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Small Form-Factor Strategies for Embedded Systems

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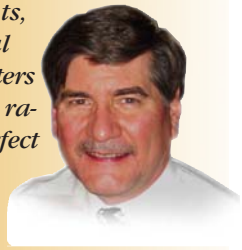

Rodger Hosking, Pentek Vice President and Co-founder

- **Product Focus:** Pentek Launches 23 models of 6U OpenVPX Boards

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- ***Updated*** edition of the *SDR Handbook*
- ***Updated*** edition of the *FPGAs for Software Radio Systems Handbook*
- ***Updated*** edition of the *High-Speed A/Ds Handbook*

The proliferation of unmanned military vehicles tasked with critical communications and radar requirements drives the need for powerful data acquisition and signal-processing products that must fit into increasingly tighter spaces. New industry standards meeting these needs offer smaller circuit boards and enclosures, optical gigabit serial links, and advanced thermal management strategies. With new resources found in the latest processors and FPGAs, system designers can now create powerful, compact systems surpassing performance levels achievable only a few years ago.

Emerging Industry Standards

The VITA and PICMG organizations actively promote and maintain standards for embedded systems suitable for commercial and military applications. Consisting of interested members from industry, academic and government organizations, each working group contributes towards the development of a new standard.

Once adopted and put into practice, refinements and extensions to these standards ensure the long life cycle support required for most government programs. Customer acceptance of a new standard fosters an open community of vendors offering compatible products compliant with the standards. Competitive market forces help keep costs down, encouraging customers to request new systems based on successful standards.

Five new small form-factor standards for embedded system modules and backplanes are currently in draft or trial use status awaiting final adoption. While each of these standards offers unique mechanical features, all of them are derivatives of existing embedded system standards. They all combine the most appropriate aspects of proven designs and leverage new technology to help reduce size, weight, power and cost (SWaP-C).

VITA 59 – Rugged COM Express: The PICMG COM Express standard defines a series of modules (cards) and backplanes supporting processors, memory, networks, and specialized I/O. VITA 59 extends COM Express for use in harsh environments of extended temperature, shock and vibration. As shown in Figure 1, this is accomplished through relatively simple mechanical modifications to the printed circuit board of the module, leaving the central PCB design largely intact.

This strategy allows developers to create two similar versions of each module, one for commercial, and one for rugged applications. Software and firmware can be developed on the commercial platform and then later deployed without changes in a fully ruggedized system.

VITA 73 – Rugged Small Form Factor: Based on the electrical specifications of VPX (VITA 46 and 48), VITA 73 aims to shrink the modules and chassis as much as possible, while maintaining full system-level performance in rugged environments. Definitions for single- and double-wide modules, both 101.5 mm deep and 71 mm across, include a variety of backplane pin configurations supporting various module functions. ➤

Figure 1. VITA 59 Rugged Com Express module adds thermal tabs to the sides of COM Express boards to pull heat out to a rugged aluminum frame (Courtesy of Men Micro)

Small Form-Factor Strategies for Embedded Systems

These include power supplies, CPUs, 2.5 in. disk drives, and payload functions such as digital and analog I/O. The backplane uses different types of pin/socket connectors for power, SATA, analog I/O, and data. Gigabit serial data pins are rated to 10 Gb/sec to handle the latest versions of popular serial standards.

VITA 74 – System Small-Form Factor Module: Like the VITA 73 specification, VITA 74 embraces all of the VITA 46 VPX electrical signal definitions for two sizes of small form-factor modules. Both are 89 mm deep and 75 mm across, with a width of either 12.68 or 19 mm. The modules connect to the backplane using the same connectors defined in VITA 57 for FMC modules and carriers, with 200 or 400 contacts, depending on the module width. Unlike VITA 73, these same connectors handle all power and signal connections to the modules.

The gigabit serial pins support rates up to at least 8 Gb/sec to support PCIe Gen. 3 interfaces commonly found in embedded platforms. VITA 74 defines a comprehensive IMPI (intelligent platform management interface) using the I^2C management bus that maintains and monitors system components and the identities of FRUs (field replaceable units).

