how it works

A PORTABLE DIGITAL HARD-DISK RECORDER BRINGS REALISTIC AUDIO TO MOVIE AND TV AUDIENCES.

Achieving the ultimate soundtrack

By Howy Stark, Zaxcom Inc

TODAY'S ENTERTAINMENT audiences have become discriminating. They're not satisfied with anything less than never-seen-before action scenes in feature films and attention-grabbing effects in TV programs, music videos, and even commercials. What just a few years ago excited them now comes across as passé.

Directors realize, though, that exciting visuals require exciting sound. Sound engineers couldn't get realistic audio on scenes such as the motorcycle chase in *The Matrix Reloaded* by working with stationary recording equipment. So, they've migrated over the past few years from sensitive and bulky DAT (digital-audio tape) and reel-to-reel recorders to portable hard-disk-based recorders. In 1997, Zaxcom produced the first such commercial digital portable hard-disk recorder, the Deva.

In fulfilling its role as a truly portable unit, the Deva has encountered the harshest of environments. For vibration and acceleration, sound engineers have used Devas on roller coasters; for altitude, they have taken a Deva to the top of Mount Everest; for high g forces, they have used it on a jet airplane; and, for heat, they've brought it to the desert, where the box became too hot to touch. In addition, the Deva gets regular use in the Australian outback, where red microdust permeates every crevice of the recorder. The Deva's sealed flash/hard-disk recording system can withstand the wide range of humidity, motion, and dust tolerance that's necessary in a professional location recorder.

The Deva can continually store multiple channels of high-quality audio data in any environment (**Figure 1**). It functions in temperatures of 0 to 120°F and records without missing any audio at forces to 150g. There's also virtually no chance that an audio engineer could lose a day's work by dropping the unit on a sidewalk or subjecting it to harsh treatment. This ultrareliability is due to the unit's memory design, which combines solid-state memory, a reliable hard disk, and additional mass-storage options.

Figure 1

A sound mixer on the set of *CSI: Miami* connects stationary and wireless microphones to the Deva II audio-recording unit.

Alternative systems, such as hard-disk recorders and others, promote recording directly to removable media, such as DVD-RAM or ORB disks (removable hard drives encased in a hard cartridge). However, these systems rely on consumer-grade media and lack the necessary reliability to serve as a primary mastering format. Further, the small-format, 1.5-Gbyte DVD disks in consumer videocameras hold insufficient data for a typical full day of production recording, which can produce 10 Gbytes of audio files per day.

Although the Deva has seen considerable success among audio professionals, the constant demands of audiences and, thus, movie producers for more exciting audio and visual effects require that the market for the equipment that makes these effects possible must be innovative with fast product-evolution cycles. Operators want more channels, more storage capacity, more features, and a more robust user interface. Thanks to advances in mass-storage

Figure 2 The Deva V includes a built-in hard disk, an optional DVD writer, and a FireWire interface that supports yet another mass-storage device. A TMS320C6713 controls the operations of all these peripherals, including the full-color touchscreen graphical user interface.

and DSP technologies, along with some innovative engineering, Zaxcom met these needs with the latest incarnation of the unit, the Deva V (**Figure 2**).

WRITE TO THREE DISKS

Weighing just 5 lbs and with an 80-Gbyte hard disk, the Deva portable 10-channel professional-audio recorder holds several days' worth of production audio recorded at rates to 200 kHz. Further, it can simultaneously record and play back, and a DSP-enabled mixer can mix any combination of inputs to any combination of outputs.

The Deva records simultaneously to an internal hard disk, an optional internal DVD/CD writer, and an external FireWire drive for remote backups. Each can have a different file format and sample rate, and all three can differ from the original sampling rate. Such conversions are often necessary for postproduction requirements. For example, telecine (changing frame rates from movie cameras to the rate needed for television) might require 48.048-kHz files, and a Protools sound-editing system may require the same audio files at 48 kHz. On the output side, the Deva can generate analog signals at any sample rate of 8 to 200 kHz, even the custom sample rates necessary when a camera runs at a nonstandard speed for special effects.

For storing data, the box accepts standard 5.25-in. DVD and CD-ROM disks, and a typical day's worth of recording easily fits on a 4.7-Gbyte-per-side DVD-RAM disk. The unit supports FAT16, FAT32, and UDF formats, so the disks it creates are readable on Macs and PCs without third-party software drivers. During years of field testing, Zaxcom engineers determined that removable-media drives are much less reliable than sealed hard disks. Thus, the Deva's mechanical design allows users in minutes to swap out the internal DVD burner should the drive get contaminated with dust or moisture.

A key specification for sound engineers is the number of I/O lines (**Figure 3**). The Deva V supplies 10 analog inputs, eight digital inputs, and eight each analog and digital outputs. To handle the analog I/Os, the system relies on the McASP (multichannel-audio-serial ports) on a Texas Instruments TMS320C6713 floating-point DSP. The McASP streams 32 channels of audio I/O through the DSP without external hardware.

In this design, the McASP accepts data from eight AES digital inputs as well as 10 analog channels from five sigma-delta ADCs that sample at rates to 200 kHz and spec both dynamic range and SNR at 123 dB. Eight analog channels target use with microphones and thus come with microphone preamps and 48V phantom power. One extra ADC accepts the audio-monitoring signal from a camera, which often serves as a scratch mix (a simple audio track that accompanies the dailies the director watches after each day's filming). The remaining audio channel works with a built-in "slate mike" that allows operators to make real-time voice notes, such as "Scene 1, Take 1," to prefix each audio file.

