RTC
THE MAGAZINE OF RECORD FOR THE EMBEDDED COMPUTING INDUSTRY

May 2014

TECHNOLOGY CONNECTED

Optical Connectivity in System Design

VPX Optical Interfaces Boost System Capabilities

New optical interfaces for VPX allow modules to communicate through backplane connectors to adjacent modules, racks and even remote systems. Compared with traditional copper connections, these optical links offer extremely high data rates across significant distances, improve data integrity and security, and reduce cable size and weight.

BY RODGER HOSKING, PENTEK

For well over 150 years, copper interconnections have served the telecommunication and radio industry admirably for nearly all implementations of industrial, commercial, military and consumer products. However, over the last 15 years, optical interconnections have advanced rapidly to meet exploding market demands for telcom, data servers, storage facilities and the Internet infrastructure. Optical links offer many advantages over copper that are critical for these applications.

Copper cables suffer from losses due to resistance, impedance mismatching and electromagnetic radiation, all of which pose serious problems for longer cables and higher signal frequencies. For example, standard unshielded twisted pair Ethernet cable is usable for lengths of about 100m, while an optical fiber cable can span from 300m up to 40 km, depending on the technology. These same effects afford optical cables one or more orders of magnitude improvement in data rates compared to an equal length of copper.

Electromagnetic radiation impacts copper cables in two significant ways. Eavesdropping on the emissions from network cables is a major security concern, not only for military and government customers, but also for corporations, banks and financial institutions. Sniffers in vehicles and briefcases now using sophisticated and sensitive electronics are hard to detect and restrict. Optical cables are extremely difficult to "tap" without physical damage and loss of connectivity.

Secondly, signals on copper cables are susceptible to noise from nearby sources of electromagnetic radiation, such as transmitters, generators and industrial machinery. This is of special concern for military and commercial aircraft and ships, as well as unmanned and land mobile vehicles, which are often packed with dozens of different electronic payloads. Optical cables are completely immune to EMI and even lightning discharges.

Optical cables are much smaller and lighter than copper cables, delivering a special advantage to weight-sensitive applications such as weapons, UAVs and aircraft. In case of a mishap, optical cables will operate just as well when submerged in seawater. They are completely immune to electrical shorting—especially important where explosive vapors may be present. To ease installation through conduits and passages, optical cables have smaller diameters and can withstand up to ten times more pulling tension than copper cables.

As the use of optical cables becomes more widespread, the cost per length can be much lower than copper cables that depend on commodity metal pricing.

Optical Cable Technology

Inside an optical cable is a cylindrical optical fiber that acts as a waveguide to propagate light. The fiber consists of a central dielectric core clad with a dielectric material having a higher index of refraction than the core to ensure total internal reflection. Two types of optical cables exist: multi-mode and single-mode fiber.

Multi-mode cables have typical core diameters of 50 to 200 micrometers, and propagate light using principles of geometrical optics. Light rays entering the core within a certain angle of the axis are completely reflected by the dielectric boundary between the core and the cladding, and travel by repeated reflections down the length of the cable. The wavelength of light typically used for multi-mode cable is 850 nm.

Single-mode cables have a much thinner core, typically 8 to 10 micrometers, and propagate light as an electromagnetic wave operating in a single transverse mode. The core diameter must be no greater than ten times the light wavelength, and two commonly used values are 1310 and 1550 nm. Single mode fiber cables carry signals over lengths 10 to 100 times greater than multi-mode cables, but require more expensive transceivers.

There are nearly 100 different types of optical cable connectors in the market, but all of them address the mechanical challenges of connecting the ends of two optical cables to retain the maximum fidelity of the light interface in spite of human factors, tolerances, contamination and environments.

Optical Transceiver Technology

Optical transceivers couple electrical signals to the light signals in optical cable. New transceiver technology is boosting data rates to 100 Gbits/s and higher, while reducing the power, size and cost of devices. Different technologies are required for emitters and detectors, but both are often combined in a single product to provide full-duplex operation.

Traditional edge-emitting lasers generate coherent infrared light between parallel layers of semiconductors, with light emanating from the edges of these layers. The latest optical emitter is called the vertical cavity surface emitting laser, or VCSEL (pronounced “vixel”) where light is emitted vertically (perpendicular to the layers). VCSELs are more economical than edge-emitters and operate at relatively low power levels. They can produce wavelengths between 600 and 1300 nm, nicely covering 850 nm for multi-mode optical interfaces.

Detectors use infrared photo diodes that can handle the required data rates using technology far less exotic than the emitters.

