



Modeling Formats and Procedures at Intel

マイケル マーマク Michael Mirmak
インテル コーポレーション Intel Corp.

JEITA IBIS Conference
March 24, 2005

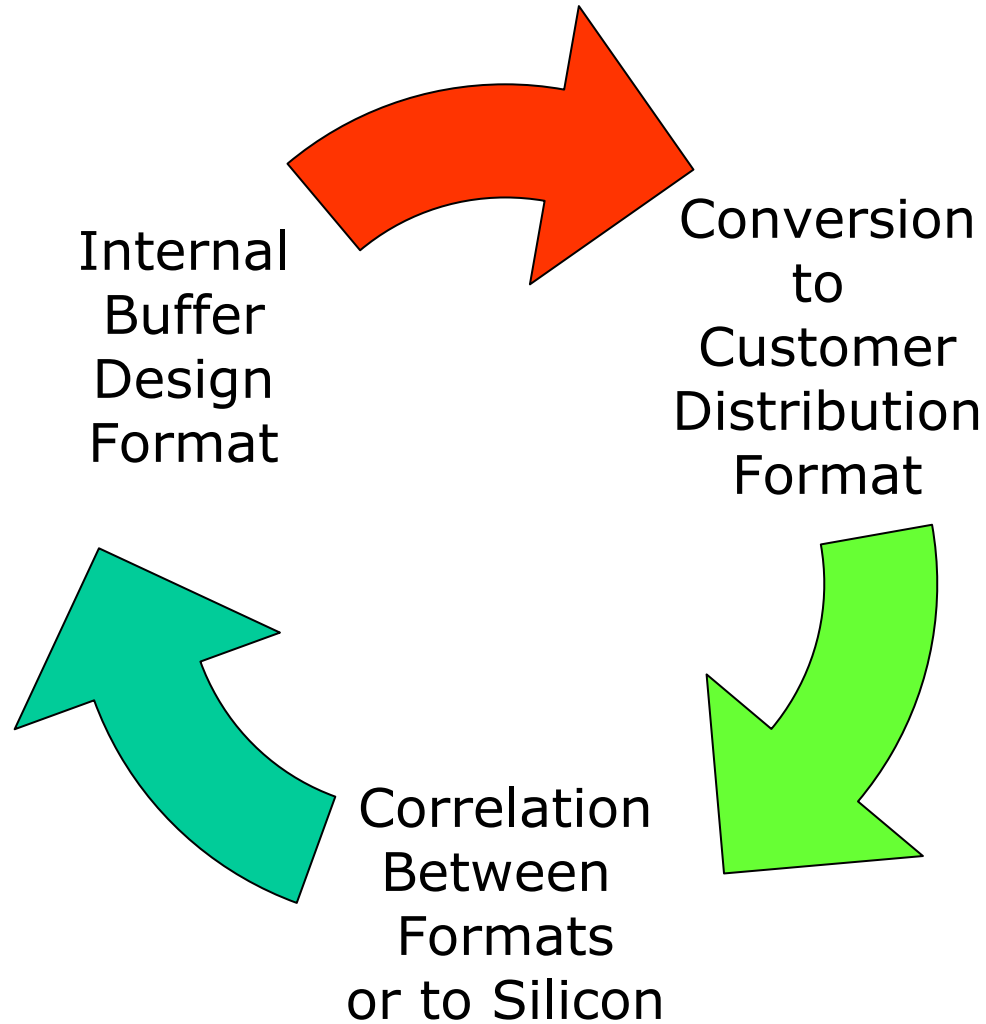
Agenda

- Introduction and Disclaimer
- Modeling Flow
- Formats Used for External Distribution
- Future Direction and Investigations
- Evaluating Model Formats
- Key Questions for the Industry

A Disclaimer

- The following information is presented as the opinion of one person at Intel. This presentation does **not** necessarily represent Intel policy, commitments or preferences.
- This is **not** presented on behalf of the IBIS Open Forum and does **not** represent the official IBIS Open Forum direction.

