IBIS–AMI Modeling Recommendations

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Agenda

- When is AMI required?
- IBIS-AMI key concepts
- General AMI recommendations
- Real-world AMI examples
When is AMI required?

- AMI is required when *adaptive filtering* is done by the Serdes Tx or Rx.
- This means that the filtering automatically adjusts to the specific channel, based on its own specific algorithm.
- For applications that use “static” filtering (ex. PCI Express Gen 1), the behavior can be represented in a circuit model, and AMI is NOT mandatory.
Despite that fact that AMI may not be REQUIRED for static pre-emphasis, it can be CONVENIENT to do so.

Folding the pre-emphasis filtering into an algorithmic model is convenient because filter settings can be modified without requiring additional characterizations to be run for the analog channel.
IBIS-AMI Key Concepts

- Circuit and algorithmic models
- “Tap” terminology
- IBIS-AMI data flow and APIs
Circuit Models and Algorithmic Models

- The Tx – to – Rx pathway is composed of 3 separate entities
  - Tx algorithmic part
  - Analog (i.e. “circuit”) channel part
  - Rx algorithmic part

- Three “decoupled” parts can be *independently* solved in time domain
  - Underlying assumption is HIGH IMPEDANCE connection between analog and algorithmic elements
“Tap” Terminology

As typically seen in “FFE” implementations
IBIS-AMI Data Flow and APIs

AMI_Init
- Initialize filter
  - Setup Data Structures

AMI_GetWave
- Waveform Processing
  - Clock and Data Recovery

AMI_Close
- Free memory etc
AMI APIs – Impulse Response or Waveforms

- **AMI_Init**
  - Takes in the impulse response of the channel
  - Algorithm in DLL decides how to best filter it
  - The filtered (and hopefully improved) “modified” impulse response is passed back to the tool

- **AMI_GetWave**
  - Takes in raw waveforms of the channel
  - Algorithm in DLL decides how to best filter it, “real time”
  - The filtered “modified” waveform is passed back to the tool, along with the clock ticks (sampling information)
General Recommendations

- Circuit vs. algorithmic model content
- When to use AMI_Init vs. AMI_GetWave
- Statistical analysis and AMI_Getwave
- Using ibischk5 for .ibs and .ami files
- IBIS-AMI and vendor-independence
Circuit vs. Algorithmic Model Content

- Don’t try to put circuit parasitics into the algorithmic portion of the model
- Leaving out circuit parasitics means you will miss reflections from impedance discontinuities that exist between the Tx output / Rx input and the interconnect channel
- These should get captured in the impulse response
- If you leave these out you will not correlate back to golden data from circuit models (ex. transistor-level IO models)
Using AMI_Init vs. AMI_GetWave

- **Basic principle – K.I.S.S.**
  - “Keep it simple, SI people!”
- **AMI_Init > modifies the impulse response**
  - If the filtering functionality sets up the coefficients once based on the channel, this API is the simplest implementation
- **AMI_GetWave > modifies the raw waveforms**
  - If the filtering functionality has real-time, dynamic adaptation of its coefficients based on the incoming waveforms, you need this API
  - If the algorithm includes clock and data recovery (CDR) functionality, this API is needed
- **Bottom line > use AMI_Init if it will do the job, otherwise use AMI_GetWave**
- **Avoid extraneous functionality, and unnecessary complexity**
Statistical Analysis and AMI_GetWave

- Pure Statistical Analysis is not generally compatible with AMI models using AMI_GetWave
- Should not assume anything about inner workings of a “black box” DLL “AMI_GetWave” algorithm
- Could have non-LTI behavior
  - Usually Receiver Models
  - Adaptive DFE
  - Pattern Dependent Equalization
  - Time Domain Clock and Data Recovery
- Only limited Statistical Analysis is possible
  - Ex. post-processing of time domain data
Using ibischk5 for .ibs and .ami File

- The IBIS5.0 golden parser “ibischk5” can operate on .ibs and .ami files (with –ami switch), ex:
  - ibischk5 <ibis_file.ibs>
  - Ibischk5 –ami <ami_file.ami>

- This should be run on all IBIS-AMI model kits delivered by model developers to users

- Users should run this on incoming models
IBIS-AMI and Vendor Independence

- The purpose of defining a standard is to enable a vendor-neutral format that users can consume with their EDA tool of choice.
- Sigrit has seen many “IBIS-AMI models” that are **full** of vendor-specific content, and will only run in a specific tool.
- This violates the spirit of the IBIS standard.
Real-World AMI Examples

- FFE – Feed Forward Equalizer
- DFE – Decision Feedback Equalizer
- Advanced DFE

All can be implemented with existing IBIS 5.0 functionality!
FFE

- FFE stands for *Feed Forward Equalizer*
- Typically used in Tx
- Mathematically
  - \( y_n = \sum w_i^* x_i \)
  - \( x_n \) – input
  - \( y_n \) – output
DFE

- DFE stands for *Decision Feedback Equalizer*
- Removes inter-symbol interference (ISI) by adding corrections to the input based on previous decisions

\[ y_n = x_n + \sum w_i^* d_i \]

- \( y_n \) - output
- \( x_n \) - input
- \( d_i \) - previous ‘i\text{th}’ decision
- \( w_i \) - i\text{th} tap weight

Diagram: A signal flow graph showing the relationship between input, output, and decision variables.
Advanced DFE

- DFE coefficients by blind adaptation
- Optional *adaptive* gain amplifier
- Optional tuning of decision point
- Optionally include precursor