VXS promises to solve even the most challenging data transfer requirements of future real-time embedded systems.

VXS: A High-Performance VMEbus Switched Serial Fabric

By Rodger Hosking

Now well into its third decade of widespread deployment, VMEbus continues as the dominant bus structure for high-performance embedded systems. In an industry characterized by a steady succession of new device offerings with speed and density increases every few months, VMEbus has retained this leadership position not simply because it was based on a sound electrical and mechanical architecture. Indeed, the major reason for its longevity has been a series of performance and feature enhancements promoted and nurtured by a broad base of VMEbus vendors.

VXS, a switched serial backplane fabric for VMEbus defined by VITA specification 41 (www.vita.com), continues that history. It will satisfy the most challenging data transfer requirements of real-time embedded systems as faster processors and interfaces emerge and ensure the continuing popularity of VMEbus by allowing legacy boards to coexist with the new VXS boards as they become available.

INNER WORKINGS OF SWITCHED FABRICS

A switched fabric is a system for connecting devices to support multiple data transfers simultaneously and is usually implemented with a crossbar switch. Data is sent in packets, with information contained in the packet header for identification, routing, and error detection and correction. To ensure adequate performance for any given system, the interconnecting fabric can be a simple as a point-to-point connection between two devices or a more complicated architecture that may include switches, routers, hubs, and repeaters. One familiar example of a switched parallel fabric is RACEway.

Because of recent advances in serial data technology, the new generation of switched fabrics uses serial links. With data bit rates now in the gigahertz range, the new serial interfaces can easily rival their parallel counterparts. In many cases, the transition from parallel to serial occurs only at the lowest levels of the OSI seven-layer model. In this way, existing protocols are maintained so that legacy products with parallel interfaces can be supported with hardware adapters that convert the physical layer interface into the new serial link.

This strategy has been extremely successful in allowing the new serial technology to be inserted seamlessly. One excellent example is the migration of parallel flat-cable SCSI to serial Fibre Channel as the interface of choice for the latest generation of high-performance hard disk drives and disk arrays. The same SCSI protocol is employed in both schemes.

One of the major benefits of the new serial interfaces is the reduced number of signal lines and smaller connectors and cable. This benefit translates into enhanced system density, simpler system integration, lower installation costs, and easier maintenance. Another benefit is the ability to use copper cables for low-cost local connections or optical cable for fast, long-haul data transmission channels. Again, the physical layer can be made completely transparent to the protocol layer.

Yet another benefit of serial links is the ability to gang multiple serial links together to boost data throughput. Since the signal within a single bit link contains embedded clock and timing information, each link can propagate on its own across the channel, and transceivers at each end can handle the multiplexing and demultiplexing for 1x, 4x, 8x, or 16x ganging in low-level hardware layer devices.

Not only are switched serial fabrics attractive alternatives to existing technology for front-panel interconnections, they also are extremely appropriate for backplane data traffic.

ATTRACTIVE ALTERNATIVES

Once the benefits of switched serial fabrics became apparent, embedded systems developers sought ways to take advantage of the technology for a wide range of interconnection needs: boards to peripherals, boards to boards, chassis to chassis, and facility to facility. Not only are switched serial fabrics attractive alternatives to existing technology for front-panel interconnections, they also are extremely appropriate for backplane data traffic to augment or replace the conventional parallel backplane bus.

Embedded system vendors are now faced with choosing from the five contending switched serial fabrics defined in the VITA 41 spec: HyperTransport, InfiniBand, PCI Express, RapidIO, and StarFabric. These fabrics were chosen because of their wide acceptance in the industry and because each is technically capable of meeting the needs of the spec.

HyperTransport (www. hypertransport.org/) is Advanced Micro Devices' solution for chip-to-chip and board-to-board connections. A universal interconnect, it replaces and improves upon existing multilevel buses used in such systems as personal computers, servers, and embedded systems, while maintaining software compatibility with PCI. HyperTransport supports asymmetric, variable-width data paths.

InfiniBand (www. infinibandtal.org) is an industry-standard, channel-based switched fabric designed primarily for server and storage system connectivity for box-to-box links. It seeks to fulfill the need for greater data center reliability, availability, and scalability, as well as greater design density for servers.

Intel's initiative for connectivity

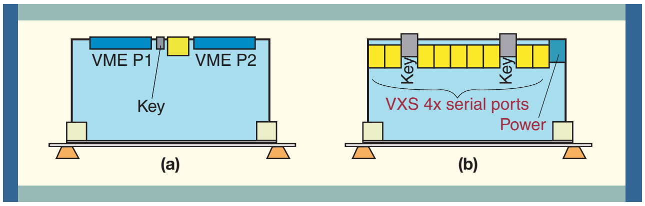

Figure 1: *As this simplified view of the VXS payload card shows (a), it has standard P1 and P2 connectors that implement the standard VME64x backplane interface, plus a new P0 backplane connector mounted between P1 and P2, which handles two 4x, full-duplex switched serial ports. The VXS switch card implements the crossbar switching to connect payload cards together. It has a 6U VME board form factor and a power connector and connectors that handle up to eighteen 4x full-duplex serial links, instead of P1 and P2 connectors (b).*

between processors and boards, PCI Express (www. pcisig. com) is compatible with the current PCI software environment. It supports chip-to-chip, board-to-board and adapter interconnections and is aimed at the next generation of computing and communications platforms.

