

Upgrading the Performance of Legacy Hard Metric Backplane Systems Using the 3M™ Ultra Hard Metric (UHM) Connector

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Abstract

System vendors are continually faced with a consequence of Moore's Law. The marketplace routinely requires improvements in data transfer rates through electronic systems because of clients insatiable demand for ever increasing bandwidth. As such, backplane systems typically have short market lives and the new product development paradigm normally requires a ground-up system redesign utilizing new silicon, software, board designs and interconnect components. One approach for lengthening the usable market life of these systems can be to build next generation daughter cards that will function in the legacy backplane. Such an approach can work if the silicon can support enhanced performance over the legacy backplane and if performance enhanced interconnects are available to mate to this backplane.

In this paper, it will be shown that the 3M™ Ultra Hard Metric (UHM) connector offers such an interconnect solution to enable stretching the usable performance life of 2mm Hard Metric (IEC 61076-4-101) connector based backplanes (Compact PCI, VME64X, PXI for example). It will be demonstrated that the UHM right-angle socket, when mated to the legacy Compact PCI or Hard Metric headers on existing backplanes, enables a significant increase in bandwidth allowing the existing system to be driven at data rates that are multiple times higher. In addition, the isolation improvement offered by the UHM connector will be shown to simultaneously provide approximately a 50% reduction in backplane connector crosstalk. Finally, different options for incorporating the UHM connector into a legacy system will be illustrated including one that allows drop-in replacement of 2 mm Hard Metric (HM) or CompactPCI (CPCI) right-angle socket connectors without any board design changes.

Upgrade or Redesign?

Design engineers are perpetually faced with the challenge of delivering higher signal speeds, signal density and better performance from their electronic systems. From consumer electronics to industrial applications, the movement toward more sophisticated software, multi-use wireless devices, and serialized data transfer are driving the need for speed.

Nowhere is this trend more pronounced than in the realm of high-speed backplane systems. Backplane applications in areas such as military, telecommunications, networking, and automated test equipment require more speed than ever. In telecommunications, consumer demand for interactive video and broadband internet service requires ever increasing bandwidth capability.

Increasingly sophisticated navigation, communications and weapons systems are driving the need for more powerful systems in military applications. And, automated test equipment must continually keep pace with the capacity and multi-gigahertz clock rates of the devices it is used to test.

System vendors are continually faced with a dilemma: should a new system be marketed to fill the customer's evolving needs or can a strategy be found to squeeze additional life out of existing systems? Advantages and disadvantages exist for each approach.

The advantages for redesigning the system are numerous. Such an approach allows for the greatest improvement in system performance and bandwidth

since legacy encumbrances are removed. Also, the new design will likely provide a longer period of relevance in the marketplace. Most importantly, the revenue potential of such a new design project can be substantial. In addition, undertaking such a project can be energizing for an organization.

However, there are many significant risks in tackling such a new development effort. Significant capital and R & D investment is typically required. Also, the lead time to introduction may be years, so the risk associated with the project may be significant while the timeframe for recouping investment may be protracted. In addition, the organization will typically need to dedicate significant resources to such a product introduction.

Extending the life of an existing system carries numerous additional advantages particularly in situations where bandwidth requirements are not increasing by an order of magnitude. Lengthening the life of existing systems typically involves hardware and/or software upgrades. Such a strategy will usually require significantly less capital investment and a shorter lead time than full system redesign. Also, fewer resources are likely to be required as compared to a new product introduction project. In addition, upgrading existing systems extends their commercial life thereby maximizing return on investment that has already been made—by both the vendor and the customer. In many cases these advantages could be attractive enough to pursue this strategy if the needed hardware exists. For systems utilizing 2 mm Hard Metric or CompactPCI connectors, such an interconnect option now exists.

3M™ UHM Sockets As An Upgrade Opportunity

UHM backplane sockets from 3M™ are footprint and mating compatible with industry standard 2 mm Hard Metric and CompactPCI connectors designed to the IEC 61076-4-101 specification. They are available in 5-row and 8-row versions and can be obtained in the same Type A, B, AB, C, D, E, DE, and F styles including the B19 and B22 sizes. These sockets are available in versions that are compatible with either the signal footprints of the Hard Metric connectors or the signal and EMI shield footprints associated with CompactPCI connectors. In addition they are fully mating compatible with existing HM or CompactPCI headers that would be resident on legacy backplanes.

