SAS-2 Zero-Length Test Load Characterization (07-013r4)

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Zero-Length Test Load

- Provides ideal connection between compliance point and instrumentation reference plane.
- May consist of printed circuit board traces, connectors and cables.
- Trace structure variations of width, length and dielectric material are typical. Test board designs need to meet impedance targets but exact effect of insertion loss is considered negligible but usually unknown.
- Connector footprint variations are a common source of varied test board performance.
- Instrumentation cables vary in length, insertion loss, termination quality and type (rigid, semi-rigid, hand-formable, etc).
- These effects can be de-embedded when using some instrumentation but can not with most.
Zero-Length Test Load Misconceptions

- All good quality SMA cables have similar electrical characteristics
- If you use connector footprint provided in the standard you will meet the impedance specifications of the standard
- The common mode impedance of trace structures on the test fixture has no effect. Only the differential impedance is important.
Challenges of Characterization

• Some compliance points utilize connectors while others don’t. How do we account for these differences?
• Of those that use connectors not all are the same
• Connector and IC component footprints dictate PCB routing methodology
• Must resolve the discrepancies or de-embed the PCB effects
Challenges of Characterization

- To limit the insertion loss variations, an $S_{21}$ mask is one possible approach. This approach is problematic if other parameters are less than ideal.
- Can we make that assumption?
- Just how good do the other parameters have to be?
- Simulations can help answer this question.
Measurement Objectives

- Network analyzer measurements are suited to de-embedding. Frequency limitations exist with calibration structures but we may be below those limits.
- Time domain instrumentation (oscilloscope) does not yet have the same level of de-embedding features.
- Need to evaluate each usage case for zero-length test load and determine what specifications are necessary and appropriate.
## Test Fixture Budgeting (Early Targets)

<table>
<thead>
<tr>
<th></th>
<th>Printed Circuit Board</th>
<th>Cable</th>
<th>Connectors &amp; Footprints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss</td>
<td>&lt; 2dB @ 3GHz</td>
<td>&lt; 1dB @ 3GHz</td>
<td>&lt; 1dB @ 3GHz</td>
</tr>
<tr>
<td>Return Loss</td>
<td>&lt; -20dB thru 3GHz</td>
<td>&lt; -30dB thru 3GHz</td>
<td>&lt; -15dB thru 3GHz</td>
</tr>
<tr>
<td>Conversion</td>
<td>&lt; -30dB thru 3GHz</td>
<td>&lt; -30dB thru 3GHz</td>
<td>&lt; -30dB thru 3GHz</td>
</tr>
<tr>
<td>Common Mode</td>
<td>?</td>
<td>Not Applicable</td>
<td>?</td>
</tr>
</tbody>
</table>

*Since most of these parameters are sensitive to interaction with other components, individual budgeting is of minimal value beyond a first guess estimate*
Next Actions

- The biggest issue is probably how to specify parameters that will yield consistent zero-length fixtures. Simulations should help.
- Zero-length specification should be influenced by the types of measurements to be performed in SAS-2. We must consider each type.
Simulation Approach

• Three different fixtures will be considered
  • Case #1: Lowest insertion loss (short trace, SMA launch and bulky 24 inch instrumentation cable)
  • Case #2: Lowest return loss (slightly longer trace, better SMA launch and thin 1 meter instrumentation cable)
  • Case #3: 2 meter miniSAS (includes fixturing losses)
  • Case #4: Mated miniSAS interface (slightly longer trace, same SMA launch and cable as #2)

• Characterize each and simulate eye diagrams to compare effects of fixtures at 3 and 6 Gbps. Use 1000 mV K28.5 transmitter model with fast and slow edge rates.
Case #1, 3Gbps, Tr: 66ps

Eye Height: 926mV
Case #1, 3Gbps, Tr: 100ps

Eye Height: 923mV
Case #2, 3Gbps, Tr: 66ps

Eye Height: 794mV
Case #2, 3Gbps, Tr: 100ps

Eye Height: 788mV
Case #3, 3Gbps, Tr: 66ps

Eye Height: 591mV
Case #3, 3Gbps, Tr: 100ps

Eye Height: 583mV
Case #4, 3Gbps, Tr: 66ps

Eye Height: 746mV
Case #4, 3Gbps, Tr: 100ps

Eye Height: 744mV
Case #1, 6Gbps, Tr: 33ps

Eye Height: 893mV
Case #1, 6Gbps, Tr: 50ps

Eye Height: 880mV
Case #2, 6Gbps, Tr: 33ps

Eye Height: 692mV
Case #2, 6Gbps, Tr: 50ps

Eye Height: 678mV

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Case #3, 6Gbps, Tr: 33ps

Eye Height: 456mV
Case #3, 6Gbps, Tr: 50ps

Eye Height: 444mV
Case #4, 6Gbps, Tr: 33ps

Eye Height: 626mV
Case #4, 6Gbps, Tr: 50ps

Eye Height: 636mV
Simulation Summary

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3Gbps (Fast)</strong></td>
<td>923mV</td>
<td>794mV</td>
<td>591mV</td>
<td>746mV</td>
</tr>
<tr>
<td><strong>3Gbps (Slow)</strong></td>
<td>923mV</td>
<td>788mV</td>
<td>583mV</td>
<td>744mV</td>
</tr>
<tr>
<td><strong>6Gbps (Fast)</strong></td>
<td>893mV</td>
<td>692mV</td>
<td>456mV</td>
<td>636mV</td>
</tr>
<tr>
<td><strong>6Gbps (Slow)</strong></td>
<td>880mV</td>
<td>678mV</td>
<td>444mV</td>
<td>626mV</td>
</tr>
</tbody>
</table>

