WHITE PAPER

by Tim Anderson and Ted Staros

Bringing the Embedded Exporter to Market

Project Is an Exercise in 'Distributed Development'

Anderson is FM/digital radio product line manager for Harris Corp.; Staros is the director of its Pacific Design Center.

In 2006, NAB representatives approached Harris to discuss how best to encourage a broader adoption and reduce the cost of HD Radio implementation across its membership. Harris was eager to have these discussions and help the NAB study the architecture chain to identify the most costly elements and those with the most potential for failure.

It was felt that the high cost of the exporter, built on a computer, has been a substantial roadblock to wider HD Radio implementation. Service lifetime and system size also have been concerns. The large PC-based exporter has inherent service lifetime and reliability limits due to fans, disk drives and thermal characteristics that leave it subject to eventual failure.

These investigations resulted in a plan for an improved HD Radio program exporter that could reduce the cost of HD Radio implementation between 10 and 20 percent (around $10,000) per station.

The embedded exporter demonstrates how industry cooperation and investment can advance the HD Radio architecture and hasten HD Radio rollout.

With financial assistance from the NAB, Ibiquity Digital developed the necessary software libraries for the next-generation exporter. Several broadcast equipment manufacturers also were subsidized by the NAB to encourage development of their own exporter solution incorporating the new Ibiquity code.

Harris' Pacific Design Center in Vista, Calif., which has significant expertise in embedded design through its studio products, led Harris' development efforts. These efforts resulted in the next-generation Harris HDE-200 Program Exporter.

The HDE-200 is an "embedded" exporter, which means that a microcontroller CPU has been embedded within the exporter, thus eliminating the cost of an external Linux x86 PC and the inherent PC hardware liabilities. The Ibiquity HD Radio codec and data encoding algorithms, and the required diversity delay, are processed within the unit.

This third-generation HD Radio Program Exporter provides a powerful hardware/software platform that offers improved reliability and ease of use at a significantly lower cost over first and second-generation products.

The HDE-200 product development has been an exercise in "distributed development," the practice by which multiple individuals, at multiple locations, working for different firms, must act as a unified development team. Participants on this project included Harris and Ibiquity staff, and a short list of dedicated supply chain partners and consultants.

Distributed development only works when all participants feel responsible for the achievement of the overall project goal. Nobody can succeed without everybody else being successful. This setup makes people consider what the "other side" thinks and encourages collaboration.

HD RADIO SYSTEM AND EXPORTER

The HDE-200 is a program exporter for HD Radio broadcasts. It allows a broadcaster to add the necessary information to broadcast one or more HD Radio digital audio or data channels within an existing analog FM channel allocation.

The exporter adds the signal encoding required by the HD Radio Exgine/Exciter. The exporter accepts the main program audio and Program Service Data (PSD). In addition, it encodes the Advanced Application Services (AAS) data and supplemental audio channels (supplied from an HD Radio Importer like the Harris HDI-100 Program Importer).

The exporter compresses the MPS audio stream, and combines services into a single IP data stream for transport to the Exgine/Exciter via the Exciter Link interface. The exporter also provides a delayed audio output of the main program audio for the legacy analog broadcast to facilitate smooth blending between the analog and digital signals at the receiver. Fig. 1 shows the physical architecture of the Generation 3 HD Radio system.

The HDE-200 exporter can be located in a studio or terminal room, as opposed to being collocated at the transmitter as in earlier generations of exporters. The data stream between the exporter and Exgine is the "Exporter to Exgine" or E2X transport protocol and may be either TCP over a bidirectional link or UDP over a unidirectional link, making it fully compatible with digital STLs, local- or wide-area networks, satellite, virtual private networks or even the public Internet

HARDWARE DESIGN

Structural and functional modularity was a central theme in the design of the HDE-200. The design team wanted an architecture that could be built of modular elements providing segregated functionality, testability, serviceability and development disciplines.