Embedded System Protocols for Optical Interfaces

Optical emitters simply translate the digital logic levels into modulation of the laser light beam, while the detectors convert the modulated light back into digital signals. This physical layer interface for transporting 1's and 0's is capable of supporting any protocol. Depending on the application, these interfaces can handle protocols from the link layer up through any of the higher layers.

For example, Xilinx FPGAs include Aurora link-layer gigabit serial transceivers designed primarily for point-to-point connectivity between FPGAs. It includes 8b/10b or 64b/66b channel coding to balance the transmission channel, and supports single- or full-duplex operation. Aurora handles virtually any word length and allows multiple gigabit serial lanes to be bonded into a single logical channel, aggregating single lane bit rates for higher data throughput. Extremely simple and with minimal overhead, Aurora is very efficient in linking data streams between multiple FPGAs within a module, or between modules across a backplane. Data rates per serial lane can be 12.5 GHz or higher.

Stepping up in complexity is the SerialFPDP protocol defined under VITA 17.1 for bit rates up to 2.5 GHz, although higher rates have been successfully deployed. It adds certain features to the low-level, link-layer data transfers to address several important needs of embedded systems. These include flow control to avoid data overruns, and copy mode to allow one node to receive data and also forward it on to another node. The copy/loop mode supports a ring of nodes with data circulating through several nodes, eventually completing a closed loop.

Fibre Channel, an older ANSI standard running at bit rates up to 16 GHz, defines several network topologies for connecting storage area networks for high-performance computing and data servers.

InfiniBand defines a flexible, low-latency, point-to-point interconnect fabric for data storage and servers with bit rates to 14 GHz today, and 25 and 50 GHz in the next few years. Bonding of bit lanes into x4 and x12 logical links boosts channel speeds. InfiniBand offers a major advantage over Fibre Channel by achieving the required performance and reliability levels of specific data center requirements through easy-to-use tools for configuring network density, speed and topology.

The venerable Ethernet protocol still dominates computer networks, with 10 GbE now commonly supported by a vast range of computers, switches and adapters. Even though Ethernet suffers from high overhead, making it somewhat cumbersome for high data rate, low latency applications, its ubiquitous presence virtually assures compatibility. Because each of these protocols offers distinct benefits and tradeoffs, they all are deployed in embedded systems using optical interfaces

New VPX Standards for Optical Interfaces

Optical interfaces of all connector and cable types have been deployed in VME and VPX systems for years with connectors mounted on the front panels—a maintenance issue for servicing and often not permitted in conduction-cooled systems. Alternatively, backplane copper signals from the module connect to rear transition modules containing the optical transceivers, adding both cost and complexity.

The VITA 66 Fiber Optic Interconnect group has developed a set of standards that bridge optical connections directly through the VPX backplane connector. The first three are variants for 3U and 6U systems and are based on MT, ARINC 801 Termini and Mini-Expanded Beam optical connector technology, respectively.

Spring-loaded ferrules containing optical cables float within metal housings to provide blind-mate connections between the module and the backplane, as shown in Figure 1. Alignment pins and holes in each half of the mating assemblies ensure exact alignment of the polished ends of each optical fiber. The metal housings are physically dimensioned to replace one or more of the standard MultiGig RT-2 VPX bladed copper connectors.

