MSIM®

High Accuracy Spice Simulator
Legend’s Products

◆ IP Library Characterization Products
  ● Charflo-Cell™: Automatic Cell/IO Library Characterization
  ● Charflo-Memory™: Automatic Memory Characterization

◆ IP Library Model Qualify Assurance Products
  ● Model Diagnoser™
    Cell/IO Library Quality Assurance and Defect Repair

◆ Circuit Simulation Products
  ● MSIM®: Accurate-Spice Simulator
  ● Turbo-MSIM™: Fast-Spice Simulator

Technology Leader in IP Characterization and IC/PCB Simulation
MSIM®
High Accuracy Spice Simulator

- Extreme accuracy and excellent convergence
- High speed and large capacity
- Extensive model support
- Multi-threaded applications on multi-core computer
- Automatic matrix solver selector for throughputs
- Built-in AWE RC Reduction
- Best price-performance

Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® Certifications

- MSIM certified by TSMC’s Spice Tool Qualification Program
  
  http://www.legenddesign.com/BW/021009.shtml

- MSIM certified by TSMC’s TMI (TSMC Model Interface) Qualification Program
MSIM® Advantages
High Accuracy and Fast Speed

- More than twice the speed of the Standard*
- Same accuracy (less than 1%) as the Standard*

* Standard means the most popular Spice simulator
MSIM® Accuracy
Benchmark on BSIM4 Model

Power Consumption Simulation
MSIM™ vs HSPICE™

- Model: BSIM4 V1.1.2
- MOS: 35,152
- Resistor: 299,479
- Capacitor: 64,125
MSIM® Model Support
Extensive Modeling Support

◆ MSIM delivers silicon-accurate models with proven implementations of
  * BSIM3
  * BSIM4
  * BSIM4 SOI
  * HiSIM1 and HiSIM2
  * Philips MM9 & MM11
  * RPI TFT

◆ Direct access of updated SPICE models from
  * TSMC
  * UMC
  * IBM
  * Chartered
  * SMIC
  * Tower

Legend
Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® Simulation Flow

Circuit Netlist → Parser and Pre-Processor → Simulation Engine → Result Database

Device Model → Parser and Pre-Processor → Simulation Engine → Result Database

Simulation Control → Parser and Pre-Processor → Simulation Engine → Result Database

RC Reduction → Simulation Engine → Result Database

Model Extraction → Simulation Engine → Result Database

Input & Setup → Simulation Engine → Result Database

Graphic Data

Measure Data

List File

Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® Multi-Thread
Multi-Core and Parallelism Support

- Enable multi-threaded application on a multi-core configuration
- Utilize the multi-thread functions for decomposing and solving matrices, and calculating device model
- Prove its outstanding efficiency on the circuits with a large number of extracted post-layout parasitics
## MSIM® Multi-Thread Benchmark Data

- Benchmark on 2 Quad-Core CPU system

<table>
<thead>
<tr>
<th>Threads</th>
<th>Run Time</th>
<th>Speed-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>319 seconds</td>
<td>1.00 X</td>
</tr>
<tr>
<td>2</td>
<td>171 seconds</td>
<td>1.87 X</td>
</tr>
<tr>
<td>3</td>
<td>121 seconds</td>
<td>2.64 X</td>
</tr>
<tr>
<td>4</td>
<td>97 seconds</td>
<td>3.29 X</td>
</tr>
<tr>
<td>5</td>
<td>80 seconds</td>
<td>3.99 X</td>
</tr>
<tr>
<td>6</td>
<td>68 seconds</td>
<td>4.69 X</td>
</tr>
<tr>
<td>7</td>
<td>64 seconds</td>
<td>4.98 X</td>
</tr>
<tr>
<td>8</td>
<td>57 seconds</td>
<td>5.60 X</td>
</tr>
</tbody>
</table>

*Technology Leader in IP Characterization and IC/PCB Simulation*
MSIM® Maxtrix Solving
Automatic Matrix Solver Selector

- Conventionally, sparse matrix solving technique is used to take advantage of the sparse in circuit matrix for the efficiency
- For nanometer technology, sparse matrix solving technique could be not efficient for the layout extracted circuits with large RC networks
- A Matrix Solver Selector has been developed and implemented in MSIM, for simulation throughputs.
MSIM® Maxtrix Solving
Benchmark Data

