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Strategies for Successful VPX System Design

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Yes, the sheer number of OpenVPX profiles can be intimidating, but these steps can help even newbie engineers capitalize on a comprehensive, open architecture standard that satisfies ruggedization levels while delivering unprecedented backplane bandwidth for mil-aero and industrial applications.

While VPX brings unprecedented levels of performance to embedded systems, it also presents entirely new design considerations and tradeoffs not found in previous architectures. The most profound difference is the wealth of dedicated gigabit serial links between VPX modules, completely overcoming the limitations imposed by the shared parallel bus backplanes of VME and CompactPCI. Not only are these links configurable to support any connection topology, they also support a mixture of gigabit serial speeds and protocols within the same system.

While OpenVPX offers standardized “profiles” to provide inter-vendor compatibility, understanding and choosing—from among hundreds of profiles— the one most closely aligned to an application’s requirements can be challenging. This article describes a VPX system design approach that lends itself to analyzing system requirements and making smart decisions as you configure your VPX applications.

The ABCs of VPX

Challenging interconnect speeds and tough operating environments are the most common justifications for launching a VPX system design. PC proliferation throughout consumer, business and government markets has spurred widespread adoption of popular gigabit serial standards for fast data movement, primarily PCIe. However, the harsh and hostile conditions of temperature, vibration, shock and altitude often required for deployed systems in military and industrial applications exceed the capabilities of standard PCs. VPX offers a comprehensive, open architecture standard satisfying the ruggedization levels while delivering unprecedented backplane bandwidth.

The original VPX specification adopted in 2007 as VITA 46 has evolved through adaptation to new technologies and new customer requirements, all promoted by a vigorous group of innovators and vendors in the embedded system community.

Figure 1. Pentek 3U VPX modules consisting of air-cooled and conduction-cooled carriers with software radio XMC mezzanine modules installed.

VITA 48 REDI (Ruggedized Enhanced Design Implementation) defines specific mechanical designs for enhanced thermal management using forced air, conduction cooling and liquid cooling methods. It also defines protective metal covers for the cards to satisfy new requirements for simplified field servicing in deployed military applications.

In 2010, the VITA 65 OpenVPX specification enhanced the original VPX standard by adding a set of well-defined nomenclatures, conventions and system architectures to enable interoperability among vendors. The gigabit serial links are designated as "pipes," defining the number of bi-directional differential serial pairs grouped together to form a logical data channel. Unlike parallel buses, all VPX pipes are strictly point-to-point connections.

OpenVPX also categorizes the different kinds of traffic carried though the pipes as "planes." The five planes defined are the utility, management, control, data and expansion planes.

In order to define architectural characteristics of systems, OpenVPX defines several "profiles." A slot profile specifies the pipes and planes found on the backplane connectors of each slot. The module profile specifies the pipes, planes, fabrics and protocols implemented on each card. The backplane profile defines how the pipes connect slots to one another. And finally, the development chassis profile includes the backplane profile and defines the dimensions, power supply and cooling method.

Getting Started with Your VPX Design

Before searching for products, first define the physical and environmental requirements of the system, including size and weight limits of the enclosure, operating and storage temperature limits, as well as maximum levels of shock, altitude, vibration and humidity. One of the most critical results of this study will be whether the system can be air-cooled or if it must be conduction-cooled; this is obviously a primary driver for component selection. Another major decision is selecting a 3U or 6U form factor.

Then identify all of the critical functions of the system including processing requirements for control, graphics, communications and DSP. Determine memory speed and density and disk storage speed and capacity. Data converters such as ADCs and DACs must be defined by channel quantity, sampling rate and resolution. Other interfaces to sensors, networks, peripherals, communication links and control ports must all be listed.

Create a block diagram of these functions and draw links to show how they must connect to each other and to the outside world. Then determine the maximum data rate for each link. One great benefit of VPX is the ability to choose the appropriate “pipe” size to sustain multiple dedicated data links between components with scalable speeds.

Be sure to consider I/O connections to the system, and whether or not front panel I/O cables are allowed for critical interfaces to analog signals, networks, control, video and storage. Many VPX modules deliver at least some of these signals through backplane connectors using rear-transition modules, so be sure to identify and list all I/O requirements and restrictions before selecting modules.

Selecting Modules

Now, conduct an industry survey to satisfy the functions in the block diagram with candidate modules that also meet the physical and environmental constraints. One good starting point is the VPX product directory on the VITA website (www.vita.com). For each candidate module, identify the OpenVPX module profiles that will define the gigabit serial protocols, pipe sizes and data rates.

Now look for modules that have links with the same serial protocol as the modules they must connect to. Modules with wider pipes and faster data rates can often adapt to another module with narrower and slower links, as long as the protocol is the same. If so, make sure that the resulting links can sustain the required rates.

Figure 2. Pentek SPARK 3U VPX Development System with single board computer, VPX switch and software radio modules installed, all ready for software development.

To help widen the field of choices, consider using VPX adapters or carriers that accommodate PMC, XMC or FMC mezzanine modules, effectively turning them into a VPX module. One example of a module that includes an XMC mezzanine can be seen in Figure 1. Each 3U carrier can accommodate one module, and some 6U carriers can accommodate two. Some carriers are simple adapters that bring the system interfaces of the mezzanine module out to the VPX backplane. Other carriers can include FPGAs and processors, including complete single board computers with one or more mezzanine sites.

This strategy yields a wealth of custom VPX module configurations, all based upon industry standard form factors and interfaces with offerings from many vendors.

Making the Connection

Each VPX backplane slot supports multiple planes implemented separately through certain size pipes defined in the slot profile. VPX backplanes connect the slots together using various topologies of point-to-point pipes between each of the connectors. Backplane profiles support a wide range of topologies including star, mesh, daisy-chain, and combinations of these.

Search through the VITA 65 standard backplane profiles best matching the interconnection requirements of the system block diagram, including specific pin assignments for the required pipes between modules. Remember, although the modules have specific fabric protocol assignments for each pipe, the slots and backplane profiles are completely fabric agnostic. As long as the backplane profile supports the required gigabit serial data transfer rate for a given link, any fabric and protocol can be used.

Often, the standard backplane profiles will support most, but not all of the required connections. There are several techniques to overcome this common obstacle. First, be sure to consider reordering module slot positions for the best fit. Then revisit the list of candidate modules to find another substitute module that has compatible backplane connections.

As a last resort, before considering the design of a custom backplane or custom module, consider using a backplane profile designed for a VPX switch module. Here, pipes from each slot are routed to a switch slot where the switch module acts as a crosspoint switch to join the pipes. The system engineer configures the switch to make the required connections between modules. Switch modules often support multiple protocols and usually include an Ethernet switch or hub for the control plane.

Using a switch module adds cost and a slot position, but offers an excellent solution for development and prototyping using standard, off-the-shelf products. To save costs and slots in a deployed program, a custom backplane can be developed. Often the recurring cost of a custom backplane is comparable to a standard backplane.

Getting a Head Start

Consider a pre-configured development system from one of the module vendors (see Figure 2) to help with the topology definition, backplane selection and interconnect strategies. This can eliminate many issues if you are an engineer embarking on your first design, making it possible to choose a final configuration after gaining experience on a working system.

One example of a VPX development platform is the SPARK VPX Development Platform from Pentek. It contains an SBC, switch card and one or more Pentek VPX modules, depending on customer requirements. It is ready to start software development with Windows or Linux operating system, drivers, and application examples fully installed and tested.

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