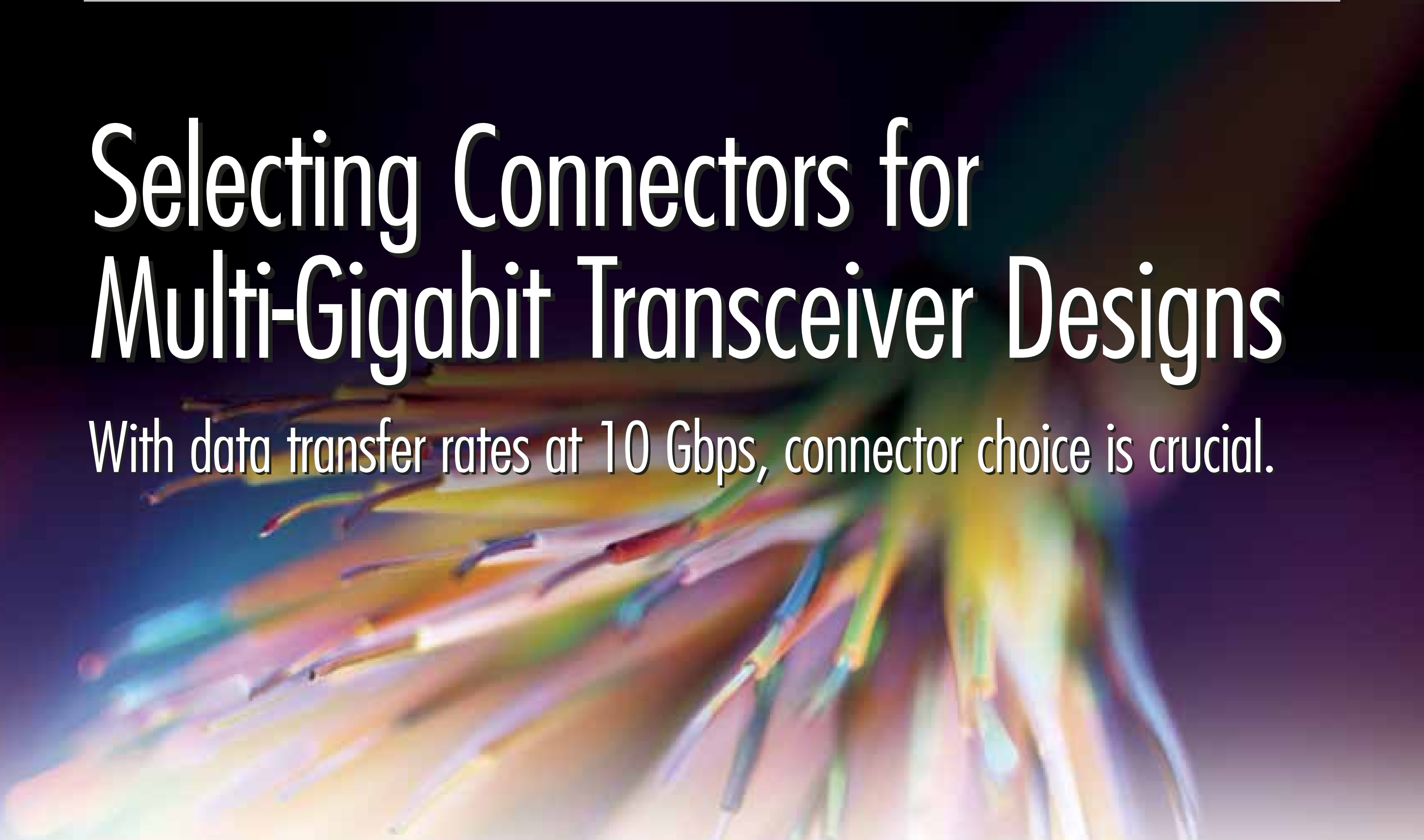

Selecting Connectors for Multi-Gigabit Transceiver Designs

With data transfer rates at 10 Gbps, connector choice is crucial.

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In modern high-speed digital designs, connectors require careful attention; you can't just use any one that's available. When designing with Xilinx® Virtex-4™ multi-gigabit transceiver (MGT) devices, with data transfer rates increasing to 10 Gbps, connectors are part of the total solution.

It is often said that the silicon, in our case the FPGA, does all the work in a system. Passive components such as connectors get the blame for increasing design cost, complexity, and size, and therefore are often neglected.

Today's digital designs enter the RF world with transfer speeds of 10 Gbps and more per data pair; thus, you can no longer ignore the overall impact connector choice has on a design.

