06-206r2 SAS-2 Data Eyes vs. De-Emphasis

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SAS-2 Phy Working Group
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Address the Concern that Fixed De-Emphasis on External Links Will Cause too Much Jitter for Short Links
  • Compare Fixed and Optimal De-Emphasis for Example External SAS-2 Links
  • Estimate the Jitter Penalty of Fixed vs. Adaptive De-Emphasis
  • Discuss Concerns with Optional Adaptive De-Emphasis Provisions

Evaluate De-Emphasis on some Example T10 Chassis S-Parameters
  • Compare Results to 06-049r1

Propose Recommendations for Discussion
Simulation Methodology

- Convert S-Parameters to Frequency Response
  - Use Mellitz Capacitive Package Model RL~7dB @ 3GHz Combined with S-Parameter Model
  \[
  H(f) = \frac{S_{21} \Gamma_L + S_{21}}{1 - S_{22} \Gamma_L + S_{11} (1 - S_{22} \Gamma_L) + S_{21} \Gamma_L S_{12}}
  \]

- Convert Frequency Response to an Impulse Response
  \[h(t) = FFT^{-1}(H(f))\]

- Measure Transmitted Pulse Shape

- Compute the Optimal (ZF) De-Emphasis Tap Weights
  \[y(t) = p(t) \ast h(t)\]
  \[C_{zf} = \begin{bmatrix}
  y(\tau) & y(\tau - T) \\
  y(\tau + T) & y(\tau)
  \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix}\]

- Filter the Measured & Estimated Channel Output with the De-Emphasis Filter
  \[\hat{y}_m(t) = y_m(t) \ast c(t) \quad \hat{y}(t) = x(t) \ast h(t) \ast c(t)\]

- Estimate the Jitter from the Data Eye \(\{\hat{y}_m(t), \hat{y}(t)\}\)

- Compare to Measured Results
Optimal De-Emphasis for iPASS Cables

Computed Optimal and Laboratory Optimization De-Emphasis

- Theoretical
- Measured

Limited by 9.9dB Max DE

6dB Max for EMI?
Optimal De-Emphasis iPASS Cables

Simulation vs Measured
- 6 Gbps Output Driver Test Chip
  - 2 Tap De-Emphasis
  - 0 → 9.9 dB De-Emphasis Capability

Optimal De-Emphasis vs Length iPASS Cables

Optimal De-Emphasis Simulated Eyes
- 1m
- 6m
- 10m
- 15m

Optimal De-Emphasis Measured Eyes
- 1m
- 6m
- 10m
- 15m

Non-Optimal DE 9.9dB Limit
**Fixed 6dB De-Emphasis**

- Simulation vs Measured
  - 6 Gbps Output Driver Test Chip
    - 2 Tap De-Emphasis
    - 0 → 9.9 dB De-Emphasis Capability

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**Optimal De-Emphasis vs Length iPASS Cables**

- Theoretical
- 6dB Fixed

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**6dB De-Emphasis Simulated Eyes**

<table>
<thead>
<tr>
<th>Length</th>
<th>Simulated Eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1m</td>
<td><img src="image" alt="1m_simulated" /></td>
</tr>
<tr>
<td>6m</td>
<td><img src="image" alt="6m_simulated" /></td>
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<tr>
<td>10m</td>
<td><img src="image" alt="10m_simulated" /></td>
</tr>
<tr>
<td>15m</td>
<td><img src="image" alt="15m_simulated" /></td>
</tr>
</tbody>
</table>

**6dB De-Emphasis Measured Eyes**

<table>
<thead>
<tr>
<th>Length</th>
<th>Measured Eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1m</td>
<td><img src="image" alt="1m_measured" /></td>
</tr>
<tr>
<td>6m</td>
<td><img src="image" alt="6m_measured" /></td>
</tr>
<tr>
<td>10m</td>
<td><img src="image" alt="10m_measured" /></td>
</tr>
<tr>
<td>15m</td>
<td><img src="image" alt="15m_measured" /></td>
</tr>
</tbody>
</table>
Jitter vs Length with Fixed and Optimal De-Emphasis

- Measurement is 2000 hit Histogram

- Minimum Length External Channel 0.5m Jitter is Simulated Only

- Jitter Penalty at 10m is higher than at 1m length

- The data to date does not support the need for adaptive Tx De-Emphasis. 6dB of Fixed Tx De-Emphasis for external links does not appear to cause too much jitter when the short links are used.