Unlike Hard Metric and CompactPCI connectors, UHM sockets contain row and column coaxial style shielding between the signal contacts to improve

system impedance match and to lower crosstalk. When used in CompactPCI systems or Hard Metric backplanes with EMI shielding, the UHM utilizes outer mating fingers on the socket to contact the outer rows of ground pins on the header. This connection provides the return ground path through the coaxial style shielding to the daughter card. However, even in the absence of a mating connection to the shielding, as will be lacking in backplanes utilizing standard 5- or 8-row Hard Metric headers without EMI shielding, the presence of the coaxial style shielding in the UHM socket provides an electrostatic ground reference that still imparts significant improvement in impedance match and crosstalk unavailable from standard Hard Metric products.

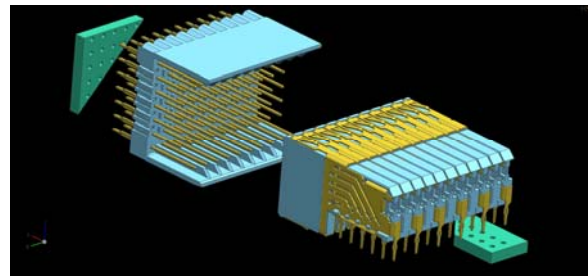


Fig 1 – 3M™ UHM socket showing press-fit signal tails and outer ground row tails mating to CompactPCI header

UHM Signal Integrity Compared to CompactPCI

In order to demonstrate the signal integrity improvement that can be obtained using the UHM connector, 3M™ designed special SI test boards for measuring high speed connector performance. A picture of one of these sets of boards is shown on the next page in Fig. 2.

These test boards were designed with 50 ohm single ended/100 ohm differential traces feeding the tested connectors from surface mount SMA connectors. The SMA connectors have a specially engineered footprint that minimizes the impedance discontinuity of the SMA's attachment to the pc board. This feature coupled with the fact that the traces utilize 1 oz copper, are 11.8 mils wide and less than 3 inches long allows risetimes of approximately 40 ps to be launched into the header connector from a 35ps risetime TDR or PRBS generator.

The boards contain two sets of differential pair pin patterns. One assumes a typical column differential pair arrangement assuming two pairs per column with the center pin in the column (the C-row) grounded. The other pattern specifies row based pairs that are separated by a ground pin. This pattern

is staggered by one position in each row so that crosstalk is reduced by keeping adjacent pairs from being directly next to each other. Both patterns are shown in Fig. 3.

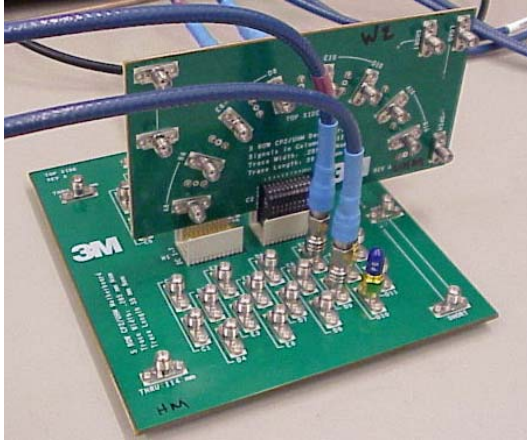


Fig. 2 – UHM/HM/CPCI test boards

Row	Column						
A	S	G	S	S	G	S	S
B	G	S	S	G	S	S	G
C	S	S	G	S	S	G	S
D	S	G	S	S	G	S	S
E	G	S	S	G	S	S	G

Row	Column			
A	S	S	S	S
B	S	S	S	S
C	G	G	G	G
D	S	S	S	S
E	S	S	S	S

Fig. 3 – Test board signal and ground patterns

Impedance profiles were measured for differential pairs in these footprints. Fig. 4 shows the differential impedance of the row-based pattern from Fig. 3. Capacitive discontinuities can be seen at approximately 1.125 ns and between 1.325 ns and 1.425 ns where the vias for the press-fit tails of the various length rows are present. One can see that the impedance of the traces is controlled within $\pm 10\%$ for rows A through C. However, rows D and E significantly exceed this threshold. Presumably this behavior occurs because of the long path lengths through these rows in the socket where the impedance mismatch caused by the contact geometry is more accentuated.

