VXS backplane design: A closer look

By Mahamud Khandokar and Justin Moll

The VME Switched Serial (VXS) specification is becoming increasingly popular. More and more vendors are developing products, and customers have been prototyping various configurations. This relatively new specification is an important step in the continuing evolution of VME and its integration with switched fabrics.

VME in the marketplace

The VMEbus has several product niches. VME64x architectures are the most popular with its ruggedness, wealth of I/O pins, and backwards compatibility. The less costly predecessor of VME64x also still serves the marketplace. In fact, it is still very common to design standard three row 6U VME into new systems when the application does not need the extra I/O pins and functionality of VME64x. Even 3U standard VME has its niche in many new designs. VXS will also have its niche as backwards-compatible VME architecture with switched fabric performance.

Not all applications will need the performance of switched fabrics. Many industrial, control, military, and other markets do not need the speed and bandwidth of VXS. Demand for legacy VME will be strong for many years to come. However, some applications need the control, tightly coupled multiprocessing, and stability of higher bandwidth VME. When implementing switched fabrics with VME, backwards compatibility is a critical factor.

Backwards compatibility

One important consideration for VME as it has evolved over the years is its backwards compatibility. From the initial three row VME 16-bit (40 MBps) to 32-bit and 64-bit (80 MBps), up to five row VME64x (160 MBps), VME has always increased performance while it has maintained backwards compatibility.

VXS is no exception. The VXS design starts with a standard VME64x backplane design and implements a high speed fabric by replacing the existing P0 connector with the MultiGig 7-Row connector, and by adding hub slots fully populated with the new connector. The backplane is still backwards compatible to VME64x/VME, allowing standard VME and VME64x cards (without the P0 connector) to be used in the system.

Backwards compatibility is an immensely important issue. Here are some of the key reasons to maintain it:

- Preservation of technology investment
- Preservation of a proven, tested platform
- Multiple vendors/choices of legacy platform
- Reuse of existing cards/components with ability to upgrade
- Less risk of obsolescence as new compatible products are available in roadmap

VITA 41 and 46 comparison

Although VITA 41 (VXS) is quickly gaining popularity, some in the industry have been waiting to see what happens with VITA 46 Advanced Module Format (working title). This is probably more out of confusion than anything else, and the VME community has not provided a clear enough message until very recently.

First, VITA 46 is not a progression from VITA 41; it is a different path for different needs. The two specifications might not compete often, and in some cases hybrids will be a good fit. Both architectures achieve many of the same goals. For example, both technologies can implement Single Star, Dual Star, or mesh switched fabrics. An example of an Elma Bustronic mesh VXS backplane is shown in Figure 1. This 5-slot switchless VXS backplane does not require switch cards for the prototyping and development of VXS systems.

One can do a larger mesh topology with VITA 46, but mesh topologies are at times more conducive to smaller segments anyway. Also, with a customized VITA 41, one can have a Single Star or Dual Star segment on a VXS backplane next to a mesh segment. This arrangement allows mesh performance to be combined with backwards-compatible VME64x legacy cards. Further, a multi-segmented mesh would allow multiple sets of mesh segments to be combined. Having multiple meshed bus segments managed and supported in a single system is an efficient use of system resources.

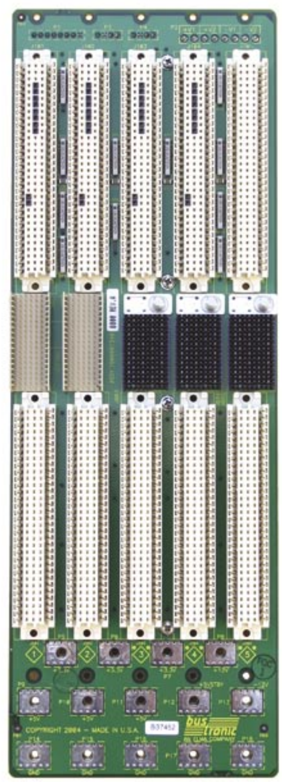

Figure 1

How about I/O pins? One can have more backplane/card I/O pins with a mesh segment with either architecture. Or, this can be achieved with a VITA 41/46 hybrid. It should be clarified that in this case, the mesh segment slots would need to resemble switch card slots, with MultiGig connectors populating the entire slot.

This concept is shown in Figure 2 and can be accomplished with a hybrid VXS configuration with separate segments, or with a VITA 41/46 hybrid.

From the backplane standpoint, one of the main differences with VITA 46 is the option of the 3U form factor and the support of a larger mesh configuration. As with any architecture, these features will not be all things to all people, but instead fit a certain niche. Also, VITA 46 is not backwards compatible (except in hybrids). So, waiting to see what happens with VITA 46 is not necessary, as the two specifications will likely serve different niches. As you can see, with creative implementations, many of the differences are minimized. Those who plan to implement VITA 46 when it becomes available can start with a VITA 41 implementation today, and then migrate to a hybrid solution in the future.

