Micron’s IBIS Model Quality Process

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Randy Wolff
Micron Technology
rrwolff@micron.com
Overview

• Micron builds in quality checks into each step of the model creation process
  ‣ Spice netlist creation
  ‣ IBIS creation process
• Quality Report documentation for customers
• Conclusions
Spice netlist creation

• Multiple pre-driver stages are included - critical timing paths unmodified

• Standard Parasitic Format (SPF) netlists are created for circuits with completed layouts

• SPF includes two flavors
  ‣ C only – Capacitance of all layout structures included
  ‣ RC – Resistance and Capacitance included
  ‣ RC is more accurate but creates unreasonably large netlists
  ‣ C only with additional PRC elements on critical nets can approach accuracy of RC netlist but be much smaller
Spice Netlist: SPF Format Effect on Vox

In this example, PRC elements were needed to properly model the effect of long, imbalanced metal lines between the pre-driver logic and pre-driver stages.

Quality ✔: Correct Vox level
Determining C_comp min/max

\[ C_{\text{model min}} = C_{\text{package}} + C_{\text{comp min}} \]

\[ C_{\text{model max}} = C_{\text{package}} + C_{\text{comp max}} \]

Quality ✔: Correct C_package and C_comp
Correlating I-V curves to Measurements

• Must match exact Process/Voltage/Temp conditions between Spice simulation and Measurement

• Process model adjustment example
  ‣ Process corners set by parameter range: -1=Slow, 0=Typical, 1=Fast
  ‣ IDSN model corners (uA/um) (for specific Vds and Vgs voltage setting)
    Slow: 359.0 Typical: 399.8 Fast: 450.9
    Silicon Measurement: 397.3, Adjusted 6.1% towards Slow (-0.061)
  ‣ IDSP model corners (uA/um)
    Slow: 173.1 Typical: 203.7 Fast: 242.1
    Silicon Measurement: 194.1, Adjusted 31.5% towards Slow (-0.315)
Correlating I-V curves to Measurements

- Model = yellow, Measurement = red

Before PVT Adjustment  
After PVT Adjustment

Quality ✓: I-V curves match measurements
Model Quality

- Model Creation Checklists

  - Spice model development
    - ✓: Transistor model libraries setup and correlated to speed grades
    - ✓: Correct power supply decoupling included in netlists
    - ✓: Variable capacitance added to PAD node for proper $C_{\text{comp}}$ variation
    - ✓: Clamp diode currents adjusted through bulk node resistance
    - ✓: All control signal combinations function properly
Model Quality

• Model Creation Checklists

  ‣ IBIS model development

  ✓: Run IBISCHK – explain any warnings
  ✓: Component names and Pin lists agree with the datasheet
  ✓: Input model parameters match the datasheet
  ✓: I/O model parameters match the datasheet
  ✓: V-t curves time correlated and on/off time relationships valid
  ✓: Combined Submodel curves show proper ODT voltage midpoint termination and resistance
Quality Reports

• IBIS Open Forum – IBIS Quality Task Group
  ‣ Released the IBIS Quality Specification, Rev 1.0, 3/31/04
  ‣ Currently working on an updated release

• Micron follows the IQ Spec, but releases a detailed report with each model
  ‣ Compares model to specification data
  ‣ Compares model to measurement data
  ‣ Compares IBIS model to HSPICE model
Quality Reports - Introduction

IBIS/HSPICE Model Quality Report

Design ID: T35M
Description: 128Mb Mobile DDR SDRAM
Marketing device name(s): MT46H8M16LFBF, MT46H4M32LFB5, MT46H8M16LFT35M, MT46H4M32LFT35M
Valid Speed Grades: -75 (266), -6 (333), -54 (370), -5 (400)
Zip File Name: t35m_ibis.zip, t35m_it_ibis.zip
IBIS File name: t35m.ibs, t35m_it.ibs – File rev: 2.0, 2.0
HSPICE File name: t35m_hspice.zip – File rev: 2.0
EBD file name (if applicable): File rev:
Die Rev: K
Date: October 8, 2008
Datasheet Link:
http://download.micron.com/pdf/datasheets/dram/mobile/128mb_mobile_ddr_sdram_t35m.pdf

E-mail at modelsupport@micron.com for questions regarding Quality Report

Device Parameters

VDDQ – Slow: 1.70 Typical: 1.80 Fast: 1.95
VDD – Slow: 1.70 Typical: 1.80 Fast: 1.95
Junction Temperature (Commercial) - Slow: 85 Typical: 40 Fast: 0
Junction Temperature (Industrial) - Slow: 100 Typical: 40 Fast: -40
VDDQ/VSSQ Decoupling Capacitance: 2.76nF
 Included in HSPICE DQ/DQS models? yes Amount per DQ/DQS model: 76.66pF
VDDQ/VSSQ Decoupling Capacitance Series Resistance: 1 ohm
Quality Reports – IQ Summary

