IBIS-AMI Post-Simulation Analysis

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IBIS Simulation Post-Processing Support

- IBIS 1.0: Vinl/Vinh
- IBIS 2.0: vdiff, Vmeas/Ref/etal.
- IBIS 3.0: [Model Spec]
- IBIS 4.0: [Receiver Thresholds], [Test Load]/[Test Data]
- IBIS 4.1: Ref_diff/etal.
- IBIS 5.0: clock_times, Rx_Rx_Receiver_Sensitivity, AMI_parameters_out (non-standard)
- IBIS 6.0: Rx_Clock_Recovery_*, Rx_DCD
- IBIS 6.1: PAM4_*Threshold, PAM4_*EyeOffset
- IBIS Accuracy Handbook (correlation FOM)
Post-Processing Methods Not Specified By IBIS

- Timing
- Eye metrics (other than Rx_Receiver_Sensitivity)
- Seed for AMI jitter processing rand() function
- Clock recovery without clock_times (other than jitter)
- Bit Error Rate (BER) calculation
- Forward Error Correction (FEC) gain
- Any other special analyses prescribed for a particular model (IEEE, JEDEC, vendor, …)
1 STATEMENT OF INTENT

In order to enable an industry standard method to electronically transport IBIS modeling data between semiconductor vendors, electronic design automation (EDA) tool vendors, and end customers, this template is proposed. The intention of this template is to specify a consistent format that can be parsed by software, allowing EDA tool vendors to derive models compatible with their own products.
Unspecified Post-Processing Methods

- **PRO:** Tools can innovate new analyses!
- **CON:** Tools can produce different results for the same analysis!
- **CON:** Tools might not implement some analyses prescribed for a particular type of buffer until IBIS support is explicit, or at least until the analysis is widely recognized.
Interoperability and Portability

• **Interoperable**: Models from different vendors run in the same simulator
  – Theory: True, if models and simulator are IBIS-compliant
  – Reality: Mostly true, with some rough spots
• **Portable**: The same model runs in multiple simulators
  – Theory: True, if models and simulators are IBIS-compliant
  – Reality: They mostly run, *but users get some incorrect/differing results*

Users expect to see the same results in different tools
Different Tool, Different Results

1. Simulation results of simulator A and simulator B differ ...
   ◆ Our simulation results and customers’ simulation results did not correlate well

   Which result should we believe?

• Might be due to simulation differences
• Might be due to post-processing differences
• Either way it’s a user expectation issue

What's Expected for IBIS-AMI from the Perspective of End-User Support, Nakane, Masao, Tokyo IBIS Summit, Nov 2017
Proposal 1: Specify Post-Processing Methods

• Examples:
  – Support specification of methods for eye height measurement
  – Support specification of seed for clock jitter modeling
Example: Determining Eye Height

• Let’s say an AMI Rx model returns these waveforms and clock ticks:

• Q1: What should the eye diagram look like?
Accumulating The Eye Diagram

• Method 1: Clock ticks are used to accumulate the eye diagram on a trace by trace basis, similar to the way a triggered scope works:
Accumulating The Eye Diagram

• Method 2: Both the waveform and clock ticks are accumulated with respect to an “ideal clock” operating at the channel data rate:
Accumulating The Eye Diagram

• Q2: Which method should be used to accumulate the eye diagram to be measured?
Accumulating The Eye Diagram

Q3: What method(s) should be used to extrapolate the time domain eye to get a statistically significant eye?

- Time Domain Only
- Extrapolated
Measuring Eye Height

- Q4: Where should eye height be reported?

Sampling time indicated by model’s clock ticks
Measuring Eye Height

• Q5: At what probability level should eye height be measured?

Red   = 1e-12
Blue  = 1e-9
Green = 1e-6
Yellow = 1e-3
Determining Eye Height

- Should users expect eye height measurements across EDA tools to be consistent?

- Should IBIS do more to ensure reporting consistency across EDA tools?
Same Rx Jitter, Different Start Points

\[ \text{actual\_time} = \text{time} + 2.0 \times \text{Rx\_Dj} \times \text{rand()} \]

Seed value?

