Modeling Formats and Procedures at Intel

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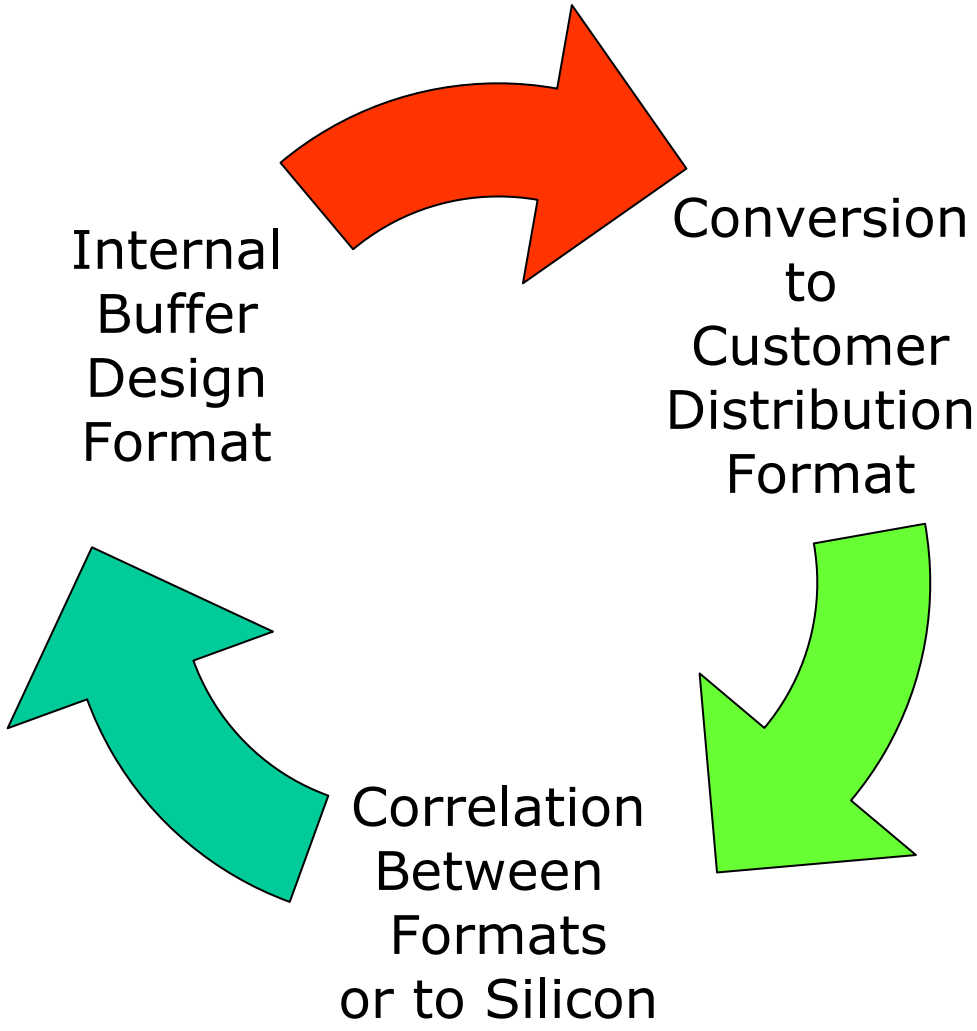
Agenda

