492408	10.1545	8.0764	6.08954	10526800000	9.4
8	35073033.988	0.29611884058	0.174196	0.164196	3.43273	2.3071	1.6145	12631900000	9.41(
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10	89561579.585	0.83686938882	0.00567807	0.00432193	13.5583	10.9613	8.47444	10526800000	9.325
11	73463674.009	0.82158888876	0.0280683	0.0180683	11.8406	9.59193	7.32263	10526800000	9.38
12	97945804.477	0.71480330825	0.010376	0.000376	12.724	10.5482	8.11093	11579400000	9.198
13	15889338.672	0.88240815699	0.162487	0.152487	4.28661	3.05502	2.16537	11579400000	9.614
14	18228905.678	0.55348591506	0.17818	0.16818	3.27781	2.24367	1.57321	12631900000	9.479
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Optimized process parameters obtained for the targeted experimental Q factor curve.

HEADQUARTERS

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