General Modeling Flow



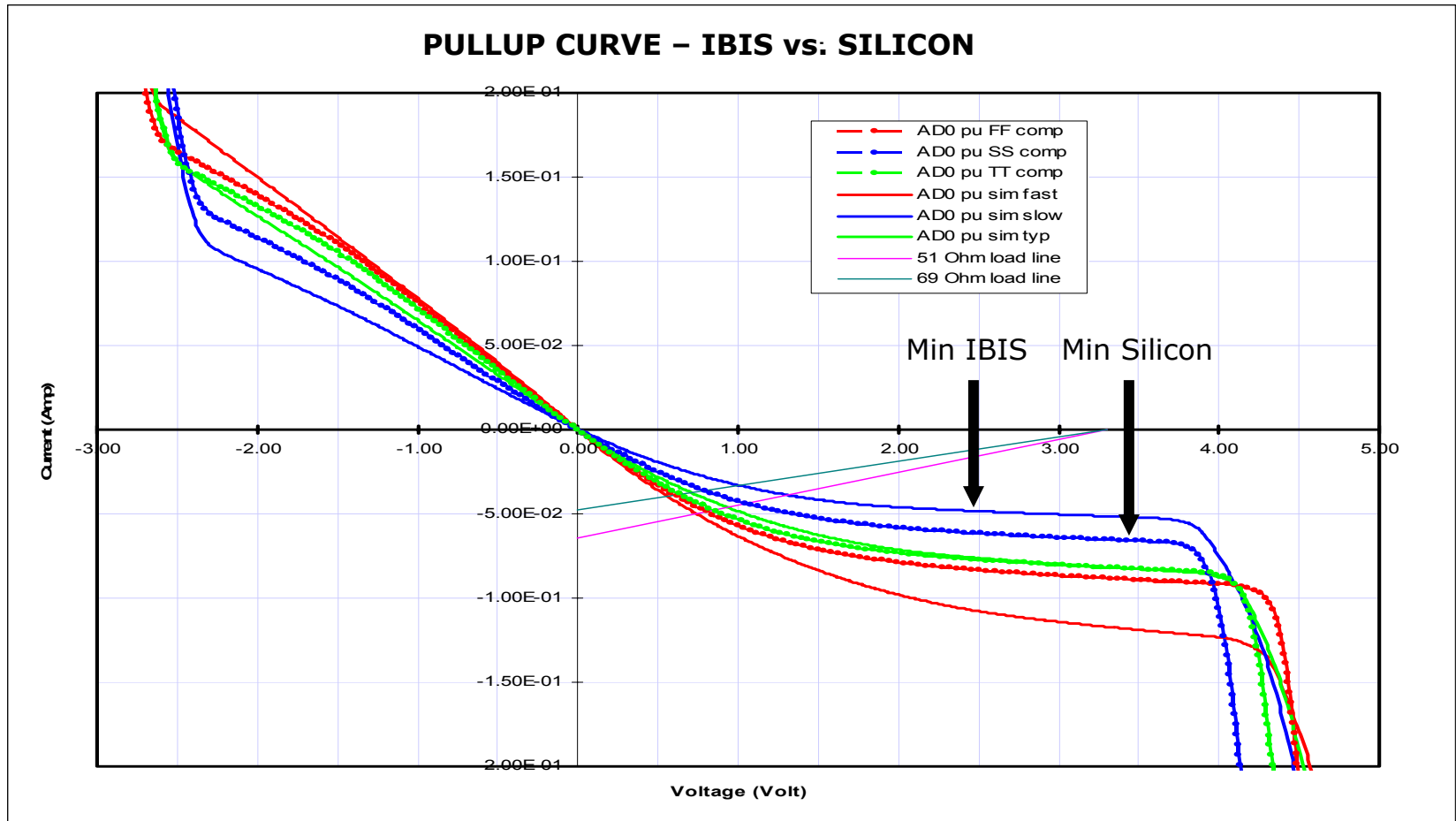
Modeling Flow

- Buffer Design
 - Internal SPICE-like format
 - Internal tool also supports IBIS, AMS languages
- Conversion to External Formats
 - IBIS is majority model type supported
 - Data generated directly from internal format
 - Other proprietary behavioral formats on case-by-case basis
 - Encrypted HSPICE used for one group of customers
 - Process file conversion used for model generation
- Correlation Over Process, Voltage, Temperature
 - I-V curve-tracing performed to correlate IBIS
 - Time- and frequency-domain analysis of systems
 - "Silicon-to-Simulation" correlation of process files to factory production data



