Considerations for high speed copper interconnect specifications

Chris Di Minico
MC Communications
Presentation objectives

• Considerations for high speed copper interconnect specifications
100GBASE-CXn and 40GBASE-CXn link

MDI

100GBASE-CXn or 40GBASE-CXn
Transmit Function

Cable assembly

MDI

Signal<p>

Lane n

Signal<n>

Signal shield

Link shield

100GBASE-CXn or 40GBASE-CXn
Receive Function
S-parameter interconnect specifications

- S-parameters are sufficient to specify interconnect-induced signal impairments e.g.,
- Measured:
  - Insertion loss
  - Return loss
  - Crosstalk
  - NEXT
  - FEXT
- Computed:
  - PSNEXT
  - PSELFEXT
- Limits:
  - Measurement based
  - InfiniBand

For 10GBASE-CX4 - All cable assembly measurements are to be made between TP1 and TP4 as shown in the Figure illustrated above.
802.3ap Channel Parameters

• Channel measurement reference: TP1 to TP4.

• Measured
  ▪ Insertion Loss
  ▪ NEXT
  ▪ FEXT
  ▪ Return Loss

• Computed
  ▪ Insertion loss deviation
  ▪ Insertion loss to crosstalk ratio
  ▪ PSNEXT, PSFEXT, PSXT

• Limits
  ▪ To support existing platforms (ATCA)

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Figure 70–1—Link block diagram
## 802.3ba lane rates under discussion

<table>
<thead>
<tr>
<th>100GBASE-CXn</th>
<th>lane rates Gb/s</th>
<th>Length (m) Passive cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>parallel</td>
<td>10 x 10</td>
<td>at least 10 m</td>
</tr>
<tr>
<td>parallel</td>
<td>5 x 20</td>
<td>at least 10 m</td>
</tr>
<tr>
<td>parallel</td>
<td>4 x 25</td>
<td>at least 10 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>40GBASE-CXn</th>
<th>lane rates Gb/s</th>
<th>Length (m) Passive cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>parallel</td>
<td>4 x 10</td>
<td>at least 10 m</td>
</tr>
</tbody>
</table>
Twinaxial media for lane options

- **4x – 8 pairs**
  - Diameter: 8.19 mm (0.322”)

- **5x – 10 pairs**
  - Diameter: 8.94 mm (0.352”)

- **10x – 20 pairs**
  - Diameter: 11.79 mm (0.464”)

- **10x – cents**
  - Diameter: 17.41 mm

- Features:
  - Differential parallel pair
  - Drain wire
  - Aluminum shield
S-parameters – 4 port network

Physical network

Signal flow graph

[S-parameter matrix of single ended measurements]
S-parameter mapping to differential and common mode

signal flow graph example $S_{d2d1}$ mapping from single ended measurements

\[
\begin{bmatrix}
    b_{d1} \\
    b_{d2} \\
    b_{c1} \\
    b_{c2}
\end{bmatrix} =
\begin{bmatrix}
    S_{d1d1} & S_{d1d2} & S_{d1c1} & S_{d1c2} \\
    S_{d2d1} & S_{d2d2} & S_{d2c1} & S_{d2c2} \\
    S_{c1d1} & S_{c1d2} & S_{c1c1} & S_{c1c2} \\
    S_{c2d1} & S_{c2d2} & S_{c2c1} & S_{c2c2}
\end{bmatrix}
\begin{bmatrix}
    a_{d1} \\
    a_{d2} \\
    a_{c1} \\
    a_{c2}
\end{bmatrix}
\]

\[
S_{d2d1} = \frac{1}{2} (S_{31} - S_{32} + S_{42} - S_{41})
\]
Convolve the interconnect's response with a worst case transmitter behavioral model and a worst case data pattern. The resulting time domain results, represented via an eye diagram, can then be compared against the VRX_EYE and TRX_EYE parameters defined in the receiver specification.
Intra-pair skew

Transmit Pulse

Differential TDT - 50% rise time - ~23 ps intra-pair skew

Pulse Response - 50% rise time skew - ~23 ps intra-pair skew
Summary

• **S-parameters are sufficient to specify interconnect-induced signal impairments.**
BACKUP SLIDES
## Lane Rate, Signaling rate, channel bandwidth

