At almost any data rate, system designers would like to make cable assemblies transparent and have the freedom to disregard all the “fun” effects such as ISI, crosstalk, reflections, EMI, and the overall signal loss introduced by long assemblies. Designers have long been battling these effects and have wished many times that “if we could only get out what we put in, then we could spread the budget out where it’s needed.” Unfortunately, the laws of physics still prevail and work against the reality of a transparent cable assembly.

Although there have been improvements in IC design to compensate for these effects, the battle has moved from 2.5 to 5 Gbs and now rages on at 10 Gbs, and the need for a complete cable link designed for high-speed is even more critical. Transmitting data at 10 Gbs not only requires a well designed cable that minimizes loss, but also in the case of backplane applications, a high-density connector system capable of minimizing reflections and crosstalk effects. Fortunately, the use of low-loss, low-skew, differential cable along with the industry’s leading backplane connector families is leading the way in meeting the needs of transmitting high-speed signals.

Even before Moore’s Law was established as a data rate benchmark, system designers faced the ever increasing bandwidth-distance-density challenges of interconnecting shelves and cabinets within a system. The number of channels and size and length of the cable bundle all compete with the available real estate to limit the maximum data rate. At 5 to 10 Gbs, system risetimes are extremely fast and the challenges to transmit multiple signals over long distances are compounded by increased skin effect losses, increased crosstalk, and increased noise sensitivity.

Designers typically choose to transmit differential signals over high-speed twinax cable to minimize noise and take advantage of lower voltage swings. Twinax cables constructed with a low dielectric constant material such as expanded polytetrafluoroethylene (ePTFE) exhibit extremely low loss and can be designed to have excellent high-bandwidth capability. In addition to loss, high-speed cables are designed to have controlled impedance profiles down the cable length with negligible variation to ensure maximum signal transfer. Maintaining constant cable geometry and uniform material characteristics not only ensures consistent impedance but also minimizes differential skew, which left uncontrolled can gener-
ate significant noise and EMI issues in a high-speed system.

Some system designers require a channel link to have enough bandwidth to transmit up to the third harmonic frequency of the primary data rate. For a 10 Gbs signal, preserving the third harmonic would require a 15 Ghz bandwidth. Careful cable design is required to minimize structural return loss and resonance effects due to repetitive discontinuities to ensure the highest transmission bandwidth. The use of low dielectric constant and low loss ePTFE dielectric materials contribute by reducing attenuation and maximizing harmonic transmission. Additionally, the use of these materials allows the use of a larger conductor to minimize loss while providing the smallest overall cable diameter.

As the diagram in Figure 1 shows, using ePTFE with a dielectric constant of 1.3 allows for more than a 20% reduction in cable diameter over an insulation with a 2.2 dielectric constant. The benefit of reduced diameter is even greater when ePTFE is compared to higher dielectric constant materials. In a system with multiple cable links, the advantage of a small cable diameter has a huge impact on the size of the overall cable bundle and significantly simplifies routing issues while maximizing link density.

An additional option that expanded PTFE offers is the use of a larger conductor size for improved loss or increased cable length while maintaining the same cable diameter as the higher dielectric material. Again, as shown in the diagram, for a given impedance target ePTFE dielectrics allow for a conductor 2 awg sizes larger than most standard cable dielectrics.

Although, a well designed cable is critical for a high-speed channel, it is only one part of the full link. In a high-density backplane, the connector system is just as critical. Connectors used in legacy backplane systems with 2 mm pitch typically meet the density requirements of multiple channels but lack the signal integrity design needed to transmit signals much higher than a few gigabits. Along with density, other parameters such as crosstalk, reflections, and loss also need to be addressed. Converging multiple high-speed signals into a single connector footprint can generate the opportunity for large amounts of crosstalk thereby corrupting data and significantly degrading the signal-to-noise ratio. Combined with impedance discontinuities and subsequent signal reflections, data streams can be degraded to the point where error rates make the system unreliable.

