Equalization of Meritec's 2mm Hard Metric Cable Assemblies

Test 244
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Scope
To determine the effects of passive equalization on eye pattern diagrams (EPD's) when high pass filters are used to compensate for cable and pc board losses. Test pc boards and cables were fabricated and, based on measurement-based simulations of the signal paths, passive networks were built into Meritec's 2mm HM connectors on the cable assemblies. The simulations of the expected EPD's were compared to actual measurements to verify that the simulations were accurate. Meritec collaborated with atSpeed Technologies Corporation to study a number of cabled backplane design applications in order to illustrate that signal rates greater than 1Gb/s are achievable by improving performance of 2mm technology with passive signal conditioning. This test explores optimizing the equalization for the entire signal path, from chip to chip, instead of equalizing just the cable or the PC board traces, separately.

Conclusions
Measurement-based predictions, confirmed by direct measurements, show that by using passive equalization to compensate for the losses and dispersion within the cable and the circuit boards, data rates extending beyond 6.375 Gb/s are achievable in FR4 using 2mm hard metric (2mm HM) technology.

Figure 1 illustrates the eye pattern diagrams (EPD) for unequalized as well as for optimally equalized links, driven at 3.250 Gb/s. The eye pattern diagram opening is...
enhanced by more than 250% and jitter is significantly reduced. It can be shown that if only the cable length had been equalized, nearly 90 ps of jitter would have had to be added to the timing budget and nearly 100 mV of signal would not have been available to the designer. The effectiveness of the chip-to-chip equalization approach is illustrated for path B since it includes the longest path in FR4 and includes 3 meters of cable.

The following graph is based on optimizing the equalization for the signal path using actual measured S-parameters for the components within the path.

![Figure 2 - Summary of Results](image)

*Figure 2 - Summary of Results*
(based on an EPD opening of 200 mv with a 1 volt stimulus)

**Signal Paths**
Test-specific pc boards were designed and fabricated. The daughter cards are 75 mil (1.9mm) thick FR-4 and backplanes are 250 mils (6.35mm) thick FR-4. All signal traces are 8mil (0.2mm) width. Standard 2mm HM components from ERNI Components, Inc. are mounted on the PC boards. The cable assemblies use Meritec's 2mm HPM-5 connectors with internal equalization and Meritec's parallel pair cable.

Two different 100 ohm parallel pair cables are simulated and tested: cable A is Meritec's part number 700269-01 and has 26 awg solid SPC conductors with foamed...
flouropolymer dielectric, aluminum/polyethylene shield, and a 26 awg drain wire; cable B is Meritec's part number 700219-01 and has 28 awg stranded TPC conductors with foamed polyolefin dielectric, aluminum/polyethylene shield, and a 30 awg drain wire.

Signal Path A: 4 inch trace on each daughter card and 2 inch trace on top side of each backplane to maximize stubs.

Signal Path B: same as A except 12 inch trace on each backplane.

Signal Path C: 4 inch trace on each daughter card and vias straight through each backplane without any backplane traces.

**Figure 3 - Signal Paths**

Figure 3 illustrates the three signal paths that are investigated:

**SIGNAL PATH A:** SMA to 4” trace on daughter card to 2mm rt.-angle connector to 2mm vertical male connector to 2” trace on backplane to 2mm vertical male connector to Meritec’s HPM-5 2mm cable assembly to 2mm vertical male connector to 2” trace on backplane to 2mm vertical male connector to 2mm rt.-angle connector to 4” trace on daughter card to SMA

**SIGNAL PATH B:** (same as A except 12” traces on backplanes)

**SIGNAL PATH C:** (same as A except no backplane traces, only through backplane)---SMA to 4” trace on daughter card to 2mm rt.-angle connector to 2mm
vertical male connector with shroud to Meritec's HPM-5 2mm cable assembly to 2mm vertical male connector with shroud to E2mm rt.-angle connector to 4” trace on daughter card to SMA

Method
The measurement-based design approach is carried out using atSpeed’s software, Oculus. A library of broadband S-parameter characteristics was developed for all the components that are to be used in each communication channel. Paths such as circuit board traces and cables are stored as per-unit-length characteristics so they can be scaled in software. After all the components (connectors, vias, PCB traces, cables, etc.) are “assembled” in Oculus and all the lengths of the scalable components (traces, cables, vias, etc.) are properly set to the desired lengths, an optimization algorithm determines the values of the passive components needed to achieve the design goals at the desired data rate. Performance is evaluated on the basis of optimizing the eye pattern diagram characteristic (height, width, jitter, template, etc.)

Lab Measurements Compared to Simulations
The following illustrations show the degree of correlation between the measurement-based predictions made with Oculus and actual measurements using a data pattern generator. The data in this study has been validated with an Anritsu data pattern generator at 1.065, 3.250 and 5.125 Gb/s. With the exception of the inherent noise of the data pattern generator, the correspondence between the measurement-based prediction and the directly measured response is well within measurement error.

Testing was performed using Meritec's HPM-5 2mm HM connectors, both equalized and unequalized, and the daughtercard/backplane test boards. The component values used in these assemblies were based on 1\textsuperscript{st} order approximations. The graph shown in Figure 2 is based on optimized component values after specific S-parameter measurements were made on the assemblies used for this comparison. The left-hand traces are the actual measurements and the right hand traces are the Oculus simulations. Note that the authors have attempted to scale the aspect ratios of the pictures so that a visual comparison can be made.
700219-01, 15 meter, 1.0625Gb/s, unequalized, path A

700219-01, 15 meter, 1.0625Gb/s, equalized, path A
700269-01, 15 meter, 1.0625Gb/s, unequalized, path A

700269-01, 15 meter, 1.0625Gb/s, equalized, path A
700219-01, 3 meter, 3.25Gb/s, unequalized, path B

700219-01, 3 meter, 3.25Gb/s, equalized, path B
700269-01, 3 meter, 3.25Gb/s, unequalized, path B

700269-01, 3 meter, 3.25Gb/s, equalized, path B
700219-01, 1.5 meter, 5.125Gb/s, unequalized, path C

700219-01, 1.5 meter, 5.125Gb/s, equalized, path C
700269-01, 1.5 meter, 5.125Gb/s, unequalized, path C

700269-01, 1.5 meter, 5.125Gb/s, equalized, path C