**10 m cable + connectors  @ 6 dB Margin**

<table>
<thead>
<tr>
<th>Maximum Lane rate</th>
<th>Maximum signaling rate</th>
<th>Info bits/baud/dim</th>
<th>Channel bandwidth</th>
<th>Copper Gauge</th>
<th>Code gain</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mb/s</td>
<td>Mbaud</td>
<td>MHz</td>
<td>AWG</td>
<td>dB</td>
<td>meters</td>
<td></td>
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<tr>
<td>10889.28</td>
<td>8180.00</td>
<td>1.33</td>
<td>4090.00</td>
<td>28</td>
<td>0</td>
<td>10</td>
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<tr>
<td>13984.52</td>
<td>10140.00</td>
<td>1.38</td>
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<td>28</td>
<td>2</td>
<td>10</td>
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<tr>
<td>17555.24</td>
<td>11360.00</td>
<td>1.55</td>
<td>5680.00</td>
<td>28</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>&gt;24950.75</td>
<td>&gt;17290.00</td>
<td>1.44</td>
<td>8645.00</td>
<td>24</td>
<td>0</td>
<td>10</td>
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<tr>
<td>&gt;30727.91</td>
<td>&gt;17400.00</td>
<td>1.77</td>
<td>8700.00</td>
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<td>2</td>
<td>10</td>
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<tr>
<td>&gt;36785.11</td>
<td>&gt;19000.00</td>
<td>1.94</td>
<td>9500.00</td>
<td>24</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>&gt;17212.31</td>
<td>&gt;13210.00</td>
<td>1.30</td>
<td>6605.00</td>
<td>28 ADVD</td>
<td>0</td>
<td>10</td>
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<tr>
<td>&gt;22044.24</td>
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<td>7730.00</td>
<td>28 ADVD</td>
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<td>10</td>
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</tbody>
</table>

Source: George Zimmerman, Solarflare Communications, Chris DiMinico, MC Communications
**Lane Rate, Signaling rate, channel bandwidth**

10 m cable + connectors @ 6 dB Margin

### Maximum achievable lane rate for each coding gain

<table>
<thead>
<tr>
<th>Maximum Lane rate Mb/s</th>
<th>Maximum signaling rate Mbaud</th>
<th>Info bits/baud/dim</th>
<th>Modulated Info bits/baud/dim (2)</th>
<th>Channel bandwidth (MHz)</th>
<th>Copper Gauge</th>
<th>Code gain</th>
<th>Length</th>
<th>Modulation</th>
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<tbody>
<tr>
<td>10889.28</td>
<td>8180.00</td>
<td>1.33</td>
<td>1.33</td>
<td>4090.00</td>
<td>28</td>
<td>0</td>
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<td>PAM-3</td>
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<td>13984.52</td>
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<td>1.48</td>
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<td>5048.89</td>
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<td>PAM-4</td>
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<td>24950.75</td>
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<td>1.44</td>
<td>1.44</td>
<td>8645.00</td>
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<td>1.77</td>
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<td>8130.84</td>
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<td>10</td>
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<tr>
<td>36785.11</td>
<td>16888.89</td>
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<td>2.18</td>
<td>8444.44</td>
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<td>10</td>
<td>PAM-4</td>
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</tbody>
</table>

(1) Channel bandwidth = 0.5 * (Maximum signaling rate)

(2) Info/bits/baud/dim adjusted for coding gain

### Maximum achievable lane rate for each coding gain that yields 1 bit/baud

<table>
<thead>
<tr>
<th>Maximum Lane rate Mb/s</th>
<th>Maximum signaling rate Mbaud</th>
<th>Info bits/baud/dim</th>
<th>Modulated Info bits/baud/dim (2)</th>
<th>Channel bandwidth (MHz)</th>
<th>Copper Gauge</th>
<th>Code gain</th>
<th>Length</th>
<th>Signaling</th>
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<td>10439.00</td>
<td>10439.00</td>
<td>1.00</td>
<td>1.00</td>
<td>5219.50</td>
<td>28</td>
<td>0</td>
<td>10</td>
<td>PAM-2/NRZ</td>
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<tr>
<td>12630.13</td>
<td>13580.00</td>
<td>0.93</td>
<td>1.00</td>
<td>6790.00</td>
<td>28</td>
<td>2</td>
<td>10</td>
<td>PAM-2/NRZ</td>
</tr>
<tr>
<td>14857.53</td>
<td>16690.00</td>
<td>0.89</td>
<td>1.00</td>
<td>8345.00</td>
<td>28</td>
<td>4</td>
<td>10</td>
<td>PAM-2/NRZ</td>
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<tr>
<td>21639.98</td>
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<td>1.00</td>
<td>10819.99</td>
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<td>10</td>
<td>PAM-2/NRZ</td>
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<tr>
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<td>25170.00</td>
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<td>1.00</td>
<td>12585.00</td>
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<td>2</td>
<td>10</td>
<td>PAM-2/NRZ</td>
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<tr>
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<td>0.89</td>
<td>1.00</td>
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<td>4</td>
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<td>PAM-2/NRZ</td>
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<td>16224.36</td>
<td>16224.36</td>
<td>1.00</td>
<td>1.00</td>
<td>8112.18</td>
<td>28 ADVD</td>
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<td>10</td>
<td>PAM-2/NRZ</td>
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<tr>
<td>18748.43</td>
<td>20159.60</td>
<td>0.93</td>
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<td>28 ADVD</td>
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<td>21194.44</td>
<td>23813.98</td>
<td>0.89</td>
<td>1.00</td>
<td>11906.99</td>
<td>28 ADVD</td>
<td>4</td>
<td>10</td>
<td>PAM-2/NRZ</td>
</tr>
</tbody>
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802.3 HSSG