Dolby® TrueHD Audio Coding for Future Entertainment Formats

For more than four decades, Dolby® technologies have enhanced the entertainment experience. The one constant throughout this period has been the continuous evolution of entertainment formats.

Since its invention more than 100 years ago, 35 mm film—and the picture and audio experience it produces—has been revitalized countless times. Multichannel Dolby Surround sound, for example, brought a new degree of realism to the cinema experience with *A Star Is Born* in 1976 and a year later with the blockbusters *Star Wars* and *Close Encounters of the Third Kind*. Soon after, Dolby Surround would quickly find its way into the world of home entertainment.

Today digital video delivery and projection technologies have made it possible to display movies in theatres with better quality than that of 35 mm film. Just as Dolby Digital technology enabled 35 mm movies to sound better and gave improved audio consistency over the life of the print, digital delivery of movies does the same for the picture side of the equation, eliminating dirt, weave, blurry prints, scratches, and lumpy splices. The 1st or the 1,000th playback of a digital motion picture is on a par with a pristine film print being played on a well-tuned projector—a cleaner presentation with fewer visible distractions.

Freedom from the physical constraints of film can lead to interesting developments such as higher frame rates for more fluid motion, or kinds of 3D imaging never before possible. Who knows what else might come along once creative minds are turned loose to explore the reaches of the high-bandwidth infrastructure being established to deliver movies to digital cinemas? We've seen how high-speed Internet access has changed the way consumers obtain their entertainment. Imagine what can happen when every major cinema in the world is tied to a huge, secure data delivery pipe.

Expanded Audio in Digital cinema

One obvious direction for digital cinema is more audio channels. There are many precedents for this move. Dolby Digital Surround EX™, for example,

divided the surround speaker array into three zones instead of the two of 5.1-channel formats. Special-venue film formats such as Imax® have used an additional speaker located at the top of the screen to enhance the sense of vertical movement. Even as long ago as 1940, Disney's *Fantasia* premiered in New York's Broadway Theatre as the first film shown commercially with multichannel sound. There's always been a desire to explore the use of more audio channels in cinemas, and digital cinema makes it practical to do so.

The Society of Motion Picture and Television Engineers (SMPTE) formed the DC28 Digital Cinema Technology Committee, which has defined new channels and speaker locations that may be applied in future digital cinemas. Of the 20 total channels described in SMPTE 428M, 7 are those of the current Surround EX 6.1-channel configuration, while the remainder include more surround arrays, half-left and half-right speakers behind the screen as with SDDS and 70 mm magnetic formats, speakers located for a sense of height, and a second Low-Frequency Effects (LFE) channel.

No one expects that all these channels will be used at the same time, nor has anyone so far mixed a movie or equipped a cinema to support them (their use is entirely optional). It will probably take a special release (like *Star Wars: Episode I—The Phantom Menace*, which introduced Dolby Digital Surround EX) to motivate producers and theatre owners to take advantage of some or all of the new channels.

Bringing the Digital Cinema Experience Home

As a result of Dolby's participation in the DC28 committee, we decided to ensure a pathway into the home for the expanded capabilities of digital cinema soundtracks by enabling Dolby TrueHD to carry additional channels. We proposed that Dolby TrueHD be adopted in next-generation high-definition (HD) disc formats, and that the standard SMPTE 428M naming conventions be used for any new channels. We are pleased to say that the Blu-ray Disc™ format has adopted this proposal for Dolby TrueHD.

Blu-ray Disc is currently limited to a maximum of eight channels, but this should be sufficient for the foreseeable future. There is no technological barrier to expand channel offerings later, however, as Dolby TrueHD is designed with compatible extensibility. Home-video companies are now beginning to offer Blu-ray Disc titles with 7.1 discrete channels encoded in lossless Dolby True HD, configured with Left Surround, Left Back, Right Back, and Right Surround channels like 7.1-channel Dolby Pro Logic® IIx.

