System and Component qualifications of VPX solutions

Create a novel, low-cost, easy to build, high reliability test platform for VPX modules

Steven Searle-Spratt – EIZO
Douglas Caldes – EIZO
Shane Dabrowski – Samtec
John Riley – Samtec

Contents

Executive Summary

EIZO and Samtec have developed a low-cost, easy to build, high reliability test platform for VPX modules. Providing PCIe Gen 3 Connectivity to an off-table CPU test. This new platform supports data rates up to 16Gbps up to 100 meters, via PCIe over fiber optics.

Embedded computing systems in rugged, mobile applications are processing ever increasing amounts of data. Systems require flexible solutions that can collect, analyze and display data while surviving in extreme environments. Optimizing low size, weight, and power (SWaP) constraints is also a must.

Rugged, mobile applications continue to adopt VPX infrastructure. VPX defines a module standard common to rugged, mobile applications. VPX solutions are rugged commercial-off-the-shelf (COTS) modules with high-speed serial interfaces such as PCI Express and Gigabit Ethernet. VPX facilitate these modules' cost-effective integration into larger systems

System integrators that develop rugged, systems are concerned with another topic: component and system level testing. Proven reliability is a must for rugged, mobile applications.

Thankfully, VITA 47 defines rugged environmental, design and construction, safety, and quality requirements for commercial-off-the-shelf (COTS) plug-in units (cards, modules, etc.) typically used in these applications. VITA 47 is meant to demonstrate not just the short-term capabilities of a module, but to ensure the long-term reliability of all aspects of the design under the harshest of real-world conditions.

Figure 1. Test platform for VPX modules

The Opportunity

Most VPX line cards are plug-in modules that cannot operate as a stand-alone product. Testing 3U/6U VPX plug-in modules to all aspects of VITA 47 can be time consuming and expensive. Additionally, test fixtures with expensive computing electronics attached to the Device Under Test (DUT) have short lifetimes. To fully test the functionality of a specific VPX card, a VPX CPU card (also called SPC (Single-Board Computer)) or a full PC/host system is required.

The History

Historically, to test, VPX line card designers would procure a fully ruggedized VPX platform to perform the test and integration. These VPX platforms would include an SBC, backplane, power supply, and chassis. Each of these components not only add significant cost, but must also be located in the Environmental Chamber, due to the VPX architecture. This yields another potential point of failure during the VITA 47 qualification process, as the DUT is no longer just the VPX line card, but rather the entire VPX platform. Isolating the DUT is always the goal, but can be challenging as peripheral hardware will always be needed.

The Solution

By locating a commercial host PC off-site from the environmental chamber and avoiding the need for a full VPX test system, this not only improves reliability but also reduces cost drastically. EIZO has developed a single slot VPX test backplane with minimal components; the VPX Connectors, Samtec's FireFly™ UEC5/UCC8 receptacles, and connectors for Video I/O. Power is directly wired in from a benchtop power supply. This reduced the test apparatus that would be subjected to the more severe conditions down to just connectors and passives, leaving the DUT and the FireFly™ as the only active components in the Test Setup. The PC located off of the shaker table could now be used as the source of PCIe using the PCOA PCIe extender card. The general architecture is shown in Figure 1.
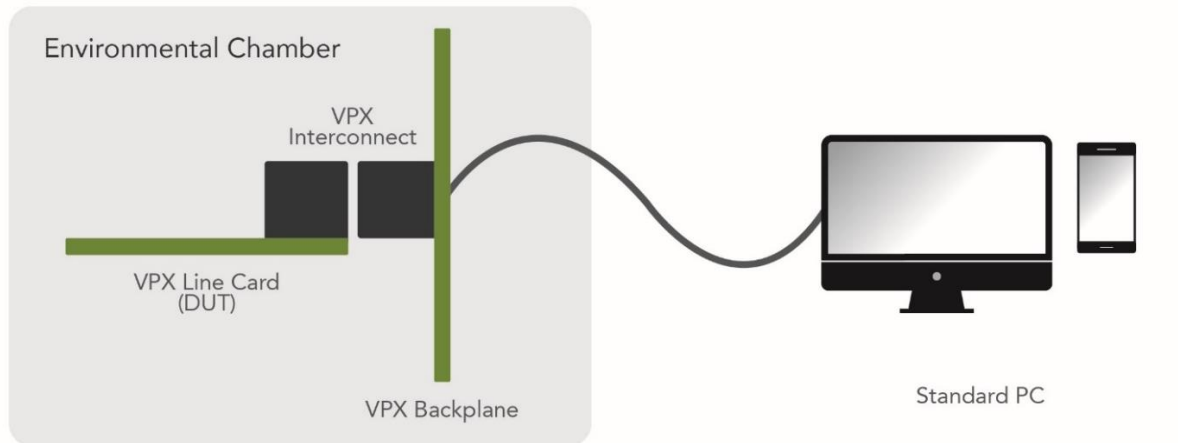
Figure 2. General configuration of the test platform for VPX modules