- Benchmark circuit data
  MOSFET: 6,926  Resistor: 65,662  Capacitor: 11,178

- Simulation statistics using Sparse Matrix
  Max allocated memory = 251 mb
  Total CPU time = 36,092.59 seconds

- Simulation Data using Matrix Solver Selector
  Max allocated memory = 97 mb
  Total CPU time = 2,589.69 seconds

- 14X Speed up, and 2.6X less usage of memory
MSIM® RC Reduction
Layout-Extracted Circuit Simulation

◆ Benchmark on D-Type Flip Flop circuit
  MOSFET: 18  Resistor & Capacitor: 1,000+

<table>
<thead>
<tr>
<th></th>
<th>Standard *</th>
<th>MSIM™</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU Time</td>
<td>300 sec</td>
<td>10 sec</td>
<td>30 X</td>
</tr>
</tbody>
</table>

The inaccuracy is less than 1%.

◆ Benchmark on SRAM ‘RR256x16’
  MOSFET: 39,464  Resistor: 200,526  Capacitor: 316,934

<table>
<thead>
<tr>
<th></th>
<th>Standard *</th>
<th>MSIM™</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>3.41 ns</td>
<td>3.39 ns</td>
<td>0.59 %</td>
</tr>
<tr>
<td>CPU Time</td>
<td>3,867 sec</td>
<td>317 sec</td>
<td>12.2 X</td>
</tr>
</tbody>
</table>

* Standard means the most popular Spice simulator

Technology Leader in IP Characterization and IC/PCB Simulation
Subcircuit Spice Model
Memory Usage/CPU Time Benchmark

- Subcircuit Spice models are popular in 65nm and below due to its flexibility. Each MOSFET has its own model.
- Subcircuit Spice models cause huge memory usage and degrade the performance.

<table>
<thead>
<tr>
<th>Circuit Type</th>
<th>MOSFET Count</th>
<th>MSIM</th>
<th>Other Popular Spice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data_in.sp</td>
<td>~10K</td>
<td>551 sec</td>
<td>293 MB</td>
</tr>
<tr>
<td>Access.sp</td>
<td>~40K</td>
<td>3,007 sec</td>
<td>1.4 GB</td>
</tr>
</tbody>
</table>
MSIM®
Applications in IC and IP

- Analog circuit design verification
  - Frequency response and transient analysis for verifying analog circuits like PLL, A/D and D/A converters, amplifiers and IO devices etc.
- Mixed-signal circuit design verification
  - Support Verilog-A behavioral modeling, vector input stimulus and vector output verification
- RF design analysis
- Cell library and memory characterization
# MSIM®

## Ring Oscillator Benchmark

101 Stage NAND2 Ring Oscillator Simulation Results / Comparison

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Standard* Accurate Mode*</th>
<th>MSIM Accurate Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time</td>
<td>Time</td>
</tr>
<tr>
<td>Time_rr</td>
<td>4.2711e-09</td>
<td>4.2527e-09</td>
</tr>
<tr>
<td>Time_ff</td>
<td>4.2711e-09</td>
<td>4.2520e-09</td>
</tr>
<tr>
<td>Average Current</td>
<td>-1.4119e-04</td>
<td>-1.4096e-04</td>
</tr>
<tr>
<td>Power Parameter</td>
<td>-7.2364e-13</td>
<td>-7.1936e-13</td>
</tr>
<tr>
<td>Time_rf</td>
<td>2.1422e-09</td>
<td>2.1325e-09</td>
</tr>
<tr>
<td>Duty Parameter</td>
<td>5.0156e+01</td>
<td>5.0144e+01</td>
</tr>
</tbody>
</table>

MSIM (Accurate Mode) 98.23 sec
Standard* (Accurate Mode) 328.68 sec

**MSIM Speed-Up**

3.35 X

*Standard means the most popular Spice simulator*

Technology Leader in IP Characterization and IC/PCB Simulation
# MSIM® Memory Benchmark

