Key Design Considerations for SFF RF Signal Recording

Design strategies with serviceable modular components are essential to a successful deployment of small form factor RF signal recorders.

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While the real-time recording of a gigahertz or more of RF bandwidth is commonly available in 19" rackmount systems, shrinking this capability into a Small Form Factor (SFF) that's suitable for UAVs, aircraft pods, or other confined spaces has proven challenging. A well-designed system provides excellent RF signal acquisition hardware that is small, lightweight and low power, and capable of operating in a wide range of working environments. Design strategies such as drive packs and other serviceable modular components are essential to a successful deployment of SFF RF signal recorders.

REAL-TIME RESULTS

The ability to record wideband RF signals in real time is critical. Wideband RF downconverters are now capable of translating a gigahertz of RF bandwidth to Immediate Frequencies (IFs) with excellent dynamic range. This requires high-performance Analog-to-Digital (A/D) converters with high enough sample rates and bit resolution to sample the entire band effectively.

A/D converters, paired with the latest FPGA technology in an XMC form factor, provide a signal conversion and processing engine that can sample signals at extremely high data rates in a small package suitable for an SFF recorder. These XMC modules serve as the recorder's front-end interface, providing the ability to move multiple gigabytes per second of data through the system. The integrated FPGA not only serves the purpose of moving data from A/Ds but provides an excellent digital signal processing engine for the recorder.

Digital downconverters, signal detection, gating, and acquisition time stamping are common processing capabilities that are often provided in standard FPGA IP loads. A well-developed set of FPGA IP greatly enhances the capabilities of an RF signal recorder.

D/A converters are often included on XMC modules, providing the ability to playback acquired signals or generate pulses. Multi-channel A/D and D/A XMC modules provide phase coherency across all channels. This is an essential capability of any real-time signal recorder.

PRECISE DATA MEASUREMENTS

Extremely small Global Navigation Satellite Systems (GNNS) receivers have emerged over the last few years with support for Galileo, GPS, and Glonass systems. These small receivers provide the ability to timestamp data acquisitions with nanosecond precision. The receivers provide 10 MHz reference clocks and Pulse Per Second (PPS) signals to the recorder's A/D XMC modules, which allow users to capture the exact timing of gated or triggered events.

GNNS receivers also provide the ability to capture the latitude, longitude, and altitude of the recorder, allowing users to capture flight paths, vehicle movement, or static ground location if required. GNNS receivers often provide options for oven-controlled oscillators to allow them to run at a wide range of temperatures or accelerometers to provide high accuracy during rapid acceleration, making them suitable for a wide array of operating environments.

STORAGE RECORDING CAPABILITIES FOR SFF ENVIRONMENTS

The challenge of maintaining similar features and performance of larger rackmount recorders is facilitated by the growing solid-state storage demand driven by data centers. V-NAND flash technology has enabled Solid-State Drive (SSD) capacity and write-rates to continue to increase in tiny package sizes. These inherent advances in solid state technology provide a path towards facilitating SFF storage capabilities.

Small drive packs, containing an array of solid-state devices, provide storage speed and capacity previously only available with many individually removable SSDs. By designing the packaging of a storage array into a drive pack, the job of managing up to 48 individual drives is replaced with the job of managing a single drive pack, providing a tremendous ease-of-use benefit.

