

The Pentek Pipeline

A quarterly publication for engineering system design and applications.

Pentek, Inc.

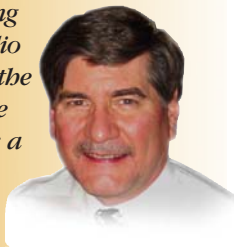
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In This Issue

- New technologies offer engineers of SDR systems opportunities to perform digital signal processing much closer to the antenna than ever before. More in the feature article.

“Many applications can benefit from pushing software radio functions up the mast to the antenna as a viable alternative to the traditional rackmount receiver systems.”



Rodger Hosking, Pentek Vice President and Co-founder

- **Product Focus:** [Pentek Launches Model 56730 AMC module](#)

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Pushing Software Radio Closer to the Antenna

New technologies offer engineers of SDR (software-defined radio) systems diverse opportunities to perform digital-signal processing much closer to the antenna than ever before. Strategies for doing so include the latest wideband data converters, monolithic receiver chips, compact RF tuners, and remote receiver modules using gigabit serial interfaces. Each approach presents benefits and tradeoffs that must be considered in choosing the optimal solution for a given application.

Wideband A/D Converters

With the emergence of monolithic A/D converters capable of sampling rates of 5 GHz and higher, engineers can now directly digitize analog RF signals covering a frequency span of more than 2 GHz. This allows the capture of wideband communications and radar signals in a single data stream, eliminating the complexity of splitting a given band into parallel adjacent sub-bands and the inevitability of input signals straddling them. While these new converters appear to simplify software radio architectures, they also impose many limitations and tradeoffs.

RF signals from the antenna must first be amplified, filtered and possibly downconverted in frequency to match the input voltage range and usable input bandwidth of the A/D converter. Optimal amplifier gain boosts the strongest signal

to the full scale input range of the A/D. Further amplification to boost weaker in-band signals will cause overloading of the A/D, which destroys the signal integrity for all signals. Thus, even one strong interfering signal will reduce the achievable dynamic range for weaker signals. This significant tradeoff occurs whenever a single A/D is used to handle a large number of signal types in a wide frequency span.

To make matters worse, as sampling rates increase, A/D converters deliver lower ENOB (effective number of bits) ratings. For example, a 5 GS/sec 10-bit A/D converter may only deliver an ENOB of 7.6 bits.

In addition, filtering is imperative to eliminate all energy outside the frequency span of interest. Otherwise, aliasing will fold out-of-band noise and adjacent signals into the digitized signal stream, degrading signal-to-noise performance and creating spurious signals.

Lastly, A/D data arriving at several gigasamples per second will overload most digital signal processors. Data de-interleaving hardware is often built into the A/D to help implementation of the electrical interface, but even so, every data sample must somehow be processed, stored or transferred. The latest families of FPGAs are especially well suited, not only in dealing with these extremely high data interface rates, but also in processing signals in real time. ▶

