IBIS-AMI & COM Co-design for 25G Serdes

DesignCon IBIS Summit
Santa Clara, California
January 31, 2020

(Previously given at Asian IBIS Summits, November 1, 4, 8, 2019)

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AGENDA

- Traditional IBIS-AMI
- COM Overview
- IBIS-AMI Co-design with COM for 25G
- Two example channels
- Co-simulation
- Conclusion
- Next Steps
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IBIS-AMI OVERVIEW

- IBIS is Input/output Buffer Information Specification
- AMI stands for Algorithmic Modeling Interface
- Analog model: drive strength/amplitude, rise/fall time, impedance
- Algorithmic model: Equalizer (CTLE, FFE, DFE), clock data recovery
IBIS-AMI FLOW

Network Characterization

Analog Channel

Analog Channel Pulse Response

Bit Sequence

TX(Init)  RX(Init)

Statistical Eye

Time Domain Analysis

TX(GetWave)  RX(GetWave)

Persistent Eye

Statistical Analysis
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The Channel Operating Margin (COM) is a figure of merit for a channel derived from a measurement of its scattering parameters. COM is related to the ratio of a calculated signal amplitude to a calculated noise amplitude as defined by Equation

\[ \text{COM} = 20 \times \log_{10} \left( \frac{A_s}{A_n} \right) \]

Where \( A_s \) is the signal amplitude, \( A_n \) is the noise amplitude.

COM has been adapted by various standards:

- IEEE 802.3
- OIF CEI
- JEDEC 204C

\( A_n \) (Peak BER Noise) = \( A_s \) - Peak BER Height
COM FLOW

Channel

Tx/Rx Bandwidth Filter

Apply Package

FFE & CTLE Filter

Create PR

DFE

Use Setting with Best SNR

Channel Operating Margin

Output EQ Suggestions

Sweep

As

Jitter Noise

Pdf's

CDF

Peak BER Height

Interface Signals(t)

COM FLOW

Tx/Rx Bandwidth Filter

Apply Package

FFE & CTLE Filter

Create PR

DFE

Output EQ Suggestions

Peak BER Height

Interface Signals(t)
COM CHANNEL TRANSFER FUNCTION

\[ H(f) = H_{Tx}(f) \times H_{TXFFE}(f) \times H_{ch}(f) \times H_{Rx}(f) \times H_{RXCTLE}(f) \]

![Diagram](image)

| Transmitter equalizer, maximum error coefficient | \( c(0) \) | 0.02 | — |
| —— | —— | —— | —— |
| Transmitter equalizer, pre-cursor coefficient | \( c(-1) \) | -0.10 | — |
| Minimum value | 0 | 0.02 | — |
| Step size | — | — | — |
| Transmitter equalizer, post-cursor coefficient | \( c(+1) \) | -0.30 | — |
| Minimum value | 0 | 0.02 | — |
| Step size | — | — | — |

![Single Bit Response](image)

![Single Bit Response](image)
COM OPTIMAL EQ SETTINGS

• COM is a figure of merit (FOM), which calculates the ratio of peak signal level to the peak noise level at the receiver sampling latch, comprehending device Tx characteristics (i.e., driver filter, FFE filter, package S-parameters), channel characteristics (i.e., S-parameters) and receiver characteristics (i.e., Rx filter, CTLE filter, package S-parameters and DFE)

• Determine optimal equalization settings
  • An exhaustive search for the best SNR used as a FOM for finding the best FFE and CTLE setting
  • FFE and CTLE are optimized jointly
  • The DFE is only used to gate the SBR

\[ FOM = 10 \log_{10} \left( \frac{A_S^2}{\sigma_{TX}^2 + \sigma_{ISI}^2 + \sigma_J^2 + \sigma_{XT}^2 + \sigma_N^2} \right) \]

- \( A_S \) – peak signal amplitude
- \( \sigma_{TX} \) – transmitter noise
- \( \sigma_{ISI} \) – residual ISI
- \( \sigma_J \) – jitter contribution to amplitude noise
- \( \sigma_{XT} \) – peak crosstalk
- \( \sigma_N \) – spectral noise at the output of CTLE
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- Can we use COM to evaluate the channel margin in early design phase of a project?
- Are the COM recommended equalization parameters suitable for the Channel?
- How can we combine the advantages of COM with IBIS-AMI?
25G CO-SIMULATION PROCESS

- Extraction of passive S parameter model of the simulation channel
- Use S parameter to do COM simulation
- IBIS simulation using COM recommended EQ parameter
- IBIS simulation to sweep EQ parameter
- Comparing the eye diagram in time domain
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Simulation Topology Configuration