Evaluation Results and Test Procedure

Results

- Pass standard functional test
  - Memory Tests via CLI
    - Read/Write on Condor DRAMs
  - OPEN GL Applications
    - No error detected
    - Video sourced from CONDOR 4000 (DUT) played on CPU Monitor
  - PCIe bus operation
    - No card freezes
    - No screen shut off or freeze frames
- No single points of failure in the test apparatus
  - FireFly™
  - DUT (Condor)

Test Procedure

The test was based on the continued functionality of the card during the full duration of the test as well as during the pre and post testing. Active full motion OpenGL applications were running on all 3 of the DVI outputs produced from a Condor 4000 3U VPX card under test allowing us to monitor the continued function of the card. The test would have been deemed a failure if we had experienced any loss, freezing, or corruption of the video feed. If the video would have frozen that would have been indicative of a PCIe failure and our investigation would have started with the FireFly™ and the PCIe interface on our card. Corruption or Full Loss of video would have more than likely indicated a hardware failure on our Condor 4000 DUT. However, at no point were any of these failures detected on our device during the full hour of Vita 47.3 V3 vibration, the OpenGL video application were only manually paused at one point in time to run an OpenCL Memory Test Application which also passed. This full vibration test was performed three times, once for each axis. (See Appendix A for applicable section from VITA 47.1)

Operating shock was conducted with 3 shock pulses in each axis. These tests included both half-sine and sawtooth shock pulses for a full total of 18 pulses. Once again, OpenGL applications were run on each screen to confirm functionality, the OpenCL Memory Test was performed before and after each axis's set of shock pulses. No failures were detected before, during, or after the shocks.

Vita 47 Altitude testing was also performed using this fixture. The FireFly™ is made with a thin optical cable (OM3 Fiber, ribbonized fiber), which is ideal for this application as the altitude chamber needs to be as airtight as possible to maintain the pressures associated with the higher altitudes. This set up only had to accommodate the power, video, and FireFly™ cables with the FireFly™ cables being the smallest of the batch. The pressure in the chamber was lowered to the equivalent of 60,000ft above sea level, this pressure was maintained for one hour. At no point during this hour did the DUT or the FireFly™ providing PCIe to it show any signs of failure. The pressure was then re-adjusted, this time to 1,500 below sea level, once again both devices passed functional testing for a full hour.