VITA 75 – Rugged Small Form Factor

Unlike the other standards, VITA 75 addresses SWaP-C challenges by defining characteristics for the system chassis, saving the details of module size and internal connectors for later extensions. VITA 75 stresses the importance of thermal management packaging techniques to place hot components as close as possible to the cold plate or chassis walls. VITA 75 proposes two types of modules: stacked and bladed. Stacked modules use a male connector on one side of the PCB and a female on the opposite side, so that adjacent modules can be joined by pressing them together. Bladed modules are joined by a backplane with connectors similar to those on VITA 46.

VITA 75 defines many different types of rugged embedded system enclosures through numerous profiles for size, mounting and cooling options. Profiles for circular military connectors to handle power, signals, networks, and other interfaces follow a well-defined nomenclature inspired by VITA 65. Likewise, numerous front panel profiles define various combinations of connectors to meet requirements for a wide range of chassis sizes and system I/O requirements.

PICMG Rugged MicroTCA: PICMG Specification 3.x defined ATCA (Advanced Telecommunication Computing Architecture) boards, backplanes and chassis for the latest generation of commercial communications equipment. AMCs (Advanced Mezzanine Cards) are daughter-cards that attach to the main ATCA carrier boards. Widespread adoption of ATCA for high-volume commercial markets helps keep product prices lower than equivalent functions from traditional COTS vendors.

The MicroTCA specification converts AMCs to modules that can be plugged into a small form-factor chassis with a backplane. Its well defined backplane topology using gigabit serial interconnections and platform management strategies, presents a very capable architecture for high-performance embedded systems for government and military applications in benign environments.

As shown in Figure 2, Rugged MicroTCA extends these systems for deployment in harsh environments of temperature, shock, vibration, humidity, etc. Specified limits proven in qualification tests of the latest versions of Rugged MicroTCA meet or exceed those of VPX. As a result, vendors of Rugged MicroTCA are now securing design wins for ruggedized military system programs.

Figure 2. Rugged MicroTCA module incorporates an AMC module in a conduction-cooled enclosure suitable for harsh environments (Courtesy of VadaTech)

Small Form Factor-Enabling Technologies

Gigabit Serial Interfaces

A common theme pervades all five of these new standards: the use of gigabit serial interconnects to eliminate the parallel bus backplanes of previous generation systems like VMEbus and CompactPCI. Virtually all consumer, commercial, industrial, and military applications have enjoyed widespread adoption of these gigabit serial standards including Gigabit Ethernet (GbE), PCI Express (PCIe), SATA, SerialRapidIO (SRIO), and others.

A single gigabit serial link can deliver high-speed data over a single differential pair at rates to 10 Gb/sec, or more. This reduces the circuit board area and the number of connector pins required to sustain a given data transfer rate.

FPGAs

FPGAs offer designers more ways to achieve smaller form factors than virtually any other device. Built-in gigabit serial interfaces and standard protocol engines for PCIe and GbE eliminate the need for additional interface chips. Custom protocol requirements, like SerialFPDP, can be configured using internal FPGA resources. This technique extends easily to simpler tasks such as custom data formatting, buffering and packetizing.

Configurable I/O ports on FPGAs handle direct connections to specialized peripheral interfaces for exotic sensors and transducers, like a 48-bit interface to a 3.6 GHz 12-bit A/D, for example. Timing, gating, triggering, and synchronization structures for critical applications like phased-array radars take ➤

Small Form-Factor Strategies for Embedded Systems

advantage of configurable logic, state machines, and counters, all inside the FPGA.

FPGAs also feature built-in advanced SDRAM controllers for direct connection to external DDR3 memory chips, essential for transient capture of radar pulses, digital delay lines and signal-processing workspace. Sophisticated circuitry automatically trains the memory timing signals for optimum performance at power up.

Front-end digital signal-processing requirements, like digital downconverters for software radios, are perfect candidates for the many DSP engines found on most FPGAs. The largest Virtex-7 device now contains 3600 DSP48E engines, vastly outstripping the raw processing power of DSPs and GPPs. This type of preprocessing can deliver two-fold savings: lower output data rates and simpler downstream processing engines.