Creating this modularity ultimately reduces manufacturing cost and lead times, and consequently reduces total cost of ownership to the customer. Some of these modular elements benefit from reuse in other Harris Studio System products.

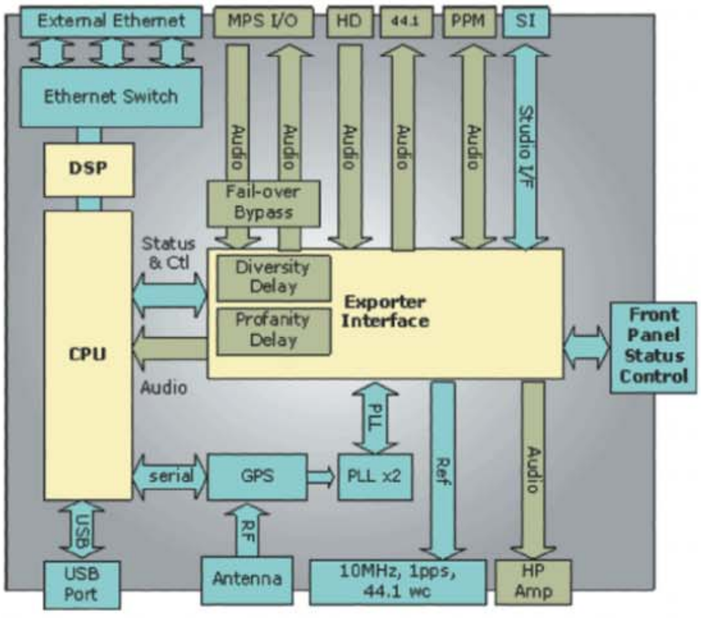

Fig. 1: Simplified HDE-200 Block Diagram

Determining the modular structure of a product requires a careful balance. Too much modularity can result in higher system cost. Too little modularity often results in longer, more costly development cycles. Fig. 1 shows a simplified block diagram of the HDE-200.

Modularity

The design team also wanted the product to reflect the modular nature of Ibiquity's reference design. By using a modular approach, at each step of the development process we can check to make sure the software will work properly on the Ibiquity reference development platform.

Being able to swap the digital signal processing employed in the Ibiquity reference platform with our version, or being able to swap in a software emulation of the same DSP codec, allows controlled comparisons of interchangeable elements. In addition, too little modularity can complicate manufacturing yield and severely limits service

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from the beginning that the Loudness Monitor might have even wider applications than the Discriminate Audio Processor itself.

You are now trying to establish a shortwave facility operated for and by handicapped folks. What started you on this project?

I've had a long and fulfilling relationship with gifted blind and visually impaired people in the audio and broadcasting fields.

Our family acquired a 16.2 acre plot of land in the town of Oregon, Wis., as the setting for a home and unique broadcast/archiving complex. This kind of space provides a means for us to preserve some of the history of broadcasting.

We have been collecting and protecting rare and fragile transcriptions, tape recordings, films and documents for decades, including much of the UCLA record and transcription library. This new property is the perfect place to properly archive and preserve these irreplaceable treasures of broadcasting's Golden Age.

The establishment of the first-of-its-kind shortwave radio service for and by visually impaired persons would dovetail perfectly with the massive audio archive. The planned non-profit, low-profile, low-power residential operation would be no more noticeable to the widely spaced neighbors than a typical ham radio station. Due to the unique characteristics of shortwave radio, even at the planned modest power levels, the signals would still be heard across the nation.

The benefits to the sightless broadcaster would be apprenticeship and a sense of achievement, and to visually impaired listeners it would offer an endless array of diverse programs created for radio — a medium that once told vivid stories and entertained without visual cues. The program mix would not only include vintage radio plays but new productions from a largely untapped reservoir of creative talent.

With buildings and antennas already in place, just as we were about to apply for our license, we were shocked to see ground stakes outlining what looked like a house foundation in close proximity to our antenna array. The land was a small, triangular parcel left over from the farm subdivision process, only about 1/6 of the minimum required for residential construction.