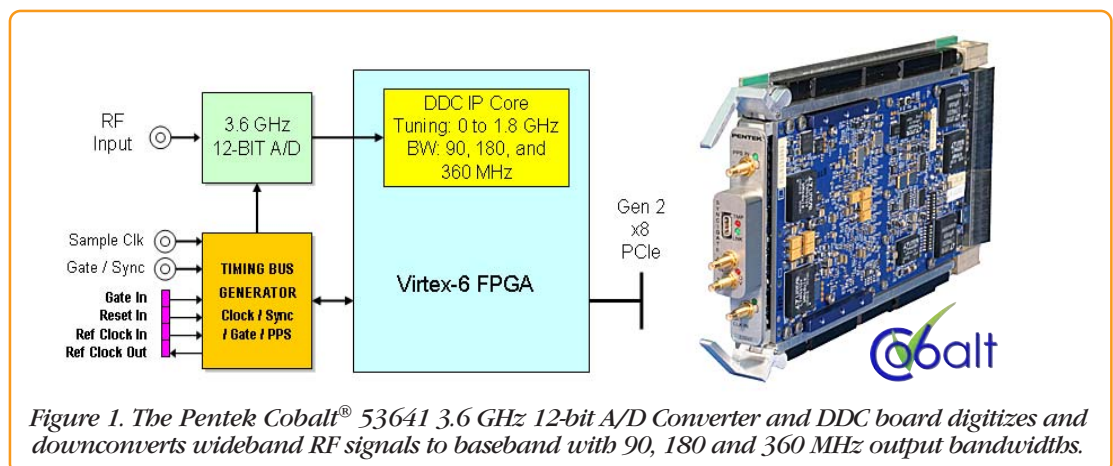


Figure 1. The Pentek Cobalt® 53641 3.6 GHz 12-bit A/D Converter and DDC board digitizes and downconverts wideband RF signals to baseband with 90, 180 and 360 MHz output bandwidths.

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A typical product example, the Pentek Model 53641 3.6 GHz A/D and DDC ruggedized OpenVPX board, is shown in Figure 1. It features a 12-bit 3.6 GS/sec A/D converter coupled to a Virtex-6 FPGA. The A/D de-interleaves samples into eight parallel 12-bit streams, delivering samples to the LVDS ports of the FPGA at 450 MS/sec each.

Inside, eight parallel engines implement a DDC (digital downconverter) that tunes across the 1.8 GHz input band. It performs frequency translation to baseband and provides digital filtering of the complex baseband output samples. Selectable output bandwidths of 90, 180 or 360 MHz, representing tunable slices of the input spectrum, are delivered to the system through a native PCIe Gen. 2 x8 interface.

Monolithic Receivers

New classes of monolithic silicon receivers offer an impressive integration of diverse RF analog circuitry required to implement a complete software radio tuner front end. These low-cost devices accept input signals directly from the antenna and deliver amplified, translated and filtered analog baseband outputs suitable for low-speed A/D converters or demodulator chips.

For example, the Maxim MAX2112, used in the Pentek Model 78690 PCI Express board shown in Figure 2, targets satellite set-top and VSAT applications including 8-PSK modulation and Digital Video Broadcast (DVB-S2) applications. It uses an LNA to boost antenna input signals falling between 925 and 2175 MHz, as well as a program-

mable-gain RF amplifier for 60 dB of overall gain control.

An integrated VCO and programmable fractional-N frequency synthesizer drive a quadrature mixer to tune across the entire input frequency range, downconverting any input signal to I+Q baseband. These baseband signals are band-limited with a pair of low-pass filters, programmable from 4 to 40 MHz.

The analog baseband I and Q tuner outputs are then applied to two Texas Instruments ADS5485 200 MHz, 16-bit A/D converters. The digital outputs are delivered into the Virtex-6 FPGA for signal processing, data capture or for routing to other board resources.

This extremely high level of integration on a single PCIe board reduces the size and cost of the receiver, and is ideal for applications restricted in space, power, weight and cost, or requiring a large number of channels.

However, while these devices work well for applications requiring only modest signal-to-noise ratios like satellite signal interception, they are not suitable for some of the more demanding government and military systems for communications, signals intelligence and radar.

Compact RF Tuners

These higher dynamic range requirements require better RF analog signal processing, including multi-conversion designs, amplifiers with lower noise figures, local oscillators with better phase noise and wider tuning

ranges, mixers that minimize unwanted spurs, and filters with better pass-band flatness, roll off and stop-band performance. Other critical factors include packaging, shielding, isolation, voltage regulation, vibration tolerance and thermal performance.

Boosting overall performance of the system is achieved by progressively improving the weakest of these signal chain elements in iterative cycles until the desired result is reached.

Each level of improvement leads directly to system level performance benefits such as lower bit error rates for digital communication systems, improved target detection range and classification accuracy for radar systems, higher intelligibility of voice interceptors, and the enhanced precision of target location and trajectory for weapons control systems.

As a result, there is a continuum of required software radio performance levels matching the operational objectives and constraints of a wide range of systems. At the low end, the monolithic receiver described above may suffice, while a very sensitive SIGINT receiver might require a large, highly-sophisticated RF subsystem.