- Signal Rate: 25Gbps
- PCB Material: Mid-loss FR4
- PCB Channel Length: 20 cm
### COM SIMULATION CONFIGURATION

#### Table 91-1 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
<th>Units</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>f_b</td>
<td>24.576</td>
<td>GHz</td>
<td></td>
</tr>
<tr>
<td>f_min</td>
<td>0.05</td>
<td>GHz</td>
<td></td>
</tr>
<tr>
<td>Delta f</td>
<td>0.01</td>
<td>GHz</td>
<td></td>
</tr>
<tr>
<td>C_d</td>
<td>[2.5e-4, 2.5e-4]</td>
<td>nF</td>
<td>(TX/RX)</td>
</tr>
<tr>
<td>z_p select</td>
<td>[12]</td>
<td></td>
<td>(test cases to run)</td>
</tr>
<tr>
<td>z_p (TX)</td>
<td>12.30</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>z_p (NEXT)</td>
<td>12.12</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>z_p (FEXT)</td>
<td>12.30</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>z_p (RX)</td>
<td>12.30</td>
<td>mm</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 91-2 C2 Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>package_tl_tau</td>
<td>6.11E-03</td>
<td>ns</td>
</tr>
<tr>
<td>package_tl_gamma0_a1_a2</td>
<td>[0.1734e-3, 3.455e-4]</td>
<td></td>
</tr>
<tr>
<td>package_z_c</td>
<td>78.2</td>
<td>Ohm</td>
</tr>
</tbody>
</table>

#### Table 92-12 Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>board_tl_taup</td>
<td>6.19E-03</td>
<td>ns</td>
</tr>
<tr>
<td>board_tl_gamma0_a1_a2</td>
<td>[4.114e-4, 2.547e-4]</td>
<td></td>
</tr>
<tr>
<td>board_z_c</td>
<td>109.8</td>
<td>Ohm</td>
</tr>
<tr>
<td>z_bp (TX)</td>
<td>151</td>
<td>mm</td>
</tr>
<tr>
<td>z_bp (NEXT)</td>
<td>72</td>
<td>mm</td>
</tr>
<tr>
<td>z_bp (FEXT)</td>
<td>72</td>
<td>mm</td>
</tr>
<tr>
<td>z_bp (RX)</td>
<td>151</td>
<td>mm</td>
</tr>
</tbody>
</table>

All parameters come from IEEE 802.3bj.
COM SIMULATION RESULT
IBIS-AMI SIMULATION WITH COM RECOMMENDED PARAMETER

Eye Diagram after RX EQ

<table>
<thead>
<tr>
<th>index</th>
<th>Width</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>2.78E-11</td>
<td>0.289</td>
</tr>
</tbody>
</table>

EQ Parameters: COM Recommend
TX: C(-1)=-0.12
C(0)=0.8
C(1)=-0.08
RX: CTLE=-5
DFE off
In the red circle is COM recommended EQ parameters produce an acceptable eye opening, but possibly less optimal than the eye opening obtained by time domain simulation.

Sweep parameter:
TX: C(-1), C(0), C(1)
RX: CTLE
Total case: 80
Time Domain Simulation

In the red circle is COM recommend EQ parameters
Simulation Topology Configuration

- Signal Rate: 25Gbps
- PCB Material: Mid-loss FR4
- PCB Channel Length: 60 cm
COM SIMULATION RESULT
IBIS-AMI SIMULATION WITH COM RECOMMENDED PARAMETER

Eye Diagram after RX EQ

<table>
<thead>
<tr>
<th>Index</th>
<th>...robe1.Height()</th>
<th>...Probe1.Width()</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.000</td>
<td>0.109</td>
<td>2.100E-11</td>
</tr>
</tbody>
</table>

EQ Parameters: Use COM Recommended
COM recommended EQ parameters produce a good time domain eye diagram.

Sweep parameter:
- TX: C(-1), C(0), C(1)
- RX: CTLE&DFE
- Total case: 100

Time Domain Simulation

In the red circle is COM recommended EQ parameters.
CO-DESIGN SIMULATION FLOW

Use COM simulation to optimize total transportation channel
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CO-SIMULATION CONCLUSION

- COM enables passive channel evaluation of high-speed signals at early design phase
- COM recommended EQ parameters are suitable for same channel in time domain simulation
- COM simulation is faster, making them more suitable for the post-layout phase of large designs to sweep EQ parameters
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NEXT STEPS

• Model crosstalk in actual link
• Co-simulation for 56G PAM-4
• Accuracy of IBIS-AMI model
• Correlation of Co-simulation with measurement