

# The Pentek Pipeline

*A quarterly publication for engineering system design and applications.*

**Pentek, Inc.**

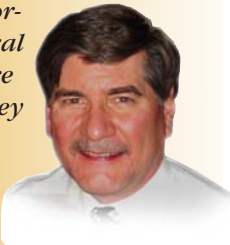
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**In This Issue**

- Processors in server-class workstations have become powerful enough to contend for demanding real-time applications. More in the feature article.

*“Embedded-board vendors should incorporate several temperature sensors at key locations around the board to help validate cooling strategies”*



*Rodger Hosking, Pentek Vice President and Co-founder*

- Product Focus:** [Pentek Launches New Line of 3U OpenVPX Products](#)

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## Cooling Strategies for Real-Time Embedded PC Systems

Processors in server-class workstations have become powerful enough to contend for some of the most demanding real-time embedded applications. Integrating these cost-effective platforms with the open-architecture board-level products required for government and military applications poses significant challenges for system designers. Adequate cooling of these power-hungry boards to assure reliable system operation is a critical need.

### Workstation Benefits and Limitations

Server-class PC workstations offer the benefits of high-end processing, fast data links, efficient power management, deep and fast memory, low latency, and capable network interfaces—all in a larger desktop or rackmount chassis. Powerful CPUs like Intel’s multicore Xeon or Core i7 processors are tightly coupled to advanced chipsets for PCIe expansion slots, multichannel DDR3 memory and 1 GbE network connections. These key factors offer specific benefits to real-time applications, where high-rate continuous and sustained data transfers between system components must be guaranteed.

Driven by the large markets for enterprise computing, web and file servers, and cloud computing, prices for these systems have become extremely competitive, compared to alternative embedded-system architectures such as VME, CompactPCI and OpenVPX. Unlike these traditional platforms, PC servers fail to provide the forced-air or conduction-cooling facilities necessary to remove the 40 to 80 watts of power typically consumed by boards containing DSPs, FPGAs, A/Ds, and D/As that are essential to many real-time embedded systems.

Instead, server motherboards rely on custom heat-sink assemblies often coupled through heat pipes to finned active-cooling radiators to remove heat from the CPU and chipsets. Hot-swap disk drives mounted in accessible front-panel bays are cooled by mid-chassis fans that pull air in from the front. Power supplies contain one or more thermostatically-controlled fans to maintain safe operating temperature limits. Two or more rear panel case fans help to evacuate hot air inside the chassis.

But the site for expansion card slots in the left rear quadrant of a server chassis has no standard provision for cooling. Furthermore, the ▶



*Figure 1. Ten temperature sensors distributed around the Pentek Model 71760 XMC module before mounting it on a PCIe carrier board ensure valid monitoring of cooling effectiveness.*

## Cooling Strategies for Real-Time Embedded Systems

rear PC panels of the slot cards act as barriers, blocking air from the mid-chassis fans that might otherwise flow across the card surfaces. Indeed, this region of the server chassis acts as a closed box, trapping heat and causing unsafe temperatures for components on these cards.

### Cooling By Design

One of the first steps in evaluating any cooling solution is accurate measurement of its effectiveness. Motherboards often include extensive temperature monitoring facilities of the CPU and other critical components as part of the BIOS and system driver software. Disk drives report temperatures through SATA and RAID controller software utilities.

Likewise, embedded-board vendors should incorporate several temperature sensors at key locations around the board to ensure that no hot spot is missed. Also, many high-dissipation devices like DSPs and FPGAs include junction temperature sensors as part of the silicon die. Monitoring these chip sensors is essential to ensure sufficient cooling for maintaining junction temperatures within the manufacturer's limits.

As an example, Figure 1 on the previous page shows the Pentek 71760 Quad 200 MHz 16-bit A/D card with ten temperature sensors, including junction sensors for the Virtex-7 FPGA and the PCIe switch. A software utility reports all ten sensor readings to help score different thermal management techniques during system integration and testing. After deployment, independently programmable threshold settings allow alarm notification to the system through a PCIe interrupt and a front panel LED—if any sensor exceeds a pre-determined temperature. This is extremely valuable as an alert to end users of a fan failure or airflow blockage during operation.