Connector manufacturers must keep track of high-speed digital design needs while meeting the demand for multiple high-speed low-loss connections in a small connector shape. Connector design, therefore, becomes increasingly difficult.

The two worlds need to be combined; therefore, we advise following these steps when selecting a connector:

- Choose your connector type – backplane, board-to-board, board-to-cable, or mezzanine
- Find manufacturers carrying connectors with the right physical parameters
- Carefully examine the manufacturer's electrical specifications, test reports, and other published references

Board-to-Backplane or Board-to-Board Connectors

Designing a system in which multiple MGT signals (3.125 Gbps to 10 Gbps) cross directly from board to board or run over a backplane need special connectors. The Teradyne™ GBx connector is a high-density, optimized differential connector family delivering data rates greater than 5 Gbps (tested up to 12 Gbps) (Figure 1).

Tyco™-AMP offers in this same range the Z-Pack HM-Zd differential connector system, designed for serial switching applications from 3.125 Gbps to 6.4 Gbps (demonstrated at 12 Gbps) (Figure 2).

Both connector families are made specifically for high-data-transfer-rate designs such as enterprise switching equipment, telecommunications equipment, and mass data storage. They are robust, have a modular setup, and offer routability and optimal system performance.

Teradyne's GbX advanced performance interconnects provide high-density optimized differential connectors. They are available in three-, four-, and five-pair versions and permit vertical and horizontal routing, making them the ideal solution for star or mesh backplane designs.

Tyco-AMP's high-speed, differential, board-to-backplane electrical connectors are an extension of the already established IEC 61076-4-101 hard metric connector family. However, HM-Zd also provides a high-speed differential solution. Z-Pack HM-Zd connectors are available in two-, three-, and four-paired versions.

In board-to-board designs where size matters, Samtec's™ QSE and QTE connector families are for data transfer rates up to 6 Gbps (Figure 3).

For board to board, with a point-to-point setup, Samtec offers a reliable cable connection based on the QSE/QTE con-