As another factor, many applications need to cover only a limited range of input signal frequencies, such as an upper-band GSM receiver handling signals between 1700 and 2000 MHz. For these band-limited systems, simpler single-conversion RF tuner architectures can still deliver good performance. In these systems a single local oscillator and mixer downconvert the RF ➤

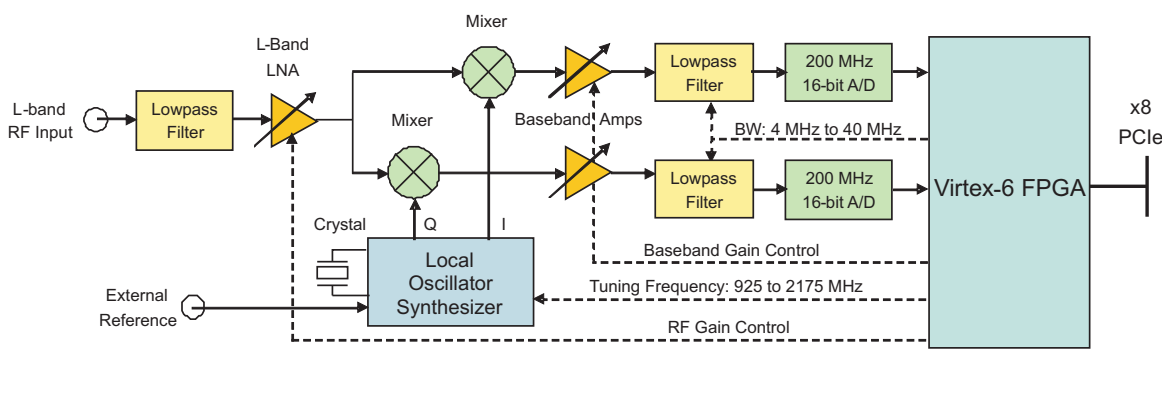


Figure 2. The Pentek Cobalt 78690 PCI Express board uses an LNA to boost L-Band signals between 925 and 2175 MHz, as well as a programmable-gain RF amplifier for 60 dB of overall gain control

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signal to a lower frequency IF signal compatible with a high-resolution A/D converter. Of course, judicious selection of amplifiers and filters, and careful analysis and suppression of mixer products are essential design tasks.

Because of the narrow tuning range, these types of RF tuners are often called “slot receivers”. They can be ideal for dedicated applications where limited frequency coverage, cost, size and weight allow placement of the tuner at or near the antenna.

One illustrative example is the Pentek [8111 Slot Receiver](#) shown in Figure 3. An input band-pass filter rejects signals outside the defined RF tuning “slot”, helping to eliminate both out-of-band noise and discrete interfering signals. The mixer and tunable local oscillator translate the RF input down to an IF frequency of 225 MHz. An IF band-pass filter excludes all signals outside an 80 MHz band centered at 225 MHz, delivering an analog output suitable for 14- or 16-bit A/D converters.

disadvantages. First, the higher the frequency, the more signal loss in the cable. To mitigate this, LNBS (low noise blocks) located on the antenna are commonly used to downconvert signals above 4 GHz (C-band and higher) to a lower frequency typically often in the L-band (1-2 GHz). Nevertheless, cables carrying these analog signals still suffer degradation and present EMI radiation and susceptibility issues. Not only do they impose a tangible weight impact in aircraft and UAVs, they also become maintenance burdens for the extremely long runs and the salt environment aboard ships.

The techniques discussed above present receiver system engineers new opportunities for digitizing signals right at the antenna. The proliferation of industry standard gigabit serial digital links offers many benefits in transmission and distribution of these digitized receiver signals. For example, GbE and 10 GbE links are so widely deployed in computer networks, WAN and LAN servers and data processing centers that

systems processors have native interfaces for SerialRapidIO and PCIe.

Each of these gigabit serial links can be delivered over copper or optical cables. Single-mode fibre cables can connect data from remote receivers up to 10 km away. This benefits large antenna array installations that must collect signals from a grid of widely spaced antennas. Optical cables are free from EMI radiation, eliminating interference to other electronics in tightly-packed manned and unmanned aircraft as well as offering security against eavesdropping. They are also immune to EMI pickup from powerful transmitters, motors and generators found in ship borne installations. Lastly, optical cables are much lighter than copper cables and are highly resistant to moisture, salt and chemicals.

