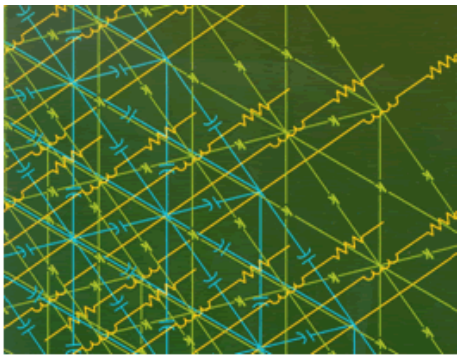
New Tools Support High-Speed Connectors

By Bob Hult, Bishop & Associates Inc.



Over the years, connectors have evolved from a relatively simple electromechanical device to a highly sophisticated element in advanced circuits. Once considered a passive device, the connector and its PCB, or wire termination, have become capable of having a significant influence on the performance of multi-gigabit circuits. In the past, connector performance was often measured only in terms of contact resistance and current rating. A standard product specification provided by the manufacturer normally provided all the information necessary to make a proper selection. Now, connector designers must also consider the additional effects of impedance, near- and far-end crosstalk, insertion loss, differential skew, and propagation delay. The bandwidth of the connector is a key criterion in many new applications. Termination to the PCB in high-speed applications can create lump capacitance and has been recognized as a greater source of signal degradation than the connector itself. Where connectors were measured in terms of milliohms and amps, S-parameters associated with the total channel now define the influence of connectors.

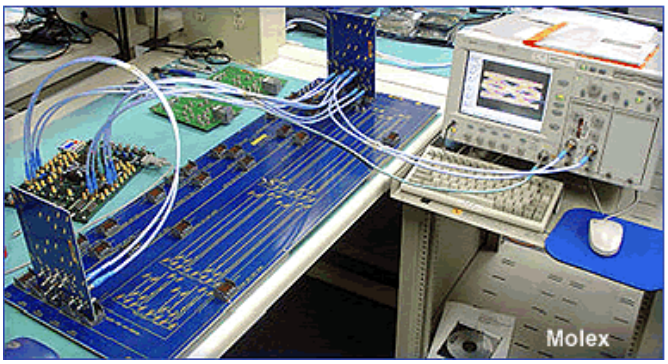
Engineers faced with addressing these issues in the development of their new products have discovered that accurate modeling and simulation of high-speed circuits has become an essential step in the design process. Predicting the behavior of each element in the channel saves precious design time and assures reliable performance of the end-product.

Connector suppliers have recognized the value of providing access to design tools that assist their customers in selecting and implementing the most appropriate interface. Connectors supported by an extensive array of tools can become a critical differentiator between competitive products. Users are relying on access to these tools and services to achieve their performance and new product release goals.

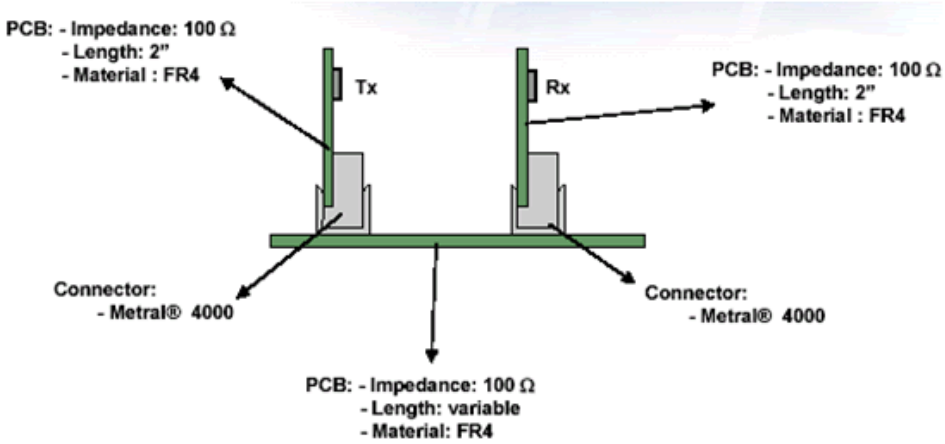
Connector suppliers provide an extensive array of performance data and support tools in the form of product specifications, TDR and crosstalk charts, eye diagrams, SPICE models, test boards, and S-parameters. Designers use this information to make decisions on the ability of a particular connector to satisfy the needs of a new application. Although basic performance characteristics, such as impedance, insertion loss, and near- and far-end crosstalk values are universally provided, the test conditions used to generate the data may not be fully disclosed. Users may find it difficult to compare data among competitive products because no universal standard for test conditions exists at this time. Factors such as the length of the circuit, PCB materials, geometry of the connector launch, design of the PCB traces, test signal type, and the number and location of aggressor lines all have a significant influence on the performance of the connector and circuit. Additional factors, such as the ambient temperature and the number and location of adjacent circuits, will influence the current rating of power contacts. The use of advanced chip signaling, such as pre-emphasis, and equalization or multi-level signaling (e.g. PAM-4), are typically not part of the test documentation—making it difficult to determine the actual influence the connector is having on the bit error rate of the channel. Connectors may be rated as having a particular bandwidth, or be suitable for use in circuits up to some defined gigabit rate, but without full disclosure of the conditions necessary to achieve that rate, the actual useful bandwidth of the connector is unclear. Attempts have been made to propose a standard test platform, but the challenge of creating a universally acceptable connector launch is daunting. Suppliers understandably want to document the performance of their product using the most favorable conditions, but the resulting data often serves only to accomplish the first level of interface selection. The ability to compare high-speed performance between competitive products, using vendor-supplied data, is a serious concern within the user community. This is especially true for companies who do not have the internal resources to conduct physical tests or run advanced simulations.