These benefits result in smaller circuit boards, fewer components, and simpler connections. At the same time, power dissipation for a given function within a Virtex-7 FPGA has dropped by one-half compared to the previous Virtex-6 generation. This eases thermal management and extends missions for battery-operated or power-sensitive applications.

Backplane Optical Interfaces

Initiatives by standards organizations for optical interconnections are now yielding product offerings. Approved standards from the VITA 66 Fiber Optic-Interconnect group define three backplane optical interfaces for 3U and 6U VPX; these are variants based on MT, ARINC 801 Termini, and Mini-Expanded Beam optical technology, respectively.

All of them support single- or multi-mode fiber interfaces by replacing one or more of the standard VPX-bladed connectors. Blind-mate connectors between the VPX module and the backplane feature spring-loaded inserts containing optical cable assemblies that float within metal housings. Alignment pins and holes in each half of the mating assemblies ensure exact alignment of the polished ends of each optical path. The MT variant in VITA 66.1 provides the highest density with up to 24 pairs of optical fibers, while VITA 66.2 and 66.3 both provide two pairs.

The unreleased VITA 66.4 standard based on the high-density MT ferrule uses a half-size metal housing for a smaller module and backplane footprint. 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. This small module interfaces 12 lanes of gigabit serial electrical signals to laser transmitters and receivers connected through 12-lane optical flat ribbon cables and terminated in an MT ferrule.

Figure 3 shows the Pentek Flexor Model 5973 3U OpenVPX carrier for FMC illustrating these small form-factor enabling technologies including PCIe Gen. 3 system interface, the Virtex-7 FPGA, and the first implementation of the proposed VITA 66.4.

Optical interfaces benefit small form-factor systems in many different ways. Optical cables are lightweight, smaller diameter alternatives to copper cables, especially important in unmanned vehicles sensitive to weight and packed tightly with electronic payloads. They are completely immune to electromagnetic susceptibility or emissions for added reliability in electrically noisy environments such as antenna masts and engine rooms, and for added security against eavesdropping.

Optical cables can transport existing gigabit serial traffic at rates beyond 10 Gb/sec, extending these interfaces between modules, chassis and racks. Depending on the optical fiber mode, these links can extend from 100 meters to several kilometers, easily covering the length of the largest aircraft and surface vessels. Remote sensors and data acquisition pods in small enclosures can be mounted close to antennas, sending digitized signals back to a central processing center across optical links.

Choosing the Best Small Form-Factor Solution

With so many proposed approaches to small form-factor embedded systems, engineers need to determine which technical aspects of each approach are most important for a particular application and carefully consider the companies backing each standard. It is highly likely that no single standard will emerge as the winner.

However, system designers waiting for a final outcome will miss out on the significant, tangible benefits available today. New extensions to these standards will be inspired by customer-driven opportunities, helping steer the technology with real-world requirements. ❑