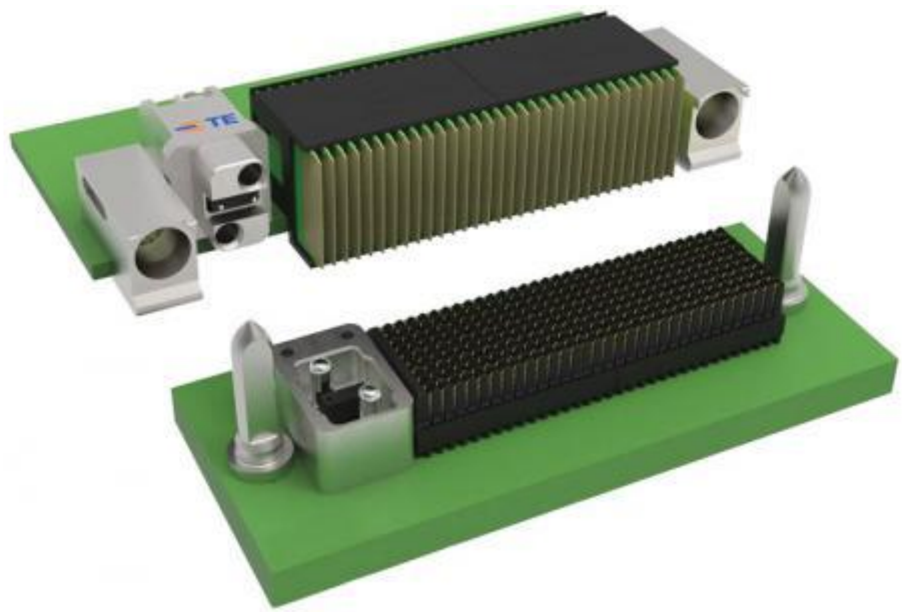

Figure 1
VITA 66.4 mating metal housings containing MT ferrules for 3U VPX replace half of the VPX P2 copper connector (courtesy TE Connectivity).
The high-density MT variant defined in VITA 66.1 provides the highest density of the three, with up to 12 or 24 pairs of optical fibers, while VITA 66.2 and 66.3 each provide 2 pairs.

A fourth standard soon to be released, VITA 66.4, uses the MT ferrule but with a metal housing half the size of VITA 66.1, and occupying only half of the 3U VPX P2 connector position. It supports either 12 or 24 pairs of optical cable. First versions of the connectors are already available from major vendors, including TE Connectivity and Molex.

To ease implementation of the optical interface, Samtec is now sampling its FireFly Micro Fly-Over system. These small modules interface 12 lanes of gigabit serial electrical signals to laser transmitters or receivers. They connect through 12-lane optical flat ribbon cables that are terminated in the MT ferrule shown in Figure 2.

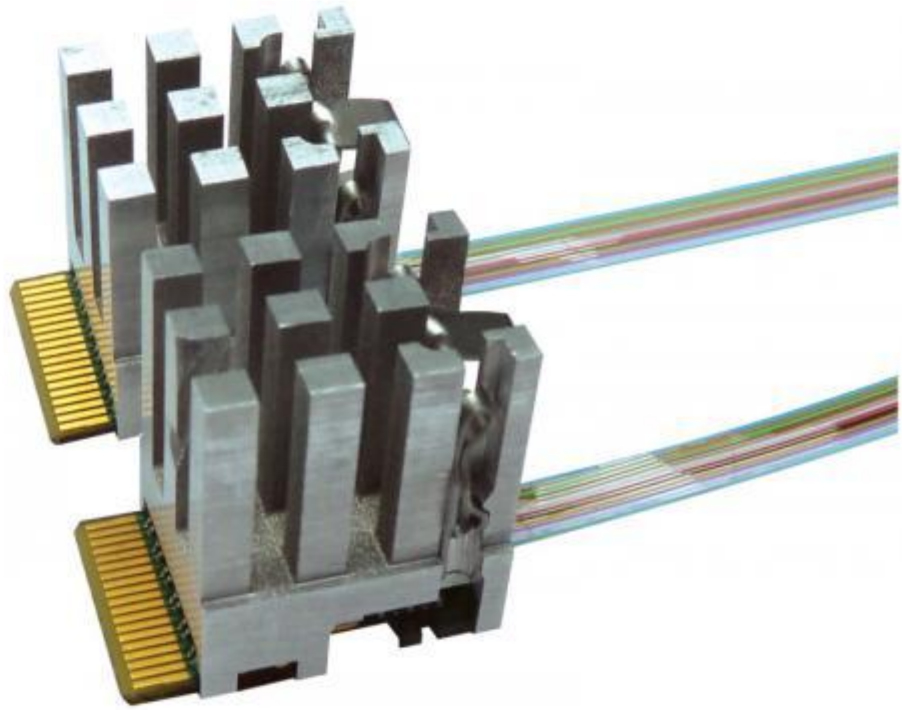

Figure 2
Samtec FireFly optical modules, each interfacing 12 gigabit serial copper signals to 12 optical fibers, joined together as flat cables.

