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Purpose

- Material characterization is a critical step in PCB ecosystem enabling
  - Need to have a robust yet accurate method for the industry
  - Available industry methods have limitations in efficiency and accuracy

- Delta-L+ can provide:
  - accurate de-embedding with full S parameter extraction
  - material extraction capability
  - allow for flexibility/capability of HVM Monitoring by smaller coupon
PCB Characterization Process

Accurate Characterization /Material Selection

Material Selection
- Intel (requirement)
- Testing House
- ODM/OEM
- Material Vendor
- PCB Manufacturer

Production Board Samples
- ODM/OEM
- PCB Manufacturer
- Testing House

Quality Control
- High Volume Manufacture Production
- PCB Manufacturer
What’s New in Delta-L+ compared to Delta-L 2.0?

• Three-category approach to address the need of PCB characterization at different stages

• Major enhancements from Delta-L 2.0:
  • Three-length (3L) method to self-check and ensure the accuracy of the de-embedding results
  • One-length (1L) method for HVM monitoring

• Future enhancements (Working In Progress):
  • Dk/Df extraction methodology
  • Surface roughness characterization methodology
Delta-L+ Metrology

Choose coupons with different length combinations at different stages of PCB Characterization

Note: Actual length may vary

<table>
<thead>
<tr>
<th>Material Selection</th>
<th>Board Sampling</th>
<th>HVM Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typically &lt;5 Boards</td>
<td>Typically 5-30 Boards</td>
<td>Sample size varies</td>
</tr>
</tbody>
</table>

Best accuracy

Most suitable for:
Material Characterization
DK/DF Extraction, Insertion Loss & Surface Roughness characterization

Cost effective

Most suitable for:
Board Quality Validation
Insertion loss & Impedance validation

Small Coupon

Most suitable for:
HVM Monitoring
Insertion loss and impedance variation, by one-length approach
Delta-L+ (3L)  Three-Line Method

3L method
1. A de-embedded by C using 2X-thru de-embedding
2. B de-embedded by C using 2X-thru de-embedding
3. dB/in comparison of (A-C) and (B-C)
4. Dk/Df extraction

Note: Other de-embedding method, such as TRL, can be implemented as well

This is an important step to validate the de-embedded results.
Criteria: < 5% (TBD) error @ up to the highest frequency of interest
Delta-L+ (2L) Two-Line Method

**Delta-L Methodology**

- **Direct through measurement for insertion loss.**
  - Insertion of structure A: IL(A) -- X1 inches + vias
  - Insertion of structure B: IL(B) -- X2 inches + vias
  - dB/inch loss = (IL(A) - IL(B)) / (X1-X2)
  - X2 cannot be too short, and X1-X2 better to bigger than 3-4".
  - **Recommendation:** The routing length of X1 is twice of X2

- No full SOLT or TRL calibration needed; compatible to TRL calibration or AFR.
- VNA or TDR/TDT measurement
  - If TDT/TDT measured is performed, it needs to be converted to S parameter first.

**Category 2 (two-line)**
Direct A – B subtraction using Delta-L 2.0

Reference: *Delta-L Methodology for Electrical Characterization, Rev. 330223-001*
Delta-L+ (1L) One-Line Method

Material Selection/Board Sampling

- Use two lines to get accurate loss characterization

HVM Monitoring

- Use only one line to monitor the HVM variation

Keep track of performance of “A”

Criteria: < 10% (TBC) variation @ Nyquist frequency for at least x samples
## Delta-L+ Usage Model

<table>
<thead>
<tr>
<th>Category</th>
<th>Primary Usage</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L</td>
<td>PCB house, HVM monitoring</td>
<td>Lowest cost solution, TDR/TDT or VNA is ok</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
<td>10 inch</td>
</tr>
<tr>
<td>2L</td>
<td>PCB House (optional) OxM seeking low cost “de-embedding”</td>
<td>This is Delta-L 2.0, TDR/TDR or VNA is ok, VNA is preferred</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
<td>10 inch</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
<td>5 inch</td>
</tr>
<tr>
<td>3L</td>
<td>Material vendor OxMs</td>
<td>VNA preferred. Prefer rigorous de-embedding (AFR, SFD, TRL, etc.)</td>
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<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
<td>10 inch</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
<td>5 inch</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Diagram" /></td>
<td>2 inch</td>
</tr>
</tbody>
</table>

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Summary

3L:
for best accuracy
Self-validation of results

2L:
cost effective approach to
remove test fixture impact

1L
Focus on relative comparison
(for high volume manufacture)