Characterization of the interconnect path is increasingly important with VITA 41, VITA 46, or any other high-performance architecture. With a new specification, Elma Bustronic decided to develop its first VXS backplane (the 12-slot Dual Star) with a high-grade laminate material and with more (but thinner) layers. Without distinct Signal Integrity (SI) modeling to provide the parameters for characterization of the backplane, we designed the first backplane to have excellent signal integrity. It is too early to perform full characterization for this new technology. However, we can look at one of the most basic elements to measure, the impedance. Let us take a look at the actual impedance of the Nelco4000 13-SI PCB and see if we were on track.

Signal integrity

At higher clock speeds, the PCB requires cleaner signal transmission without compromising the stability of the system. Signal integrity issues such as reflections, crosstalk, frequency dependent transmission line loss, and dispersion can lead to the propagation of poor system performance throughout the interconnect. As VXS is a relatively new specification, we will first measure the impedance of the PCB.

Backplane construction

The routing of a VXS backplane for superior performance can be challenging. In the higher slot sizes, the number and length of the traces can have a detrimental effect on the signal integrity. Particularly with a large backplane, it takes creative and intelligent routing schemes from an experienced designer.

The avoidance of undesirable stubs for upper layer backplane traces presents some tough design choices. One option would be to have these worse case vias backdrilled; a costly fabrication process which removes the unused portion of the plated via structure below the layer at which the signal is terminated. Another possibility would be to minimize the length of via stubs by choosing a laminate with a lower dielectric constant. This path was chosen by Elma Bustronic for its 12-slot Dual Star Backplane.

To provide an illustration, let us look at two VXS backplanes – the 5-slot switchless mesh (where the mesh spans 3 of the slots) and the 12-slot Dual Star. The 5-slot backplane with traces that span three slots has a FR-4 PCB. The larger backplane with traces that span 8 slots has a Nelco4000-13SI PCB which is made of a high-grade material.

To ensure a clean signal, it is necessary to understand and control impedance in the signal transmission environment. Impedance mismatches (due to vias and connectors) and variations can cause reflections that decrease signal quality. Time Domain Reflectometry (TDR) measures the reflections that result from a signal traveling through a transmission environment such as a circuit board trace, cable, or connector. The impedance value of a typical transmission line is a function of the trace geometry and the dielectric constant of the surrounding environment.

The analyzed VXS backplanes featured the following. The 12-slot Dual Star VXS has an 18-layer controlled impedance stripline design. To ensure the highest possible results in early development, the initial version was fabricated using Nelco 4000-13SI material, a laminate with a lower dielectric constant than FR-4. The material also has a significantly lower loss tangent value than FR-4. Therefore, the backplane has superior signal integrity and stronger overall performance, but this will not be necessary for all designs and requirements.

Elma Bustronic SI engineers are looking at using FR-4 for new 12-slot designs, and are confident that with intelligent routing strategies and HSPICE simulation studies, the backplane would still have more than adequate performance while keeping

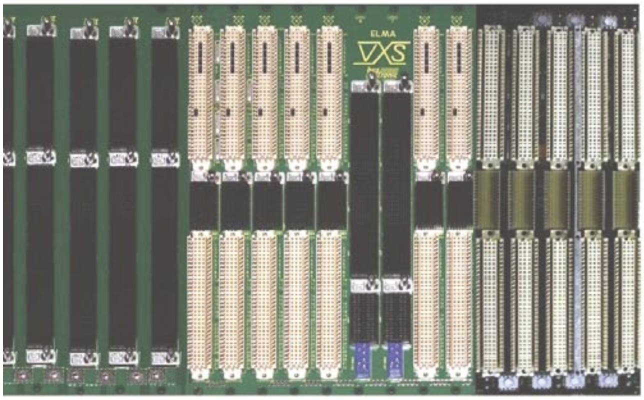

Figure 2

the layer count at a minimum. But, this is a topic for a future discussion.

The 5-slot switchless backplane has a 10-layer controlled impedance stripline design in standard FR-4. Both the 5-slot and 12-slot were designed in a 7U height to allow extra power bugs below the card cage for high current options and for easy cabling.

The connector is the MultiGig RT-2 7-row from Tyco Electronics. The company gives an approximate capability of 6.4 Gbps. With a unique wafer design, the connector does not have a typical pin and socket interconnection.

5- and 12-slot impedance measurements

Only the longest trace connection paths of the 12-slot Dual Star were tested.

Layer_INT04_Slot06_J1_G10

The expected impedance of the trace line for the 12-slot VXS backplane (6380.2 mil) was 65 ± 10% ohm. The TDR signal that we used for our measurements had a 35 ps rise time, which is quite fast compared to real life. The signal distortion due to inductive and capacitive discontinuities will be less for a slower rise-time signal. The measured average impedance of the trace line was 68.7 ohm as shown in Figure 3.

