White Paper

Putting the audio
back in audio / video

CRESTRON

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Introduction

With its ability to transport high definition digital audio and video, HDMI® is a great format for connecting high-end devices in point-to-point configurations, or even basic switching systems (*e.g.*, one display, an A/V receiver, and a collection of sources). However, when there is a need for high definition audio and video in a large and complex distribution environment, HDMI presents some challenges, especially regarding audio.

To overcome those challenges, a modern digital A/V distribution system must be engineered from the ground up to manage audio as thoughtfully as it manages video. Too many systems on the market treat audio as merely an afterthought. This shortcoming results in system designers and integrators having to take on these challenges themselves, with inelegant systems of disparate components. Time and money must be invested at each job to overcome the same problems, over and over again. Alternatively, the designer could simplify his design, but the cost is a diminished experience for the end user.

Crestron's DigitalMedia product line was designed to be the best digital transport network for video and audio signals. Thousands of hours of engineering and design were invested in building a system that eliminates the complexities of mixing high definition audio and video in one system. The result is a distribution network that can provide the best possible experience for end users, without the extra time, equipment, and troubleshooting associated with less evolved approaches to solving HDMI's audio challenges.

In this paper, we will investigate some of the situations where DigitalMedia's sophisticated audio features can improve user experience, while simplifying design and installation. We will also explore some of the technologies and architectures that make this possible.

Breadth of audio format support

The Crestron DigitalMedia product portfolio includes over 70 products, with support for five different types of audio inputs: HDMI, S/PDIF optical, S/PDIF coaxial, Serial Digital Interface (SDI), and analog stereo. Each of these input types has unique format capabilities, and DigitalMedia supports all major formats for each type of input. Via HDMI, DigitalMedia supports multichannel PCM, high resolution lossless formats from Dolby (TruHD) and DTS (Master Audio), and the low-bitrate compressed formats (AC-3, DTS). Using S/PDIF inputs, DigitalMedia can receive stereo PCM or low-bitrate compressed formats. SDI can carry up to eight channels of PCM audio, and DigitalMedia can receive them all. Finally, DigitalMedia supports analog stereo inputs.

It is important to note that all of these audio formats can be routed over any type of DigitalMedia infrastructure – CAT5, multimode fiber, and single mode fiber.

Any of these input types – digital or analog – can be routed through a DigitalMedia network to any type of audio sink. If a particular format is more than an audio sink can handle (for example, DTS Master Audio routed to a stereo-only TV), then DigitalMedia's downmixing DSPs can create a CD-quality stereo mix compatible with the audio sink. (More on audio downmixing on page 11.) DigitalMedia provides analog outputs for connectivity to analog-only audio sinks.

It is important to note that all of these audio formats can be routed over any type of DigitalMedia infrastructure – CAT5, multimode fiber, and single mode fiber. Regardless of your source format and your sink capabilities, DigitalMedia can guarantee your audio is delivered, reliably, in the highest quality possible.
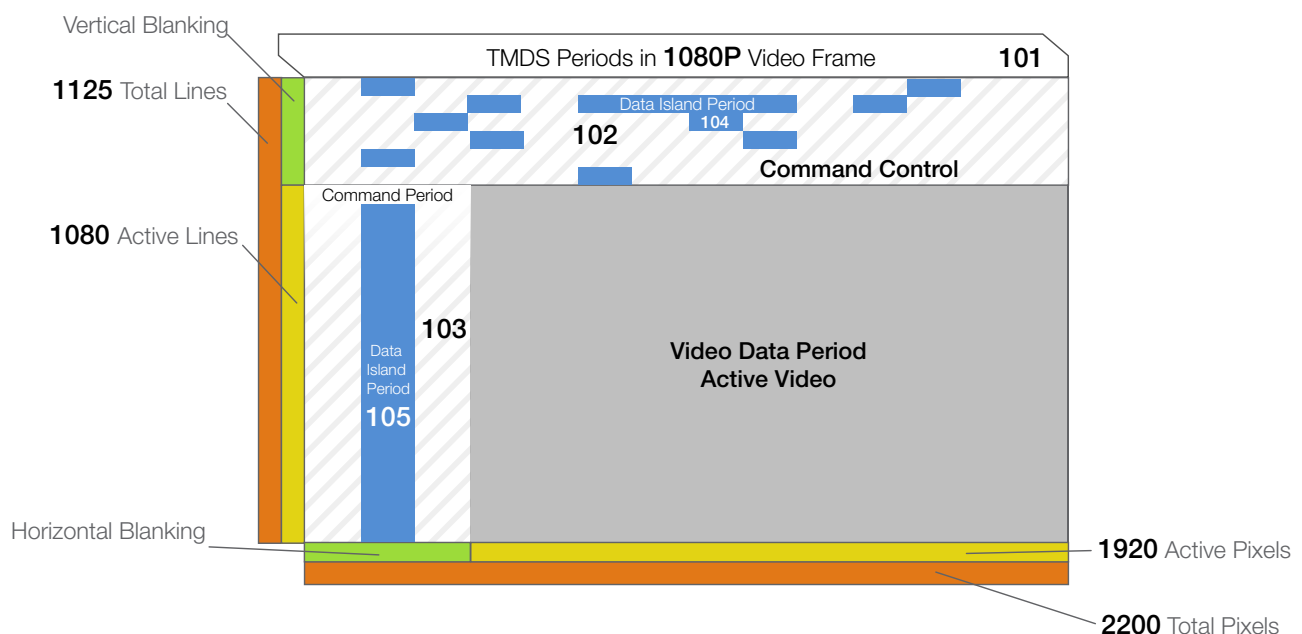
"Free run" video mode

HDMI is a high speed video bus. It transmits data in an electrical encoding called transition-minimized digital signaling. While the vast bulk of data transmitted over an HDMI cable is video data, high resolution audio data is carried on the same wires. Figure 1 shows a graphical representation of a standard 1080P HDMI video frame (101). Inside the blanking intervals (102, 103) are "data island periods" (*e.g.*, 104, 105). These data island periods are where the audio is embedded. More to the point, there is no separate or secondary channel for the audio stream. Audio is contained inside the video data. This means that when there is no video, there can be no audio.

