PCI-SIG ENGINEERING CHANGE NOTICE

<table>
<thead>
<tr>
<th>TITLE:</th>
<th>OCuLink Cable Spec ECN</th>
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<tbody>
<tr>
<td>DATE:</td>
<td>March 23, 2018</td>
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<tr>
<td>AFFECTED DOCUMENT:</td>
<td>OCuLink 1.0</td>
</tr>
<tr>
<td>SPONSOR:</td>
<td>Alex Haser (Molex), Jay Neer (Molex)</td>
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**Part I:**

1. **Summary of the Functional Changes**
   The IL/ fitted IL requirements have been clarified. The language of this portion of the spec has been reworked to eliminate confusion and provide uniformity in the subsections included in the following document.

2. **Benefits as a Result of the Changes**
   The signal integrity requirements necessary for OCuLink compliance have been clarified. The method for calculating fitted IL has been simplified. The equations for limit lines have been redefined to report values as losses (positive values).

3. **Assessment of the Impact**
   This section of the spec has been made easier to follow and is therefore less likely to misinterpret.

4. **Analysis of the Hardware Implications**
   Connectors and cables must adhere to the fully specified signal integrity requirements described in the following text.

5. **Analysis of the Software Implications**
   None, this change does not affect software.

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**Part II:** Changes are reflected in Sections 7.3 through 7.3.6 (begins on the next page).
7.3 Mated Cable Assembly Electrical Specifications

The OCuLink cable assembly contains insulated conductors terminated in a connector at each end for use as a link segment between host boards. This cable assembly is primarily intended as a point-to-point interface between host boards using controlled impedance cables. All mated cable assembly measurements are to be made between TP1 and TP4 with CCB test fixtures, which includes a connector mated to either end of the cable assembly. CCB test fixtures are to be removed before comparing measured performance against the specifications listed in this section. It is recommended measurements be de-embedded using a TRL calibration (see Section 7.4 for more information on de-embedding). All requirements are to be met when analyzed in an 85 Ω reference frame.

The mated cable assembly specifications are based upon twin axial cable characteristics. Table 7-1 provides a summary of the cable assembly characteristics and references addressing each parameter. Limits apply to 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s data rates and are written in terms of baud frequency. Baud frequencies are 2.5 GHz, 5 GHz, and 8 GHz for the 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s data rates, respectively. Note that plots show loss (positive values).

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<th>Value</th>
<th>Unit</th>
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<td>Maximum total cable assembly, Lane-to-Lane skew (Sc)</td>
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7.3.1. Characteristic Impedance and Reference Impedance

The nominal differential characteristic impedance of the cable assembly is 85 Ω. The differential reference impedance for cable assembly must be 85 Ω.
7.3.2. Mated Cable Assembly Differential Insertion Loss

The differential insertion loss of each pair of a mated OCuLink cable assembly, in dB, must be less than the maximum limit defined in Equation 7-1, as illustrated in Figure 7-5.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-1

\[ ILC_{\text{Cable}}(f) = 2 + 5.5\sqrt{f} + 0.5 f \]

for \( 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz} \)

Where:

- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- \( ILC_{\text{Cable}}(f) \) is the maximum mated cable assembly insertion loss, in dB

Figure 7-5: Maximum Mated Cable Assembly Insertion Loss

This insertion loss limit is intended to accommodate cables up to 2 m long (using 34 awg).
7.3.3. **Mated Cable Assembly Differential Return Loss**

The differential return loss of each pair of the mated OCuLink cable assembly, in dB, must be greater than the minimum limit defined in Equation 7-2, as illustrated in Figure 7-6.

**2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:**

\[
R_{\text{Cable}}(f) = \begin{cases} 
10 \text{ dB} & \text{for } 0.05 \text{ GHz} \leq f \leq 2 \text{ GHz} \\
(12 - f) \text{ dB} & \text{for } 2 \text{ GHz} < f \leq f_b \text{ GHz} 
\end{cases}
\]

Where:
- \(f\) is the frequency, in GHz
- \(f_b\) is the baud frequency, in GHz
- \(R_{\text{Cable}}(f)\) is the maximum mated cable assembly return loss, in dB

**Figure 7-6:** Minimum Mated Cable Assembly Return Loss
7.3.4. Mated Cable Assembly Differential to Common-mode Return Loss

The differential to common-mode return loss of the mated OCuLink cable assembly, in dB, must be greater than the minimum defined in Equation 7-3, which is illustrated in Figure 7-7.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-3

\[
DCMC_{\text{Cable}}(f) = 20 - \left(\frac{2}{3}\right) f \\
\text{for } 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz}
\]

Where:

- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- \( DCMCRL(f) \) is the minimum mated cable assembly differential to common-mode return loss, in dB

![Figure 7-7: Minimum Mated Cable Assembly Differential to Common-mode Return Loss](image)
7.3.5. Mated Cable Assembly Differential to Common-mode Conversion Loss minus Insertion Loss

The difference between the mated OCuLink cable assembly differential to common-mode conversion loss and the cable assembly insertion loss, in dB, must be greater than the minimum limit defined in Equation 7-4.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-4

\[
\text{DCMC-ILCable}(f) = 10 \text{ dB for } 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz}
\]

Where:

- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- \( \text{DCMC}(f) \) is the mated cable assembly differential to common-mode insertion loss, in dB
- \( \text{ILCable}(f) \) is the mated cable assembly differential insertion loss, in dB

7.3.6. Mated Cable Assembly Common-mode Return Loss

The common-mode return loss of the mated OCuLink cable assembly, in dB must be greater than the minimum limit defined in Equation 7-5.