- seed = 1
- seed = 2
But We Also Have Requests for More FEC Support in IBIS-AMI

<table>
<thead>
<tr>
<th>Topic</th>
<th>Authors</th>
<th>Company</th>
<th>Date/Location</th>
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<tbody>
<tr>
<td>Necessity for Integrating FEC Functionality for PAM4 in AMI Simulations</td>
<td>Xiaoqing Dong* and Nick Huang**</td>
<td>Huawei Technologies* and Shenzhen Zhongzeling Electronics**</td>
<td>Feb 3, 2017 DesignCon IBIS summit</td>
</tr>
<tr>
<td>Necessity for Integrating FEC Functionality for PAM4 in AMI Simulations</td>
<td>Xiaoqing Dong and Nick Huang</td>
<td>Huawei Technologies</td>
<td>Nov 11, 2016 Shanghai IBIS summit</td>
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<tr>
<td>FEC Applications for 25Gb/s Serial Link Systems</td>
<td>Tao Guo and Shunlin Zhu</td>
<td>ZTE Corporation</td>
<td>Nov 09, 2015 Shanghai IBIS summit</td>
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<tr>
<td>Introduction of FEC IL Gain Estimation Method In High Speed Link</td>
<td>Xiaoqing Dong and Chunxing Huang</td>
<td>Huawei Technologies</td>
<td>Nov 15, 2011 Shanghai IBIS summit</td>
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IBIS supports FEC only through PAM4_Mapping
Most FEC Requests Are For Deterministic FEC Gain Calculation Support

- The requests are for FEC gain *post-processing, not simulation*
- FEC gain can be estimated, given:
  - RX eye probability bathtub curve
  - DFE coefficients
  - Possibly other model-specific parameters
- FEC gain calculation algorithms exist today, but are not made public

“Current EDA tools can process time domain and statistical analysis very well, but the lack of DFE coefficients outputting function and lack of voltage bathtub sometimes makes FEC analysis inconvenient.”

“FEC gain analysis method is recommended to be supported by EDA tools (IBIS Specification), including error propagation analysis function.”

-- Xiaoqing Dong, Chunxing Huang
FEC Has a Data Separation Problem

- FEC gain calculation requires:
  - AMI parameter values including DFE coefficients
  - Probability curve from simulation
  - FEC gain algorithm

Simulator Has (or could have):
- Bathtub probability curve
- All coefficients and settings

Simulator Lacks:
- FEC gain algorithm

Rx Has (or could have):
- All coefficients and settings
- FEC gain algorithm

Rx Lacks:
- Bathtub probability curve
Proposal 2: Help Models Report Post-Processing Results

• Some models want to convey additional analysis results to users:
  – Adaptation or training results
  – FEC gain calculation
  – Future IEEE, JESD requirements, etc.

• Tools can implement these, but there is less incentive to implement analyses that are specific to one or a few models

• In some cases tools only need to understand file and AMI_parameters_out model outputs
Rx Models Could Calculate FEC Gain

- Pass simulation outputs to a new AMI_Report() function
- Must be called after last AMI_GetWave(), before AMI_Close()
- Tools need only show HTML report, not necessarily understand it
- Could support any specialized calculation, not just FEC

**Simulator**

- AMI_memory_handle
- Time domain waveforms
- Statistical probabilities
- Show report data

**Rx AMI_Report()**

- All final coefficients and settings
- FEC gain algorithm
- Produce HTML report, or
- Return CSV table
- Use DLL_ID
- Has AMI_parameters_out

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AMI_parameters_out HTML Display

(FEC_Gain (Usage Out) (Type String)
(Format Value "") | Not used for Out
(ParamOutType HTML_File))

(Model(FEC_Gain "sim1_RX1_FECGain.HTML"))

From new AMI_Report function

* http://ibis.org/summits/feb17/dong.pdf
AMI_parameters_out Data Display

(CDR_Phase  (Usage Out) (Type Float)  
(Format Value 0.0) | Not used for Out  
(ParamOutType CSV_XYLine)  
(ParamOutUnits “seconds,UI”))

(Model(CDR_Phase "0.0,0.03125")(Model(CDR_Phase "3.10E-09,0.03125")  
(Model(CDR_Phase "6.20E-09,0.03125")  
(Model(CDR_Phase "9.30E-09,9.18E-05"))

Using AMI_GetWave, no new function required
Summary

• IBIS specifies relatively little about post-processing
  – Some portability issues are actually due to differences in post-processing implementation
  – We could better meet users’ expectations of portability by specifying additional post-processing details

• New post-processing analyses such as FEC gain are desired but not yet fully supported by IBIS
  – A new AMI_Report() function could calculate FEC gain and other new analysis products
  – AMI_parameters_out could be made more useful for displaying analysis data