Sometimes in a digital content distribution network, it is useful to carry audio even when there is no video available (or desired). For example, a user might want to plug in a portable music source at a remote system input (*e.g.*, a DigitalMedia transmitter). In a normal HDMI extender, audio cannot be transmitted without adding a video source to the mix. The user who wants to plug in an iPod®, but hasn't brought a laptop, is out of luck.

DigitalMedia transmitters and input cards include "free run mode," which automatically generates a 640x480 flat black frame to carry audio without need for an extra video source. This signal is generated automatically any time there is no video source connected to a DigitalMedia input. In a few circumstances, this may be undesirable (for example, if you are using automatic HDMI switching downstream). Therefore, free run mode may be easily disabled.

Figure 1: Representation of a complete HDMI video frame

Vertical Blanking

1125 Total Lines

TMDS Periods in **1080P** Video Frame   **101**

Data Island Period
104

102

Command Control

Command Period

1080 Active Lines

103

Data
Island
Period
105

Video Data Period
Active Video

Horizontal Blanking

1920 Active Pixels

2200 Total Pixels

Full breakaway audio switching

DigitalMedia offers total flexibility in routing audio and video signals. They may be routed and switched together, or they can be broken apart and routed independently from one another. This capability is referred to broadly as "breakaway switching." To achieve this, every part of a DigitalMedia system must be engineered with this feature in mind, including remote input transmitters, input and output cards, and the switch chassis themselves.

The most basic digital audio and video

Formats like HDMI, S/PDIF, SDI, etc. are all designed for transmission between A/V devices over cables. Such formats employ complex techniques to minimize things like pin count, EMI susceptibility, and corruption over long distances. Conversely, on a circuit board inside an A/V device, more basic signaling formats are used to avoid complexity and ensure compatibility between many different chips and devices. Two of those basic formats are discussed in this article.

I2S Audio

Digital audio components require an ultra-low jitter commu-nications path so that audio integrity is always maintained. To achieve this, I2S was invented back in the 1980s. It consists of three signals: data, bit clock, and word clock. Data carries all of the audio data. Bit clock is the low-jitter clock that aligns the transmitter and receiver. Word clock helps the receiver know when one word (sample) starts and ends, and also help it know whether a sample is from the left or right channel.

Parallel Digital Video

A digital video signal is a collection of pixels. Each one of those pixels is broken down into three sub-pixels (red, green, blue). Each sub-pixel's brightness is represented by a few bits – typically eight to twelve. A single pixel, therefore, is represented by 24 to 36 bits. This is the color depth. In parallel digital video signaling, there is one wire for each one of those bits. DigitalMedia supports HDMI deep color – 36 bits. Therefore each parallel digital video connection on a DigitalMedia circuit board is 36 wires, plus a pixel clock. Each time the pixel clock ticks (up to 165 million times per second in an HDMI 1.3 system), the next pixel is loaded onto the 36-bit bus.
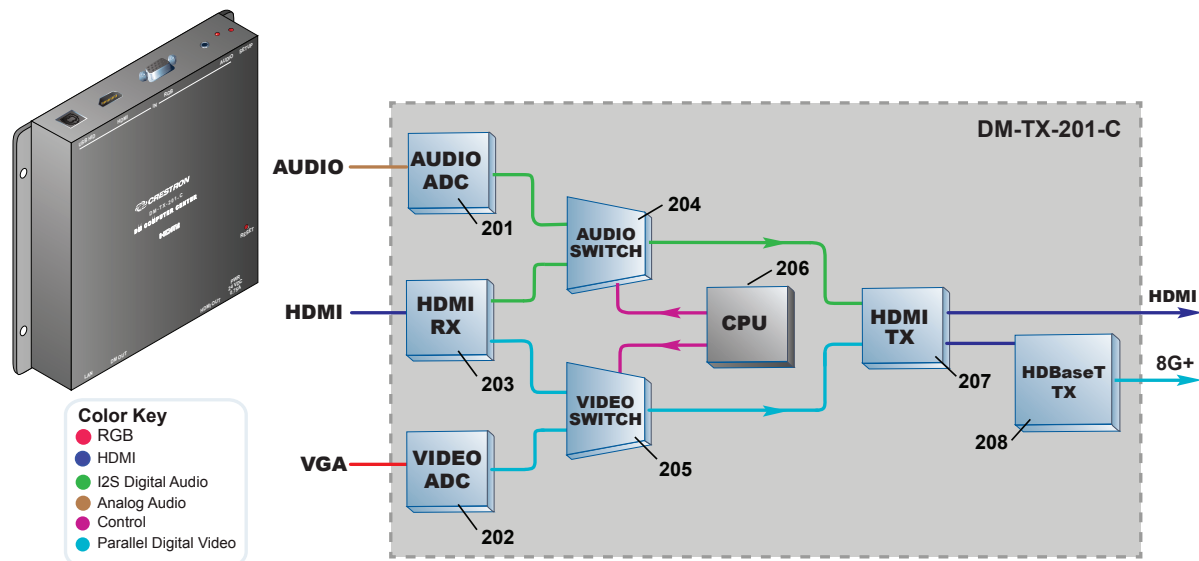
Breakaway switching in a DigitalMedia transmitter

It is common for a laptop computer to support HDMI video output, without including audio in the HDMI stream. When a user arrives at a podium or conference table ready to plug in such a laptop, what happens? A DigitalMedia transmitter makes it easy to mix HDMI video with analog audio. The architecture of a DigitalMedia transmitter makes this possible.