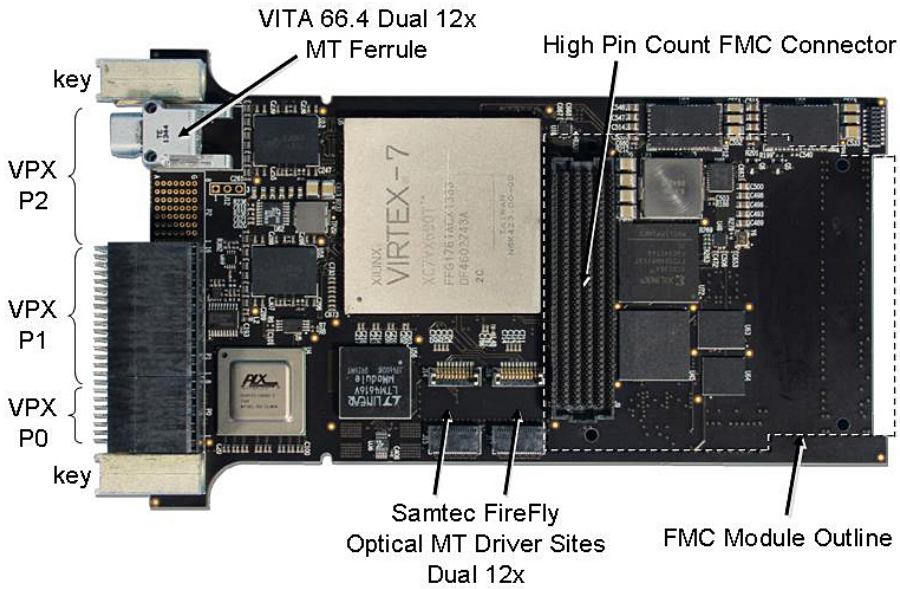


Figure 3. The Pentek Model 5973 3U OpenVPX FMC Carrier uses Samtec FireFly™ Micro Flyover which delivers 12 optical fiber pairs to the proposed VITA 66.4 backplane I/O
(More information on the Model 5973 on page 5)

Making Product Development Easier for You

Now Shipping!

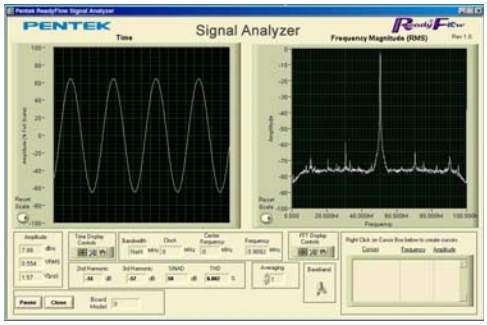
Model 8267 Development System for OpenVPX Onyx, Cobalt and Flexor Boards

SPARK Development Systems

The Model 8267 is a fully-integrated, 3U OpenVPX development system for Pentek Cobalt, Onyx and Flexor software radio, data acquisition, and I/O boards. It was created to save engineers the time and expense associated with developing a system that ensures optimum performance of Pentek boards. More information:

pentek.com/go/pipe8267

Start Application Development Today!



Pentek's Signal Analyzer is a full-featured analysis tool that continuously displays live signals in both time and frequency domains. The signal analyzer is available with all SPARK development systems.

Also Shipping!

Model 8266 Development System for PCI Express Onyx, Cobalt and Flexor Boards

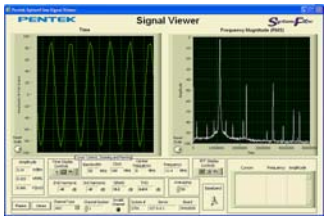
SPARK Development Systems

The Model 8266 resolves the typical hardware and software compatibility obstacles inherent in new PC development platforms. All hardware is installed in appropriate slots with proper cabling, power and cooling strategies, and optimized BIOS. More information:

pentek.com/go/pipe8266

Video Spotlight

*View **SystemFlow Software** for Talon Recorders*



Topics include: API, GUI, Signal Viewer and Analyzer, Libraries, and the NTFS system

Download the SystemFlow Simulator and see how easy it is to set up and use our Talon Recorders!

Video Spotlight

View Virtex-6 Board Ideal for Multichannel Waveform Generation

Cobalt Model 78670
Quad 1.25 GHz, 16-bit D/A

Downloadable Segment & Product Catalogs

Analog & Digital I/O

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Radar & SDR I/O

Software & FPGA Tools

High-Speed Recorders

Onyx/Cobalt Catalog

Product Focus

Model 5973

3U OpenVPX Virtex-7 Processor and FMC Carrier

Features

- High-pin count FMC site supports a wide range of analog and digital I/O
- Supports Xilinx Virtex-7 VXT FPGAs
- GateXpress supports dynamic FPGA reconfiguration across PCIe
- 4 GB of DDR3 SDRAM
- PCI Express (Gen. 1, 2 and 3) interface up to x8
- Optional optical Interface for backplane gigabit serial interboard communication
- Compatible with several VITA standards including: *VITA-46, VITA-48, VITA 57.1, VITA-66.4 and VITA-65 (OpenVPX™ System Specification)*
- Ruggedized and conduction-cooled versions available

FlexOr GateXpress

The Flexor™ Model 5973 is a high-performance 3U OpenVPX board based on the Xilinx Virtex-7 FPGA. As a stand-alone processor board, it provides an ideal development and deployment platform for demanding signal-processing applications.