- 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

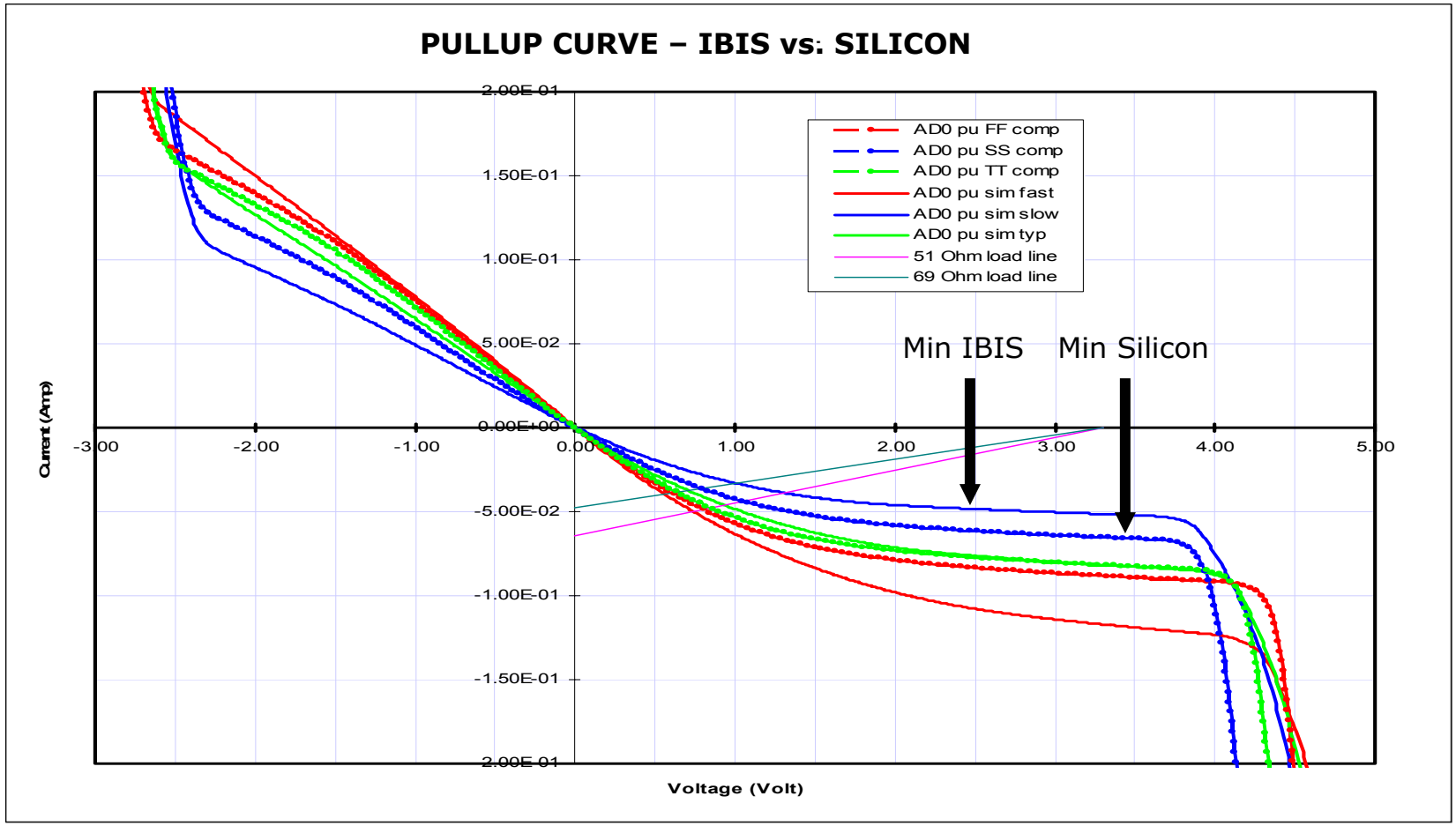


Modeling Flow

- 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

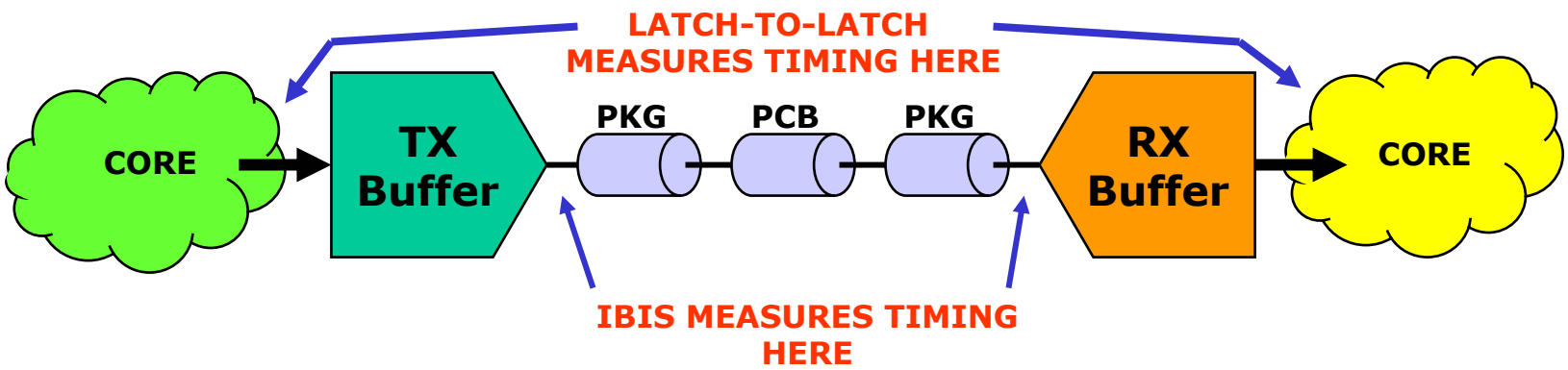
Curve-Tracing Example

- 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 HSPICE remain
  - Longer term: IBIS divisions will move to AMS+IBIS
    - **Teams using encrypted HSPICE 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?**

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 is 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!***