A DigitalMedia transmitter makes it easy to mix HDMI video with analog audio.

Figure 2 shows a simplified illustration of a DM-TX-201-C DigitalMedia transmitter with HDMI, VGA, and analog audio inputs. The analog signals (VGA and audio) are digitized by high precision analog-to-digital converters (201 and 202). The HDMI signal is put into an HDMI receiver (203) which separates the video and audio into basic streams. At this stage, all audio is in the I2S format, and all video is parallel digital video. Those all-digital signals are fed into separate multiplexers for audio (204) and video (205). Now the transmitter's CPU (206) may individually select which audio and which video to feed into the HDMI transmitter (207). The transmitter takes those basic digital signals and assembles them together into a new HDMI stream for output. In the case of the DM-TX-201-C, a copy of that HDMI signal is fed out to a local output, and also to an HDBaseT transmitter (208) for long distance transmission to a DigitalMedia switch or receiver.

Figure 2: Block diagram representing a DM-TX-201-C transmitter

## Breakaway switching in a DigitalMedia chassis

Any audio input may be combined with any video input, and the combination may be routed to any output.

In a DigitalMedia matrix switch, audio and video may be routed with complete independence. Any audio input may be combined with any video input, and the combination may be routed to any output. Also recall that audio may be routed on its own (thanks to free run mode, described earlier). Different mixes of audio/video inputs may be used at each output, thanks to the extremely flexible architecture of DigitalMedia switches.

To understand breakaway switching in a DigitalMedia matrix, we start at the input card. Let's examine a DMC-HD HDMI input card. Figure 3 shows a simplified block diagram of a DMC-HD HDMI input card for DigitalMedia. For clarity, loop outputs are not shown. The only input to this card is HDMI. The HDMI signal is fed into an HDMI receiver (301) which breaks the HDMI signal down into separate I2S audio and parallel digital video. Video and audio are both routed to an HDMI transmitter (302) that feeds the incoming HDMI audio and video signal directly into the backplane connector (303), where the matrix will route the signal to one or more output cards.

The interesting feature to note is that the I2S digital audio signal is also routed to a secondary set of pins on the backplane connector (303). Let's examine how the backplane handles these two separate feeds.

Figure 3: Simplified block diagram of a DMC-HD HDMI input card
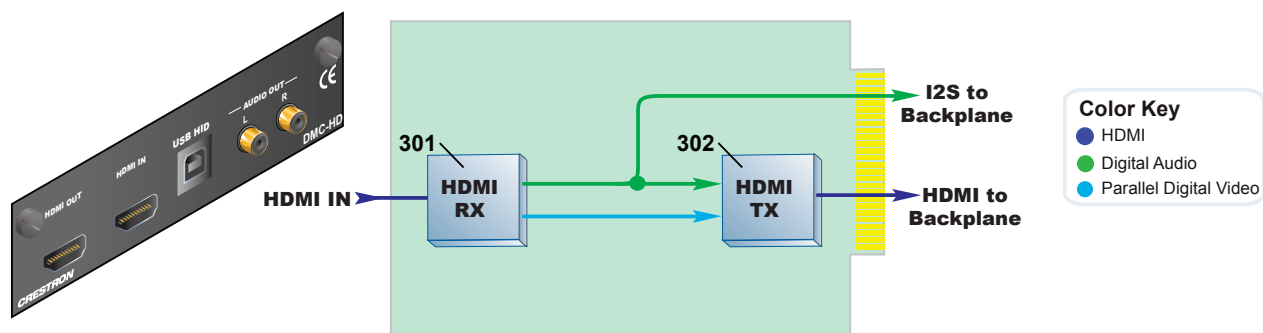
Color Key
- HDMI
- Digital Audio
- Parallel Digital Video

Figure 4 shows a basic layout of a DigitalMedia matrix switch, including (in this example) three input cards (401, 402, 403), three output cards (404, 405, 406), and the backplane itself (407). The keen observer will immediately note that there are not one but two switches on the backplane. The main switch of course is the high-speed HDMI crosspoint (408). The HDMI crosspoint is fed by the HDMI output of each input card, carrying the uncompressed video and audio, including, potentially, high definition audio. The "trick" to DigitalMedia's breakaway capability, however, is the secondary I2S audio crosspoint (409). The audio crosspoint is fed by the secondary audio outputs of each input card.

Similar to the input cards feeding HDMI and I2S audio into the backplane, each output card receives an HDMI feed and an I2S audio feed. Let's take a closer look.