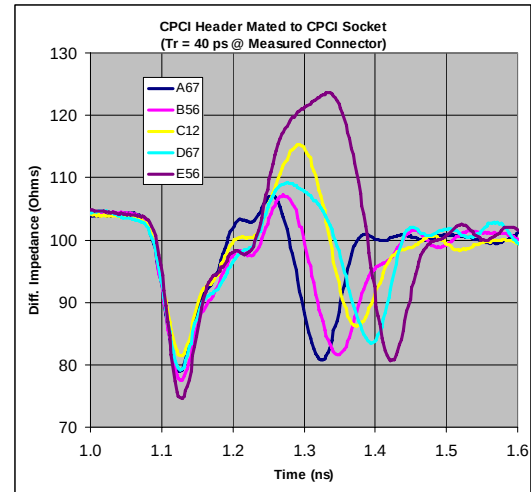


Fig. 4 – Impedance profiles for CompactPCI socket mated to CompactPCI header for row based pairs

Examining the impedance plots for the same pairs in the UHM shown in Fig. 5 demonstrates an improvement in the impedance control through the connector. The UHM connector's coaxial style shielding provides an impedance reference along the entire transmission path through the connector that keeps the connector's differential impedance controlled within a 10% tolerance around 100 Ohms.

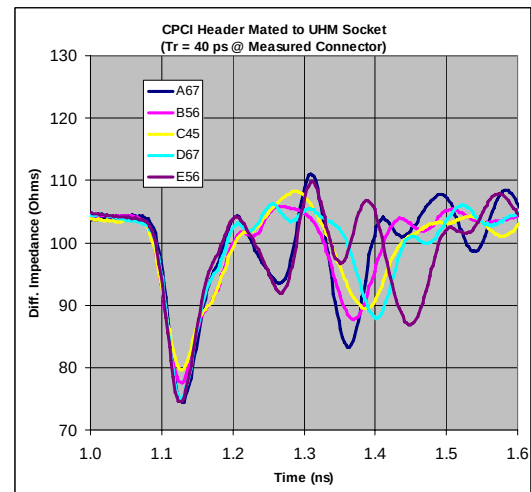


Fig. 5 – Impedance profiles for 3M™ UHM socket mated to CompactPCI header for row based pairs

Looking at the channels in the second pin pattern, the column-based pair pattern, one can see an improvement with the UHM connector as well. In Fig. 6 measurements are illustrated for AB-row and DE-row pairs. It can be seen that the CompactPCI connectors show a significantly larger discontinuity at the back side vias in the plots. This phenomenon occurs because there is a low impedance

discontinuity associated with the CPCI socket whose response is directly adjacent to the CPCI socket vias.

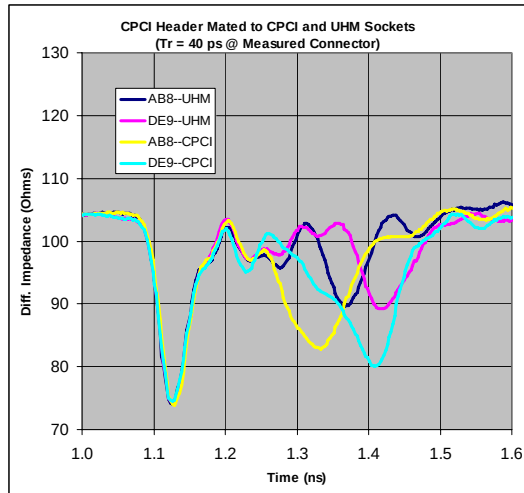


Fig. 6 -- Impedance profiles for CPCI socket and 3M™ UHM socket mated to CompactPCI headers for column based pairs

Crosstalk is another enemy of signal integrity. Excessive crosstalk from simultaneous switching of multiple channels can significantly diminish noise margins for electronic systems. Open pin-field CompactPCI connectors include EMI shielding over top of the outside rows of pins to suppress noise radiated from the connector. However, such shielding does little to reduce field coupled crosstalk occurring between adjacent channels inside the connector.