**Full-Circuit ‘Access Time’ Simulation Results / Comparison**

This SRAM circuit has 21,087 MOS, 73,374 Rs and 44,639 Cs

<table>
<thead>
<tr>
<th>Access Time</th>
<th>Standard* Accurate Mode</th>
<th>MSIM Accurate Mode</th>
<th>HSPICE Default Mode</th>
<th>MSIM Default Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time</td>
<td>Time</td>
<td>Difference</td>
<td>Time</td>
</tr>
<tr>
<td>O[0] rise</td>
<td>1.4776ns</td>
<td>1.4769ns</td>
<td>-0.0474%</td>
<td>1.5414ns</td>
</tr>
<tr>
<td>O[24] rise</td>
<td>1.4832ns</td>
<td>1.4823ns</td>
<td>-0.0607%</td>
<td>1.5214ns</td>
</tr>
<tr>
<td>O[0] fall</td>
<td>1.5448ns</td>
<td>1.5441ns</td>
<td>-0.0453%</td>
<td>1.4821ns</td>
</tr>
<tr>
<td>O[24] fall</td>
<td>1.5446ns</td>
<td>1.5445ns</td>
<td>-0.0065%</td>
<td>1.4821ns</td>
</tr>
</tbody>
</table>

Standard* Accurate Mode is taken as ‘GOLD’ for comparison

*Standard means the most popular Spice simulator

Technology Leader in IP Characterization and IC/PCB Simulation
# MSIM®
## Phase Locked Loop Benchmark

### 250MHz PLL Circuit Simulation Results /Comparison

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Standard* Accurate Mode</th>
<th>MSIM Accurate Mode</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>2.0040e-06</td>
<td>2.0038e-06</td>
<td>0.01%</td>
</tr>
<tr>
<td>Lock Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last Single Clock Cycle Time</td>
<td>3.9999E-09</td>
<td>3.9971e-09</td>
<td>0.07%</td>
</tr>
<tr>
<td>Average Clock Cycle Time</td>
<td>4.0000E-09</td>
<td>3.9998e-09</td>
<td>0.00%</td>
</tr>
<tr>
<td>Power</td>
<td>3.2518e-04</td>
<td>3.2295e-04</td>
<td>0.69%</td>
</tr>
</tbody>
</table>

MSIM (Accurate Mode)
- 2794 seconds

Standard* (Accurate Mode)
- 6096 seconds

**MSIM Speed-Up 2.16 X**

*Standard means the most popular Spice simulator*

*Technology Leader in IP Characterization and IC/PCB Simulation*
### MSIM® Complex IO Circuit Benchmark

#### Complex IO Circuit Simulation Results / Comparison

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Standard* Accurate Mode</th>
<th>MSIM Accurate Mode</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>1.095e-09</td>
<td>1.095e-09</td>
<td>0.00%</td>
</tr>
<tr>
<td>Rise delay</td>
<td>1.007E-09</td>
<td>1.0071e-09</td>
<td>0.01%</td>
</tr>
<tr>
<td>Fall delay</td>
<td>2.489E-09</td>
<td>2.496e-09</td>
<td>0.26%</td>
</tr>
<tr>
<td>Rise slew</td>
<td>2.493e-09</td>
<td>2.498e-04</td>
<td>0.22%</td>
</tr>
<tr>
<td>Fall slew</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MSIM (default Mode)**

- **33.94 seconds**
- **MSIM Speed-Up**
  - **45.5 X**

**Standard* (default Mode)**

- **1,550.14 seconds**

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*Standard means the most popular Spice simulator

**Legend**

Technology Leader in IP Characterization and IC/PCB Simulation
Special Model Interface

- Verilog-A model
- CMI (Common Model Interface) model
- TMI (TSMC Model Interface) model
- LCD Panel model
- S-Parameter model
LCD Panel Circuit Simulation
Dynamic $C_{LC}$ and Advanced TFT Model

- Dynamic effect of Effective Capacitor can be simulated by MSIM

- Dynamic effect of Transmittance can be simulated by MSIM
Hybrid Modeling Flow
A Complete Device Modeling Solution

Raw Data 1
3rd Party Tool
$ Model Extractor
Parameters
$ MSIM Simulator
Results

Raw Data 2
Hybrid Modeling
MSIM
$ Model Extractor
Parameters
MVIEW
Curve-fitted Modeling Waveforms

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Hybrid Modeling Example
Model Parameters by Curve Fitting

Advanced Threshold Voltage Shift Model

Parameters extracted from MSIM built-in Model Extractor by curve-fitting

\[ A = 0.0280863 \]
\[ \beta = 0.247142 \]

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Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® for Optimization