Blu-ray Disc Capacity Enables New Levels of Audio Quality

The Blu-ray Disc format has made it possible to complement a pristine HD picture with sound quality that until now has been heard only on high-resolution DVD-Audio recordings. The combination achieves levels of quality attained by no prior A/V consumer format.

The prospect for additional channels provided an ideal opportunity to update MLP Lossless™ technology for a new role as a movie soundtrack codec on HD discs. In addition to implementing a variety of technical revisions and extensions, we have also distinguished this enhanced version with a new name: Dolby TrueHD.

Dolby TrueHD assures pure lossless audio performance, bit-for-bit identical to the original studio master soundtrack. The core technology of Dolby TrueHD is MLP Lossless, first pioneered on DVD-Audio. As a result, MLP Lossless has been in use longer and more widely than any other lossless audio technology, proving itself to consumers and industry experts alike.

Dolby TrueHD is a lossless PCM audio format built around the following techniques:

- Lossless matrixing, which reduces the data rate by taking advantage of interchannel correlations, and is also used for downmixing
- Decorrelation, which takes advantage of the predictive nature of audio
- Huffman (entropy) coding, which is a more efficient coding process modified to allow fewer bits to be assigned for commonly occurring values within the data stream
- Managed FIFO buffering across transmission, which smoothes the encoded data rate

Compared with MLP Lossless on DVD-Audio, Dolby TrueHD supports double the maximum bit rate (18 Mbps); double the possible number of channels (14.0); more options for stereo support (including delivering a totally separate stereo mix rather than a downmix); the addition of metadata as used in Dolby Digital, including dialogue normalization and dynamic range control; and support for all the new channels introduced in SMPTE 428M.

Channel Extensions, Downmixing, and Dolby TrueHD

One channel extension technique is the method by which MLP Lossless, Dolby TrueHD, and MPEG-2 LII deliver compatible downmixes for soundtracks with expanded channels. In these codecs, a 7.1-channel soundtrack is first downmixed to create a 5.1 mix, which is supplemented by a two-channel extension (which we'll call "extension B"). The 5.1 mix is then further downmixed to a two-channel stereo mix, and another supplemental stream is created that carries the 3.1-channel "extension A." So the 7.1-channel program is delivered in three separate components: a two-channel mix, the 3.1-channel extension A, and the two-channel extension B.

The total payload is still 7.1 channels, with preconfigured subsets to create two-, 5.1-, and 7.1-channel presentations. If a listener desires a stereo presentation, the decoder plays only the two-channel downmix, thereby minimizing DSP resources for the simplest hardware products—a useful idea. If a listener selects a 5.1 presentation, the decoder reconstructs it from the

two-channel downmix plus the 3.1-channel extension A substream by means of rematrixing. If a listener wants a 7.1 presentation, the decoder reconstructs it by rematrixing the reconstructed 5.1-channel program with the final two-channel extension B substream.

This all works nicely—on paper. However, when used with lossy codecs that rely on psychoacoustic principles such as noise masking, this rematrixing can reveal coding artifacts that were otherwise inaudible. It's not that the coding artifacts have increased; instead, they become physically separated from the sound that originally masked them. As a result, the main sound and the coding artifacts may be directed to different loudspeakers, taking different acoustic paths to the listener and resulting in a phenomenon called "coder unmasking."

Different Strategies for Differing Coding Technologies

Other codecs using a lossy core paired with a lossless extension treat them together, with the inevitable result that one or the other suffers. Either the lossy audio is potentially degraded by rematrixing, as explained earlier, or the lossless audio payload is materially increased because of the extra channels it carries. We chose to handle the lossy and lossless codecs independently, thereby elegantly avoiding these compromises by using the optimal method for each codec.

Due to the substream structure of Dolby TrueHD, a single Dolby TrueHD program can be used to deliver a two-, six-, or eight-channel presentation, each with precise control over the presentation as defined by the content producer. This means that an HD player needs to decode only the number of channels it can output, thus enabling more economical DSP decoder designs.