XMC and PMC, both industry-standard mezzanine modules for embedded systems, can be adapted to PC servers through the use of PCIe carrier cards that bring the PCI or PCIe interface of the modules down to PCIe edge fingers for the motherboard card slots. In these boards, most of the heat is dissipated on the inside surface of the module which faces the carrier card. One



Figure 2. A wrap-around heat sink assembly pulls heat from components on the underside of the XMC module so it isn't trapped by the PCIe carrier card.

effective solution, shown in Figure 2, is to provide a wrap around copper or aluminum structure for the XMC module that pulls heat from the hotter inner components and dissipates it on the outer surface of the board where more airflow is available.

### Effective Fan Strategies

Faced with the thermally-unfriendly environment of the server chassis, many mass-market graphics processor cards have an active heat sink, incorporating a small fan within the cooling fins. For embedded XMC modules, a cutout opening in the PCIe carrier card directly under the hottest components allows clearance for an aluminum heat sink that conducts heat through the cutout to fins on the other side of the carrier card. An embedded fan forces air across the fins for active cooling.

This strategy works extremely well for PMC/XMC module adapters for high-power FPGA-based embedded system boards like the one shown in Figure 3. This adapter reduces temperatures of the FPGA silicon junction by 10°C or more.

Air-flow sensor probes can be helpful to locate the dead spots and determine if moving a fan or using a different fan with a higher CFM rating could be more effective. Since air flow is hard to visualize, the best solution is often found by trial and error.

One or more case fans placed directly above the expansion cards blowing downward between the cards is one of the most effective cooling techniques. Since this type of fan is not provided in most server chassis, a special bracket or mounting plate must be fabricated that attaches to the chassis. This requires a chassis with a height of at

least 4U to provide vertical clearance for the fan itself and a large enough gap under the top cover to allow adequate air intake.

Figure 4 on the next page shows a single 120 mm case fan mounted on a custom plate in a 4U rackmount chassis. When properly implemented, this type of fan can provide up to 15°C of additional cooling.

### Card Relocation

Another strategy for optimal cooling is simply moving the expansion cards to slot positions that offer the best airflow or clearance. Often, the best slot is the end slot towards the center of the chassis. Although a server motherboard typically has a maximum of seven card slots, the choice of slots is often limited by other considerations. Each one can differ in its interface (PCI or PCIe) and in the number of PCIe ▶

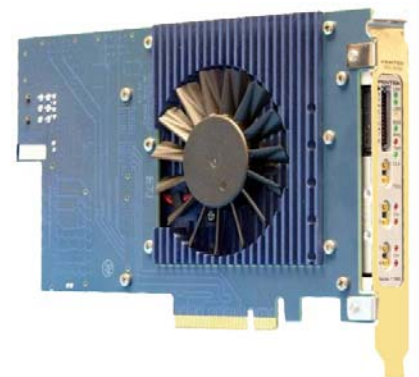


Figure 3. A fan-equipped heat sink attached through a cutout in the PCIe carrier card, removes heat effectively from the hot components on the inside surface of the attached XMC module.



## Cooling Strategies for Real-Time Embedded Systems

lanes. The number of PCIe lanes defines the maximum potential data transfer bandwidth of a card slot, so cards requiring the highest transfer rates are only supported by certain slots.

In addition, the PCIe chipset often imposes certain maximum lane restrictions on combinations of slots used. For example, an x16 slot could be reduced to x8 if another card is plugged into the adjacent slot. Therefore, the system designer must often trade-off between the card slot positions and the data transfer rates to achieve the best cooling configuration.

### Summary

Successful thermal management requires multiple strategies, both at the board design level and during system integration. Embedded cards should be equipped with thermal sensors and software monitoring utilities. Taking advantage of these sensors, in addition to sensors for motherboard components and disk drives, can help during system integration and testing, and benefit the end user.