We're still seeking the advice, legal or otherwise, to help salvage this project and at least a part of our recorded heritage before time and the elements erase the archives forever.

Steve Callahan is the director of engineering for Rhode Island Public Radio. ■

Exporter

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by substitution, unless the substitution is of the entire device.

The HDE-200 broke down into four component modules: Exporter Interface; CPU, a.k.a. microcontroller; digital signal processor; and user interface.

The Exporter Interface is the physically largest element of design. It contains the input and output structures, diversity delay management and Global Positioning System. Central to this design is that the Exporter Interface may be fabricated and tested in a manner that provides isolation of the other components.

The Exporter Interface is the element that provides the application-specific functions this product demands. Every other modular element — the DSP, the CPU and the user interface — are general-purpose devices. This assembly is purpose-specific.

The CPU in our design required careful study. Cost, system and Direct Memory Access performance, power consumption, the development tool chain, vendor support, component availability, Ethernet and USB host support were prime considerations. Again, modularity and our ability to segregate the CPU function from other development threads were critical to the design requirements.

It was decided to use an ARM9-based Atmel processor on a 144 pin SODIMM module. The module looks like a slightly oversized laptop memory device. Measuring 2.6 × 2.3 inches, the compact form factor is deceptively powerful (see Fig. 2).

Our DSP structure was the easiest choice, as Ibiquity made this one for us. The primary software component of the DSP, Ibiquity's codec thread, was to be provided with its intellectual property safely protected in an inscrutable, machine-readable, binary format. This covert code was compiled to run exclusively on a TI 6713 DSP chip.

Our user interface also was an easy choice. User interface elements that could be readily adapted had already been developed by the Harris Pacific Design Center for our studio products. We chose to reuse a control panel element from our VistaMax audio management system family of products.