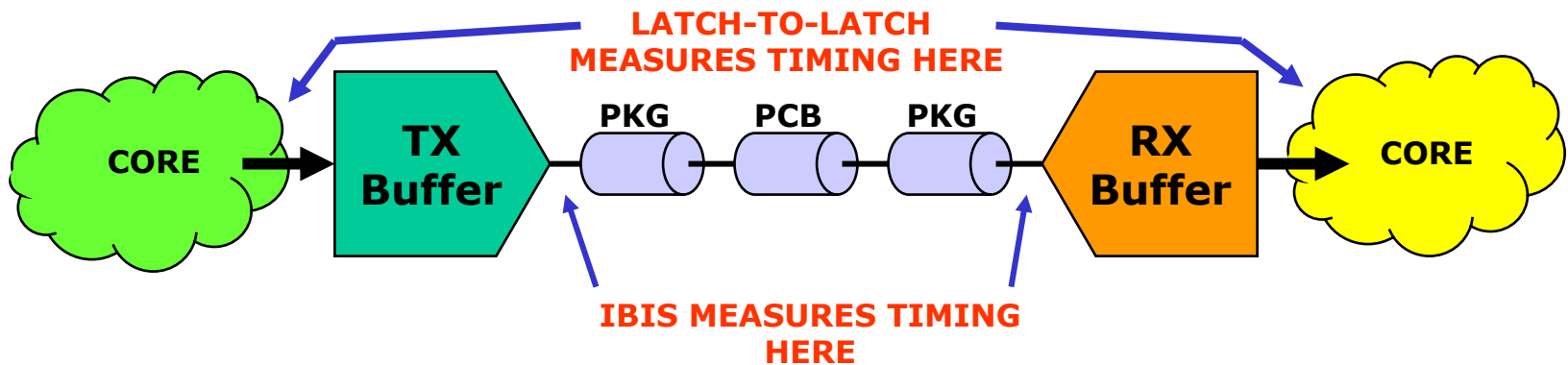
Curve-Tracing Example

- IBIS defines "envelope" for silicon data
 - Weakest IBIS should be weaker than silicon, etc.



External Formats

- Different divisions use different formats
 - Format choices based on customer demand and capabilities, internal technical analysis
- Reasons for use of proprietary SPICE
 - Control over buffer features (example: impedance)
 - Latch-to-latch: more ps from timings at core!



Transistor-Level SPICE Modeling

- Why are transistor models popular?
 - Familiar to users
 - More detail seen as more accuracy (misconception)
 - Behavioral models add some effort, burden
 - Encrypted transistor very simple to distribute – just include everything and send files to customers
 - Behavioral models require conversion, correlation
 - Transistor simulation faster as computer speed increases
 - PI, SSO still very difficult at transistor-level
 - Behavioral methods sometimes difficult to use
 - Example: impedance control in IBIS
 - Latch-to-latch detail not seen in behavioral models
 - AMS is promising here

Studies of Behavioral Modeling Types

- Intel team is studying formats
 - Behavioral Modeling Workgroup meets weekly
 - Mission: develop methods for IBIS, AMS modeling; analyze new proposals (ex. SPICE macromodeling)
- Key goals
 - Develop standardized methods, templates for AMS
 - Add features: latch-to-latch, new controls (ex. impedance)
 - Correlate AMS against internal format, proprietary SPICE
- Ideal: a single format that can be used company-wide
 - Short term: IBIS, encrypted HSPIICE remain
 - Longer term: IBIS divisions will move to AMS+IBIS
 - **Teams using encrypted HSPIICE will evaluate AMS capabilities, consult with customers**
 - No compelling case for SPICE macromodeling yet