Rethinking Software Radios

There is no substitute for appropriate analog RF signal conditioning prior to A/D conversion, and each technique presents

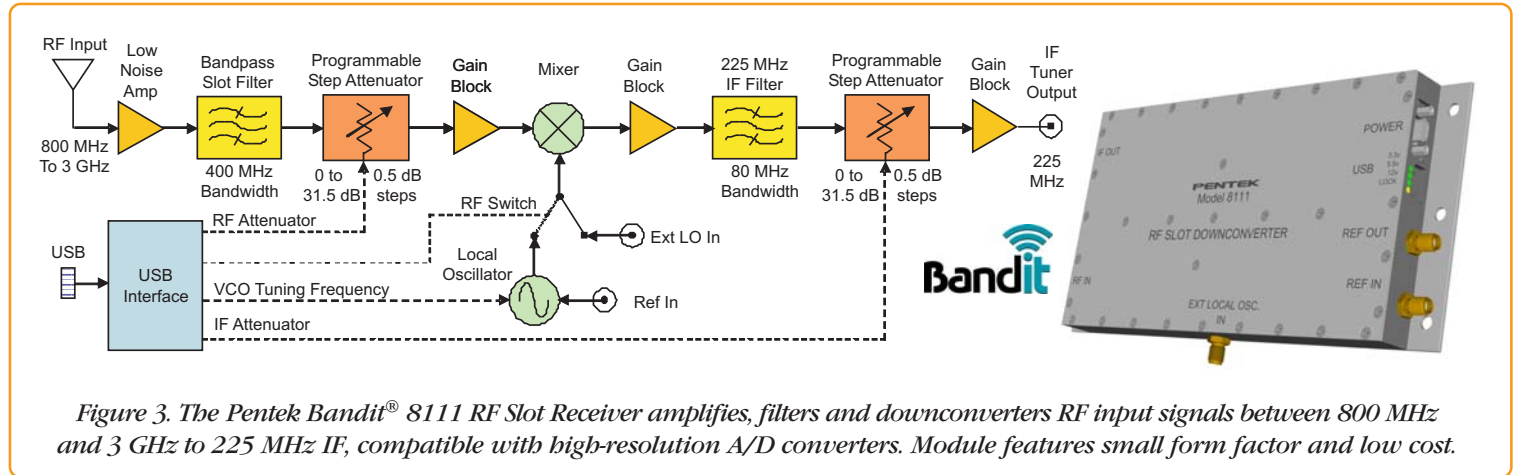


Figure 3. The Pentek Bandit® 8111 RF Slot Receiver amplifies, filters and downconverts RF input signals between 800 MHz and 3 GHz to 225 MHz IF, compatible with high-resolution A/D converters. Module features small form factor and low cost.

Low-noise amplifiers and programmable attenuators in the signal chain boost antenna signal levels to match the full-scale input voltage of the A/D. Pentek offers seven different models, each covering a different 400 MHz slot between 800 MHz and 3 GHz. An overlap of 100 MHz between adjacent slots ensures that any 80 MHz signal band can be accommodated.

Remote Receivers

Delivering high-frequency RF signals through long coaxial cables from the antenna to the receiver system has several

commercial competition has driven down costs of components, switches, bridges, cables and other infrastructure.

In the embedded computing market, FPGA vendors not only offer built-in PCIe ports, they also offer native light-weight gigabit serial protocols such as Xilinx’s Aurora and Altera’s SerialLite. These, along with SerialFPDP, are ideal for delivering raw A/D or baseband I+Q samples from an FPGA-based front end. At the receiving end, host bus adapters are available for all of these protocols, and many embedded

its own application-specific tradeoffs. Nevertheless, the added benefits of antenna site software radio receivers are numerous.

FPGAs can implement essential DDC functions and deliver digital baseband samples across an industry-standard digital gigabit serial link. Because these links are full-duplex, the same cable provides a path for control and status functions for the host. Digital receiver data can be easily distributed to multiple destinations using low cost switches and readily archived on storage servers, as shown in Figure 4 on the next page. ➤

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For sensitive signals and classified information, data encryption can be easily included before transmission. Additional preprocessing algorithms such as radar pulse-compression, FFT energy calculations, scanning and threshold detection can be incorporated within the FPGA to reduce transmission data rates and offload these processing tasks from the host system.