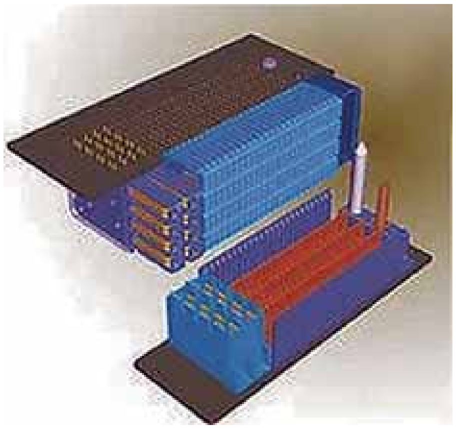

Figure 1 – Teradyne Gbx connector

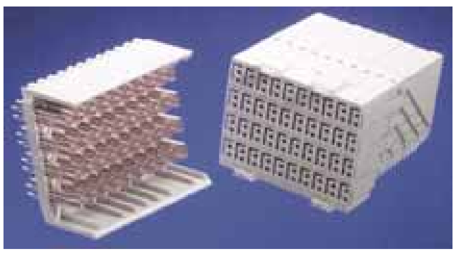

Figure 2 – Tyco-AMP Z-Pack HM-Zd connector

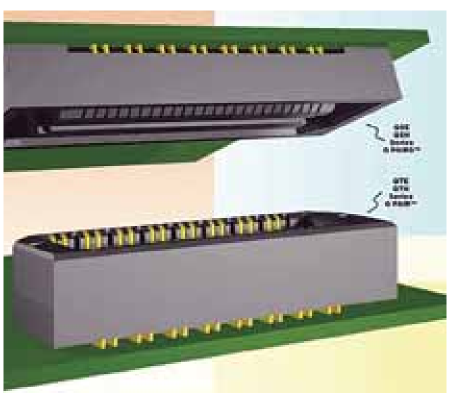

Figure 3 – Samtec QSE and QTE connector

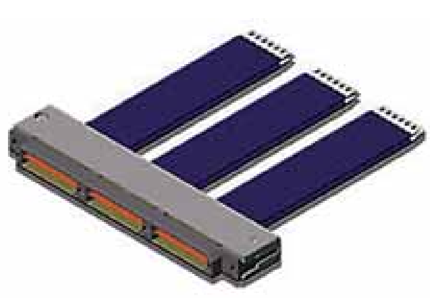

Figure 4 – Samtec ribbon cable

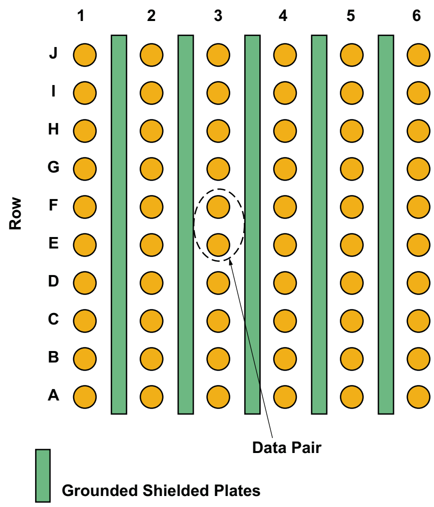

Figure 5 – Stripline construction of NexLev

nector technology. The 50 ohm controlled impedance, 38 AWG mini coax ribbon cable (Figure 4) is available with as many as 240 signal lines, as well as a differential or single-ended flex-strip solution.

You can create custom connector specifications for both the QSE/QTE and ribbon cable on Samtec's website and download cable specifications and test reports on cross-talk, travel delay, and impedance.

Mezzanine Board-to-Board Connectors

Mezzanine card systems are mostly used to relocate high-pin-count devices onto mezzanine or module cards, simplifying board routing without compromising system performance.

Mezzanine cards need a high bandwidth and high amount of parallel connections as well as several serial connections. Teradyne's version is the NexLev connector family, with performance up to 12 Gbps. This connector enables a vast amount of connection possibilities at different connector heights.

The NexLev connector is built in a stripline construction, providing a continuous ground plane for each signal contact (Figure 5). The connectors come as ten-row connectors with 100, 200, or 300 positions at possible stacking heights from 10 mm to 30 mm. You can find technical figures at *www.teradyne.com/prods/tcs/products/connectors/mezzanine/nexlev/signintegr.html#differential*.

Samtec offers a similar solution with its YFS/YFT single-ended and differential-pair-array connector arrays called SamArray (Figure 6). These connectors have a performance up to 10 Gbps and comprise a vast amount of single-ended connections. Differential signaling is obtained through pin layout (Figure 7).

Connectors are offered as five-, eight-, or ten-row with as many as 50 contacts per row, for stacking heights from 5 to 25 mm. Technical figures are provided in PDF format at *www.samtec.com/signal_integrity/technical_specifications/electrical.asp?series=YFS-DP&stack=25&menu=Signal_Integrity*.

Mezzanine connectors have a BGA footprint and can be treated by assembly machines as regular BGA components. Experience with these connectors showed that before soldering, they are best glued to the PCB. If not glued, there is a great chance that the connector will move during soldering.

Connectors for Cable Connections

For design reasons you may not be able to use the connectors described above. In this case you can still turn to older solutions, such as the well-known SMA connector and the small MMCX connector.

SMA is an acronym for "SubMiniature version A," first developed in the 1960s. They are 50 ohm, semi-precision subminiature units that provide excellent electrical performance from DC to 18 GHz with a threaded interface. These high-performance connectors are compact in size and have outstanding mechanical specifications.

Besides the standard straight, 90 degrees, and edge-launch version, an SMT-mount device version is now also available (Figure 8). This SMT version is preferable over the other because of its performance characteristics.

The MMCX series is sometimes also called MicroMate. It is the smallest RF connector and was developed in the 1990s. MMCX is a micro-miniature connector series with a lock-snap mechanism, allowing for 360 degrees rotation and thus enabling great flexibility in PCB layouts. MMCX connectors conform to the European CECC 22000 specification.

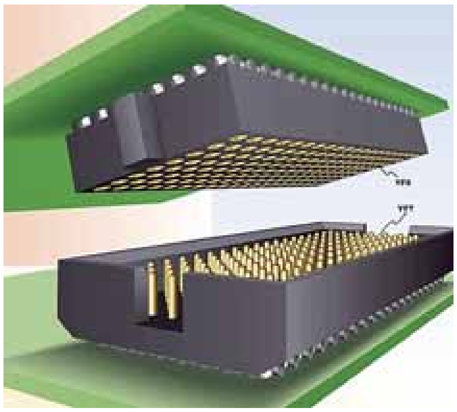

Figure 6 – Samtec YFS/YFT connector

MMCX products range to 6 GHz for a 50 Ω interconnect system. A set of connectors includes surface mount, edge card, and cable connectors. Here the SMT version is preferable (Figure 9).