The 5973 includes a VITA-57.1 FMC site providing access to a wide range of I/O options. When combined with any of Pentek's analog interface FMCs, it becomes a complete multi-channel data conversion and processing subsystem suitable for connection to IF, HF or RF ports of a communications or radar system.

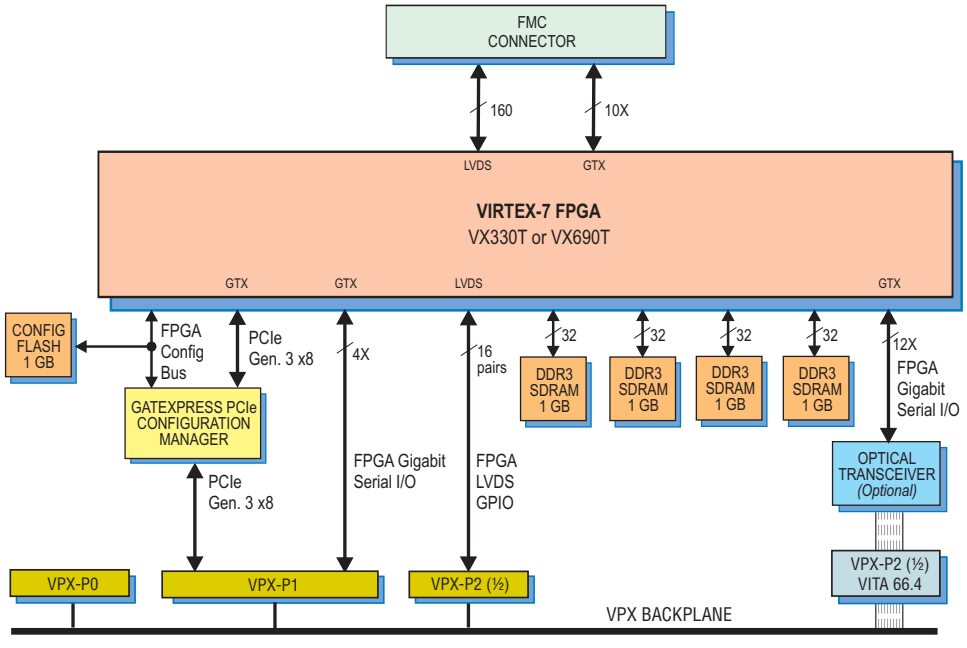
When used with Pentek's gigabit serial copper or optical interface FMCs, the 5973 becomes a high speed data streaming and processing interface. Its built-in data capture and playback features and Gen. 3 x8 PCIe interface make it a turnkey solution.

Board Architecture

The architecture organizes the FPGA as a container for signal-processing applications where each function exists as an intellectual property (IP) module.

When integrated with a Pentek FMC, the 5973 is delivered with factory-installed applications ideally matched to the board's analog or digital interfaces. These can include A/D acquisition and D/A waveform playback engines for simplifying signal capture and playback.

Data tagging and metadata packet generation, in conjunction with powerful linked list DMA engines, provide a streamlined interface for moving data on and off the board and identifying data packets with channel, timing and sample count information.



IP modules for DDR3 SDRAM memories, controllers for all data clocking and synchronization functions, a test signal generator, and a PCIe interface complete the factory-installed functions and enable the 5973 and its installed FMC to operate as a complete turnkey solution without the need to develop any FPGA IP.

The 5973 can be optionally populated with one of two Virtex-7 FPGAs to match the specific requirements of the processing task. Supported FPGAs are the VX330T or VX690T.

Sixteen pairs of LVDS connections are provided between the FPGA and the VPX P2 connector for custom I/O. For applications requiring custom gigabit links, a 4X connection is supported between the FPGA and the VPX P1 connector to support serial protocols.

The 5973 supports the emerging VITA-66.4 standard that provides 12 optical duplex lanes to the backplane. With the installation of a serial protocol, the VITA-66.4 interface enables gigabit backplane communications between boards independent of the PCIe interface.