The row and column shielding in 3M™ UHM connectors serves to intercept this coupling and reduce crosstalk even when the shielding is grounded only on one side of the connector. Such a situation will exist when plugging a daughter card with the UHM socket into an existing Hard Metric connector backplane where the outer ground rows are not present.

Fig. 7 shows comparable multiline near end crosstalk (NEXT) waveforms for both CompactPCI and UHM sockets plugged in to a CompactPCI header. These NEXT responses were generated by a 40 ps risetime step reaching the tested connector. In both cases victim and aggressor channels were column based pairs utilizing the D and E rows. While the crosstalk amplitude is sizeable in both cases, the amplitude is more than 25% lower in the UHM connector. In addition the tallest portion of the waveform is much narrower in the UHM connector. Such performance occurs because the width of the crosstalk pulse in the CompactPCI connector is a

result of significant coupling existing all along the connector's length. In the instance where the UHM socket is used, the coupling in the socket half of the interconnect is lowered substantially. The impact of this difference is that the NEXT pulse width of the most substantial portion of the amplitude is greatly diminished. This characteristic is a predictive indicator that at slower risetimes more typical of signals in the low multi-gigahertz range, the NEXT performance of the UHM connector will show noticeable improvement over the open pin field HM.

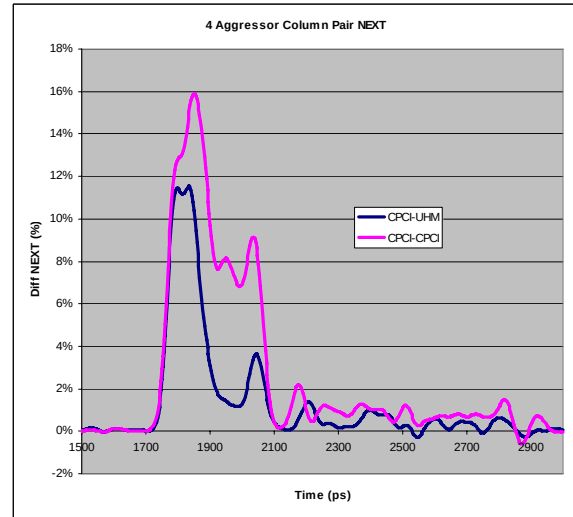


Fig. 7 – Differential NEXT plots with 4 nearest aggressors energized around a victim differential pair

In Fig. 8 a plot has been made that shows the 4-pair aggressor multi-pair NEXT from Fig. 7 filtered over a range of risetimes. It can be seen that the difference in performance between the two connectors is initially slightly more than 4%. This difference translates into a 27% improvement associated with the UHM connector. The difference in performance maintains this 4% difference to risetimes above 200 ps. At this risetime, such a difference represents a full 40% improvement in the differential NEXT levels. At risetimes slightly greater than 200 ps, the total crosstalk through the CompactPCI-UHM interconnect has dropped down to 6% of the driven signal. For the CompactPCI-CompactPCI connector, crosstalk does not drop to this level until the risetime has diminished all the way down to 500 ps.

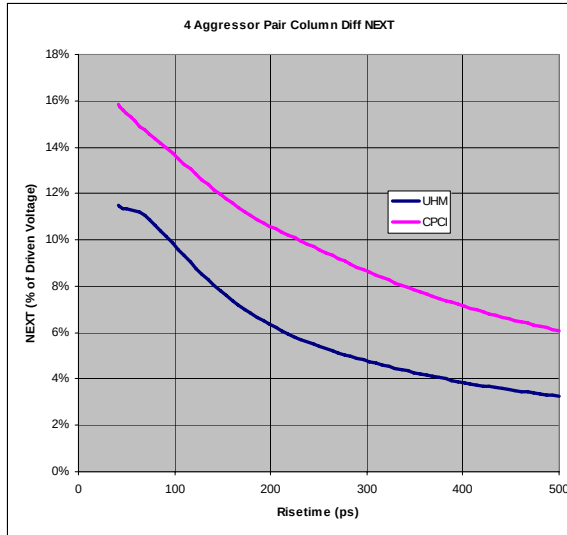


Fig 9 – Peak Differential NEXT from 4 nearest aggressors plotted as a function of aggressor risetime

The impact of this near end crosstalk on data transmission in an adjacent channel can be significant. To demonstrate this fact, eye diagram measurements were obtained through an active channel in the connectors while an adjacent channel acted as an aggressor. In order to emphasize the potential impact that differential NEXT can have, the test setup was arranged as shown below in Fig. 10. The victim line is assumed to be carrying data sent on a channel with the receiver on the near end. Concurrently, data is being sent through the aggressor channel with the near end acting as the transmitter end of that channel.