ELIMINATE AN FPGA

Although the Deva V can send audio signals from serial ADCs directly to hard disks, its predecessor system had to deserialize and buffer the audio data and load it onto the DSP's data bus. That job required an FPGA, which not only increased the system power consumption, but also added considerably to the overall development time. The Deva V's C6713 now performs all these tasks. It also supplies 256 kbytes of internal memory to handle serious audio processing, thus eliminating a bottleneck between the DSP and the external memory. The DSP connects to 256 Mbytes of SDRAM, which the designers tied directly to the proces-

sor via its EMIF (external-memory-interface) port. This large, 32-bit-wide memory area forms a 10-second audio buffer from which the unit continuously streams data onto the hard disk.

A key component in the Deva V is the hard disk. The design team evaluated all the commercial models they could find and determined the most reliable one to be a unit normally intended for laptop PCs—a 2.5-in., 80-Gbyte removable drive. To further enhance the disk's reliability in unusually harsh conditions, designers surround it with a foam cushion and use a ribbon cable rather than a connector mounted to a pc board. The disk drive itself contains an accelerometer, which shuts down the drive if it detects dangerously high levels of shock or vibration. When the drive is inactive, the SDRAM buffers data; if that memory fills before the disk restarts, the box then sends data to its 4 Gbytes of flash memory. That memory can cache more than an hour's worth of audio, so when the unit comes to rest after an episode of violent movement, and the disk spins up again, the unit can automatically dump the flash memory onto the removable hard disk.

Besides the accelerometer in the hard disk, the Deva V incorporates a secondary accelerometer that helps prevent data loss on the internal DVD writer using a similar caching scheme. This DVD writer provides an economical way to send the daily audio files to the studio for postprocessing and archival. Should a user lose or damage a DVD disk, which happens more often than you might expect, the production sound mixer can at a moment's notice burn a new DVD disk.

A professional recorder needs to store uncompressed audio, so MP3 or other lossy-compression schemes are not options. A single production day of uncompressed 24-bit audio can occupy much more than 10 Gbytes. Due to the vast amounts of data that must be sent to the postproduction house every day, Zaxcom developed a new file format, the .ZAX file. It not only implements lossless compression, which creates a file roughly one-third the size of the original, but also includes a time-code stamp, as well as notes concerning the scene, take, and other metadata, such as channel labels containing actors' names. This format makes it possible to mirror more data on a removable disk and reduces the time it takes for engineers in the studio to read data from DVD disks.

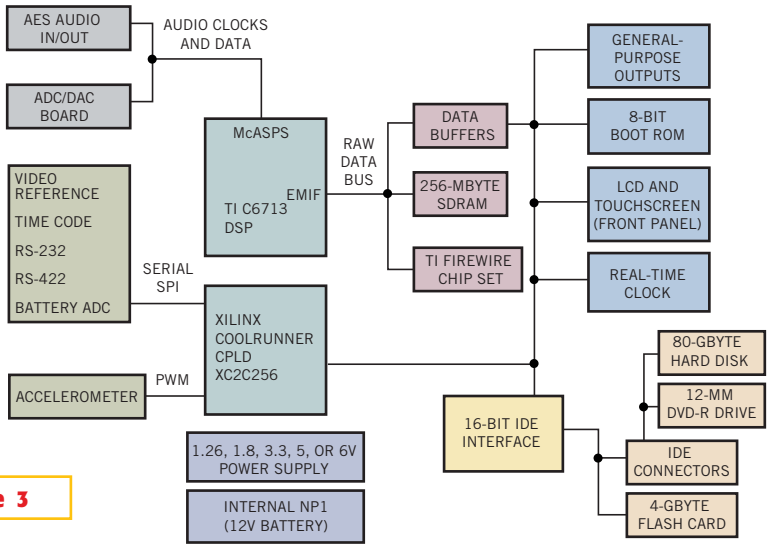

Figure 3

All analog inputs and outputs go through the McASP port on a TMS320C6713, which also provides a convenient and fast interface to the memory necessary to buffer data if the Deva's internal hard disk parks. In this way, the hard disk protects itself from dangerous operating conditions, thereby preventing data loss or physical damage to the drive heads.

PLAYING MANY ROLES

Working with multiple storage options places interesting demands on the unit's DSP, which runs a complex mixer algorithm and operates on signals with sampling rates as high as 200 kHz. The DSP also performs highpass filtering to remove wind noise on microphone inputs. However, the design team intends in future revisions to leverage the remaining DSP MIPS to implement a binaural headphone-monitoring algorithm that allows the operator to monitor a surround-sound microphone array in 3-D with a set of headphones. This algorithm requires a large digital filter that involves the application of 2048 coefficients to each input channel from a special microphone. Such a computationally intensive operation is possible only with a powerful DSP onboard.

The Deva contains not a conventional microcontroller but rather just one processor, the C6713. This floating-point device handles everything from audio algorithms to FireWire arbitration and even a full-color graphical user interface, and its wide dynamic range makes it easier to write audio algorithms. By avoiding work with a DSP/CPU combination either separately or on one die, the design team could concentrate on one instruction set and one development environment.

Working in tandem with the DSP is a Xilinx CoolRunner CPLD, which provides general-purpose digital-I/O lines, RS-232, RS-422, and time-code port UARTs. It also handles clock generation and controls several serial peripherals, such as the touchscreen and the IDE interface to the internal drives.□

Author's biography

Howy Stark is the director of product development at Zaxcom Inc (www.zaxcom.com), where he designs hardware and writes DSP software for professional-audio equipment targeting the TV and film industries. He recently received a Scientific Academy Award for the contribution that the Deva hard-disk recorder has made to the film industry. Stark has a bachelor's degree in electrical engineering from Grove City College (Grove City, PA) and has taken various graduate-DSP courses at Rutgers—The State University of New Jersey (Brunswick). Previously, he was employed at Eventide Inc as a design engineer for various professional-music and avionics products.

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