2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

Equation 7-5

\[
\text{CMRLCable}(f) = 2 \text{ dB for } 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz}
\]

Where:

- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- \( \text{CMRLCable}(f) \) is the minimum mated cable assembly common-mode return loss, in dB
7.3.7. Mated Cable Assembly Crosstalk

Crosstalk between differential pairs influences the data signals and any subsequent loss and jitter budgets. All system board and cable assembly designs must properly account for any crosstalk that may exist among the various pairs of differential signals. Crosstalk is due to coupling through a channel, either at the near-end (NEXT) or at the far-end (FEXT). The total contribution from all aggressors on a particular victim is captured by the multi-disturber or powersum crosstalk.

The NEXT loss that couples within a channel is from Lanes that transmit data in the opposite direction as the victim Lane. Therefore, MDNEXT loss on a receive Lane must be summed across contributions from the four transmit Lanes at the near end of the mated cable assembly, yielding four aggressors total for a four-Lane interface.

Similarly, the FEXT loss that couples within a channel is from the Lanes that transmit data in the same direction as the victim Lane. Therefore, MDFEXT loss on a receive Lane must be summed across contributions from the three remaining receive Lanes at the far end of the mated cable assembly, yielding three aggressors total for a four-Lane interface.

Equation 7-6 provides the calculation for MDNEXT loss; Equation 7-7 provides the calculation for MDFEXT loss.

\[
\text{Equation 7-6: } \text{MDNEXT}(f) = -10 \log_{10} \sum_{i=0}^{3} 10^{-NL_i(f)/10} \text{ for } 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz}
\]

Where:
- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- \( \text{MDNEXT}(f) \) is the multi-disturber near-end crosstalk loss at frequency \( f \)
- \( NL_i(f) \) is the NEXT loss at frequency \( f \) of victim-aggressor combination \( i \), in dB
- \( i \) is the victim-aggressor pair (0 to 3)

\[
\text{Equation 7-7: } \text{MDFEXT}(f) = -10 \log_{10} \sum_{i=0}^{2} 10^{-FL_i(f)/10} \text{ for } 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz}
\]

Where:
- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- \( \text{MDFEXT}(f) \) is the multi-disturber far-end crosstalk loss at frequency \( f \)
- \( FL_i(f) \) is the FEXT loss at frequency \( f \) of victim-aggressor combination \( i \), in dB
- \( i \) is the victim-aggressor pair (0 to 2)
The MDNEXT loss and MDFEXT loss summed on each receive Lane of a mated OCuLink cable must be greater than the limits defined in Equations 7-8 and 7-9 respectively. These limits are illustrated in Figure 7-8.

### 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

**Equation 7-8**

\[
\text{MDNEXTCable}(f) = 31.5 - 12.5 \log_{10} \left( \frac{f}{4} \right) \text{ dB for } 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz}
\]

Where:

- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- MDNEXTCable is the minimum mated cable assembly MDNEXT loss, in dB

### 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s:

**Equation 7-9**

\[
\text{MDFEXTCable}(f) = 31 - 15 \log_{10} \left( \frac{f}{4} \right) \text{ dB for } 0.05 \text{ GHz} \leq f \leq f_b \text{ GHz}
\]

Where:

- \( f \) is the frequency, in GHz
- \( f_b \) is the baud frequency, in GHz
- MDFEXTCable is the minimum mated cable assembly MDFEXT loss, in dB

**Figure 7-8:** Minimum Mated Cable Assembly MDNEXT Loss and MDFEXT Loss
7.3.8. Lane-to-Lane Skew

The time delay across a cable assembly at any point is measured using zero crossings of differential voltage of the compliance pattern, while simultaneously transmitting on all physical Lanes. The compliance pattern is defined in the *PCI Express Base Specification*. The skew for a mated cable assembly is quantified as the difference between the longest and shortest time delays measured for a given assembly. The maximum skew permitted for 2.5 GT/s, 5.0 GT/s, and 8.0 GT/s OCuLink cable assemblies is 0.9ns.

7.3.9. Within-Lane Skew

Maximum within-Lane skew is not specified in this specification in the time domain. Within-Lane skew is instead controlled in the frequency domain by means of the restrictions on differential-to-common mode return loss and differential-to-common mode conversion loss minus insertion loss.