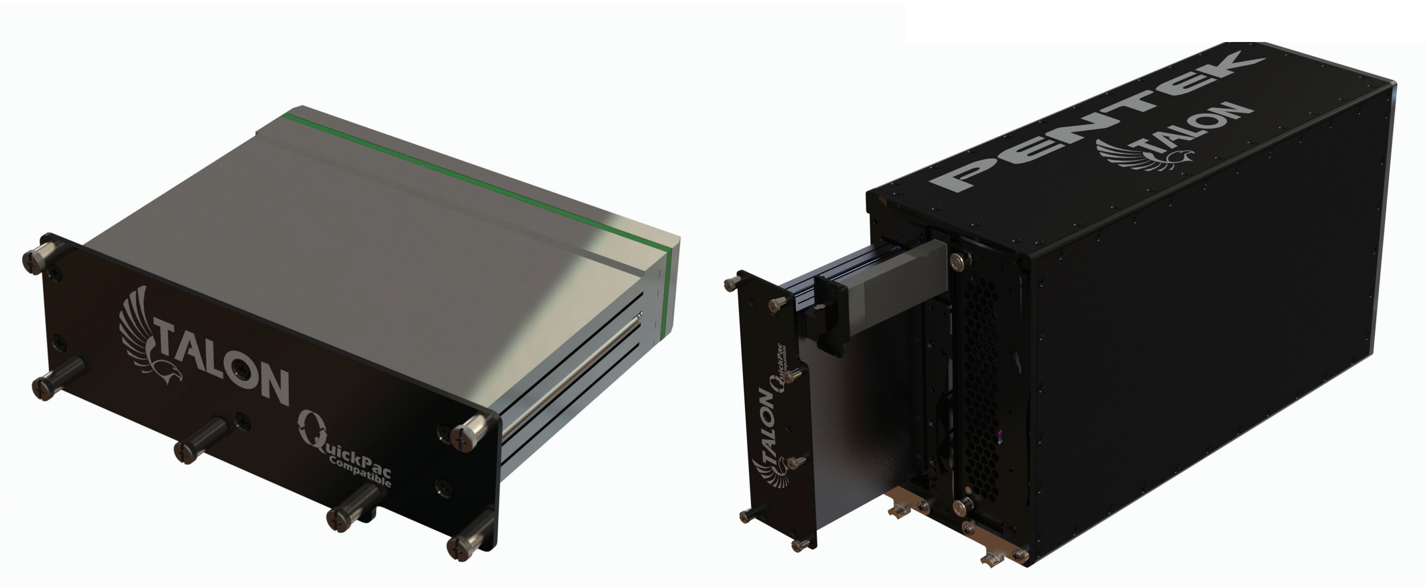

Figure 1: Left: Pentek's QuickPac drive pack for Talon SFF recorders. At right: Pentek's Talon SFF Recorder with the Removable QuickPac inserted.

A single high-insertion-cycle connector designed into the drive pack provides a far more reliable mechanism for the removable storage media than standard SATA connectors typically available in rack-mount systems. Well-designed drive packs can hold tens of Terabytes of data and are capable of storage speeds in Gigabytes per second. Drive packs should be designed to be easily removable, allowing the recorder to remain hard mounted.

HANDLING THERMAL ISSUES

One of the issues in reducing the package size of the data storage media is maintaining a thermal environment that will allow the drive pack to perform at its highest level. Solid state memory controllers will throttle access speeds if the thermal environment is not adequately managed, which is not only an essential concern for the storage media but for all electronics in the SFF recorder. A set of A/Ds can draw 10 watts or more. FPGAs can draw 25 watts. CPUs typically draw between 35 and 90 watts. High-performance RAID controllers often draw 15 to 25 watts, and drive packs can draw tens of watts. While efforts can be made to minimize power consumption, heat management is one of the most critical aspects of the recorder's design.

To operate in a wide array of environments, it is important to protect electronics from environmental elements such as water, humidity, sand, dust, and salt fog. A hermetically sealed chassis is desirable but brings with it the issue of heat mitigation of internally mounted electronics. Custom designed heat sinks that provide conductive thermal paths to the walls of the chassis provide some relief, but chassis walls still require sufficient air flow to be effective. Plenums can be used to create air channels throughout the chassis to provide a more efficient cooling design. Custom heat sinks integrated into plenum walls provide cooling by allowing air to be channeled directly through all heat sinks, allowing all system electronics to remain sealed from the outside environment while being adequately cooled.

Integrating a fan into the plenum helps assure air flows through heat sinks, providing an excellent cooling solution. One of the advantages of sealing all system electronics from the outside environment is that electronics can self-heat easier than if exposed to cold temperatures. The self-heating process can be easily negated if a fan in the plenum tube is blowing air across heat sinks, so it is imperative to have control over this fan. Integrated fan controllers should be used to monitor the environment and switch fans off to allow for self-heating and then re-engage when components become hot. This balance between hot and cold is easily calibrated, ultimately providing a recording system that can operate at both temperature extremes. It is significant to note that while the measures described for thermal management will help to provide an ideal environment for the recorder's electronics, it is essential to use industrial grade components when possible.

