Comparison of Equalization Schemes for 6Gbps SAS Channels

Joe Caroselli, Amaresh V. Malipatil
High Speed Interface Systems Engineering
LSI Logic
Introduction

• Review of simulator and parameters
• Overview of channels
• Presentation of results
Simulator Review
Three System Model Approach

Analytic Simulator
   (Architecture Determination)

Semi-Analytic Simulator
   (BER, Statistical Eye)

Bit By Bit Simulator
   (Eye Diagrams, Jitter Tolerance, Frequency Offset, Timing, Loop Convergence)

Ease of Modification

Complexity

Speed
Analytic Model

- **Includes**
  - Intersymbol Interference
  - Tx Jitter
  - Electronics (White) Noise
  - Crosstalk

- **Does Not Include**
  - Receiver Sensitivity
  - Duty Cycle Distortion
  - Other Sources of DJ
Required SNR

SNR Required at Slicer for $10^{-15}$ BER

$$SNR = \frac{d^2_{\text{min}}}{\sigma^2}$$

$$Pr_{err} \approx \frac{1}{2} \text{erfc}\left(\frac{\sqrt{SNR}}{2\sqrt{2}}\right)$$

- Approximately 24dB is required for an error rate of $10^{-15}$
Overview of Simulations

- Equalization architectures with a linear FIR feedforward (FF) filter in the TX, and a decision feedback (FB) equalizer in the Rx are compared.
- The number of taps in the feedforward and feedback equalizers are varied.
- The effect of one near-end crosstalk aggressor is considered.
- A simple RC model with pole at 0.75*baud rate is used for the transmitter.
- Mellitz capacitor-like package model included on both transmitter and receiver.
Parameters Used

- Only DJ is from ISI
  - No DCD, PJ included
- $0.010\text{UI} \sigma$ RJ added
- Signal-To-Electronics Noise Ratio 45dB
- Crosstalk added as noted
- Ideal receiver sensitivity assumed
Description of Results

- SNR at optimal sampling point is shown. No measurement of horizontal eye opening is presented.
- x-axis shows number of DFE taps used
- Each line represents a different number of feed-forward (FF) equalizer taps used in the TX
- Crosstalk is assumed to occur at the same frequency as the signal. The worst case crosstalk phase at the ideal sampling point is selected.
- All tap values are ideal.
TCTF Backplanes
### Comparison to T10/05-428r0 Vertical Eye Opening

<table>
<thead>
<tr>
<th></th>
<th>6dB FFE No DFE</th>
<th>0dB FFE 5-tap DFE</th>
<th># DFE taps/ dB de-emph</th>
<th># DFE taps/ dB de-emph</th>
<th># DFE taps/ dB de-emph</th>
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<th># DFE taps/ dB de-emph</th>
<th># DFE taps/ dB de-emph</th>
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<tbody>
<tr>
<td>HP01</td>
<td>0.10</td>
<td>0.20</td>
<td>0 / 7.0 dB</td>
<td>0 / 7.0 dB</td>
<td>0 / 7.0 dB</td>
<td>0 / 7.0 dB</td>
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<tr>
<td>HP02</td>
<td>0.10</td>
<td>0.22</td>
<td>0 / 6.4 dB</td>
<td>0 / 6.4 dB</td>
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<tr>
<td>HP03</td>
<td>0.12</td>
<td>0.25</td>
<td>0 / 6.6 dB</td>
<td>0 / 6.6 dB</td>
<td>0 / 6.6 dB</td>
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<tr>
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<td>0.25</td>
<td>0 / 5.4 dB</td>
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<tr>
<td>HP05</td>
<td>0.11</td>
<td>0.22</td>
<td>0 / 6.5 dB</td>
<td>0 / 6.5 dB</td>
<td>0 / 6.5 dB</td>
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<td>0 / 8.3 dB</td>
<td>0 / 8.3 dB</td>
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<tr>
<td>HP07</td>
<td>0.11</td>
<td>0.21</td>
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<td>HP08</td>
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<td>0.19</td>
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<td>0 / 8.7 dB</td>
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<td>0.11</td>
<td>1 / 5.7 dB</td>
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<td>0.01</td>
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<td>1 / 6.2 dB</td>
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<td>0.22</td>
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<td>0 / 6.1 dB*</td>
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<td>0 / 4.1 dB**</td>
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</table>

* HP12 with HP20 or HP22 as aggressor.
** HP13 with HP21 or HP23 as aggressor.
Conclusions

• Dell, Molex and TCTF require no DFE or 1-tap DFE

• HP Channels require more DFE compensation and the DFE requirements vary significantly depending on the victim and the aggressor. (See following detailed results)

• A reasonable compromise between chip area & power and the number of channels that can be supported is:
  • Reference TX: 1post-cursor FFE tap (plus possibly one pre-cursor FFE tap)
  • Reference RX: 1 (or possibly 2) DFE taps
Summary of Results
HP Backplanes
Victim-HP03 Aggressor-HP19

SNR at Slicer(dB) vs Number of Feedback Taps

SNR = 24 dB → BER $10^{-15}$
SNR = 23 dB → BER $10^{-12}$
Victim-HP26 No Xtalk

SNR at Slicer (dB)

Number of Feedback Taps

SNR=24 dB → BER $10^{-15}$
SNR=23 dB → BER $10^{-12}$
Dell Backplanes