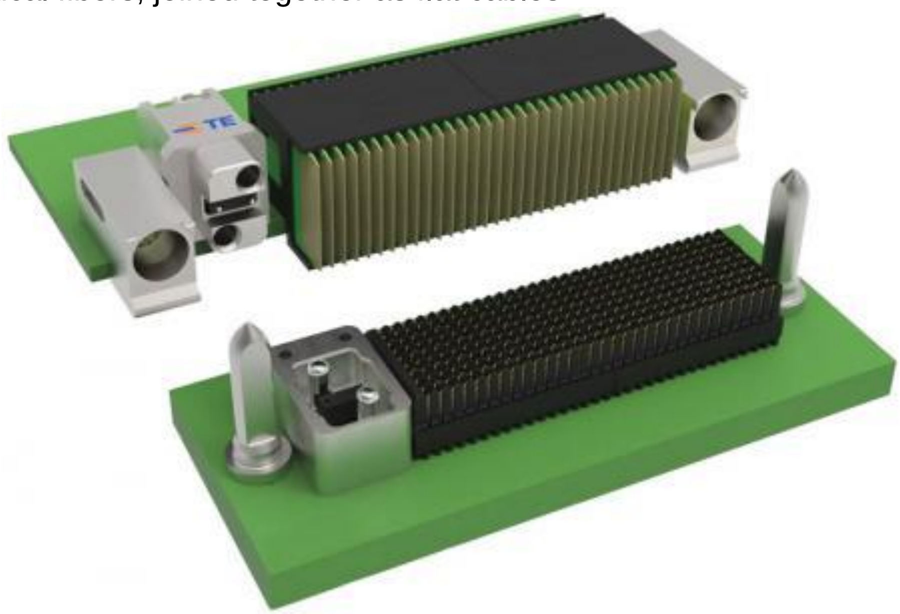

Figure 2
Samtec FireFly optical modules, each interfacing 12 gigabit serial copper signals to 12 optical fibers, joined together as flat cables.

Capable of operating at speeds of up to 14 GHz using 850 nm multi-mode technology, a pair of these compact modules delivers data at over 16 Gbytes/s in both directions. They are especially well-suited for direct connection to the gigabit serial transceivers found on FPGAs.

Figure 3 shows a product implementation of the proposed VITA 66.4 optical backplane interface. This Virtex-7-based 3U VPX carrier for FMC modules connects the Samtec FireFly modules directly to the Xilinx GTX gigabit serial I/O pins, supporting a variety of popular FPGA-based protocols.

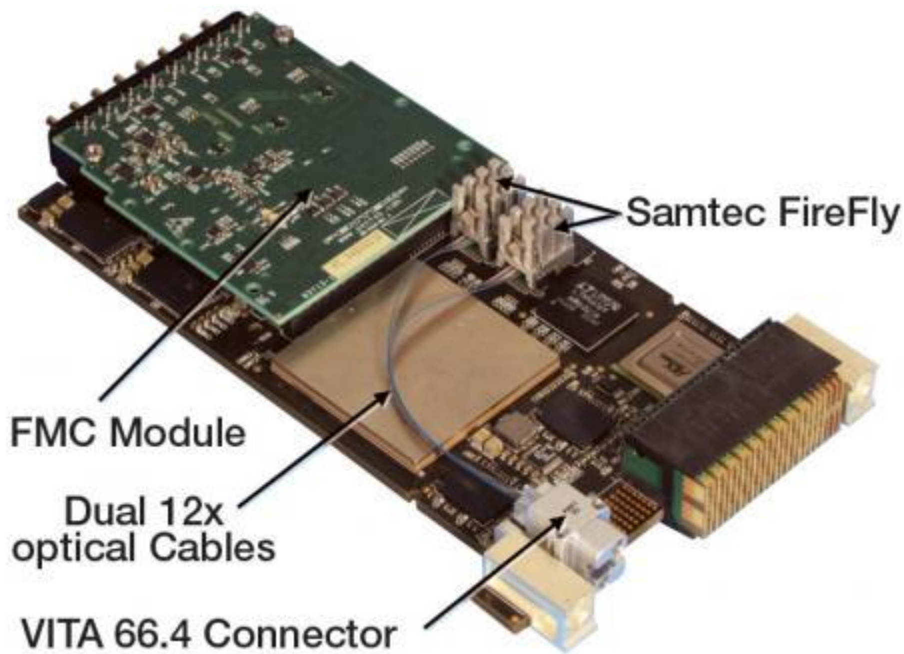

Figure 3
Pentek Model 5973 3U VPX Virtex-7 FMC Carrier uses two Samtec FireFy optical modules for the VITA 66.4 backplane interface.
This product approach eliminates cumbersome front panel connectors, simplifies installation and maintenance, and reduces system complexity. VITA 66.4 complements the standard PCIe Gen 3 x8 copper interface with a full duplex, multi-mode fiber link delivering more than 10 Gbytes/s of I/O to other systems, racks or sensors located at distances of 100 meters or more.

As these backplane optical interfaces gain acceptance, embedded system designers will leverage the speed, distance, weight and size advantages they offer to create new architectures and open up new applications. Such interfaces will help high-performance embedded computing support the new sensors, processors, storage devices and memories that are pushing data traffic to increasingly higher limits. Achieving these objectives requires open industry standards based on new technology in optical cables, optoelectronics and protocols. A new optical backplane interconnect standard offers several advantages over earlier implementations.

Pentek
Upper Saddle River, NJ
(201) 818-5900
www.pentek.com