For more information, detailed specifications, and a price quotation on the Model 5973 go to: pentek.com/go/pipe5973 ❑

Coming soon! Model 7070 PCI Express Virtex-7 Processor and FMC Carrier

Product Focus

Model 3312

4-Channel 250 MHz 16-bit A/D, 2-Channel 800 MHz 16-bit D/A - FMC

The Flexor™ Model 3312 is a multi-channel, high-speed data converter FMC module. It is suitable for connection to HF or IF ports of a communications or radar system. It includes four 250 MHz, 16-bit A/Ds, two 800 MHz, 16-bit D/As, on-board programmable clocking, and multiboard synchronization for support of larger channel-count systems.

When combined with the Model 5973 3U OpenVPX Virtex-7 Processor and FMC Carrier, the board set becomes a turnkey data acquisition and signal generation solution. For applications that require custom processing, this board set is an ideal IP development and deployment subsystem.

Features

- Four 250 MHz 16-bit A/Ds
- One digital upconverter
- Two 800 MHz 16-bit D/As
- Sample clock synchronization to an external system reference
- VITA 57.1 high-pin count FMC
- Creates a complete radar and software radio interface solution when combined with the Model 5973 3U OpenVPX Virtex-7 FMC carrier board
- Ruggedized and conduction-cooled versions available

FlexorReady Flow Board Support Libraries

A/D Acquisition Engine

When used with the 5973, the 3312 features four A/D acquisition IP modules for easily capturing and moving data. Each module can receive data from any of the four A/Ds, a test signal generator or from the D/A waveform playback IP module in loopback mode.

Each IP module can have an associated memory bank on the 5973 for buffering data in FIFO mode or for storing data in transient capture mode. All memory banks are supported with DMA engines for easily moving A/D data through the 5973's PCIe interface.

These powerful linked-list DMA engines are capable of a unique acquisition gate-driven mode. In this mode, the length of a transfer performed by a link definition need not be known prior to data acquisition; rather, it is governed by the length of the acquisition gate. This is extremely useful in applications where an external gate drives acquisition and the exact length of that gate is not known or is likely to vary.

For each transfer, the DMA engine can automatically construct metadata packets containing A/D channel ID, a sample-accurate time stamp and data length information. These actions simplify the host processor's job of identifying and executing on the data.

D/A Waveform Playback Engine

When used with the 5973, the 3312 features a sophisticated D/A waveform play- back IP module. A linked-list controller allows users to easily play back to the D/As waveforms stored in either on-board or off-board host memory.

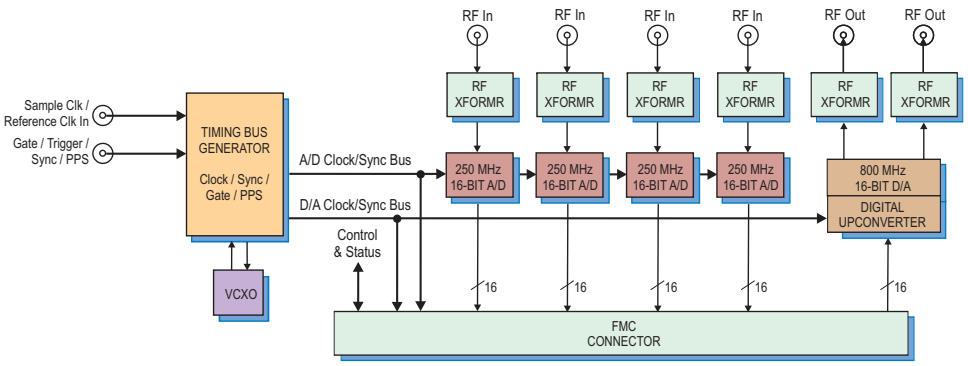
Digital Upconverter and D/A

A TI DAC5688 DUC (digital upconverter) and D/A accepts a baseband real or complex data stream from the FPGA and provides that input to the upconvert, interpolate and D/A stages.

When operating as a DUC, it interpolates and translates real or complex baseband input signals to any IF center frequency up to 360 MHz. It delivers the output to the 16-bit D/A converter.

If translation is disabled, the DAC5688 acts as a dual interpolating 16-bit D/A with output sampling rates up to 800 MHz. In both modes the DAC5688 provides interpolation factors of 2x, 4x and 8x.