- A procedure for automatic searching instance or model parameters to meet design goal
- Optimization function can be applied for .DC, .AC and .TRAN analysis
- Optimization method can be native, bi-section or pass-fail
- Flexible measurements in optimization process
- HSPICE-compatible format
MSIM® Portability

◆ Platforms
  ● Redhat Enterprise Linux
  ● Windows XP
  ● Solaris on X86

◆ Environments
  ● JEDAT - ASCA
  ● SpringSoft – Laker-ADP
  ● Cadence - ADE
  ● Mentor – DAIC
MSIM® with ASCA
Jedat’s AnalogCreator Platform

MSIM seamlessly integrated into Jedat’s ASCA with
- High throughputs
- Optimized simulation and debugging setup

Legend
Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® with Laker-ADP
Silicon Canvas’ Analog Design Platform

MSIM seamlessly integrated into Laker-ADP with
- Enhanced productivity
- Speedup of simulation and debugging process

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Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® with Virtuoso

**MSIM-Virtuoso Ocean Interface**
- The input to MSIM is the circuit netlist from Virtuoso database, and simulation controls from users
- The output from MSIM is the measurement, the list and waveform files including PSF format

**MSIM-Virtuoso ADE Interface**
- MSIM is fully compatible with HSPICE options including option ARTIST and PSF.
- MSIM can be invoked in the same way as HSPICE does from ADE, after some simple environment setup.

Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® for Characterization
Cell / IO / Memory Characterization

- Standard / IO Cell Library Characterization
  - Legend Design Technology’s CharFlo-Cell!
  - Magma’s SiliconSmart
  - Cadence’ SignalStorm
  - Library Technology’s LibChar
  - In-house characterization tools

- Memory Compiler Characterization
  - Legend Design Technology’s CharFlo-Memory!
  - In-house characterization tools

Legend
Technology Leader in IP Characterization and IC/PCB Simulation
MSIM® with CharFlo-Cell!
Cell/IO Library Characterization

- The integration of CharFlo-Cell! products and MSIM has been successfully completed
- MSIM has been the primary circuit simulator used in QA flow of CharFlo-Cell! products
- The speed and accuracy of MSIM complements the strengths of the CharFlo-Cell! technology
- MSIM circuit simulator runs multiple times faster than traditional SPICE simulators without loss of accuracy
**MSIM® with Charflo-Memory!**
Memory IP Characterization

- **Register File ‘RF2R1W16X128S’**

  Access Time (5 input slopes and 5 output loadings)
  
  **25 Simulation Jobs**

<table>
<thead>
<tr>
<th></th>
<th>CPU Time</th>
<th>Gains</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MSIM®</td>
<td>7 Hours 17 Minutes</td>
<td>1.0 X</td>
</tr>
<tr>
<td>4 MSIM®</td>
<td>2 Hours 8 Minutes</td>
<td>3.4 X</td>
</tr>
<tr>
<td>8 MSIM®</td>
<td>1 Hour 13 Minutes</td>
<td>6.0 X</td>
</tr>
<tr>
<td>25 MSIM®</td>
<td>18 Minutes</td>
<td>23.9X</td>
</tr>
</tbody>
</table>

**Legend**

*Technology Leader in IP Characterization and IC/PCB Simulation*
MSIM® Compatibility

- **HSPICE format**
  
  *Command*
  
  `% msim –i ckt.sp –o ckt.lis -hsp`  
  
  The flag *-hsp* turns on HSPICE format and output naming convention

- **Spectre Format**
  
  *Command*
  
  `% msim –i ckt.sp –o ckt.lis -spectre`  
  
  The flag *-spectre* turns on Spectre format.

- **Eldo Format**
  
  *Command*
  
  `% msim –i ckt.sp –o ckt.lis -eld`  
  
  The flag *-eld* turns on Eldo format and output naming convention
Conclusion

◆ MSIM is an excellent circuit simulator by
  ● Innovative algorithms and schemes
  ● Optimized codes and structures
  ● Silicon-accurate BSIM3 and BSIM4 modeling
◆ MSIM certified by TSMC Spice Tool Qualification
◆ MSIM supports multi-threaded applications on a
  multi-core computer, with flexible licensing
◆ MSIM automates the selecting matrix solver for
  layout-extracted circuits, with much higher speed-up
◆ MSIM provides best price-performance

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Technology Leader in IP Characterization and IC/PCB Simulation