The functional testing process was the same as the hour for vibration using the same OpenGl and OpenCL applications. In order to create this configuration some novel components had to be assembled as outlined in Figure 2 and detailed below in Figure 3.
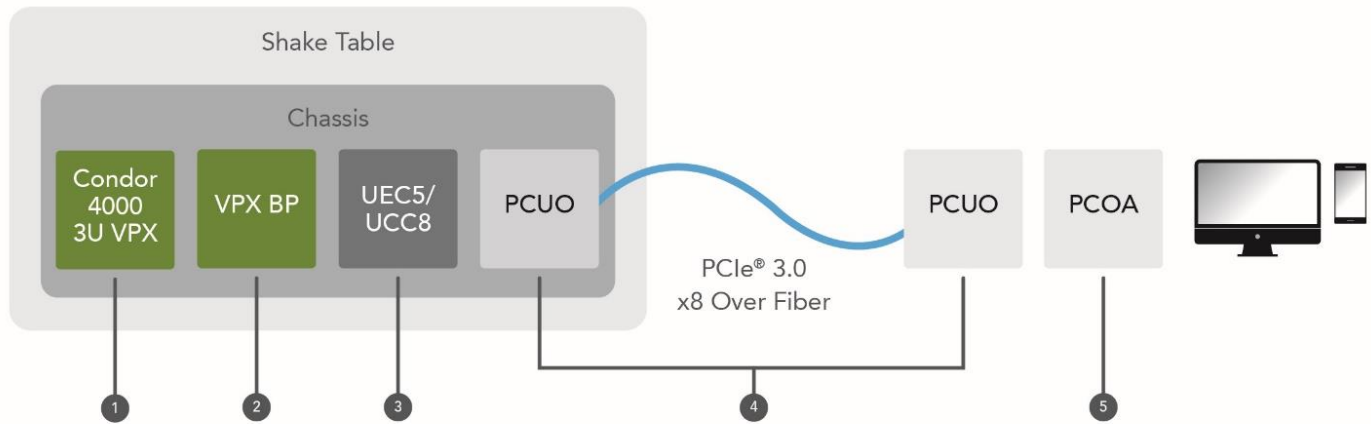
Figure 3. Detailed configuration of the test platform for VPX modules.

Test Elements

Condor 4000 3U VPX Series – Graphics with GPGPU Capabilities (Fig. 3, Item 1)

The EIZO supplied Condor 4000 3U VPX Series boards, shown in Figure 4, are leading edge 3U VPX form factor graphics/video cards for use in applications that require ultra high-end graphics and computation. Based on AMD's Radeon E8860 GPU, the Condor 4000 3U VPX offers groundbreaking performance with 60% better performance than the previous series.

The Condor 4000 3U VPX is available in Conduction Cooled form factor and has 6 Multi-Format video outputs available from the rear VPX P2 connector on the card. Dual Link DVI is available as a factory configured option. Two optional VPX rear transition modules are available (sold separately). One gives access to 4 DisplayPort outputs and the other gives access to 2 Single-Link DVI outputs. VPX-REDI covers are also available.
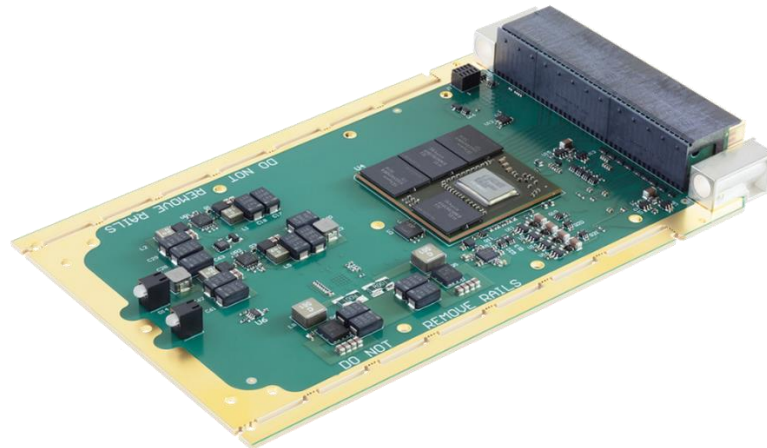
Figure 4. Photograph of Condor 4000 3U VPX Module provided by EIZO

The Condor 4000 3U VPX is ideal for ultra high-end graphics processing as well as general purpose graphics processing (GPGPU) applications such as radar, video surveillance/analysis and other mission computing applications. It offers 768/48 GFLOPs single/double precision performance at 45W max power consumption. The board can operate at higher speeds than the XMC form factor equivalent because it runs in a slot by itself, which allows for improved cooling.

While Windows and Linux drivers are included with the hardware, other real time operating systems (RTOS) such as VxWorks may be supported as per customer requirements. Currently, VxWorks drivers are available at additional cost. DO-178B or DO-178C compliant RTOS drivers for use in safety critical environments are also available (optional). The card has a long life cycle and will be available beyond the year 2030.