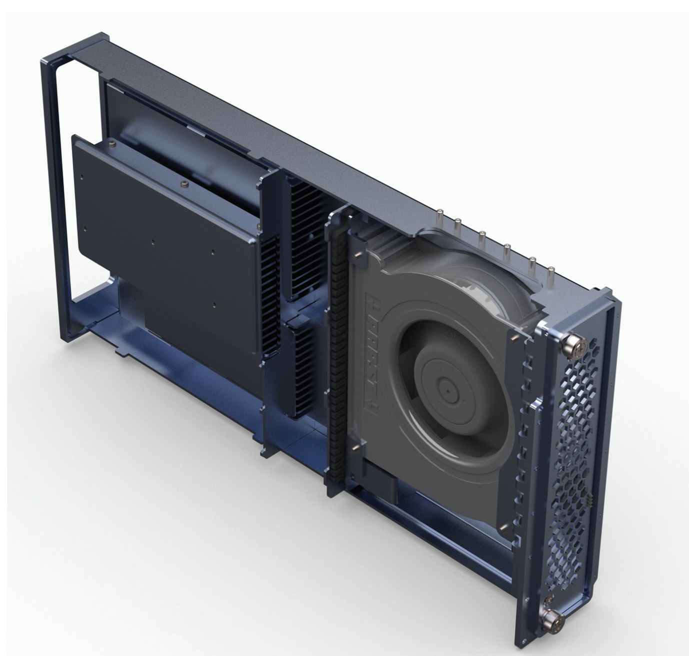

Figure 2: Pentek's Talon SFF Recorder's Inner Plenum with an exposed wall.

WHY THE OBSESSION WITH SIZE, WEIGHT, AND POWER (SWAP)?

Designing for size, weight, and power reduction require additional strategies. Component selection and efficient design help to control the power consumption and dissipation of the recorder, allowing for less material to be used for both heat sinking and reducing the total weight of the package. Weight and power have a direct relationship in that the lower the power consumption, the less heat dissipated by the system. To design for reduced weight, we must minimize the power consumption of the system and use lightweight materials like aluminum with efficient thermal paths to the cooling channels designed into the system.

High-speed recording systems often do not require a tremendous amount of processing power. Since hardware DMA controllers are used to move data to disk, processors are often used to simply "manage" the data flow. The latest Intel® I7 processors are now offered in versions with lower clock rates and power consumption. An eighth-generation I7 clocking at 2.4 GHz limits power consumption to 35 watts and can be configured to draw as little as 25 watts. Furthermore, efficient FPGA designs allow signal processing to reside in smaller, more efficient FPGAs. Xilinx's Kintex 7 family offers excellent performance with significant power reduction over previous generation FPGAs.

FEATURES NEEDED WHEN IN USE

It is important to design a system that can be installed in an aircraft or vehicle in a permanent fashion, but still provide easy access to the user. Easy-to-swap, modular components like fans, drives, and other parts of non-volatile memory within the recorder allow the system to be easily serviced and sanitized of classified or otherwise sensitive data. All removable components should be accessible via the front panel of the system using captive hardware without requiring special tools.

Software must include a straight forward and simple Application Programming Interface (API) to control the system as well as a suite of RF signal analysis tools to allow users to instantly analyze recorded data. RF signal recorders typically provide a Gigabit Ethernet (GbE) interface for control of the unit from an external computer. The interface can also be used to stream data to allow users to monitor RF signals prior to, during, and after a recording.

Designing a system in a standard form factor helps to simplify the installation process by providing familiar mounting mechanisms in a common and proven footprint. ARINC 404 is an aeronautical standard that specifies mechanical dimensions of line replaceable units (LRUs) and their racking systems in aircraft. ARINC 404 specifies dimensions for several sizes of ATRs (Air Transport Racks).

Small form factor devices can be immensely rugged and designed for versatile use in varying conditions. Modular components can be swapped out as needed to allow easy adaptation, service, and removal of sensitive data for improved security. Pentek's ability to create widely adaptable equipment can make doing the right job at the right time a far less difficult task.

Chris Tojeira is the Technical Director and Chief Architect of the Recording Systems Product Line of Pentek, Inc. Chris has over 22 years' experience in the electronics industry and has held positions as a Senior Software Engineer, Strategic Account Engineer and Applications Engineering Manager for Pentek. He holds a BS degree in Electrical Engineering from Rutgers University in NJ.