It is apparent that many applications can benefit from pushing software radio functions up the mast to the antenna as a viable alternative to the traditional rackmount receiver systems. □

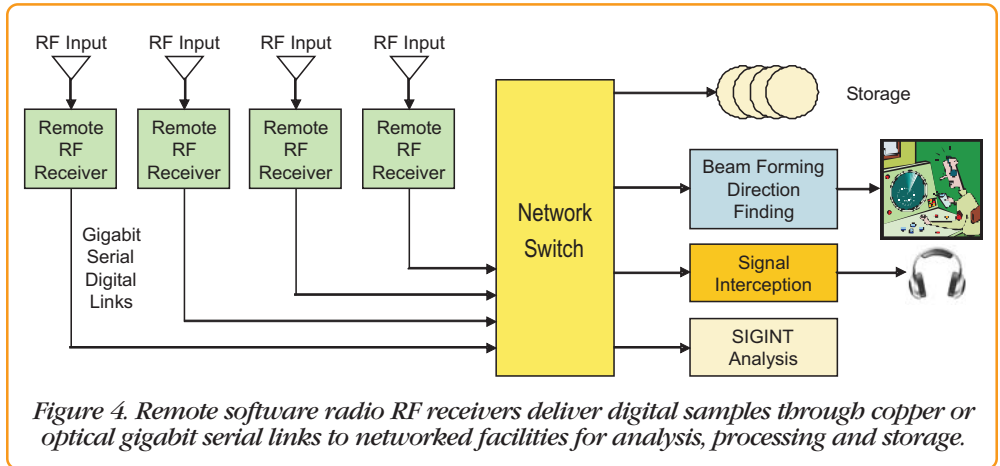


Figure 4. Remote software radio RF receivers deliver digital samples through copper or optical gigabit serial links to networked facilities for analysis, processing and storage.

[The Model 53641](#) 3.6 GHz, 12-bit A/D Converter and DDC with Virtex-6 FPGA is also available in the following formats:

[3U OpenVPX: Model 52641](#)

[PCIe: Model 78641](#)

[XMC: Model 71641](#)

[AMC: Model 56641](#)

[3U cPCI: Model 73641](#)

[6U cPCI: Models 72641 & 74641](#)

[The Model 78690](#) L-Band RF Tuner with two 200 MHz A/Ds and Virtex-6 FPGA is also available in the following formats:

[XMC: Model 71690](#)

[AMC: Model 56690](#)

[3U OpenVPX: Model 52690](#)

[3U OpenVPX: Model 53690](#)

[3U cPCI: Model 73690](#)

[6U cPCI: Models 72690 & 74690](#)

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Model 8266 PC Development System for PCIe Onyx and Cobalt Boards

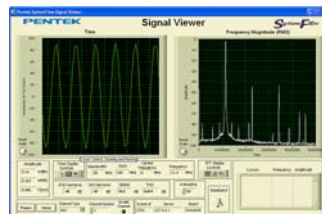


The Model 8266 resolves the typical hardware and software compatibility obstacles inherent in new PC development platforms. All hardware is installed in appropriate slots with proper cabling, power and cooling strategies, and optimized BIOS. For more information: pentek.com/go/pipe8266

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

Model 56730

AMC Onyx Board with 1 GHz A/D, 1 GHz D/A and Virtex-7 FPGA

Features

- Supports Xilinx Virtex-7 VXT FPGAs
- GateXpress® supports dynamic FPGA reconfiguration across PCIe
- One 1 GHz 12-bit A/D
- One 1 GHz 16-bit D/A
- 4 GB of DDR3 SDRAM
- PCI Express (Gen. 1, 2 & 3) interface up to x8
- AMC.1 compliant
- IPMI 2.0 compliant MMC (Module Management Controller)
- Dual-µSync clock/sync bus for multiboard synchronization
- Optional front panel LVDS connections to the Virtex-7 FPGA for custom I/O



Model 56730 is also available in AMC, PCI Express, OpenVPX, and CompactPCI formats.