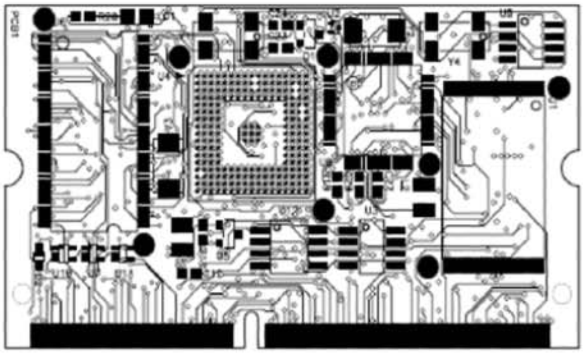

Fig. 2: ARM9-based SODIMM CPU Module

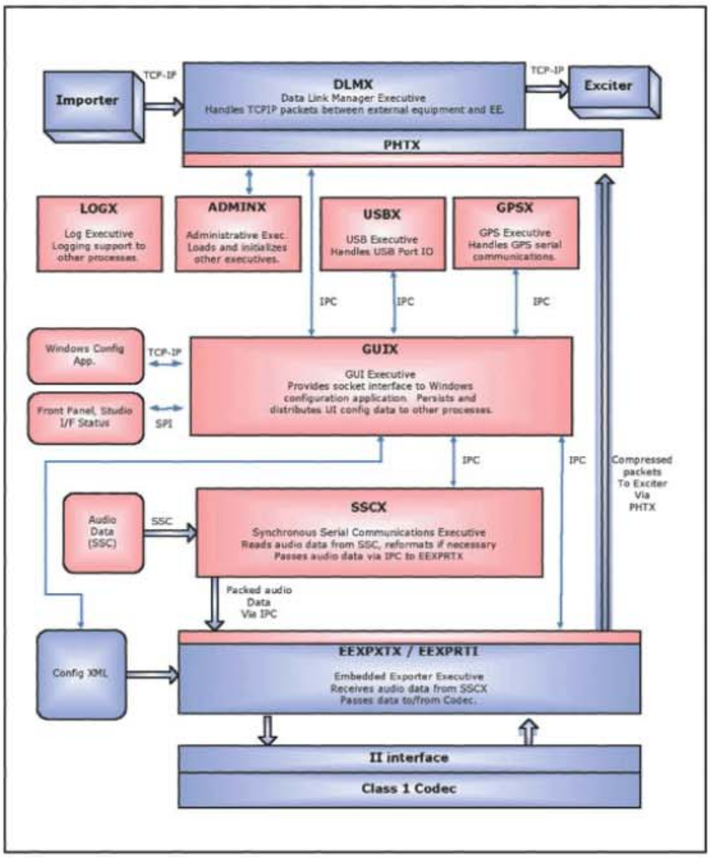

Fig. 3: Modules illustrated in red were developed specifically for the HDE-200.

Reliability

Reliability of a product can be easily reduced to a single driving factor: power dissipation. This one factor influences all aspects of hardware failure.

By designing to a restricted power budget, we eliminated our reliance on forced-air cooling. Fans fail and their filters become choked with dust. Moving parts like fans and disk drives create their own power burdens, which drive up total power consumption. A failure of one of these components often results in a total system failure. Consequently, designing a product capable of performing to specification using only convective and radiant dissipation was a primary design goal of this project.

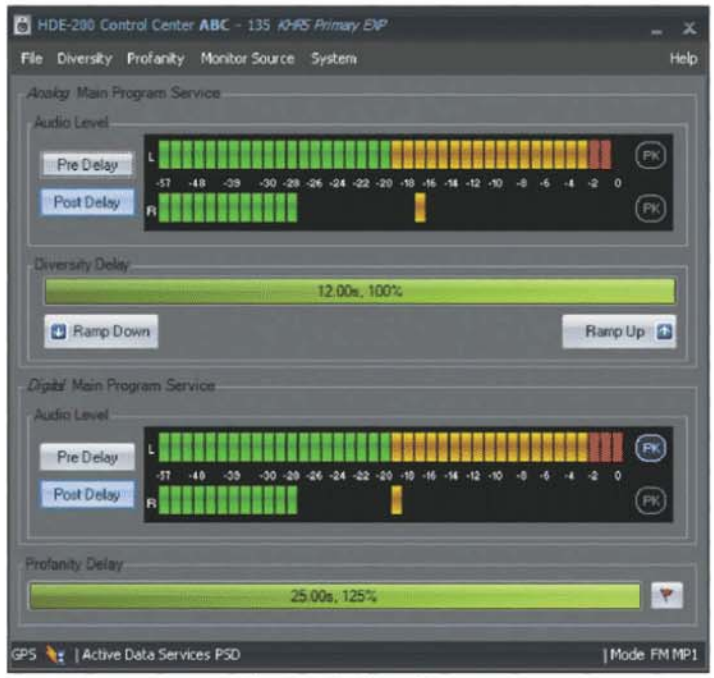

Fig. 4: HDE-200 Control Center

The lower cost of the platform could save broadcasters more than $100 million.

The total power dissipation of the HDE-200 measures at less than 15 W. As a bonus, with no fans, this device can be placed in even the most acoustically sensitive locations.

Incorporating the control architecture within our platform allows our audio diversity delay to remain intact even if a microcontroller reboot is required, something previous designs could not do.

SOFTWARE DESIGN

Software library transformation from a PC environment to an embedded model would appear somewhat straightforward. It's anything but.

To achieve the cost advantages of an embedded system, one must break free of the hardware foundation of the PC platform. Gone are specialty PCI bus audio cards and expensively packaged GPS subsystems, as well as the user interface with mouse and keyboard.

Replacing these are new, efficient software structures to interface with application-specific real-time signal input and output. Our need to maintain functional modularity across the PC to embedded transformation required significant up-front planning.