Figure 4. A top-mounted 120 mm fan blows air down onto expansion cards

Conducting heat from hot components like FPGAs through metal structures to fins that are exposed to airflow is essential for maintaining silicon-junction temperature margins. Fans incorporated within the card heat sinks, or mounted separately, provide targeted air flow in the poorly-ventilated

card slot area of most server chassis. Finally, card slot relocation can make a difference.

Experience is invaluable in the often elusive and frustrating task of cooling embedded PC systems. Applying these common-sense strategies will help system designers find the best solution. □

### Start Application Development Today!

Model 8266 PC Development System for PCIe Onyx and Cobalt Boards

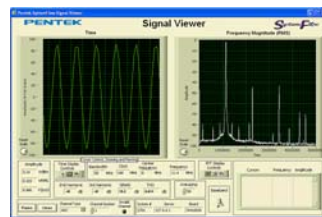


The Model 8266 resolves the typical hardware and software compatibility obstacles inherent in new PC development platforms. All hardware is installed in appropriate slots with proper cabling, power and cooling strategies, and optimized BIOS. For more information: [pentek.com/go/pipe8266](http://pentek.com/go/pipe8266)

### Video Spotlight



View **SystemFlow Software** for Talon Recorders



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

### Video Spotlight

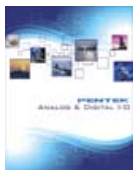


View **Virtex-6 Board** Ideal for Multichannel Waveform Generation



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

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# Product Focus

## OpenVPX Products

### Pentek Launches New Line of OpenVPX Products with Lower Power Consumption and Cost

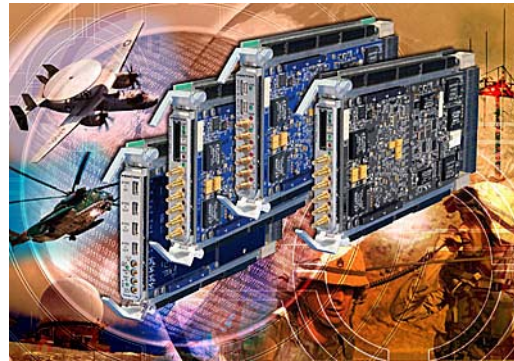
Pentek recently announced the 52xxx board family of power- and cost-reduced versions of the 53xxx family of products. These compact 3U OpenVPX software radio modules incorporate Xilinx Virtex-6 or Virtex-7 FPGAs for on-board signal processing. The 52xxx boards represent a complete family of ruggedized and commercial grade boards for high-performance military and avionics applications utilizing the industry's most advanced FPGA technology.

By combining processing, data conversion, and preconfigured functions, the 52xxx family is suitable for such applications as SIGINT and COMINT receivers for UAVs, airborne communication transceivers and radar countermeasures, shipboard diversity transceivers and armored vehicle anti-IED systems. The 15-watt power savings boosts packaging densities, processing efficiencies and overall system performance.

Pentek customers using the 52xxx series can now achieve a substantial savings in their power and cost budgets without taking a hit on performance. In addition, the 52xxx OpenVPX products benefit from a parallel offering of functionally-equivalent PCI Express cards. This way, customers can jump start their development effort in a low-cost desktop PC, and then deploy 3U OpenVPX 52xxx boards in the final application system.

Pentek's 52xxx OpenVPX boards feature ruggedized construction and extended temperature options—essential for military equipment. The products are available in commercial and rugged packages, with air-cooled and conduction-cooled options. The boards support PCIe x4 over the VPX P1 connector, a popular configuration for 3U OpenVPX modules. The 52xxx boards are fully compatible with Pentek's 53xxx 3U OpenVPX boards which include a fully programmable serial fabric crossbar switch.

The 52xxx family provides developers with a high level of processing power. Pentek installs numerous signal processing, data acquisition and control functions in the Virtex FPGA to support popular radar and communications applications.