\[
\hat{y}(t) = x(t) * h(t) * c(t)
\]

\[
\hat{y}_m(t) = y_m(t) * c(t)
\]
**HP Chassis Simulation Comparison**

**Simulation Comparison**

<table>
<thead>
<tr>
<th># DFE</th>
<th>dB DE</th>
<th>ZF DE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP01</td>
<td>0</td>
<td>7.0 dB</td>
</tr>
<tr>
<td>HP02</td>
<td>0</td>
<td>6.4 dB</td>
</tr>
<tr>
<td>HP03</td>
<td>0</td>
<td>6.6 dB</td>
</tr>
<tr>
<td>HP04</td>
<td>0</td>
<td>5.4 dB</td>
</tr>
<tr>
<td>HP05</td>
<td>0</td>
<td>6.5 dB</td>
</tr>
<tr>
<td>HP06</td>
<td>0</td>
<td>8.3 dB</td>
</tr>
<tr>
<td>HP07</td>
<td>0</td>
<td>6.8 dB</td>
</tr>
<tr>
<td>HP08</td>
<td>0</td>
<td>8.1 dB</td>
</tr>
<tr>
<td>HP09</td>
<td>0</td>
<td>8.7 dB</td>
</tr>
<tr>
<td>HP10</td>
<td>1</td>
<td>5.7 dB</td>
</tr>
<tr>
<td>HP11</td>
<td>1</td>
<td>6.2 dB</td>
</tr>
<tr>
<td>HP12</td>
<td>0</td>
<td>6.1 dB</td>
</tr>
<tr>
<td>HP13</td>
<td>0</td>
<td>4.1 dB</td>
</tr>
<tr>
<td>HP14</td>
<td>0</td>
<td>2.9 dB</td>
</tr>
</tbody>
</table>

**Simulation Model**

\[ x(t) = \sum a_i \delta(t-kT) \]

- **Tx Pulse Shape**
- **Tx DE or FFE**
- **Tx Pkg Model**
- **Channel**
- **Rx Pkg Model**
- **y(t)**

**Chassis HP1 → 14**

- **Optimal DE vs Channel number**
- **Frequency in GHz**

**06-049r1**

**06-206r1**
HP Chassis Simulation Comparison

HP Chassis 1→9 Optimal DE
Based on Test Chip Tx Pulse

- h1z f Vpp= 0.9 Q−15 dB
- h2z f Vpp= 0.99 Q−15 dB
- h3z f Vpp= 1 Q−15 dB

- h4z f Vpp= 1 Q−15 dB
- h5z f Vpp= 0.91 Q−16 dB
- h6z f Vpp= 0.79 Q−14 dB

- h7z f Vpp= 0.91 Q−15 dB
- h8z f Vpp= 0.86 Q−15 dB
- h9z f Vpp= 0.78 Q−13 dB

Simulations Consistent with 06-049r1 and Support the Assertion that 2 tap DE Adequate for these Channels

HP Chassis 1→9 Fixed DE
DE Levels Based on 06-049r1

- h1 l 7 dB DE Vpp= 0.93 Q−15 dB
- h2 l 6.4 dB DE Vpp= 1 Q−15 dB
- h3 l 6.6 dB DE Vpp= 1.1 Q−15 dB

- h4 l 5.4 dB DE Vpp= 1 Q−16 dB
- h5 l 6.5 dB DE Vpp= 0.94 Q−16 dB
- h6 l 8.3 dB DE Vpp= 0.81 Q−15 dB

- h7 l 6.8 dB DE Vpp= 0.95 Q−16 dB
- h8 l 8.1 dB DE Vpp= 0.91 Q−15 dB
- h9 l 8.7 dB DE Vpp= 0.79 Q−13 dB

Note: DE level based on assumed pulse shape in 06-049r0 not optimal for Simulated Pulse Shape
**HP Chassis Simulation Comparison**

### HP Chassis 10→14 Optimal DE

Based on Test Chip Tx Pulse

- h10zf Vpp= 0.84 Q=13 dB
- h11zf Vpp= 0.84 Q=13 dB
- h12zf Vpp= 0.84 Q=17 dB

- h13zf Vpp= 1 Q=17 dB
- h14zf Vpp= 1.3 Q=16 dB

**Simulations Consistent with 06-049r1 and Support the Assertion that 2 tap / 1 tap DFE DE Adequate for these Channels**

### HP Chassis 10→14 Fixed DE

DE Levels Based on 06-049r1

- h10 5.7 dB DE Vpp= 0.84 Q=14 dB h11 6.2 dB DE Vpp= 0.9 Q=13 dB h12 6.1 dB DE Vpp= 0.86 Q=19 dB

- h13 4.1 dB DE Vpp= 1 Q=18 dB h14 2.9 dB DE Vpp= 1.3 Q=16 dB

**Note: DE level based on assumed pulse shape in 06-049r0**

HP10,11 expected to need 1 tap DFE
Optimal and Fixed De-Emphasis for External Links has been Investigated

- Simulated and Measured Results Match Well
- Fixed 6dB De-Emphasis Does not Cause Excessive Jitter for Short Links

Simulations Consistent with 06-049r1

Recommendations

- Do not define “optional” primitives for adaptive De-Emphasis in the Training Sequence unless technical need determined.
- Do Provide Adjustable De-Emphasis for Internal Links.
- Do Assume a Maximum of 6dB De-Emphasis for Link Analysis and Specification.
- Determine a Compliance Test Methodology for External Links.