Model 56730 is a member of the Onyx® family of high performance AMC modules based on the Xilinx Virtex-7 FPGA. A high-speed data converter, it is suitable for connection to HF or IF ports of a communications or radar system. Its built-in data capture and playback features offer an ideal turnkey solution as well as a platform for developing and deploying custom FPGA processing IP.

It includes 1 GHz A/D and D/A converters and four banks of memory. In addition to supporting PCI Express Gen.3 as a native interface, the Model 56730 includes a front panel general-purpose connector for application-specific I/O .

The Onyx Architecture

Based on the proven design of the Pentek Cobalt family, Onyx raises the processing performance with the new Virtex-7 FPGAs from Xilinx. The FPGA has access to all data and control paths, enabling factory-installed functions including data multiplexing, channel selection, data packing, gating, triggering and memory control. The Onyx architecture organizes the FPGA as a container for data-processing applications where each function exists as an intellectual property module.

Xilinx Virtex-7 FPGA

The Virtex-7 FPGA site can be populated with one of two FPGAs to match the specific requirements of the processing task. Supported FPGAs are VX330T or VX690T. The VX690T features 3600 DSP48E1 slices and is ideal for modulation/demodulation, encoding/decoding, encryption/decryption, and channelization of the signals between transmission and reception. For applications not requiring large DSP resources or logic, the lower-cost VX330T can be installed.

GateXpress for FPGA Configuration

The Onyx architecture includes GateXpress, a sophisticated FPGA-PCIe configuration manager for loading and reloading the FPGA. At power up, GateXpress immediately presents a PCIe target for the host computer to discover, effectively giving the FPGA time to load from FLASH. This is especially important for larger FPGAs where the loading times can exceed the PCIe discovery window, typically 100 msec on most PCs.

A/D and D/A Converters

The front end accepts an analog HF or IF input with transformer coupling into a Texas Instruments ADS5400 1 GHz, 12-bit A/D. The D/A is a TI DAC5681Z 1 GHz, 16-bit device with a 2x or 4x interpolation filter.

PCI Express Interface

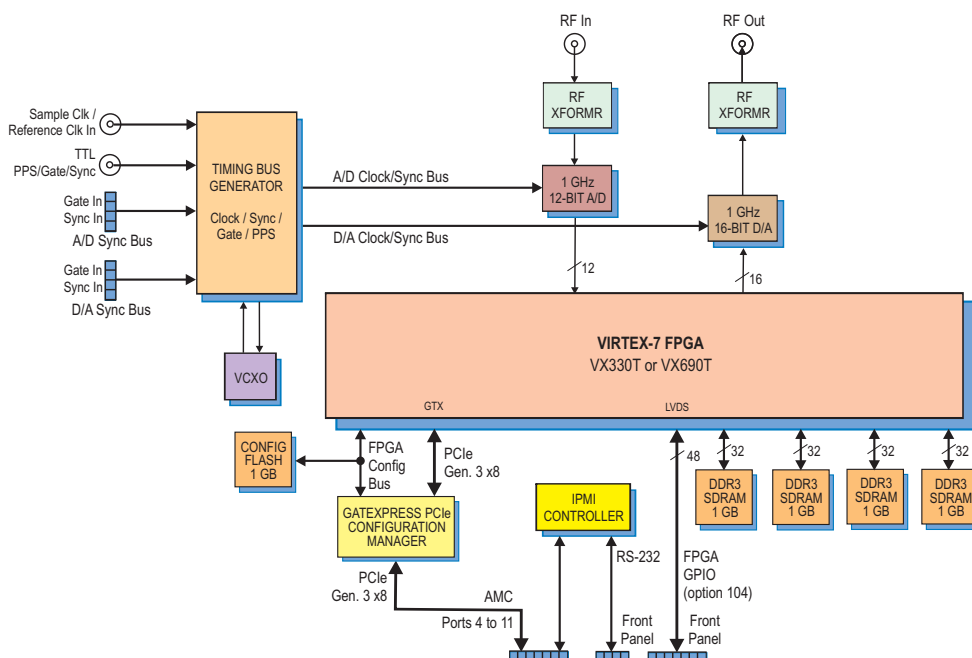
The Model 56730 includes an industry-standard x8 interface fully compliant with PCI Express Gen. 1, 2 and 3 bus specifications.