Model	Description	Xilinx FPGA
<a href="#">Model 52620</a>	Triple 200 MHz A/D, DUC and Dual 800 MHz D/A .....	Virtex-6
<a href="#">Model 52621</a>	Triple 200 MHz A/D with DDC, DUC and Dual 800 MHz D/A .....	Virtex-6
<a href="#">Model 52660</a>	Quad 200 MHz, 16-bit A/D .....	Virtex-6
<a href="#">Model 52661</a>	Quad 200 MHz 16-bit A/D with Quad DDC .....	Virtex-6
<a href="#">Model 52662</a>	Quad 200 MHz 16-bit A/D with 32-Channel DDC .....	Virtex-6
<a href="#">Model 52690</a>	L-Band RF Tuner and Dual 200 MHz A/D .....	Virtex-6
<a href="#">Model 52720</a>	Triple 200 MHz A/D, DUC and Dual 800 MHz D/A .....	Virtex-7
<a href="#">Model 52760</a>	Quad 200 MHz, 16-bit A/D .....	Virtex-7
<a href="#">Model 52650</a>	Dual 500 MHz A/D, DUC and Dual 800 MHz D/A .....	Virtex-6
<a href="#">Model 52651</a>	Dual 500 MHz A/D, DDC, DUC and Dual 800 MHz D/A .....	Virtex-6
<a href="#">Model 52630</a>	Single 1 GHz 12-bit A/D and 1 GHz 12-bit D/A .....	Virtex-6
<a href="#">Model 52670</a>	Quad 1.25 GHz, DUC and 16-bit D/A .....	Virtex-6
<a href="#">Model 52671</a>	Quad 1.25 GHz, DUC w. Extended Interpolation, and 16-bit D/A ....	Virtex-6
<a href="#">Model 52640</a>	Single 3.6 GHz or Dual 1.8 GHz 12-bit A/D .....	Virtex-6
<a href="#">Model 52641</a>	Single 3.6 GHz or Dual 1.8 GHz 12-bit A/D with DDC .....	Virtex-6
<a href="#">Model 52610</a>	LVDS Digital I/O .....	Virtex-6
<a href="#">Model 52611</a>	Quad Serial FPDP Interface - Optical or Copper .....	Virtex-6
<a href="#">Model 5292</a>	High-Speed Synchronizer and Distribution Board .....	None
<a href="#">Model 5294</a>	High-Speed Clock Generator .....	None

### Develop in PCIe and Deploy in OpenVPX



*The 52xxx OpenVPX products benefit from a parallel offering of functionally-equivalent PCI Express cards. You can jump start your development effort in a low-cost desktop PC, and then deploy 3U OpenVPX 52xxx boards in the final application system.*



# Product Focus

## Model 52610

### General Information

Model 52610 is a member of the Cobalt® family of high-performance 3U VPX boards based on the Xilinx Virtex-6 FPGA. This digital I/O board provides 32 LVDS differential inputs or outputs plus LVDS clock, data valid, and data flow control on a front panel 80-pin connector. Its built-in data capture and data generation feature offers an ideal turnkey solution as well as a platform for developing and deploying custom FPGA-processing IP.

In addition to supporting PCI Express Gen. 1 as a native interface, the Model 52610 includes a general-purpose connector for application-specific I/O.

### The Cobalt Architecture

The Pentek Cobalt Architecture features a Virtex-6 FPGA. All of the board's data and control paths are accessible by the FPGA, enabling factory-installed functions for data flow and memory control. The Cobalt Architecture organizes the FPGA as a container for data-processing applications where each function exists as an IP (intellectual property) module.

## 3U OpenVPX Board with LVDS Digital I/O and Virtex-6 FPGA

### Features

- 32 bits of LVDS digital I/O
- One LVDS clock
- One LVDS data valid
- One LVDS data suspend
- Supports LXT and SXT Virtex-6 FPGAs
- Up to 2 GB of DDR3 SDRAM
- PCI Express interface
- Optional user-configurable gigabit serial interface
- Optional LVDS connections to the Virtex-6 FPGA for custom I/O to the carrier board
- Ruggedized and conduction-cooled versions available



Model 52610 is also available in XMC, PCI Express, AMC, and CompactPCI formats.



Each member of the Cobalt family is delivered with factory-installed applications ideally matched to the board's interface. The 52610 factory-installed functions include 32-bit acquisition and generation IP modules, to support either input or output functions, respectively.