Figure 4: Simplified block diagram of a DigitalMedia switch with three inputs and three outputs
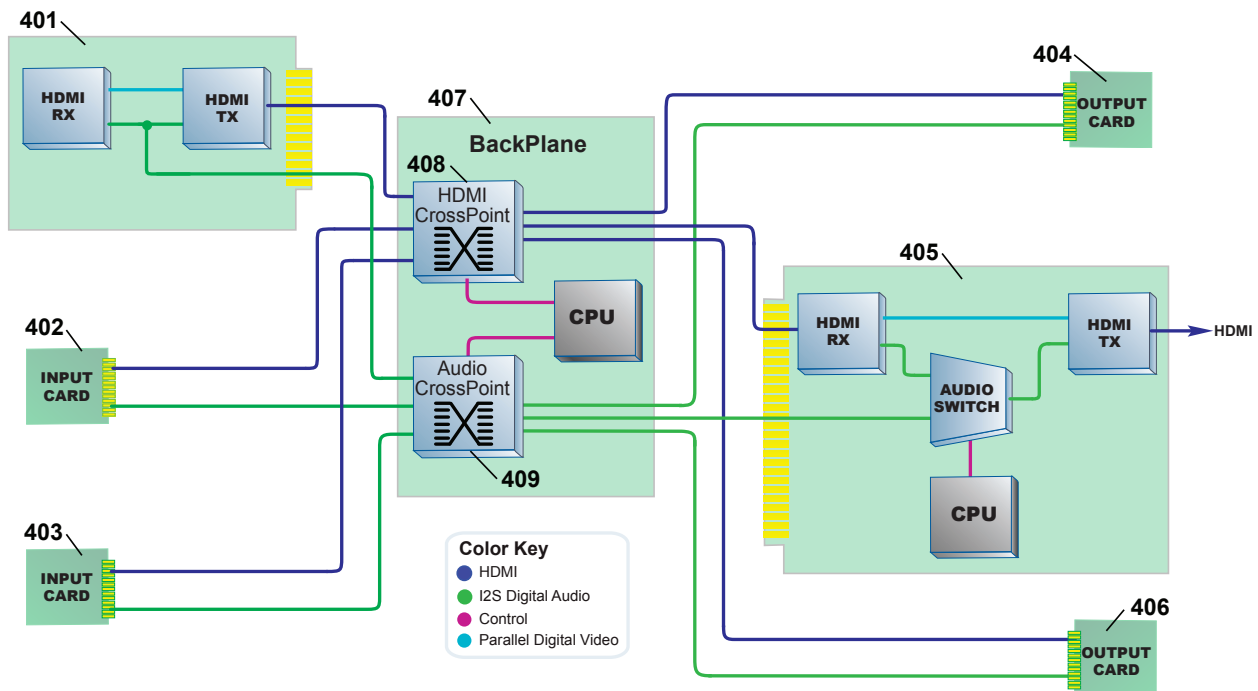
Figure 5 shows a simplified block diagram of a DigitalMedia output card. For simplicity, it is assumed that a DigitalMedia output card is a single-channel device. (In reality, of course, each DigitalMedia output card is a two-channel device, and output cards are packaged into modules of four or eight total outputs.) The backplane HDMI feed is sent to an HDMI receiver (501), which decodes the signal into I2S digital audio and parallel digital video. That video feeds an HDMI transmitter (502) for output, but the

Figure 5: Simplified block diagram of a DMC-HDO HDMI output card
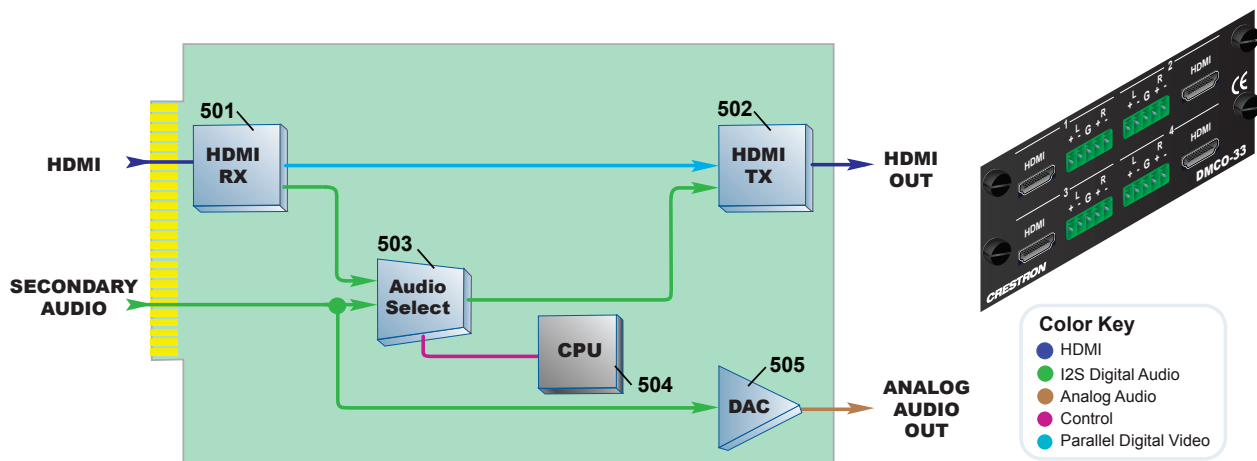
A DigitalMedia matrix may combine any video source with any audio source, enabling complete breakaway audio and video switching.

HDMI audio is fed into another audio multiplexer (503) which selects between the two audio feeds: HDMI audio from the backplane HDMI crosspoint, and I2S audio, coming from the secondary audio crosspoint. This means that the audio fed to the HDMI transmitter (502) could come from the same HDMI input as the video (non-breakaway), or from any other input card via the secondary audio crosspoint (breakaway audio). The output card's CPU (504) can select whichever audio is appropriate, based on user input. In this way, a DigitalMedia matrix may combine any video source with any audio source, enabling complete breakaway audio and video switching.

DSP downmix

How the secondary audio matrix enables multiple audio tracks

What if your audio sinks have different capabilities than one another?