VPX Backplane Design by EIZO (Fig. 3, Items 2 & 3)

Each backplane design will be different depending on the system and application that is being evaluated. EIZO used the same board materials and VPX connector configurations that will be used in the final evaluation. Samtec's UCC8 and UEC5 connectors were added to connect critical signals to the commercial host PC off-site from the test environment. By simplifying the backplane design this focuses all test efforts on the connectors and passives, leaving the DUT and the FireFly™ as the only active components.
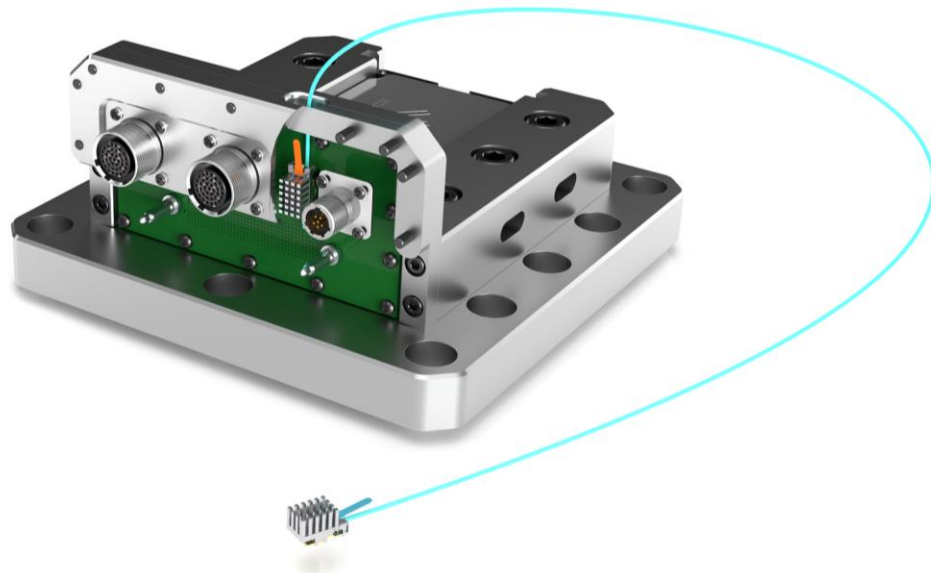
Figure 5. Example of a backplane design by EIZO, including a PCUO and UEC5/UCC8 series from Samtec.

PCUO Series – PCI Express -Over-Fiber FireFly™ Optical System (Fig. 3, Item 4)

Samtec's FireFly™ based PCI Express®-Over-Fiber solution, shown in Figure 6, offers key features that solve the challenges of transmitting the PCIe® protocol over longer links. The miniature size of Samtec's high-density optical engines allows them to be easily designed into the downstream system, ultimately making these systems smaller. Highly flexible, small diameter, industry standard optical patch cords provide connection to the control system.

PCIe® card electromechanical height compliant heatsink

8 G T p s

MTP® connectors for high-density panel applications and minimal keep out areas on the board