IP modules for DDR3 SDRAM memories, a controller for all data clocking, a test signal generator, and a PCIe interface complete the factory-installed functions and enable the 52610 to operate as a complete turnkey

solution without the need to develop any FPGA IP.

### Acquisition IP Module

The board can be configured for digital input mode by the setting of a jumper. In this case, the board accepts input data Clock and input data Valid signals. This supports a continuous input Clock with data accepted only when the Data Valid line is true.

### Generation IP Module

The board can be configured for digital output mode by the setting of a jumper. In this case, the board generates output data Clock and output Data Valid signals. This supports a continuous output Clock with data valid only when the Data Valid line is true.

### PCI Express Interface

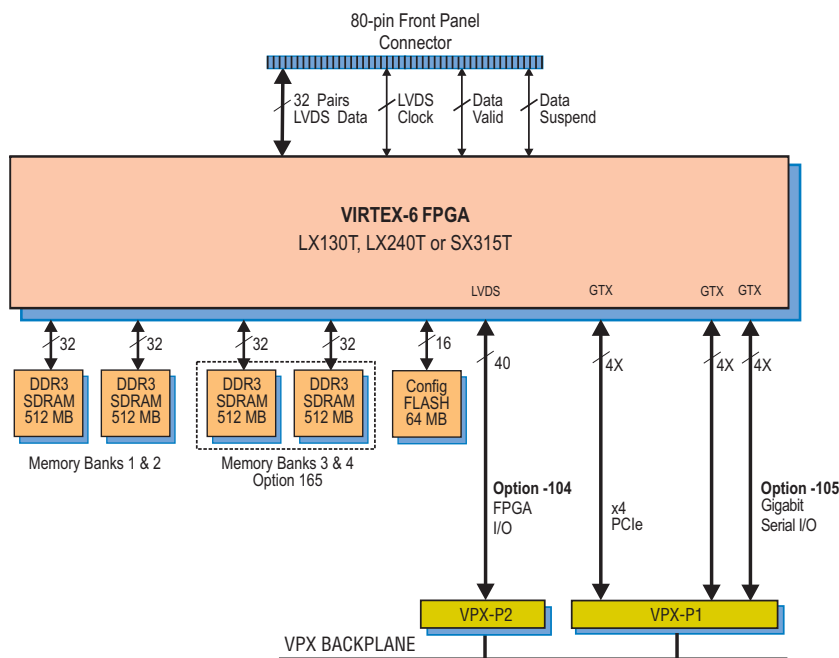
The Model 52610 includes an industry-standard interface fully compliant with PCI Express Gen. 1 bus specifications. Supporting a PCIe x4 connection, the interface includes multiple DMA controllers for efficient transfers to and from the board.

### Memory Resources

The 52610 hardware architecture supports up to four independent 512 MB memory banks of DDR3 SDRAM.

For more information and a price quotation on the Model 52610, go to:

[pentek.com/go/pipe52610](http://pentek.com/go/pipe52610) □



# Product Focus

## Model 5294

### 3U OpenVPX Board Serves as High-Speed, High-Purity Clock Generator

#### General Information

Model 5294 High-Speed, High-Purity Clock Generator provides fixed-frequency sample clocks to 3U OpenVPX Cobalt and Onyx boards in multiboard systems.

It enables synchronous sampling, playback and timing for a wide range of multichannel high-speed data acquisition and software-radio applications.

#### Sample Clock Synthesizer

The Model 5294 uses a high-precision, fixed-frequency, PLO (Phase-Locked Oscillator) to generate an output sample clock. The PLO accepts a 10 MHz reference clock through a front-panel SMA connector.

The PLO locks the output sample clock to the incoming reference. A power splitter then receives the sample clock and distributes it to four front panel SMA connectors.

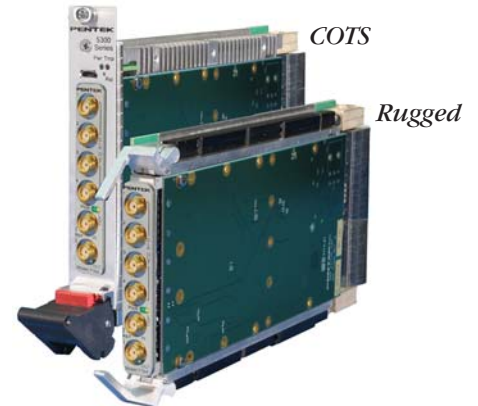
The 5294 is available with sample clock frequencies from 1.4 to 2.0 GHz.