The ultimate method to predict high-speed channel performance is for the user to design and build prototype boards and cables that will incorporate the specific physical and electrical characteristics of its intended application. The cost of this approach limits its usage to the largest OEMs with deep pockets, and can become a serious resource and time drain if significant circuit parameters are changed during the design process. Fabricating custom test boards can significantly reduce risk, especially when new technology is being introduced. This method also permits close comparison of the performance of competitive products under nearly identical conditions.

Vendor-supplied test boards provide a lower-cost alternative to custom boards and allow a customer with the proper tools and expertise to verify connector performance using parameters closely approximating their anticipated application environment.

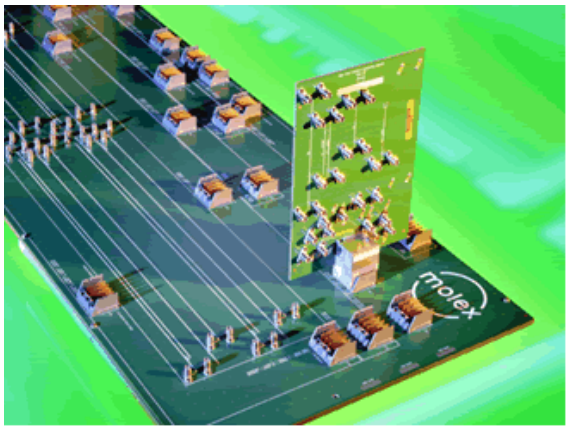


Test boards vary widely from supplier to supplier, but typically include at least two daughtercards pluggable to a backplane with defined material and design rules. Connectors are mounted on the daughtercard and the backplane to permit a variety of tests to isolate connector characteristics and connector/circuit performance. Signals are injected via precision co-axial connectors and closely monitored as they propagate through the circuit.



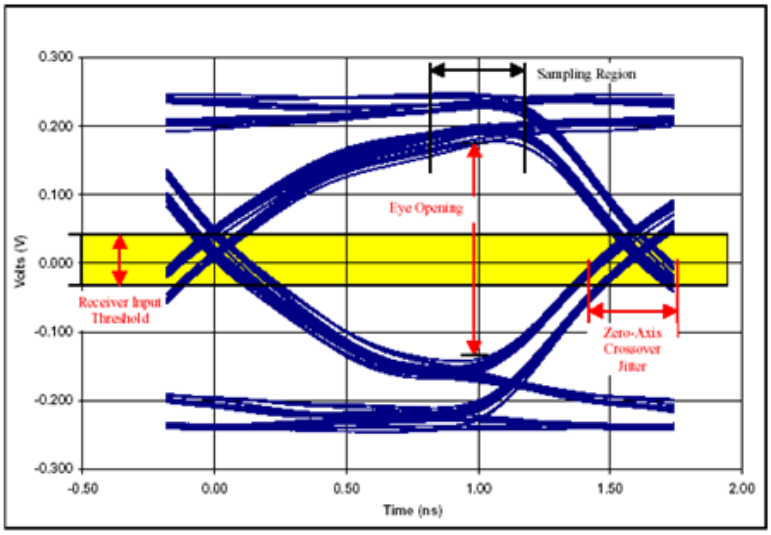
These evaluation boards are either sold, or more commonly, loaned to potential users to generate performance data that more closely approximates the conditions of the specific customer application.