Expecting that we would encounter various software library compatibility issues as well as inter-process communication problems, the software team was cautious. To offset these challenges, we focused on our modularity mindset. Given our distributed development program, the key to a modular approach was to focus on the first rule: The more moving parts one needs to accommodate, the more complexity and risk one introduces into the system development.

Our modular implementation of the software design allowed a substantial re-use of stable and time-proven software modules. A new code structure, specific to the hardware efficiencies of the HDE-200, was crafted to integrate with these pre-established modules.

One of the best lessons learned from this distributed development effort is the importance of inviting remote contributors to the each other's development centers periodically. Digital collaboration and information sharing is helpful, but nothing can replace the interaction and camaraderie of occasional face-to-face meetings.

IMPROVEMENTS TO THE EXPORTER PLATFORM

As part of the development of a new exporter, we were able to incorporate the latest improvements included in the new Ibiquity core software.

Transmission Control Protocol (TCP) has been incorporated by Ibiquity into the E2X transport layer providing "guaranteed delivery" of data between the exporter and Exgine/Exciter over a bidirectional link. This provision relaxes the significantly more stringent network performance

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requirements of UDP, which remains an available option for transport over unidirectional links.

To unify communications between the various HD Radio components, HD Protocol was developed by Ibiquity. HDP supports protocol content creation and distribution as well as command and control across the entire HD Radio system from local, centralized and/or remote locations.

Fig. 5: HDE-200 Front View

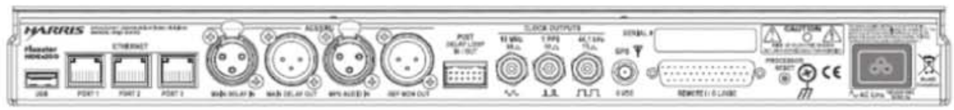

Fig. 6: HDE-200 Rear View

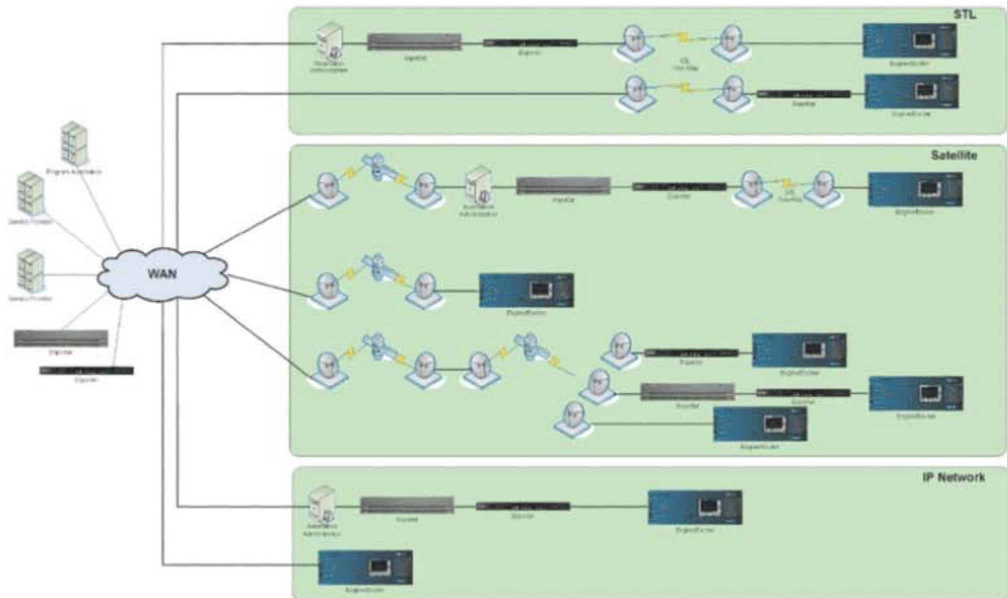

Fig. 7: HDP Networking Configuration

HDP is an extensible, general-purpose protocol for use over unidirectional and bidirectional links, and is now the standard protocol underlying the HD Radio broadcast system architecture.