RapidIO is targeted at chip-to-chip and board-to-board connections for real-time COTS embedded systems and has strong support from Motorola. It's promoted by the RapidIO Trade Association, whose founding members are, in addition to Motorola, Alcatel, EMC, Ericsson, IBM, Lucent, Mercury Computer Systems, Texas Instruments, and Tundra Semiconductor.

Originally developed by StarGen, a fabless semiconductor company, with the assistance of the StarFabric Working Group, StarFabric (www. starfabric.org) targets backplane and chassis-to-chassis applications and supports multiple classes of traffic. Its strength lies in providing transparent serial links between PCI devices.

These five fabrics are all vying for position. Aside from some valid technical pros and con for each, the key issues tend to be business ones. For example, which major vendors are backing each standard? How easily can these new fabrics be integrated into existing software operating system environments? What components are available for bridging to existing hardware and processors? What kinds of switches are available? Finally, can the fabric technology components achieve sufficiently high volume production to make the parts inexpensive, power-efficient, and easily connected?

RAPIDIO FOR REAL-TIME APPLICATIONS

Nevertheless, one of the switched fabrics, RapidIO, is especially well suited to real-time embedded systems.

The objectives of this high-performance standard are fast interprocessor communication, DSP networking, and high-speed backplane interconnects, as well as efficient chip-to-chip and board-to-board transfers. These goals are addressed with scalable serial bit rates of up to 10 GHz. Performance and efficiency are achieved through a combination of a low-overhead protocol and hardware error detection and correction. By offloading these tasks from the processor, RapidIO is extremely well suited for real-time applications, where shared coherent memory, channel predictability, and low latency are essential.

At the physical layer, RapidIO uses the same differential current-mode signaling as such other standards as Fibre Channel, InfiniBand, and IEEE 802.3 XAUI.

During the last few years, the VITA 41 committee of the VMEbus Standards Organization has been defining a switched serial backplane fabric for VMEbus called VXS. The specification defines a VXS payload card, a VXS switch card, and a connector scheme for various possible backplanes to support VXS.

'FABRIC-AGNOSTIC'

Because of the "fabric wars," the VXS specification was defined to be fabric-agnostic, in that there are five subspecifications, one for each of the five fabrics described above. The basic switched fabric architecture chosen to connect the boards across the backplane is a ganged 4x, full-duplex serial channel. Each interconnect thus supports data flow in both directions simultaneously.

Although serial bit rates are defined up to a maximum of 10 Gb/s, the first systems support lower frequencies. With the 4x ganging and a nominal bit frequency of 2.5 GHz, both the input path and the output path of these systems are capable of moving data at 1 Gb/s.

VXS CARDS

The VXS payload cards are processor, CPU, memory, and data converter 6U VMEbus cards with a VXS interface. They have standard P1 and P2 connectors that implement the standard VME64x backplane interface. A new P0 backplane connector mounted between P1 and P2 handles two 4x, full-duplex switched serial ports (Figure 1a).

At a 2.5-GHz clock frequency, each VXS payload card can move data in and out at an aggregate rate of 4 GB/s, two orders of magnitude above the original VMEbus backplane specification.

The VXS switch card has a 6U VME board form factor, but unlike the payload card, it has no P1 and

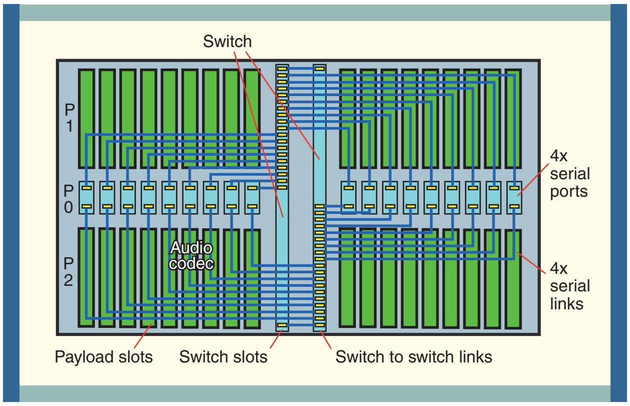

Figure 2: *This example of a 20-slot VXS backplane holds 18 payload cards divided equally in each half and two switch cards occupying the two center positions. One serial link of each payload card is wired to one of the switch cards; the second link is wired to the other.*

P2 connectors. Instead, the space normally used for the P1 and P2 connectors along the rear edge of the board is populated with a power connector and connectors that handle up to eighteen 4x full-duplex serial links (Figure 1b). The VXS switch card implements the crossbar switching to connect payload cards together.

VXS switch cards can have any number of crossbar switches and any number of serial ports. They may also include other interfaces to networks for communication and storage devices, as well as front-panel serial ports to other VXS switch cards in the same chassis or in adjacent racks. Optical serial ports could be used for remote high-speed data transfers.

VXS BACKPLANE

The VXS backplane can have many different layouts to accommodate specialized system needs, but it will normally handle cards and one or more switch cards. The standard board-to-board pitch of 0.8 in. is maintained throughout, and other VMEbus card-cage mechanical hardware (card guides, frames, and so on) is compatible. The ob-jective is to connect the two 4x serial links of each payload card to links on the switch card or cards to support the necessary board-to-board connectivity. Some smaller systems may require only a few payload slots and a very simple switch card; others may need to use a full-width backplane and multiple switch cards to handle the required traffic.

Since there is a maximum of 18 serial link connections on each switch card, all 18 payload cards can be connected to each other through two redundant paths, namely, through both of the two switch cards. This dual redundancy is attractive for many applications re-quiring fault tolerance and high availability. The two switch cards also have additional serial links that join switch cards together, providing yet another path for routing. ◆

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