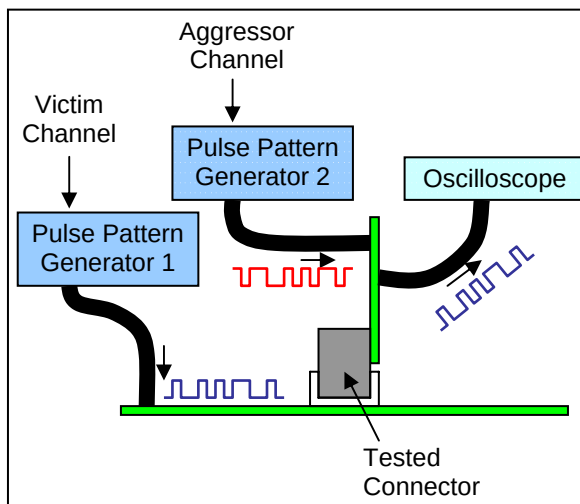


Fig 10 – Measurement setup for demonstrating differential NEXT influence on transmitted eye pattern through victim line

Such a situation can occur if a system is built with transceivers on both ends of the channels or if transmit and receive channels happen to sit adjacent to each other in the connector.

Two different pulse pattern generators were used to perform this testing. An Advantest D3186 Pattern Generator was used to generate the bit stream through the victim channel. The data rate was adjusted to 5 Gb/s. The data pattern sent through the aggressor channel was provided by a Microwave Logic gigaBERT-1400 TX. This instrument was set to 1.2 Gb/s—a data rate far slower than the victim channel. However, with a risetime of approximately 160 ps, the gigaBERT instrument demonstrates risetimes more typical of data transmission in the 1-5 Gb/s range. It was felt that taking this approach provides a more realistic representation of the impinging crosstalk risetime than splitting the 30 ps risetime data stream from the Advantest D3186. An additional advantage exists as well: since the data patterns come from two separate instruments, their triggers are separate as well and the timing of the data transitions will be more random.

The following figures serve to illustrate the influence of the crosstalk in this transmission scenario. Fig. 11 shows a reference eye diagram through back-to-back calibration traces on the test boards. Each of these calibration traces mimics the SMT SMA connector and stripline trace used to feed each of the tested connectors on the test boards. This eye diagram serves to show the best possible transmission measurement absent the influence of the CompactPCI or UHM connectors. One can note that the amplitude of the input bit stream was 220.5 mV and the eye opening, as measured on a statistical basis by the scope, was 169 mV. These values yield an eye opening of almost 77% at 5 Gb/s.

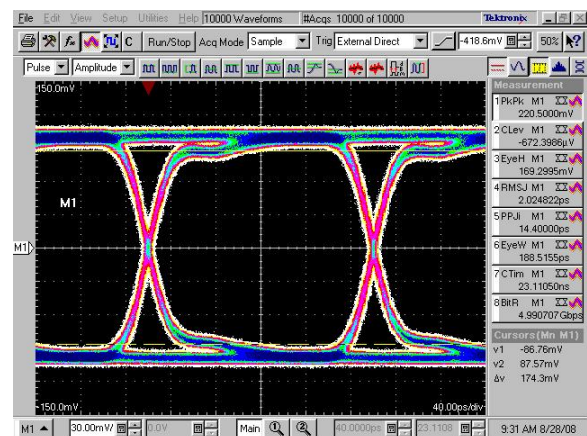


Fig 11 – Benchmark differential eye pattern through measurement system and test pc board at 5 Gb/s

The next two eye diagrams, Figs. 12 and 13 show the eye patterns through a CompactPCI connector. The measured channel consisted of a D-row pair as the victim and the adjacent E-row pair as the aggressor. The eye opening in Fig. 12 is 140 mV high which translates in to a 63% eye opening (based on the same 220 mV peak obtained from the benchmark plot in Fig. 11). When this data is compared to the eye seen in Fig. 13, a significant difference is obvious. The eye in Fig. 13 has a height of 110.5 mV and is only 50% open. In addition the peak-to-peak jitter has increased from 13.6 ps to 31.2 ps. Clearly, if crosstalk was present from other neighbor channels or if two of these connectors are used in a backplane configuration, the performance of this interconnect would be deemed insufficient to support the tested data rate.