It should be noted that it is also possible for the two- and 5.1-channel presentations to be carried independently if it is important to avoid downmixing due to artistic reasons. In this case, however, the bit rate will increase due to the carriage of additional channels.

Greater Efficiencies with Movie Content

MLP Lossless as applied to DVD-Audio content typically yields 2:1 lossless audio compression, largely due to the characteristics of 5.1-channel music, which is continuous and harmonically rich. Movie soundtracks, on the other hand, have extended periods of significantly less complexity, such as dialogue only and even silence. Because dialogue is the primary storytelling element, music and surround are not always present. Unoccupied spectrum or channels, of course, increase the effective compression efficiency.

Depending on the complexity of the mix, and the sample rate and word lengths of the digital master, Dolby TrueHD achieves compression ratios from 2:1 to almost 4:1, putting it on par with some lossy codecs in terms of disc space—but with perfect audio quality. As a result, content providers can include lossless Dolby TrueHD soundtracks for enthusiasts, with ample capacity left over for high-quality, alternative-language tracks and bonus features encoded with Dolby Digital Plus or Dolby Digital. There's no need to compromise picture quality or minimize additional soundtracks or features, unlike systems that encode the lossy core and lossless extension as a single bitstream. Keeping these elements separate also means that either bitstream can be altered during the production process without requiring a QC check of the other, a benefit for content creators.

Connectivity

Blu-ray Disc players may have one or more output connections. These include HDMI™, 5.1- or 7.1-channel analog, and traditional digital coaxial or optical outputs. Each connector may support one or more possible signal types. Thus consumers must select a player equipped with the output configuration that is compatible with their A/V receiver. Consumers can no longer assume that every player will work with every A/V receiver.

Many A/V receivers and processors manufactured today have six (or even eight) analog audio inputs originally intended for DVD-Audio or SACD playback. These work equally well for Blu-ray Disc players' analog outputs, and provide the full-bandwidth audio performance available from Dolby TrueHD without having to upgrade the receiver or processor.

A growing number of A/V receivers now include HDMI inputs, providing a direct digital connection for both audio and video with the new optical disc players. This ensures not only that the full quality of Dolby TrueHD will be available but also that any digital postprocessing—such as bass management, room compensation, speaker equalization, and Dolby Pro Logic IIx processing—can be performed in the A/V processor directly on the source audio without any extra analog and digital conversion steps along the way.

An A/V receiver equipped with HDMI 1.3 and Dolby TrueHD can decode Dolby TrueHD soundtrack bitstreams transported directly from any device equipped with HDMI 1.3 and bitstream out capability. Built-in decoding of Dolby TrueHD in the playback device enables high-definition audio playback though older A/V receivers equipped with HDMI inputs. All HDMI connections, including version 1.3, can transport Dolby TrueHD signals (decoded to PCM) to your A/V receiver for playback.

An A/V receiver with Dolby Digital decoding that has only a coaxial or optical digital audio input needs only a Blu-ray Disc player with a Dolby Digital Compatible Output that provides a compatible Dolby Digital bitstream from its internal mixer.

Through use of the variety of connections and proper signal types, Blu-ray Disc players can ensure complete compatibility with any existing A/V system, and ensure that each playback system attains the highest audio performance it was designed to achieve, without compromise.

Conclusion

Dolby's extensive work in digital cinema standards has influenced the development of Dolby TrueHD, a highly sophisticated lossless audio codec designed to deliver highest quality, enhanced flexibility, extended channel support, and a defined pathway to future expandability while simultaneously offering a variety of playback compatibility options for legacy A/V receivers and surround processors.

Dolby TrueHD delivers the lossless audio experience demanded by home theater enthusiasts for high-definition video content and will surely delight the most demanding audio critics, hence becoming a valued feature for audio and video content makers.

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