You can purchase ready-made, custom, and length-matched cable interconnect for this type of connection from different sources and choose between flexible or semi-rigid cabling.

Connector Basics

Suppose you've selected your IC devices and your board has been laid out with all of the right design rules, such as:

- Controlled impedance traces
- Controlled time delay of stubs
- Stubs shorter than about 20% of the fastest signal's rise time
- Time delay of discontinuities shorter than about 15% of the fastest signal's rise time.
- Adjacent traces paced far enough apart to keep crosstalk at an acceptable level
- A stack-up with power and ground planes on adjacent layers of silicon
- A continuous return path under each signal trace

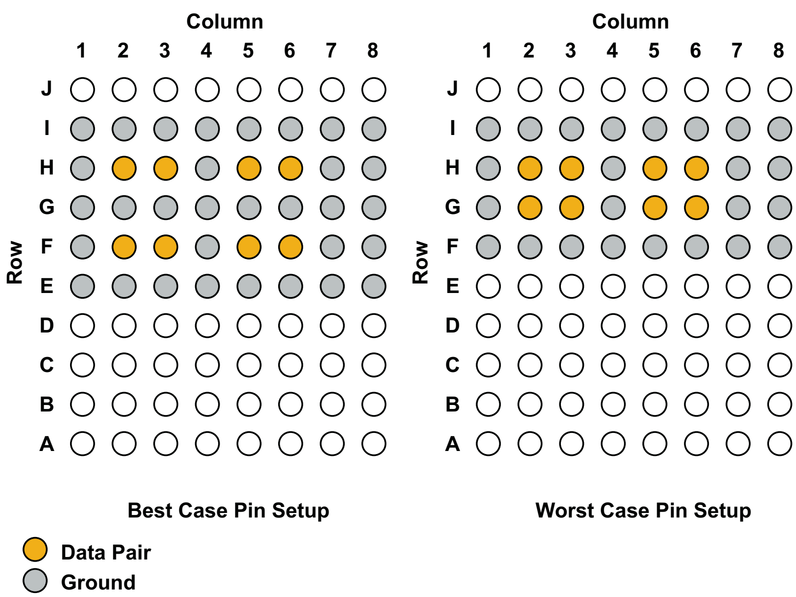

Figure 7 – Best- and worst-case pin layout for YFS/YFT

Figure 8 – SMA edge launch, SMT

Figure 9 – MMCX edge launch, SMT

You're not quite done yet. In high-performance systems, every element must be optimized for the entire system to meet performance, schedule constraints, size, and cost. It is like a chain – every link must be strong for the whole to meet the demanding performance specs of today's high-speed products.

How can components like connectors affect system performance? Usually the potential problems are lumped into two categories: timing and noise, together referred to as signal integrity (SI).

What is important when selecting connectors?

- EMI, translated to series inductance
- Crosstalk, translated to mutual inductance
- Signal propagation, as parasitic capacitance

Series Inductance

The most fundamental effect a connector adds to a circuit is series inductance. The primary factor for the series inductance is the pin length of the connector. Together with the series inductance of each connector pin, the pin layout of the connector determines the radiated EMI (electromagnetic interference).

Signals traveling through a connector need a current return path (ground). Even if no return path is provided through the connector, large inductive loops can be created (Figure 10). This will result in substantial EMI emission.

Differential signaling solves the problem of current return paths by eliminating it. Differential signaling uses two identical but opposite signals. The return paths are therefore also opposite to each other (Figure 11). This effect will cancel out. The only signal returning from a differential pair is because of an imbalance between the two signals. The subtraction of both signals will not be exactly zero.