- IBIS Quality Summary included based on IQ 1.0 specification
- Report will detail IQ 1.1 spec once released
- IBIS model does not include full IQ Summary, but instead states:
  | IQ SUMMARY Overall Quality of component and models Level 2b
  | See Micron IBIS Model Quality Report for full IQ SUMMARY
Quality Reports – IOH/IOL vs. Spec
## Quality Reports – C_comp, ODT & Slew Rates vs. Specification

### C_comp

<table>
<thead>
<tr>
<th>DQ</th>
<th>IBIS</th>
<th>Datasheet (DDR3-1600)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IBIS</td>
<td>Min</td>
</tr>
<tr>
<td>DQ</td>
<td>C_comp</td>
<td>1.55pF</td>
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<tr>
<td></td>
<td>C_package</td>
<td>0.20pF</td>
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<tr>
<td></td>
<td>C_total</td>
<td>1.75pF</td>
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<tr>
<td>INPUT</td>
<td>C_comp</td>
<td>0.6pF</td>
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<tr>
<td></td>
<td>C_package</td>
<td>0.17pF</td>
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<tr>
<td></td>
<td>C_total</td>
<td>0.77pF</td>
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<tr>
<td>CLK</td>
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<tr>
<td></td>
<td>C_package</td>
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<tr>
<td></td>
<td>C_total</td>
<td>0.96pF</td>
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### ODT

<table>
<thead>
<tr>
<th></th>
<th>TYP</th>
<th>MIN</th>
<th>MAX</th>
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<tbody>
<tr>
<td>Vinl (V)</td>
<td>0.575</td>
<td>0.5375</td>
<td>0.6125</td>
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<tr>
<td>Vinh (V)</td>
<td>0.925</td>
<td>0.8875</td>
<td>0.9625</td>
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<tr>
<td>llinl (A)</td>
<td>-0.0073</td>
<td>-0.0068</td>
<td>-0.00793</td>
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<tr>
<td>llinh (A)</td>
<td>0.007425</td>
<td>0.00615</td>
<td>0.00789</td>
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<tr>
<td>Rtt (Model)</td>
<td>23.77</td>
<td>22.12</td>
<td>27.03</td>
</tr>
<tr>
<td>Rtt (datasheet-in units of ZQ/12)</td>
<td>1.00</td>
<td>0.90</td>
<td>1.60</td>
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<tr>
<td>Rtt (datasheet)</td>
<td>20.00</td>
<td>18.00</td>
<td>32.00</td>
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</table>

### Slew Rates

<table>
<thead>
<tr>
<th>Model</th>
<th>Slew Rate (V/ns)</th>
<th>Simulation</th>
<th>Datasheet</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>min</td>
<td>Typ</td>
</tr>
<tr>
<td>DQ_34_1066</td>
<td>Rising</td>
<td>2.27</td>
<td>2.84</td>
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<tr>
<td></td>
<td>Falling</td>
<td>3.24</td>
<td>4.03</td>
</tr>
<tr>
<td>DQ_34_1333</td>
<td>Rising</td>
<td>3.15</td>
<td>3.25</td>
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<td>Falling</td>
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<tr>
<td>DQ_34_1600</td>
<td>Rising</td>
<td>3.83</td>
<td>3.87</td>
</tr>
<tr>
<td></td>
<td>Falling</td>
<td>4.25</td>
<td>4.45</td>
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</table>
# Quality Reports – C_comp & IOH/IOL vs. Measurement

<table>
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<th>IBIS</th>
<th>Measured</th>
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<td>Typ</td>
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<td><strong>DQ</strong></td>
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<td></td>
</tr>
<tr>
<td>C_comp</td>
<td>1.55pF</td>
<td>1.72pF</td>
</tr>
<tr>
<td>C_package</td>
<td>0.20pF</td>
<td>0.22pF</td>
</tr>
<tr>
<td>C_total</td>
<td>1.75pF</td>
<td>2.02pF</td>
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<tr>
<td><strong>INPUT</strong></td>
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<td></td>
</tr>
<tr>
<td>C_comp</td>
<td>0.6pF</td>
<td>0.77pF</td>
</tr>
<tr>
<td>C_package</td>
<td>0.17pF</td>
<td>0.25pF</td>
</tr>
<tr>
<td>C_total</td>
<td>0.77pF</td>
<td>1.31pF</td>
</tr>
<tr>
<td><strong>CLK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_comp</td>
<td>0.76pF</td>
<td>0.87pF</td>
</tr>
<tr>
<td>C_package</td>
<td>0.20pF</td>
<td>0.21pF</td>
</tr>
<tr>
<td>C_total</td>
<td>0.96pF</td>
<td>1.29pF</td>
</tr>
</tbody>
</table>

![Graph showing C_comp and IOH/IOL data](image-url)
Quality Reports – IBS vs. HSPICE

Test load

T-line: 50 ohms, Td=0.5ns
Conclusions

• Model users demand quality models

• IBIS Quality Committee work is essential for standardizing quality levels and methods

• IBIS Quality checklists work to maintain quality standards

• Quality Reports go above and beyond checklists to document thorough model checking

• Demand Quality models from vendors!
  ‣ Show them examples of quality models.