We have established that DigitalMedia is a complete video and audio switch, with full breakaway audio routing capability to complement the powerful video routing capabilities of the switch. But what if your audio sinks have different capabilities than one another? Home theater audio is typically managed by a powerful HDMI A/V receiver, supporting all the latest and greatest high definition audio formats such as Dolby® TruHD and DTS Master Audio. That's great, but the TV in the kitchen can only support stereo PCM audio. HDMI itself can only carry a single audio stream – high definition, or stereo. Not both.

Traditionally there are two approaches to solve this problem:

1. Manage your high-quality HDMI audio in your HDMI matrix, leaving stereo audio management to an entirely separate distribution system. This approach requires that you limit your sources to those devices which can simultaneously output high definition HDMI audio and low quality analog audio, and requires you to manage the expense, cabling, and integration of two complex and disparate systems.

2. Give up your high definition audio. Configure your sources to output stereo only and route these signals through your HDMI distribution system.

Unlike traditional HDMI, DigitalMedia can carry two separate audio streams simultaneously.

Obviously, neither of these choices is ideal.
DigitalMedia solves this problem elegantly by taking advantage of the secondary audio crosspoint and adding in some audio DSP horsepower to create its own stereo downmix of high definition audio content. Unlike traditional HDMI, DigitalMedia can carry two separate audio streams simultaneously.

Figure 6 shows another DigitalMedia input card, this time a DMC-HD-DSP. This is the same input card shown in Figure 3, but with the DSP (603) added for downmix capability. The high definition audio stream is fed, untouched, directly to the HDMI transmitter (602) and on to the HDMI crosspoint in the backplane. But rather than rely on the source to provide a stereo-only signal to send to the secondary audio crosspoint, a DSP (603) is fed by the digital audio output from the HDMI receiver (601). This DSP can accept any HDMI audio format and convert it to a simple stereo downmix. It is this downmix that is fed to the secondary audio crosspoint on the backplane.

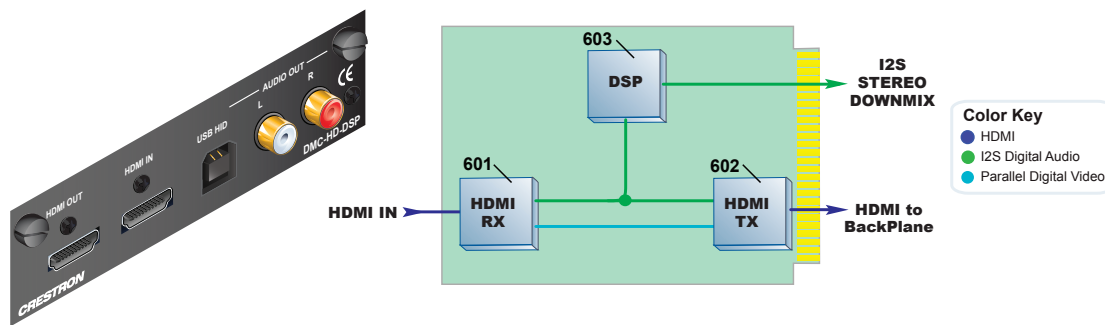**Figure 6:** Simplified block diagram of a DMC-HD-DSP HDMI input card with DSP downmixer
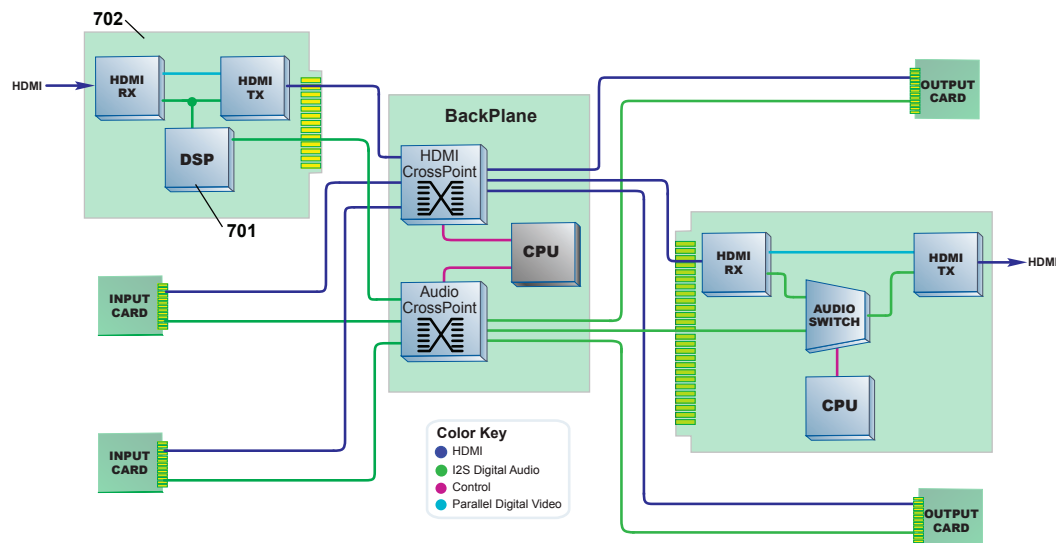

Figure 7 is a re-hash of Figure 4, illustrating the addition of a DSP (701) to the input card (702). Using DSP input cards everywhere guarantees a proper stereo downmix for all of the secondary audio feeds.

Figure 7: Simplified block diagram of a DigitalMedia switch with DSP input cards

Using downstream EDIDs to intelligently select the right audio track

Refer back to Figure 5, showing a DigitalMedia HDMI output card. Imagine we are not using breakaway audio; the HDMI audio signal and secondary audio signals coming from the backplane are both from the same input card (and therefore the same source). Now, however, the HDMI audio is high definition multichannel and the secondary audio is its stereo downmix. Obviously we need the stereo downmix to feed the DAC (505) for analog output, but what about the HDMI output? How will the user know which audio track to feed to the HDMI output? How will the user make this selection?