Mutual Inductance

Current loops illustrate mutual inductive coupling in Figure 12. Current leaving

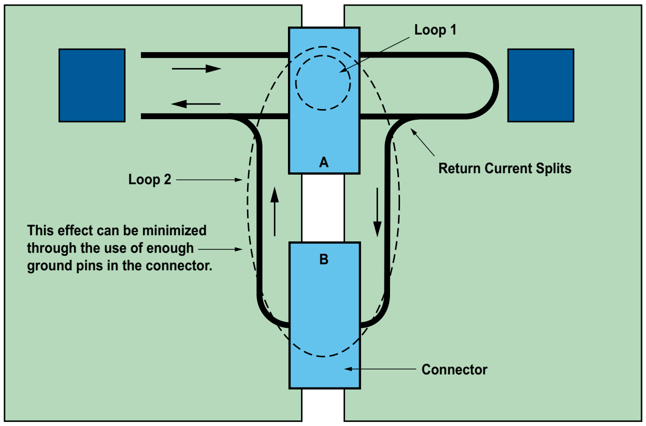

Figure 10 – EMI generated due to improper current return paths

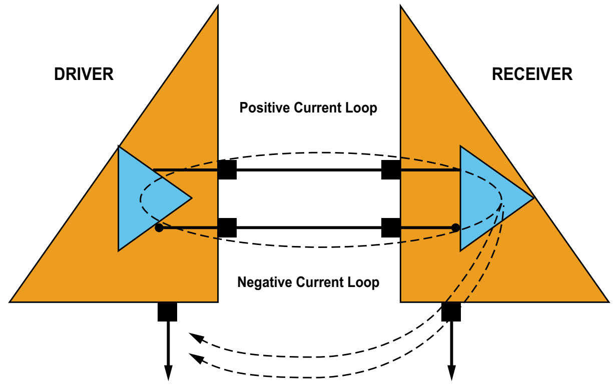

Figure 11 – Differential eliminated returned signal currents

device A returns through signal return path X. Even currents leaving devices B and C have signal return paths through Y and Z.

Because all of these paths overlap, magnetic fields from one path induce electric voltages (noise) in other paths. The induced noise will be larger or smaller with the physical location of a path. In our example, Y will receive more noise than Z because it shares more area.

Do not worry about crosstalk between differential signals. Because of their nature, crosstalk is canceled out.

Parasitic Capacitance

Mutual and shunt (pin-to-pin) capacitance is another effect that comes with a connector – usually you can ignore it. The effect capacitance has is to slow down system edge rate. In multi-drop backplane applications, parasitic capacitance places more burdens on connectors than in point-to-point applications.

Signals transmitted pass each tap on the bus; the cumulative effect of the parasitic capacitance can distort the signals and the series inductance of the source connector.

Connector Selection

To provide excellent high-speed connectors, manufacturers need to control and manage the above parameters as well as a lot more. Engineers now have access to an extensive amount of data measured and calculated by connector manufacturers.

On most manufacturers' websites, electrical, mechanical, and SI information is available, together with PCB drawing and simulation aids:

- Mechanical
  - – Dimension drawing in PDF format
  - – 3D models in IGES, STEP, or Parasolid ACIS format
  - – Mechanical qualification and stress test reports
  - – PCB layout tool library components
- Electrical
  - – Electrical test reports
  - – Application notes
  - – SI parameters and results
  - – Datasheets
- Simulation
  - – IBIS and SPICE models

An extra service offered by Samtec is the "Final Inch" website, for designing a connector break-out region on a PCB.

The manufacturers mentioned in this article are not the only high-speed connector manufacturers on the market. There are other companies such as ERNI™, Hirose, Molex™, Amphenol™, and Radiall™ manufacturing (under license) similar connectors. Many other companies have their own range of high-speed connectors.

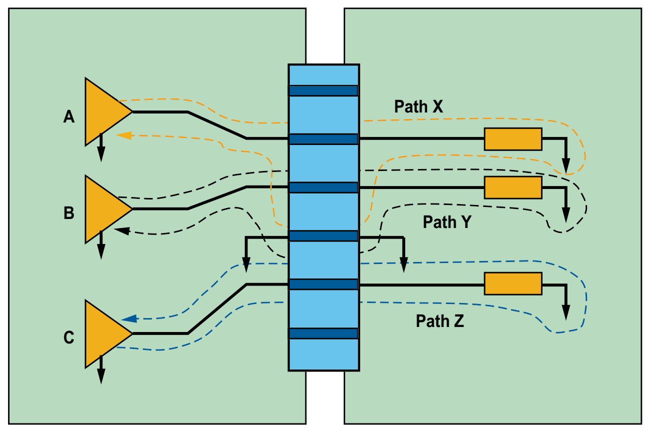

Figure 12 – Mutual inductive coupling through a connector

Conclusion

Today's high-speed digital design engineers can benefit from the RF knowledge of connector suppliers, using the information available in datasheets, application notes, and on the Internet.

You can use this article as a starting point for better PCB and connector design.

For more information, see the books "High-Speed Digital System Design" by Stephen H. Hall, Garrett W. Hall, and James A. McCall; "High-Speed Digital Design" by Howard Johnson; or visit *www.johnson-comp.com, www.samtec.com, www.samtec.com/sudden_service/current_literature/q-pairs/index.html, www.samtec.com/sudden_service/current_literature/SamArray/index.html, www.teradyne.com/prods/tcs,* and *hmzd.tycoelectronics.com.*