Designers in larger companies use vendor-supplied data to do an initial analysis of the suitability of the interface for their application. If the data looks promising, they may request a test board from the vendor to verify actual performance in their environment. Smaller companies who do not have the considerable equipment and experienced personnel resources to do this level of analysis will use the data supplied and try to leverage the experience and choices of larger companies.



For example, Molex offers their GbX reference demonstrator, which is a 38"x13" 20-layer backplane, fabricated using several different PCB materials and a matrix of signal line geometries and lengths. Users are able to more closely replicate actual application circuits to determine the optimal combination of connector, SERDES, and PCB design rules for their needs.

Recognizing the need to look at the performance of the entire channel, connector suppliers have begun to provide eye diagrams of a given defined circuit, including the connector. This visual representation of the ability of a channel to accurately deliver distinguishable signals provides a quick measure of how well a specific combination of components, materials, and circuit design can provide the level of performance needed in a new design.



The eye diagram has become a useful tool to quickly evaluate the performance of a circuit. One can immediately see the loss of signal integrity resulting from a longer circuit path, jitter, impedance discontinuities, etc. The “closing of the eye” provides a visual indication of signal distortion.

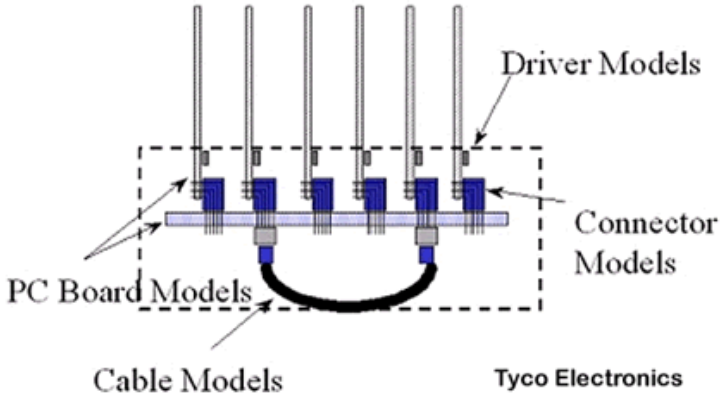
Several connector manufacturers have begun providing S-parameter data to model, simulate, and validate next-generation designs. The transition from time to frequency domain modeling has begun, and accurate S-parameter models for high-performance chips and connectors are now starting to become available to users.

Circuit designers appear to be generally satisfied with the level of support they receive from the major suppliers, and use the reputation and demonstrated expertise of their chosen connector manufacturer as a major connector selection criterion. Phone or personal access to SI experts is an important resource to systems designers at smaller companies.

Recognizing the challenge that users face in selecting the most effective interface in a specific application, connector suppliers have been actively expanding their design support capabilities. The ability to offer exceptional technical support has become a defining criterion of successful high-speed connectors in today’s market. Competitive pressure to gain print position on new programs is driving an extensive package of new tools, including broad marketing exposure and one-on-one engineering support, that are capable of walking a potential user through initial introduction, performance documentation, circuit simulation, prototype verification, and production.

Leading high-speed connector manufacturers are continuing to introduce a variety of support mechanisms focused on simplifying the selection and utilization of their products. SPICE-compatible connector models have become a basic design tool and have been part of the signal integrity support package offered by connector manufacturers for many years. The accuracy of single- and multi-line connector models is being upgraded to predict performance at speeds as high as 10+ Gb/s.

Designers integrate connector models with other product models for each element of a specific channel. This helps to determine if the circuit is capable of performing to specification without the time and expense of fabricating physical test boards.



The level of technical expertise and experience necessary to properly model a high-speed circuit, and accurately interpret the results, varies widely within the industry. Even some of the largest corporations have lost experienced signal integrity engineers to downsizings and retirement. Recognizing the need to do more than simply provide data, connector suppliers have expanded their SI departments and are actively developing tools to simplify the evaluation and selection process.

Tyco Electronics, in addition to providing a full palate of performance data, simulation models, and customer drawings via their website, offers its circuit and design team of signal integrity specialists to assist customers in evaluating channel performance and to also provide high-speed system circuit design, layout, and simulation assistance.