Fortunately, leading connector manufacturers have stepped up to the challenge with significantly improved high-speed backplane connector systems. The copper technology roadmap published by the International Electronics Manufacturing Initiative, iNEMI, has identified the connector systems that will take the industry from 5 to 10 Gbs and beyond, as shown in Table 1. Four companies in particular have developed backplane connectors that address the signal integrity needs for high-density, high-speed backplane systems. Teradyne Connector Systems (TCS), ERNI, Tyco, and FCI all have high-speed offerings with innovative designs.

TCS offers the VHDM™ connector family, including one designed specifically for high-speed differential signaling, VHDM-HSD™. This connector uses an integrated shield design and is typically implemented for data rates from 1.0 to 5 Gbs. On a 2 mm grid, the 8-position version provides 38 differential pairs per linear inch. For the 6 to 10 Gbs data rates, TCS has developed the GBX® Connector family with increased density and performance where the four pair version gives designers the option of 55 differential pairs per linear inch with exceptionally low reflection and crosstalk profiles.

The ERNI Group of Companies and Tyco have teamed up to jointly develop a backplane connector for data rates from 2.5 to 6.125 Gbs. ERNI has named their version the ERmetZD and Tyco calls it the Z-PACK HM-Zd. It was designed for differential signaling with an “L” shield design that provides excellent crosstalk and impedance control through the connector. The four pair design provides 40 differential pairs per linear inch. ERNI also has the ERmet Zero XT that uses sport surface mount technology for performance beyond 10 Gbs.

The AIRMAX VS® backplane connector from FCI is an innovative design that uses a staggered pin field and edge coupling technology to enhance signal integrity.
along with an air dielectric. This creative signal integrity approach allows system designers the freedom to scale their systems from 2.5 to 12 Gbs without a significant change in their platform design. It’s available with 3 mm spacing and provides 63 pairs per linear inch with the five pair module.

All of these connectors are being implemented in systems that require line cards to reliably connect and communicate at high speeds with system backplanes. However, many systems need to communicate between shelves within the box and with other system cabinets outside the box.

Interconnecting with cable assemblies designed to mate with these high-speed connector families is critical to system reliability and performance. Ensuring mechanical compatibility and signal integrity designs that have as good or better performance than the backplane connector allows designers the options of higher data rates or longer length or potentially smaller cable bundles. Minimizing crosstalk and impedance reflections is a signal integrity challenge in both the backplane connector and the mating cable connector. At high data rates with extremely fast risetimes even the smallest features of a connector can have an impact. Conductor spacing, termination technique, and strain relief, along with the transmission characteristics of the cable, need to be individually modeled and included in a system simulation to verify performance. Complete cable link modeling allows designers to simulate the performance of the link from transmitter to receiver including all the board, via, connector, and cable effects. For high-speed connector and cable assembly designers, it is critical to minimize the features that impact the system risetime. By design, high performance connector systems require high performance cable assemblies.

Most high-speed systems today use various types of signal conditioning on the transmit and/or receive side of the channel link. These technologies significantly improve the bandwidth and enable the use of longer cables or higher data rates. Combining signal conditioning with cable assemblies designed for high-speed dramatically increases margins and signal-to-noise ratios, enabling higher levels of error-free system performance. Low loss twinax cable constructed with ePTFE is ideal for differential transmission and maximizes the benefits of signal conditioning.

Expanded PTFE cables also lend themselves to the density and performance requirements of the high-speed connectors identified by NEMI’s copper roadmap for high performance systems. Cutting edge connectors such as ERNI’s ERmet-ZD, FCI AIRMAX VS and Teradyne’s GBX are giving designers more options with increased data rates while minimizing crosstalk and optimizing impedance profiles. Although transparent cable assemblies are not a reality, the combination of high-speed connector systems and low loss ePTFE cable is aiding in the bandwidth-distance-density battle and helping to make 10 Gbps solutions a reality.

References:

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