In fact, the user will not need to be involved at all. Neither will the system integrator or programmer. DigitalMedia will intelligently and automatically select the correct audio track by checking the EDID of the downstream device it detects on its HDMI output.

Figure 8 shows a complete block diagram of a DigitalMedia HDMI output card (801) utilizing both of its HDMI outputs. Output 1 is connected to a television (802) which supports only stereo audio as reported in its EDID (803). HDMI transmitter 1 (804) reads this EDID information and passes it to the CPU (805), which configures audio switch 1 (806) to select the secondary (downmix) audio track for transmission to the display. The display receives the stereo downmix and has no problem playing it back for the user in the kitchen.

Output 2 is connected to a high-end AVR (807) whose EDID (808) reports compatibility with all high definition audio formats. Recognizing that the AVR (807) is HD-audio capable, the output card CPU (805) will select the high definition HDMI audio for channel 2 output. Users in the home theater enjoy rich multichannel surround sound.

For simplicity, the above example uses an HDMI output card connected directly to the displays. These very same principles and architectures apply when using 8G output cards with DigitalMedia Room Controllers as well. This same EDID-based decision-making happens at every output of a DigitalMedia switch, so each downstream audio device can receive the best audio track it can handle. This automatically guarantees each user the optimum audio experience from the equipment they are using.

Figure 8: Complete block diagram of a DMC-HDO HDMI output card with connected audio devices
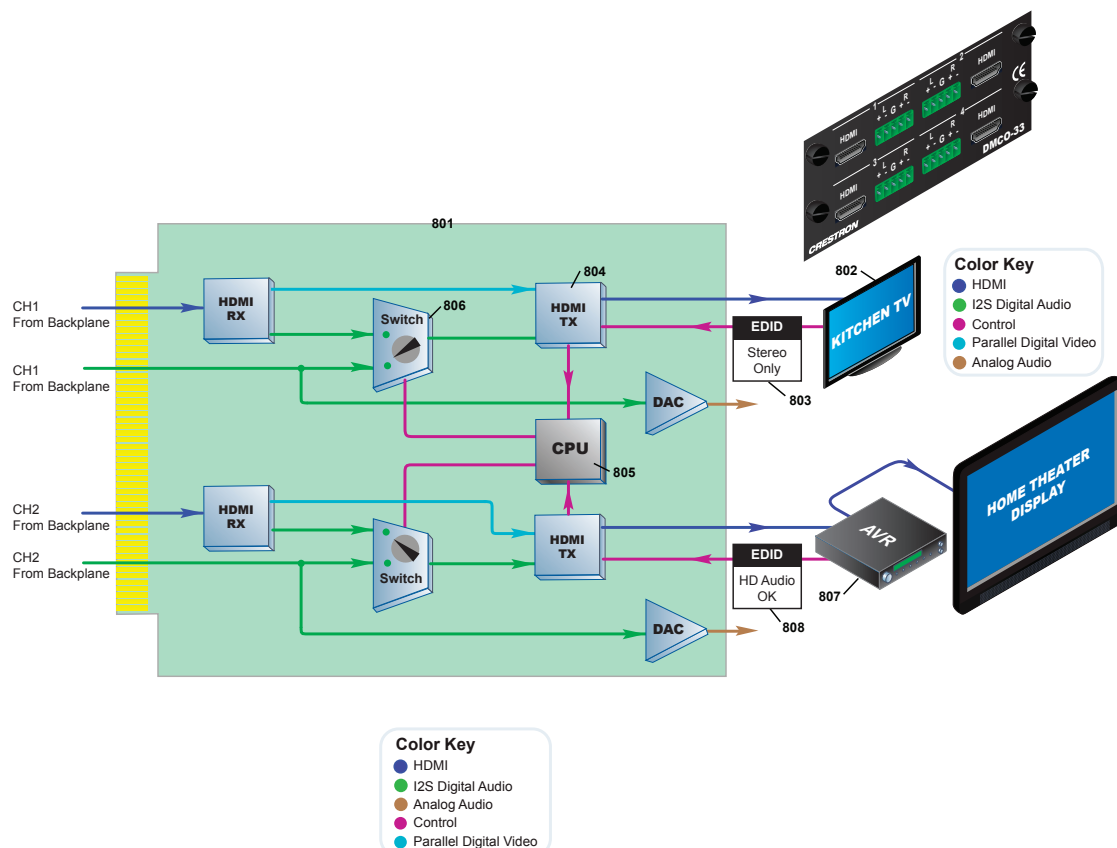
Integration of DigitalMedia with Sonnex

DigitalMedia is a great solution for routing video and audio throughout a facility. Still, there are many applications that call for a separate and dedicated audio distribution system, like Crestron Sonnex™ or with an external mixing console. This is especially true when there are many more audio-only zones than A/V zones. DigitalMedia is engineered to easily integrate with your audio distribution system.

A key problem for the integration of audio and video systems is sharing of sources. If your source only has a single output, you must include extra signal splitters or DAs to connect it to both systems. You may also need to convert digital outputs to analog, depending on the capabilities of your source and your audio distribution system. DigitalMedia makes this integration simple by providing audio loop outputs for each system input.