Low insertion force 2-piece connector system

PCI-SIG®, PCI Express® and the PCIe® design marks are registered trademarks and/or service marks of PCI-SIG. MTP® is a registered trademark of US Conec Ltd.
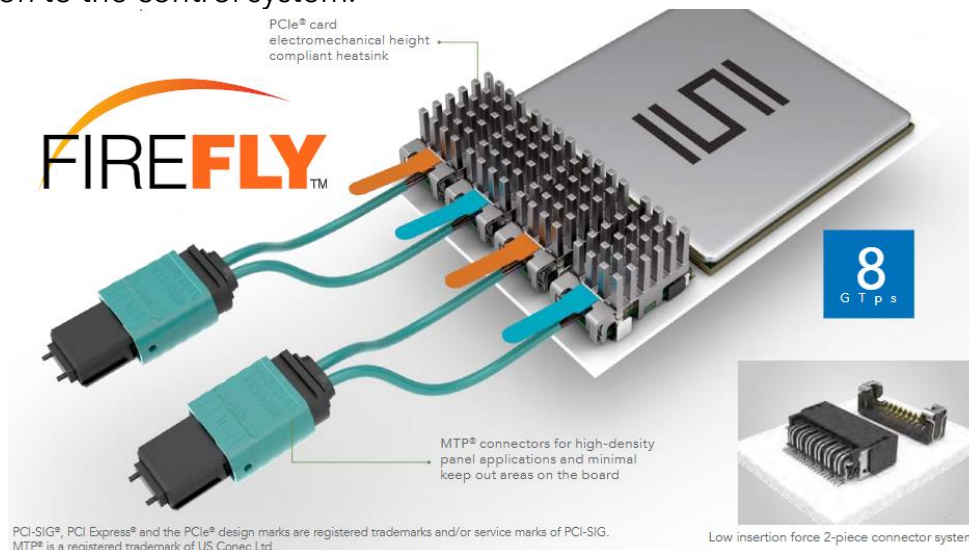
Figure 6. PCIe® Mid-Board Optics provided by Samtec

Other key features include:
- o Gen 3/4 x4, x8 and x16 widths
- o Support for PCIe® low power states
- o Duplex auxiliary signals allow both transparent and non-transparent bridging
- o High-performance signal quality with BER better than 1E-15
- o Enables links up to 100 m
- o Enables nontraditional FPGA/ASIC based endpoints
- o Industry leading miniature footprint allows close placement to the IC, which enables lower drive voltages/pre-emphasis resulting in reduced power consumption
- o Host/Target adaptor card supporting transparent and NTB links in development

Samtec's FireFly™ system is uniquely positioned to support high speed optical transmission in an extremely small, rugged form factor.
Historically, PCIe was not developed for optical transmission. The protocol requires many 'checks & balances', requires side-bands to guarantee transmission, requires electrical idle periods, and is extremely low latency, all of which are challenging for optical engines.

Samtec's PCUO product is an extremely small and rugged form factor that handles all of the challenges listed above. By reducing latency, carrying two sidebands, and working through electrical idle, the PCUO can transmit native PCIe data optically without user manipulation to the base protocol.
Due to this ease of use, this makes it a staple in PCIe test fixtures that need ultimate SI performance or longer reach.

PCOA Series - PCI Express®-Over-Fiber Adaptor Card (Fig. 3, Item 5)

PCI Express®-Over-Fiber Adaptor Card features Samtec's PCI Express®-Over-Fiber FireFly™ optical cable, shown in Figure 7, solution with key features to enable clear signal transmission with increased reach and cost optimization. By supporting the PCIe® Gen 3/4 protocol, the adaptor card delivers high data transfer rates with low latency, power management and guaranteed transmission.
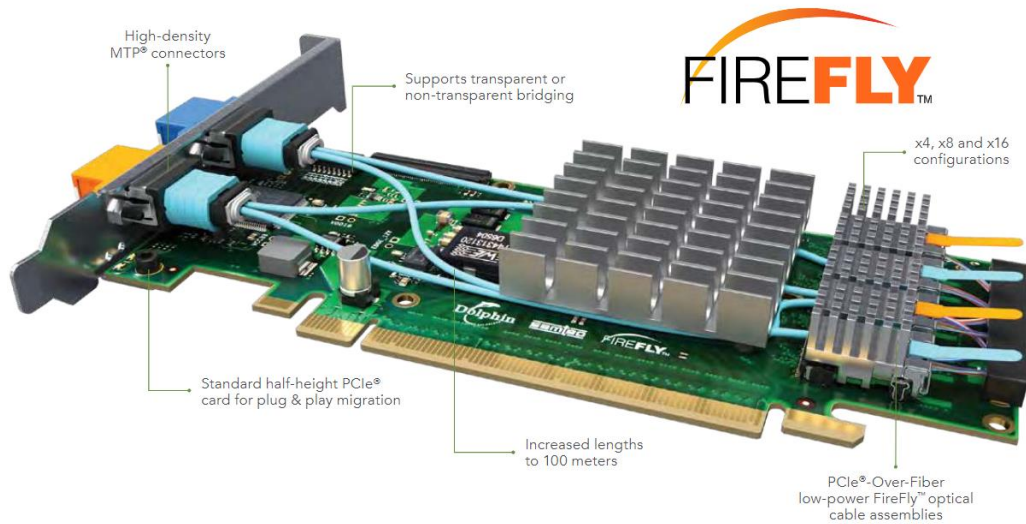
Figure 7. PCI Express®-Over-Fiber Adaptor Card provided by Samtec