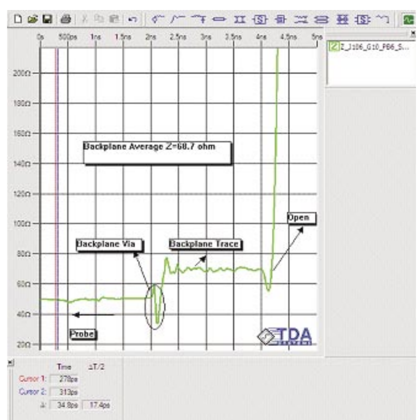

Figure 3

Layer_INT03_Slot07_J0_A15
The expected impedance of the differential trace line for the 12-slot VXS backplane (5232.5 mil) was 100 ± 10% ohm. The measured average value of the differential trace line was 106 ohm as shown in Figure 4.

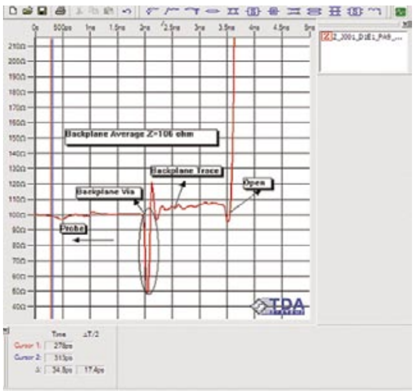

Figure 4

Layer2_Signal_Slot03_J0_CD12
The expected impedance of the differential trace line for the 5-slot VXS backplane (2892.6 mil) was 100 ± 10% ohm. The measured average value of the differential trace line was 99.8 ohm as shown in Figure 5.

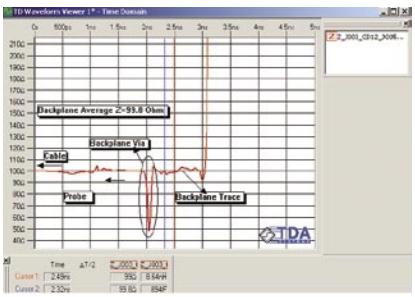

Figure 5

The measured impedance values were very satisfactory for the 5- and 12-slot backplanes, therefore affirming their design. However, impedance measurements are just the first step. In the near future, Elma Bustronic will post signal integrity information on VXS backplanes including model extraction, HSPICE simulation, and in depth backplane characterization. As we cannot include all of this information in one article and we will be performing different studies at various stages, we plan to publish the results piecemeal.

The signal integrity is just one element of VXS design. Another important issue in the success of VXS will be to make the prototyping and development processes easy and cost-effective. One required facet is a backplane that is convenient in size and configuration to perform this task.

Switchless VXS backplanes

New products are being introduced to ease the development of a VXS system. As switch cards for VXS are not yet readily available, it would be helpful to have a platform that allows early development without switches.

One solution is a switchless system that serves as a platform for developing and testing new VXS cards, and is cost-effective for smaller applications and demonstration systems. Developed by Elma Bustronic in cooperation with Pentek, the Pentek Model 6821 is a 12-bit 215 MHz A/D and Dual Virtex-II Pro FPGA VME/VXS backplane. This 5-slot switchless VXS backplane (Figure 1) allows the direct connection of up to three node cards without the requirement for a switch card. It is the first in a family of VXS products supported with the new switchless VXS system.

Elma and Elma Bustronic have also been working with Transtech DSP (recently acquired by VMETRO) on systems that combine the Transtech's multiprocessor FPGA products with Elma's high-performance VXS backplanes and enclosures. Elma Bustronic is also assisting the VITA 46 subcommittee in developing a backplane pinout for that specification.

The unique switchless VXS backplane could be used to develop and test communication between end-point cards, support small system needs, and allow the demonstration of VXS node cards prior to the availability of switch silicon. As a VXS switch card is inherently compliant with a particular data transport protocol, this backplane can be used to test multiple data transport protocol end-point designs without the need to invest in multiple switch card types.

Compliant to the VITA 41.x specification, the 5-slot backplane combines three payload slots plus two conventional VME64x slots and allows design engineers to take full advantage of VXS immediately.

Conclusion

There are many parameters to VXS backplane design and a number of configurations. For instance, many forget that mesh segments can be implemented as standalone backplanes or in hybrids. This adds to the versatility of VXS. Various laminate materials are another factor. In special cases, a high-grade dielectric material can provide higher signal performance. In most cases, FR-4 is more than adequate to maintain signal integrity for demanding applications. Regardless, the backplane designer and manufacturer must use creative and well thought-out design strategies for superior performance. Ω

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