Figure 9 shows a complete block diagram of a DigitalMedia input card (in this case, DMC-HD-DSP). The source feeds its audio directly into the card via HDMI. As we have seen earlier in this article, that audio is fed into the backplane for routing. However, the output of the downmixing DSP (901) is additionally fed into a digital to analog converter (DAC, 902). An additional feature of the DAC is that it may have its output gain controlled by the CPU (903). This function provides volume control for the output, independent of other gain or volume settings throughout the DigitalMedia system. Volume control on this output means that nothing more than a power amp and speakers are necessary to achieve full audio distribution integration.

Figure 9: Complete block diagram of a DMC-HD-DSP input card with DSP downmixer
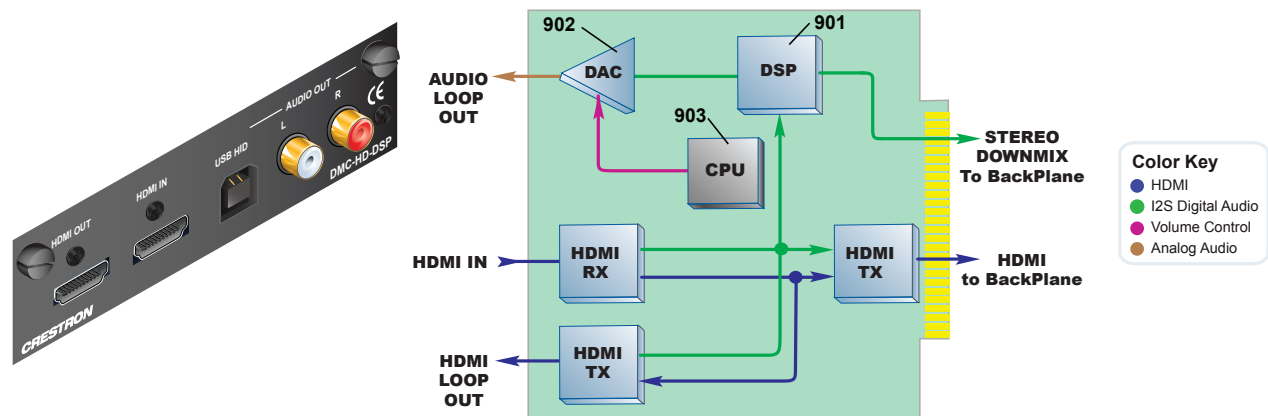
Figure 10 shows a collection of DigitalMedia input cards, highlighting their analog RCA loop outputs.

Figure 10: A selection of DigitalMedia input cards with audio loop outputs

DMC-HD-DSP

DMC-C-DSP

DMC-S-DSP

DMC-SDI

Figure 11 shows an application diagram demonstrating integrated connectivity between DigitalMedia and Sonnex.

In this configuration, any source may be routed to any DigitalMedia video destination, but all sources are completely available to the audio distribution solution, without the need to use up valuable DigitalMedia video outputs.

Figure 11: Application diagram demonstrating DigitalMedia and Sonnex integration with 2-Channel and Multi-Channel distribution
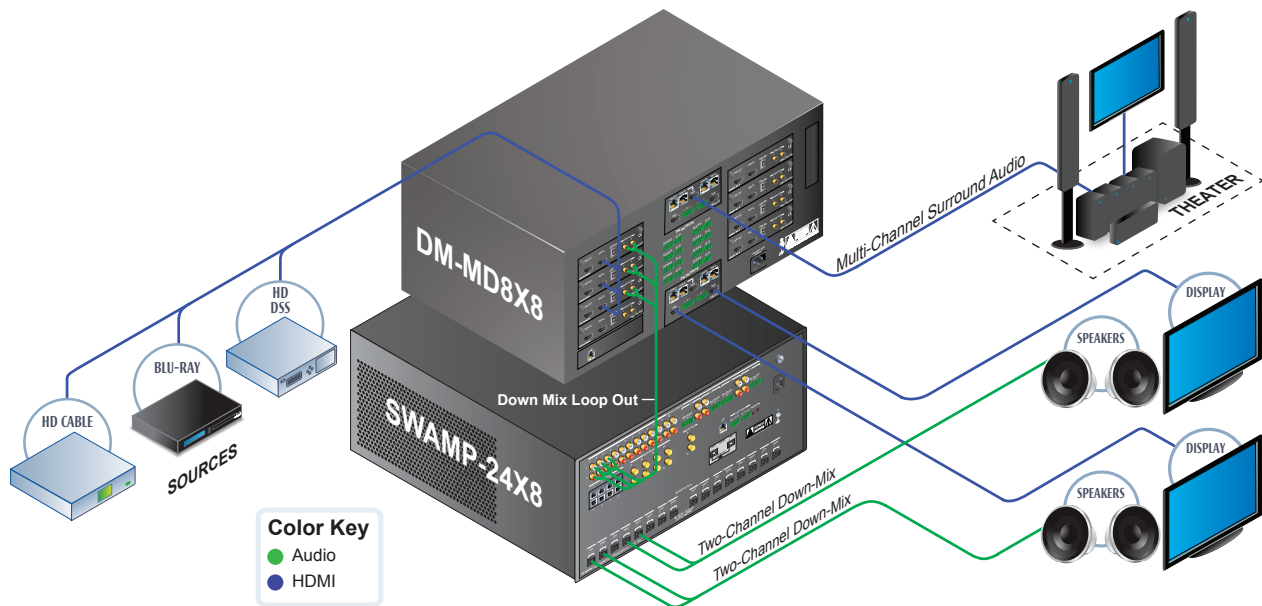
HD-DA-2 as a utility device

Not only is the HD-DA-2 a reliable, HDCP-compliant HDMI distribution amp, it is also a handy audio problem solver. Perhaps your source is a PC with DVI video and S/PDIF audio. The HD-DA-2 can combine the S/PDIF audio from a TOSLINK® or coax source with HDMI video and provide dual HDMI outputs with this new mix of audio and video.