#### On-board Reference Clock

In addition to accepting a reference clock on the front panel, the 5294 includes an

#### Features

- Provides sample clock for up to four separate 3U OpenVPX Cobalt or Onyx boards
- Locks to user-supplied 10 MHz reference clock or on-board reference
- Oven-controlled crystal oscillator provides an exceptionally precise clock



Model 5294 is also available in XMC, PCI Express, AMC, and CompactPCI formats.

on-board 10 MHz reference clock. The reference is an OCXO (Oven-Controlled Crystal Oscillator), which provides an exceptionally precise frequency standard with outstanding phase-noise characteristics.

#### Physical Characteristics

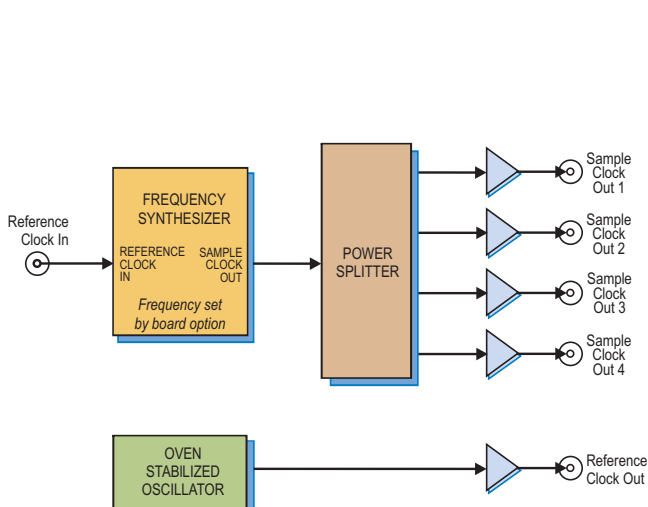
The 5294 is a standard 3U VPX board. The board does not require programming and the PCIe interface connector is used solely

for power. The board can be optionally configured with a PCIe-style, 6-pin power connector allowing it to be used in virtually any chassis or enclosure.

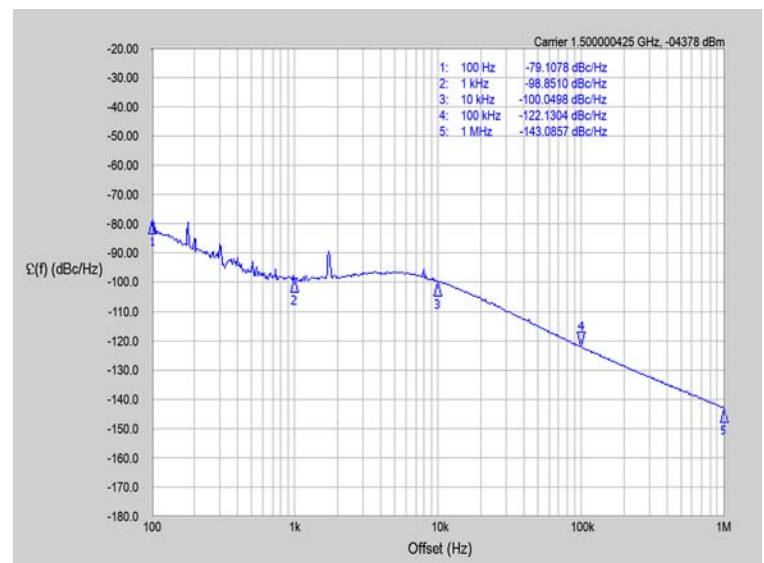
For more information, detailed specifications, and a price quotation on the Model 5294 go to:

[pentek.com/go/pipe5294](http://pentek.com/go/pipe5294) □

#### Clock Generator Block Diagram



#### Sample Clock Phase Noise



Typical Phase Noise in 1 Hz BW