Other key features include:
- PCUO Series - PCI Express®-Over-Fiber FireFly™ Optical Cable System
- PCIe® x16 edge card connector
- Supports Gen 3/4 platform
- Scalable configurations for cost optimized performance
    - x4: single, dual or quad
    - x8: single or dual
    - x16: single
- Transparent or non-transparent bridging for system flexibility and multi-processor support
- Easy migration into existing and new architectures with a half-height PCIe® card
- Reconfigurable host or target operation
- Enables computer-to-computer or computer-to-endpoint over long distances
- Features PCI Express®-Over-Fiber FireFly™ optical cable assemblies (PCUO Series)
    - Enables lengths to 100 meters
    - Bidirectional sidebands for reset and cable present
    - Miniature footprint enables smaller endpoints
    - Galvanic isolation for high voltage systems
- Ideal for high-performance and applications requiring robust data transmission: AR/VR high-definition cameras, video editing systems, security systems, data acquisition, industrial applications

Appendix A

VITA 47.1 Vibration

4.4.3 Vibration Class V3

Rule 4.4.3-1: Class V3 Plug-In Module **shall** withstand vibration as defined in Table 4.4.3-1 for 1 hour per axis. [VM = T]

Table 4.4.3-1: Vibration Class V3

Class	Frequency	Power Spectral Density (PSD)
V3	5 Hz to 100 Hz	PSD increasing at 3dB/octave
	100 Hz to 1000 Hz	0.10 g^2/Hz
	1000 Hz to 2000 Hz	PSD decreasing at 3dB/octave

VITA 47.1 Shock

4.5.2 Operating Shock Class OS2

Rule 4.5.2-1: The Plug-In Module **shall** withstand exposure to either 40g, 11 millisecond, half-sine, or 40g, 11 millisecond, terminal sawtooth shock pulses in all three axes. Equivalent SRS spectrums are acceptable. [VM = T]

[VM = T]

Rule 4.5.2-2: Testing **shall** be accomplished in accordance with MIL-STD-810H, Method 516, Procedure I. [VM = T]

Appendix B

Contributing Partners

Samtec

Founded in 1976, Samtec is a privately held, global manufacturer of a broad line of electronic interconnect solutions, including IC-to-Board and IC Packaging, High-Speed Board-to-Board, High-Speed Cables, Mid-Board and Panel Optics, Flexible Stacking, and Micro/Rugged components and cables. Samtec Technology Centers are dedicated to developing and advancing technologies, strategies and products to optimize both the performance and cost of a system from the bare die to an interface 100 meters away, and all interconnect points in between. With 33 locations in 18 different countries, Samtec's global presence enables its unmatched customer service. For more information, please visit http://www.samtec.com.

EIZO Rugged Solutions

EIZO Rugged Solutions develops and manufactures XMC, 3U VPX, and PCIe form factor electronic hardware products with capabilities such as multi-format display and raw video capture, processing, encode/decode, streaming, and recording. Using industry-leading GPU technology from NVIDIA and AMD, EIZO's products support advanced GPGPU computing, artificial intelligence, deep learning, data archiving and multi-format conversion. EIZO products support video IO formats such as 3G-SDI, RS-170, STANAG 3350, HDMI, PAL, SECAM, NTSC, ARINC-818, CoaXPress, and more. EIZO serves several markets that include defense, avionics, aerospace, ISR, naval, EW, and SIG-INT. All graphics, video, and standalone encoding products are designed to be MIL-STD-810 compliant and are manufactured in the USA. For more information, please visit https://www.eizorugged.com/.