Samtec has packaged their signal integrity product support package under the “Final Inch™” program, which consists of three elements. HSPICE

and Ibis models include the connector footprint, vias, and scalable trace fan-outs. Downloadable Gerber and DXF footprint and trace routings can be cut and pasted into the users' PCB layout software. Test and evaluation kits that are loaned to customers allow lab evaluation of both the connector as well as Final Inch designs. The Final Inch test boards and models are based on standard materials and manufacturing practices, which demonstrate connector performance using the most practical solution.

Molex has partnered with Xilinx and Mentor Graphics to develop a new high-speed channel performance evaluation tool for serial circuits operating at 10+ Gb/s. Channel Margin technology not only establishes a reference construction at optimal performance, but this interactive hardware and simulation tool is capable of introducing controlled channel degradation to determine the operating margin. Users of this tool are able to determine the effect of changes in the three critical circuit parameters of insertion loss, return loss, and crosstalk. By changing parameters of the circuit and observing the results in channel performance, the selection of standard FR-4 PCB material and standard PCB layout rules may become feasible. Designers are able to build confidence in the robustness of their design, which can result in reduced costs and design cycle time, both critical to the success of a new product. They also offer their Backplane Products Configurator, an online tool that allows users to create custom daughtercard proposal drawings and bills of materials. This service currently supports their VHDM, VHDM-HSD, VHDM RAM, and GbX backplane product lines to registered users.

Amphenol TCS recently introduced their DesignLink® support tool. This online resource consists of a unique set of proprietary backplane system design tools coupled with immediate technical information delivery. Designers are able to gain 24/7 access to a library of support tools, including:

1. Product and footprint drawings compatible with Allegro, in IGES, Pro-E, Solidworks, and STEP formats.
2. A variety of HSPICE electrical models in both single-pair and matrix configurations. These connector-only models were derived from physical S-parameter measurements.
3. A library of mechanical and electrical interactive design analysis tools, including:

    A. Chassis slot pitch
    B. Connector comparison matrix
    C. Connector wipe analyzer
    D. Engagement force analyzer and latch designer
    E. Front panel analyzer
    F. Mating sequence analyzer
    G. Backplane channel analyzer
    H. Backplane power layer resistance analyzer
    I. Connector current vs. temperature analyzer
    J. HPC loss analyzer
    K. Maximum trace current-carrying analyzer
    L. Maximum via current-carrying analyzer
    M. Power plane capacitance analyzer
    N. Skew analyzer
    O. Star architecture bandwidth analyzer
    P. Chassis thermal analyzer
    Q. En60960 creepage and clearance analyzer

Many of these tools provide valuable insight into circuit behavior up to 10 GHz, and can greatly reduce time spent in determining the basic operating parameters of a new product. The Design Link Portal was formally announced in June 2006 and is currently a free resource to registered users.

Being successful in the high-speed connector market requires much more today than a product line and a data sheet.

Bishop & Associates Comments:

- Suppliers of multi-gigabit connectors are expected to provide basic performance data that is used to do the initial screening. Simulation and physical verification will confirm actual system performance. Lack of a standard test methodology makes direct comparison of data between competitive interfaces difficult.
- Complexity and the imperative to hit the target window of opportunity associated with the design of high-speed circuits has made extensive customer support an essential element in the support of high-speed connectors.
- Recent market recessions, staff layoffs, retirements, and a general shortage of experienced signal integrity engineers has made circuit design support from external resources, such as connector suppliers, a major factor in the connector selection process. The inability to provide this advanced level of technical support could eliminate a competitor for consideration in new product designs.
- Support tools currently available from connector suppliers vary widely, but normally include a mix of TDR and matrix crosstalk charts, SPICE models, S-parameter data, and test boards. Some suppliers offer extensive custom simulation services, and one-on-one design support. Others provide a series of reference designs with documented performance, which can be plugged directly into a customer circuit.
- Recognizing the expansion of the market, limited internal staff, and the imperative for 24/7 customer access to support, some connector suppliers have begun offering a greater array of support tools on the web.
- The costs associated with providing this extensive level of support must be included in the total price of the hardware, which may be putting pressure on profit margins given the trend of decreasing cost per line for high-speed connectors in general.

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Robert Hult has been in the connector industry for over 36 years. Hult began his career as a sales engineer for Amphenol. He joined AMP in 1972 and served in several management positions through 1996. In 1997, Hult joined Foxconn as group marketing manager for Intel, Chandler, Arizona, U.S.A. Prior to joining Bishop & Associates, Hult was the regional application engineering manager for Tyco Electronics.

Hult graduated in 1968 from Bradley University with a Bachelor of Science degree in electronics technology and a minor in business.