Or perhaps your source is HDMI-only, but you need to feed the audio into an analog pre-amp or audio distribution system. HD-DA-2 can extract stereo audio from an HDMI signal, convert the audio to analog, and send that signal out via RCA jacks. Connect the analog outputs to your audio distribution system and HDMI outputs to your display. Additionally, the HD-DA-2 can be used as a pure extractor, without connecting a display.

Figure 12 shows a block diagram of the HD-DA-2. A S/PDIF to I2S converter (1201) selects between coaxial or optical S/PDIF inputs and converts the selection to I2S. This I2S signal, plus the I2S signal from the HDMI receiver (1202) feed the digital audio multiplexer (1203). The multiplexer sends its audio to a DAC (1204) for analog output; to an I2S-to-S/PDIF converter (1205) for S/PDIF output; and to an HDMI transmitter (1206) for output. Video is passed directly, in parallel digital form, from HDMI receiver (1202) to HDMI transmitter (1206) for output, and the transmitter (1206) has dual outputs, to provide the DA functionality.

Figure 12: Block diagram representing an HD-DA-2 distribution amplifier
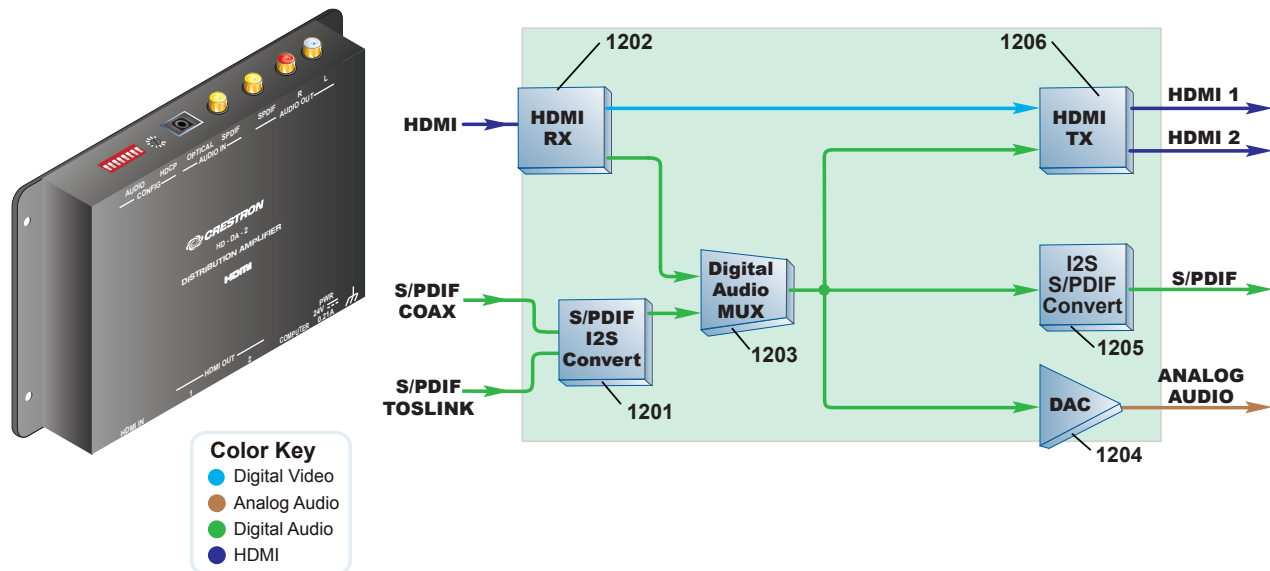
Wrapping it up

The HDMI standard presents challenges to managing high definition audio and video in a large and complex distribution environment. System designers and integrators have had to take on these challenges by employing less than ideal configurations of disparate components, resulting in a diminished end user experience.

Before you select an HDMI distribution system, it's essential to fully understand the capabilities of the solution and identify limitations. It's easy to make assumptions based on years of experience with analog systems that simply don't hold true in today's digital landscape. For example, when you spec a digital AV matrix switcher you may assume that the switcher is capable of full matrix routing of audio and video. While this seems obvious, it's wrong.

Worst of all, most digital AV switchers cannot offer breakaway switching, and are limited in their ability to mix and match audio formats (including analog!) with HDMI. You should have a detailed spec of the switch's capabilities and be very careful to make sure that the digital solution you request or purchase meets all of your requirements. No one likes surprises. Engineered from the ground up to manage audio as thoughtfully as it manages video, DigitalMedia is the only solution that eliminates the complexities of mixing high definition audio and video in one system, providing exclusive capabilities, such as downmixing and transporting multiple streams of audio to multiple sources.

The end result is a distribution network that can provide the best possible end user experience without all the extra time, equipment, and troubleshooting associated with less evolved approaches to solving HDMI's audio challenges.

System Design and Capabilities

Designed to distribute the full breadth of audio and video formats and format conversions	✔
Ability to distribute both analog & digital audio without purchasing additional cards	✔
Supports breakaway audio switching	✔
Analog audio available from every HDMI output	✔
No restrictions on distributing surround sound audio	✔
Distribution of signals containing HDCP over CAT5e, multimode fiber, and single mode fiber transmitters or receivers	✔
Input cards & transmitters that include "free run mode," which carries audio without need for an extra video source	✔
Full breakaway audio switching	✔
DSP downmixing (Transmits multichannel audio stream and a 2-channel downmix of the same source at the same time)	✔
Uses EDID to automaticly select the correct audio track	✔
Audio loop outputs for each system input	✔