For more information, detailed specifications, and a price quotation on the Model 3312 go to: pentek.com/go/pipe3312 ❑



Coming soon! Model 3316 8-Channel 250 MHz, 16-bit A/D FMC Module

Product Focus

6U OpenVPX Products

Pentek Launches Extensive Line of Cobalt and Onyx 6U OpenVPX Products

Pentek has just announced the addition of 6U OpenVPX boards to the Pentek product line: the Models 57xxx with one XMC module installed and the Models 58xxx with two XMC modules installed. These products extend the Pentek building block strategy of using Cobalt Virtex-6 and Onyx Virtex-7 XMC FPGA modules on carriers for open architecture industry-standard form factors.

Pentek's 6U VPX boards for data acquisition, software radio and digital signal processing offer flexible, gigabit serial fabric connections for demanding radar, beamforming, communications, and signal intelligence applications. These new boards are designed for both lab and rugged environments with deployable conduction-cooling options.

Building Block Strategy

The 6U VPX Model 57xxx and Model 58xxx boards accommodate either one (57xxx) or two (58xxx) Cobalt or Onyx XMCs, significantly increasing the functional density of a VPX slot. With the 57xxx versions, users can install their own XMC module in the second site.

Board Connectivity

The 6U OpenVPX boards take advantage of the increased I/O to the backplane by adding optional LVDS lines from the FPGA on each XMC to user pins of the VPX backplane connectors. Optional dual x4 user-configurable gigabit serial links provide additional interconnect options between the two installed XMC modules and the VPX backplane.

The VPX product strategy leverages Pentek's wide range of proven FPGA-based XMCs featuring advanced IP cores and high-performance I/O, all fully supported with development software and FPGA design tools. This strategy affords Pentek customers faster delivery and increased performance, while reducing risks and speeding embedded system development.

The table includes all the currently available Cobalt and Onyx 6U OpenVPX products. Click on each model for its datasheet.

Model	Description	Xilinx FPGA
Model 57610	LVDS Digital I/O	Virtex-6
Model 57611	Quad Serial FPDP Interface	Virtex-6
Model 57620	Triple 200 MHz A/D and Dual 800 MHz D/A	Virtex-6
Model 57621	Triple 200 MHz A/D, DDC, DUC and Dual 800 MHz D/A	Virtex-6
Model 57630	1 GHz A/D and 1 GHz D/A	Virtex-6
Model 57640	Single 3.6 GHz or Dual 1.8 GHz 12-bit A/D	Virtex-6
Model 57641	Single 3.6 GHz or Dual 1.8 GHz 12-bit A/D with DDC	Virtex-6
Model 57650	Dual 500 MHz A/D and Dual 800 MHz D/A	Virtex-6
Model 57651	Dual 500 MHz A/D, DDC, DUC and Dual 800 MHz D/A	Virtex-6
Model 57660	Quad 200 MHz, 16-bit A/D	Virtex-6
Model 57661	Quad 200 MHz A/D with DDC	Virtex-6
Model 57662	Quad 200 MHz A/D with 32-Channel DDC	Virtex-6
Model 57663	1100-Channel GSM Channelizer with Quad A/D	Virtex-6
Model 57670	Quad 1.25 GHz, 16-bit D/A	Virtex-6
Model 57671	Quad 1.25 GHz, 16-bit D/A, DUC, Extended Interpolation	Virtex-6
Model 57690	L-Band RF Tuner and Dual 200 MHz A/D	Virtex-6
Model 57720	Triple 200 MHz A/D and Dual 800 MHz D/A	Virtex-7
Model 57721	Triple 200 MHz A/D, DDC, DUC and Dual 800 MHz D/A	Virtex-7
Model 57730	1 GHz A/D and 1 GHz D/A	Virtex-7
Model 57741	Single 3.6 GHz or 2-Channel 1.8 GHz 12-bit A/D with DDC	Virtex-7
Model 57751	Dual 500 MHz A/D, DDC, DUC and Dual 800 MHz D/A	Virtex-7
Model 57760	Quad 200 MHz, 16-bit A/D	Virtex-7
Model 57761	Quad 200 MHz A/D with DDC	Virtex-7