How to Evaluate A Model Format

- **Seven** basic desires for a modeling solution
 - "I want it to be accurate"
 - "I want it to be fast in my simulator"
 - "I want it to protect my IP"
 - "I want it to be standardized"
 - *Works for more than one tool*
 - "I want it available soon"
 - "I want it easy to use/implement/automate"
 - "I want maximum flexibility in describing my buffer design's behavior"
- A "perfect" solution can only meet **six** desires (so far)



Customer Solutions and the 7 Rules



Parameter	Proprietary Encrypted SPICE	IBIS 3.2/4.0	IBIS + AMS	IBIS + Macromodeling
Accuracy	**	**		
Availability			*	*
Ease of use/implementation				
Flexibility				
IP Protection				
Speed			**	**
Standardization				*

*	can change, depending on tool support/committee efforts
**	depends on model implementation

	Meets all of need
	Meets most or some of need
	Meets most or some of need, with difficulty
	Cannot meet need

Questions for Industry

- Transistor encrypted SPICE is very popular
 - Is either AMS or Macromodeling **more compelling**?
- Will customers support **behavioral modeling**?
 - Behavioral models are faster in simulation, but take more effort to generate
 - Can customers be convinced they are accurate?
- What is the best **long-term** industry solution?
 - Macromodeling standardization will take time
 - Should we develop macromodeling specification or educate industry about AMS usage?
- How will IP be protected?
 - Behavioral modeling uses algorithms, not process details or design netlists
 - Some design algorithms may be sensitive
 - Behavioral encryption may require standardization



BACKUP



What is the greatest use for IBIS?

- IBIS originally consisted of two parts
 - Device model behavioral data: V-t, I-V tables, etc.
 - **"Snapshot" at certain conditions (Temp, etc.)**
 - Interface specs, for user automation: Vinh, Vmeas, etc.
 - Power supply information fits in both categories
- With AMS or Macromodeling, some of IBIS redundant
 - Behavioral modeling under IBIS very limited (no equations)
 - Both alternatives are much more flexible than IBIS
- IBIS interface specifications are still very useful
 - AMS, Macromodeling describe device design behavior
 - Still a need for a standardized SI "wrapper" around behavior
 - **Includes evaluation criteria**
 - **Would help user judge device performance in system**
 - **IBIS serves this need! Evaluation parameters for SI**
 - **Need IBIS-based user-defined specs, measurements**

Solutions and the 7 Rules

- IBIS 3.2/4.0
 - Advantages
 - **Fast, IP protecting, standard, easy to use/implement**
 - **Available immediately in tools**
 - Disadvantages
 - **Not accurate for certain functions (e.g., freq. dep. C)**
 - **Not flexible (table-based, not equation-based)**
- AMS + IBIS
 - Advantages
 - **Flexible, standardized, can be fast**
 - **Can be accurate, depending on correlation effort**
 - Disadvantages
 - **Greater challenges to implementation**
 - **Additional learning for users, model authors**
 - *Templates would reduce this problem*
 - **Not available in tools yet**
 - **IP protection?**

*Other names and brands may be
claimed as the property of others



Solutions and the 7 Rules

- SPICE Macromodeling
 - Advantages:
 - **EDA tools already support controlled sources**
 - **Low barriers to use by *behavioral* experts**
 - **Has flexibility beyond native IBIS**
 - Disadvantages:
 - Obstacles to standards development
 - **Creating a standardized SPICE syntax**
 - **Can this be done in less than two years?**
 - New features still require creation of new keywords
 - **Same development delay as in traditional IBIS**
 - **Can controlled sources cover all equations?**
 - Still behavioral!
 - **More value than transistor-level models?**
 - ***Behavioral modeling expertise required!***