No pre-emphasis used
Measurements with Pre-emphasis

- Focusing on cases 1 and 2, how do the eye height and peak-to-peak values compare for the pre-emphasis settings of 0dB, 3dB and 6dB
Case #1, 3Gbps, Tr: 66ps, 3dB

Eye Height / Max Eye: 690mV / 946mV
Case #1, 3Gbps, Tr: 100ps, 3dB

Eye Height / Max Eye: 690mV / 925mV
Case #2, 3Gbps, Tr: 66ps, 3dB

Eye Height / Max Eye: 649mV / 848mV
Case #2, 3Gbps, Tr: 100ps, 3dB

Eye Height / Max Eye: 646mV / 840mV
Case #1, 6Gbps, Tr: 33ps, 3dB

Eye Height / Max Eye: 686mV / 923mV
Case #1, 6Gbps, Tr: 50ps, 3dB

Eye Height / Max Eye: 686mV / 907mV
Case #2, 6Gbps, Tr: 33ps, 3dB

Eye Height / Max Eye: 622mV / 772mV
Case #2, 6Gbps, Tr: 50ps, 3dB

Eye Height / Max Eye: 623mV / 751mV
Case #1, 3Gbps, Tr: 66ps, 6dB

Eye Height / Max Eye: 493mV / 943mV
Case #1, 3Gbps, Tr: 100ps, 6dB

Eye Height / Max Eye: 493mV / 944mV
Case #2, 3Gbps, Tr: 66ps, 6dB

Eye Height / Max Eye: 473mV / 846mV
Case #2, 3Gbps, Tr: 100ps, 6dB

Eye Height / Max Eye: 473mV / 850mV
Case #1, 6Gbps, Tr: 33ps, 6dB

Eye Height / Max Eye: 481mV / 910mV
Case #1, 6Gbps, Tr: 50ps, 6dB

Eye Height / Max Eye: 486mV / 910mV
Case #2, 6Gbps, Tr: 33ps, 6dB

Eye Height / Max Eye: 463mV / 795mV
Case #2, 6Gbps, Tr: 50ps, 6dB

Eye Height / Max Eye: 462mV / 791mV
### Simulation Summary

<table>
<thead>
<tr>
<th>Case</th>
<th>3Gbps</th>
<th>6Gbps</th>
<th>3Gbps</th>
<th>6Gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>DE: 0dB (Slow)</td>
<td>923mV</td>
<td>880mV</td>
<td>788mV</td>
<td>678mV</td>
</tr>
<tr>
<td>DE: 0dB (Fast)</td>
<td>926mV</td>
<td>893mV</td>
<td>794mV</td>
<td>692mV</td>
</tr>
<tr>
<td>DE: 3dB (Slow)</td>
<td>925mV</td>
<td>907mV</td>
<td>840mV</td>
<td>751mV</td>
</tr>
<tr>
<td>DE: 3dB (Fast)</td>
<td>946mV</td>
<td>923mV</td>
<td>848mV</td>
<td>772mV</td>
</tr>
<tr>
<td>DE: 6dB (Slow)</td>
<td>944mV</td>
<td>910mV</td>
<td>850mV</td>
<td>791mV</td>
</tr>
<tr>
<td>DE: 6dB (Fast)</td>
<td>943mV</td>
<td>910mV</td>
<td>846mV</td>
<td>795mV</td>
</tr>
</tbody>
</table>

Three and six dB measurements are pk-pk at eye midpoint of the emphasized bit. Zero dB measurements are of the eye opening.
Simulation Summary

Zero dB results are slightly misleading.
Eye Height vs. Insertion Loss

- To better understand how insertion loss effects eye height simulations were repeated with PCB trace models. The trace structure was selected to obtain 100 ohms differential and noticeable skin effect losses. The trace length was computed to obtain 0.5 to 6 dB of insertion loss at 3 GHz in increments of 0.5 dB

- Eye height measurements were made by taking approximating the average value obtained after transition bits
Trace Model Insertion Loss

![Graph showing the trace model insertion loss with GHz on the x-axis and dB on the y-axis. The graph includes lines for different cases: case1, 0.5dB, 1dB, and 3dB.]
Eye Height vs. Channel Loss

Reduced Eye Height vs. Channel Loss (dB)

(Insertion Loss Measured at 3 GHz)
Comparison to Nyquist for 6Gbps

(Insertion Loss Measured at 3GHz)
Fixture De-embedding

- De-embedding appears to be a reasonable method for removing errors in near-end measurements induced by test fixtures and cables.

- However, some level of expertise in modeling tools and the availability instrumentation that can characterize fixturing and cables is required.

- Can we obtain a crude estimate of bit amplitude by measuring insertion loss at the Nyquist frequency and by applying fractional power $x$?
  - Estimate $= S_{21}(\text{Nyquist})^x$
  - For this case, $x = 0.72$ is selected.
Results of Eye Height Estimation and Error

Eye Height Estimated from S21 at Nyquest

Channel Loss (dB)

Reduced Eye Height

60% 70% 80% 90% 100%

6Gbps
S21@3GHz

Estimation Error

Channel Loss (dB)

Error

(Insertion Loss Measured at 3GHz)
Fixture De-embedding by Estimation from Nyquist

- This simple sample indicates that rigorous modeling of test fixture effects may not be required in order to obtain accurate estimates of transmitter waveforms
- This assumption may fail if return loss effects are no longer negligible
Fixture Return Loss

- Clearly the insertion loss is a major factor in the waveform degradation. The return loss may also be a factor.
- Cases 1 and 2 may be constructed to instrumentation quality standards and minimize reflected power. How do they compare to the 3rd case?