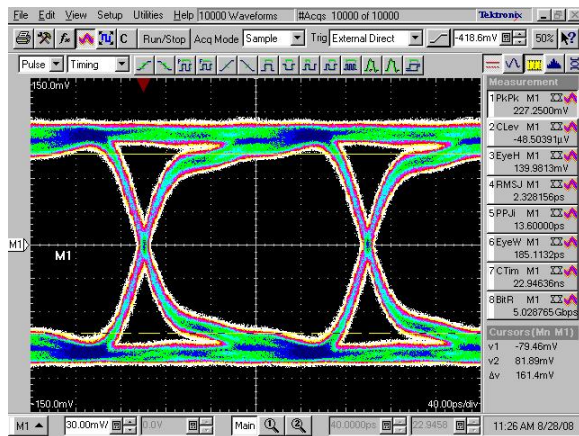


Fig 12 – CompactPCI Header—CompactPCI socket, D-row pair measured at 5 Gb/s with no crosstalk influence

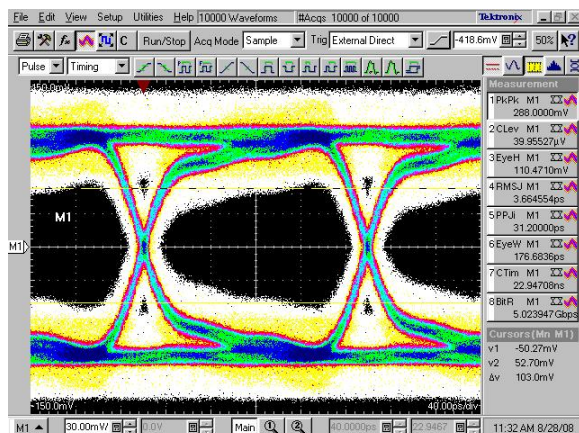


Fig 13 – CompactPCI Header—CompactPCI socket, D-row pair measured at 5 Gb/s with crosstalk influence

Figs. 14 and 15 show similar eye diagrams for the CompactPCI header mated to the UHM socket.

Examination of Fig. 14 shows an eye height of 161 mV which translates in to an eye opening of 73%. This value is a significant improvement over the the CompactPCI interconnect even without the influence of crosstalk. Once crosstalk from row E is added to the victim pair in row D, the contrast between the two connectors becomes quite stark. The eye in Fig. 15 is hardly any different from that of Fig. 14. The height has only decreased by 2 mV to 159 mV and the opening is still 72%. Clearly, there is still much headroom left when using the UHM connector. It is not difficult to anticipate this connector providing adequate signal margins when utilized in a traditional backplane configuration with the additional crosstalk impact from other neighboring channels included. 3M™ is currently fabricating a sample backplane suitable for fully exploring the performance limits of the UHM connector in such an application.

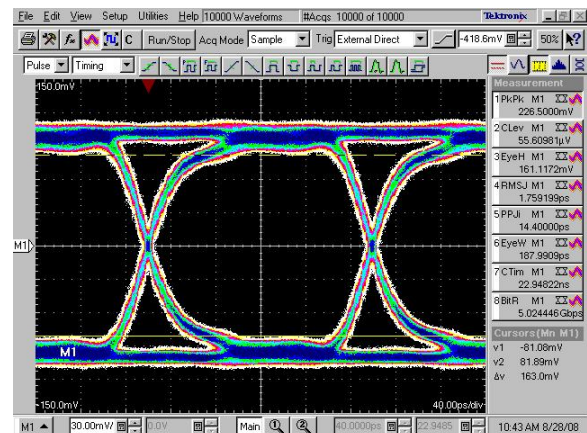


Fig 14 – CompactPCI Header—3M™ UHM socket, D-row pair measured at 5 Gb/s with no crosstalk influence