AMC Interface

The Model 56730 complies with the AMC.1 specification by providing an x8 PCIe connection to AdvancedTCA carriers or µTCA chassis. Module management is provided by an IPMI 2.0 MMC (module management controller).

For more information and a price quotation on the Model 56730, go to:

pentek.com/go/pipe56730 □



Product Focus

Model RTR 2728

One-Channel RF/IF, 1 GS/sec Rugged Portable Recorder

Features

- Portable system measuring 16.9" W x 9.5" D x 13.4" H
- Lightweight: approximately 30 pounds
- Rugged aluminum alloy chassis
- Shock- and vibration-resistant SSDs perform well in vehicles, ships and aircraft
- Recording of IF signals up to 2 GHz
- Signal bandwidths to 500 MHz
- Real-time aggregate recording rates up to 2.0 GB/sec
- Up to 7.6 TB storage with hot-swappable SSD drives
- NTFS file format and high-performance Windows® workstation with Intel® Core™ i7 processor



The Talon® RTR 2728 is a turnkey, multi-band recording and playback system that allows the user to record and reproduce high-bandwidth signals with a lightweight, portable and rugged package.

The RTR 2728 provides recording rates of up to 2.0 GB/sec and is ideal for the user who requires portability and solid performance in a compact recording system.

The RTR 2728 is supplied in a small footprint portable package measuring only 16.9" W x 9.5" D x 13.4" H and weighing just 30 pounds. With measurements similar to a small briefcase, this portable workstation includes an Intel Core i7 processor a high-resolution 17" LCD monitor, and a high-performance SATA RAID controller.

SystemFlow Software

Included in this system is the Pentek SystemFlow recording software. SystemFlow features a Windows-based GUI (Graphical User Interface) that provides a simple means to configure and control the system.

Custom configurations can be stored as profiles and later loaded when needed, allowing the user to select preconfigured settings with a single click.

SystemFlow also includes signal viewing and analysis tools, that allow the user to monitor the signal prior to, during, and after a recording session. These tools include a virtual oscilloscope and spectrum analyzer.

Architecture

Built on a Windows 7 Professional workstation, the RTR 2728 allows the user to install post-processing and analysis tools to operate on the recorded data. The RTR 2728

records data to the native NTFS file format, providing immediate access to the recorded data.

Rugged & Flexible Recorder

The RTR 2728 is configured in a portable, lightweight chassis with eight hot-swap SSDs, front panel USB ports and I/O connections on the side panel.

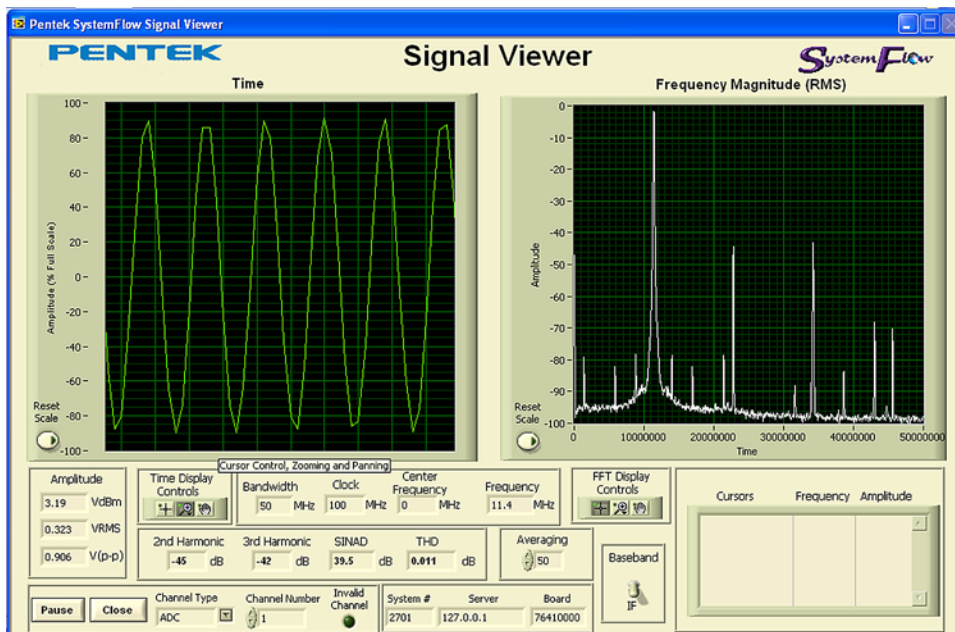
It is built on an extremely rugged, 100% aluminum alloy unit, reinforced with shock absorbing rubber corners and an impact-resistant protective glass. Using shock- and vibration-resistant SSDs, the RTR 2728 is designed to operate reliably as a portable field instrument.