HDP also improves security by enabling the ability to digitally sign messages being received from other broadcast components and systems.

Increased flexibility also has been added by allowing the Main Program Service codec to be configured as low as 32 kbps leaving 64 kbps for supplemental audio and data services in MP1. This allows for a 32 kb Main Program Service and 32 kb for HD2 and HD3 supplemental audio services.

An additional feature added by Harris through the HDE-200 Control Center software is the ability to "discover" the other Harris HD Radio components (Importer and Exciter) on the network. This allows easier setup and maintenance of the signal chain.

HDE-200 UPGRADES

Three optional upgrade kits are available: Profanity Delay Upgrade kit; Arbitron PPM Encoder Interface Kit; and Combined Profanity Delay/Arbitron PPM Encoder Interface kit.

POSSIBILITIES

Multi-Point, Multimedia Origination and Distribution

The addition of HDP supports unidirectional and bidirectional network configurations for content distribution to the various HD Radio system components. HDP content also may be generated locally from the studio administration equipment and directed to various program paths. Within the HDP structure, content can be anything that might be transported over HD Radio. This could include weather, traffic, navigation or digital signage data, audio, video, pictures, audio files and program metadata.

Fig. 7 shows the diverse possibilities for origination and distribution.

Encoded Host Audio Transport is an expansion of the E2X protocol, whereby an additional high-bandwidth, low-latency audio stream is encoded into the existing HD streams for transporting the main legacy analog program over the E2X/IP stream, with the analog host audio program being extracted at the Exgine.

It is expected that the HAT will provide up to a 256 kb, HDC-encoded stereo audio channel, and will require approximately 500 kb of additional transport bandwidth. This could result in an overall HD+FM system transport bandwidth reduction of 600 kb, freeing up precious STL resources for additional services and increased system headroom.

ERROR CORRECTION AND TRANSPORT ROBUSTNESS

By embedding low-density parity-check (LDPC) codes or turbo codes into the optional HDP Protection Fragmentation Transport layer, along with packet filtering and Quality of Service mechanisms, it is possible to greatly improve the performance of the unidirectional UDP E2X link as part of the Exporter/Exgine architecture to reduce component count, system complexity and cost.

GENERATION 3 AM HD

The HDE-200 Exporter will support AM HD Radio modes as well as FM modes. Development of an Exgine-based AM exciter will support Generation 3 architecture on AM.

SUMMARY

Realization of the embedded exporter demonstrates how industry cooperation and investment can advance the HD Radio architecture and hasten HD Radio rollout. With the introduction of the FlexStar HDE-200 exporter at the 2008 NAB Show, HD Radio broadcasters now have an exporter that boasts a unique set of features to better support multiple HD Radio streams over a single, dedicated IP connection.

The lower cost of the embedded exporter platform could result in saving broadcasters more than $100 million implementing HD Radio over the coming years. While reducing the cost of HD Radio implementation and fortifying the robustness of the system have been the prime motivators, continuing development has and will continue to bring many new and exciting applications and features. ■

READER'S FORUM

LIKE MARCONI HIMSELF

I really enjoyed the interview with Larry Cervon in the April 16 Engineering Extra ("A Lifetime in Broadcast Equipment").

In 1999, I had just gone to work for SCMS Inc., and we were at the fall Radio Show in Orlando. One day at breakfast, my boss Bob Cauthen introduced me to Larry Cervon.

Being a career radio geek, I of course knew who I was talking to, and could not have been more in awe if it had been Marconi himself.

I had a few occasions to talk with Mr. Cervon, and enjoyed hearing his stories and reflections on Gates and BE. I also was totally surprised at his crystal-clear memory of events large and small.

When we were at the airport wrapping up a conversation about pictures of gear in the various catalogs,

I made a comment about the one-of-a-kind console Gates built for WABC, off the top of my head saying that the picture was in (catalog) number 98, the green one.

No, he replied politely, 98 was orange. That catalog was printed in the '60s!

Bob Mayben
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