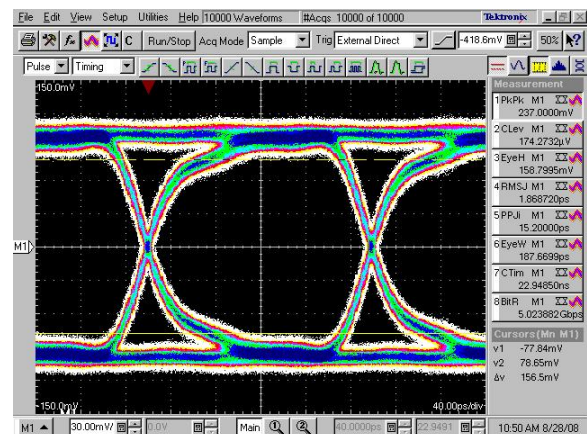


Fig 15 – CompactPCI Header—3M™ UHM socket, D-row pair measured at 5 Gb/s with crosstalk influence

Upgrade Options Using 3M™ UHM and HSHM Connectors

System designers have numerous considerations when looking to utilize a more advanced interconnect scheme in a system design. Typically they must generate new pin assignments and a routing pattern for escaping these connectors. Sometimes these considerations have an impact on the stack-up for the board designs.

In the simplest scenario, 3M™ UHM sockets can be substituted for existing 2 mm Hard Metric or CompactPCI connectors. If the noise constraints of other parts of the system (pc board losses, timing margins, device noise margins, etc.) can support higher speeds, data rates can be increased, equalization can be implemented (if needed) and system through-put can be multiplied. This approach can work effectively in situations where system upgrades have been deemed possible using existing boards and chips. Typically, if existing boards are used with new chip sets, the opportunity is present to further augment system performance if the chosen chip set contains equalization capabilities.

If CompactPCI connectors are being used in the existing backplane, UHM sockets may be chosen with outer ground fingers that mate to the outer rows of ground pins in the header. On the other hand, if Hard Metric headers are present in the existing system, UHM sockets with or without the outer ground fingers may be used on the new daughter cards.

If the new card design is intended to be an upgrade for the existing system as well as a typical line card for a new system, the UHM sockets used will be compatible with backplanes utilizing Hard Metric/CompactPCI headers as well as 3M™ HSHM headers. In addition to being compatible with IEC 61076-4-101 style headers, the UHM socket also features openings in its front face that allow the ground blades from the HSHM header to mate with its ground shielding. This compatibility allows UHM sockets to be used in newer designs where all of the signal positions in the connector can be dedicated to carrying data, thus obtaining maximum signal density from the '61076' style footprint.

In Harmony With the Past But Looking To the Future

Systems based on backplane architectures have a large installed base in existing electronic infrastructure. To improve upon the performance of

these systems requires vendors and customers alike to ponder the trade-offs associated with replacing such systems with new designs or upgrading current hardware. Upgrades are often not possible but with the 3M™ UHM connector, a new option does exist for systems utilizing 2 mm Hard Metric or Compact PCI style hardware. Comparison of signal integrity data shows that the UHM connector exhibits improved impedance match and significantly lower differential NEXT than CompactPCI connectors. This performance difference was demonstrated to be a key reason why CompactPCI style connectors cannot be used to carry data in the multi-gigabit realm with even one neighboring aggressor active while the UHM socket provides the substantial improvement in noise margins needed to allow 5 Gb/s transmissions when mated with standard 2 mm Hard Metric headers.

Of course the data demonstrated in this paper only examined the behavior of one connector alone. Typical backplane channels involve transmission over two daughter cards, two backplane connectors and the backplane. Measurements comparing these same connectors in a backplane configuration would provide a better quantification of the limit to the improvement offered by the UHM connector. 3M™ has designed such a backplane but did not have the fabricated article in hand at the time of this publication. Further data will be forthcoming to illustrate the comparative performance of the UHM socket mated to CompactPCI and 2 mm Hard Metric connectors and can be obtained by contacting the authors.