The eight hot-swappable SSDs provide storage capacities of up to 7.6 TB. Drives can be easily removed or exchanged during or after a mission to retrieve recorded data. Multiple RAID levels including 0, 1, 5, and 6 provide a choice for the required level of redundancy.

At the heart of the RTR 2728 are Pentek Cobalt® Series Virtex-6 software radio boards featuring 1 GHz A/D and D/A converters. This architecture allows the system engineer to take full advantage of the latest technology in a turnkey system.

For more information, detailed specifications, and a price quotation on the Model RTR 2728 go to:

pentek.com/go/pipe2728 □



Product Focus

Model 5620

AMC Board with Bandit Two-Channel Analog RF Wideband Downconverter

The Bandit® Model 5620 is a two-channel, high-performance, stand-alone analog RF wideband downconverter. Packaged in a small, shielded AMC board with front-panel connectors for easy integration into RF systems, the board offers programmable gain, high dynamic range and a low noise figure.

With an input frequency range from 400 to 4000 MHz and a wide IF bandwidth of up to 390 MHz, the 5620 is an ideal solution for amplifying and downconverting antenna signals for communications, radar and signal intelligence systems.

Programmable Input Level

The 5620 accepts RF signals on two front-panel SSMC connectors. LNAs (Low Noise Amplifiers) are provided, along with two programmable attenuators allowing downconversion of input signals ranging from -60 dBm to -20 dBm in steps of 0.5 dB. Higher level signals can be attenuated prior to input.

Input Filter Options

An optional five-stage lowpass or bandpass input filter can be included with several

Features

- Accepts RF signals from 400 MHz to 4000 MHz
- Accepts RF input levels from -60 dBm to -20 dBm
- Baseband IF output with up to 390 MHz bandwidth
- Internal OXCO or external 10 MHz frequency reference



Model 5620 is also available in XMC, PCI Express, OpenVPX, and CompactPCI formats.

available frequency and attenuation characteristics for RF image rejection and harmonic suppression.

Quadrature Mixers

The 5620 features a pair of Analog Devices ADL5380 quadrature mixers. The ADL5380's are capable of excellent accuracy with amplitude and phase balances of ~0.07 dB and ~0.2°, respectively.

Tuning Accuracy

The 5620 uses an Analog Devices ADF4351 low-noise, on-board frequency synthesizer as the LO (Local Oscillator). Locked to an external input reference for accuracy with a fractional-N phase-locked loop, its frequency is programmable across the 400 to the 4000 MHz band with a tuning resolution of better than 100 kHz.

On-board Reference Clock

In addition to accepting a 10 MHz reference signal on the front panel, the 5620 includes an on-board 10 MHz crystal oscillator which can be used as the reference to lock the internal LO frequency synthesizer.

This reference is an OCXO (Oven Controlled Crystal Oscillator), which provides an exceptionally precise frequency standard with excellent phase noise characteristics.

Wideband Output

Output is provided as baseband I and Q signals at bandwidths up to 390 MHz. Alternatively, either I or Q output can be used at some intermediate offset frequency convenient to the application. User-provided in-line output IF filters allow customizing the output bandwidth and offset frequency to the specific application requirements.

For more information, detailed specifications, and a price quotation on the Model 5620 go to: pentek.com/go/pipe5620

