Information

Dolby Audio Coding for Future Entertainment Formats

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Introduction

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. And if 2005 is any indication, there's no end in sight.

Since its invention by Thomas Edison more than 100 years ago, 35 mm film—and the picture and audio experience it produces—has been revitalized countless times. Without a doubt, the introduction of the 1976 hit *A Star Is Born* in multichannel Dolby Surround sound redefined the big screen experience. And with its effective use a year later in the blockbusters *Star Wars* and *Close Encounters of the Third Kind*, surround sound brought a new degree of realism to the cinema experience. Soon after, Dolby Surround would quickly find its way into the world of home entertainment.

Digital video delivery and projection technologies have progressed to the point where it is now commercially viable to display movies in theatres with a quality level that is better than that of 35 mm film. Just as Dolby Digital enabled 35 mm movies to sound better and gave improved audio consistency over the life of the print, digital delivery of movies will do the same for the picture side of the equation, eliminating dirt, weave, blurry prints, scratches, and lumpy splices. For cinema purists, the first or the 1,000th playback of the motion picture will present quality on par with a pristine film print being played on a well-tuned projector. For most consumers, the experience will be essentially as it has always been—only cleaner, with fewer visible distractions.

Once freed from the physical constraints of film, we'll begin to see interesting developments such as the use of higher frame rates for more fluid motion, or kinds of 3-D imaging never before possible. And who knows what else might come once creative minds are turned loose to explore the reaches of the high-bandwidth infrastructure being established to deliver movies to digital cinemas via satellite. 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 D-Cinema

One obvious direction for D-cinema is for more audio channels to drive existing or additional speakers; precedents for this supposition already exist. Dolby Digital Surround EX™ promoted the concept of dividing the surround speaker array into three zones instead of two (as is the case with 5.1-channel formats). Other specialty-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. In 1940, Disney's *Fantasia* premiered in New York's Broadway Theatre with more channels than today's cinemas.[1] There's always been a desire to explore the use of more audio channels in cinemas, but with D-cinema it finally becomes practical to do it.

The Society of Motion Picture and Television Engineers (SMPTE) formed the DC28 Digital Cinema Technology Committee, which is defining the range of new channels and speaker locations that may be applied in future digital cinemas. Of the 20 total channels described in SMPTE 428M,[2] seven are those of the current Surround EX 6.1-channel configuration, and 13 provide additional capabilities. Four of the 13 new channels drive speakers that expand upon existing surround arrays, providing more directional control to the back and sides of the theatre. Another pair flanking the center speaker has been used before in SDDS and 70 mm formats. The remaining seven channels drive totally new speaker locations: a wide pair at the front, four vertical channels for an added sense of height, and even a second LFE channel.

No one expects all these channels will be used at the same time, but then again no one has mixed a movie using any of the new locations yet, nor has a commercial cinema been built to support their use. It will probably take a special event—like the release of *Star Wars:* Episode I—*The Phantom Menace*, which introduced Dolby Digital Surround EX—to motivate theatre owners to retrofit their speaker systems and take advantage of a new audio mix. Depending on the type of movie, the film mixer may wish to use different subsets of the speaker array to achieve specific effects, so cinemas will need further flexibility to automatically reconfigure their speakers accordingly.

Bringing the D-Cinema Experience Home

Dolby's participation in the DC28 committee led us to the conclusion that it would be important to ensure a future pathway for bringing the expanded capabilities of D-cinema soundtracks to home playback systems. Two actions have occurred as a result. The first is that Dolby's next-generation audio codecs were designed to carry several additional channels. In addition, Dolby proposed not only that these codecs be adopted in next-generation high-definition (HD) disc formats (HD DVD and Blu-ray Disc), but that they should also incorporate the standard SMPTE 428M naming conventions for the new channels. We are pleased to say that both new high-definition optical formats have adopted this proposal. While they are currently limited to a maximum capacity of eight channels, that may serve perfectly well for the foreseeable future. However, should there be justification to expand channel offerings in the future, there is no technological barrier preventing such expansion, as Dolby's audio codecs are designed with compatible extensibility.

Dolby's codec offerings for HD disc formats are based on extensions of the well-proven Dolby Digital and MLP Lossless™ technologies, which are worldwide standards for DVD-Video and DVD-Audio, respectively.

Dolby Digital Evolves into Dolby Digital Plus

Dolby Research and Technical Development engineers were challenged to find a way to bring these new channels to home theaters of the future, yet to do so in a manner that would maintain the utility of the tens of millions of digital 5.1-channel home theater systems, all of which support Dolby Digital decoding. From its inception, Dolby Digital was not bound to any prior channel extension methodology, and could therefore benefit from the subsequent developments of other multichannel codecs.

One example of a channel extension technique is the method by which MLP Lossless, Dolby TrueHD, and MPEG-2 LII deliver compatible downmixes for soundtracks with expanded channels, as shown in Figure 1. 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.

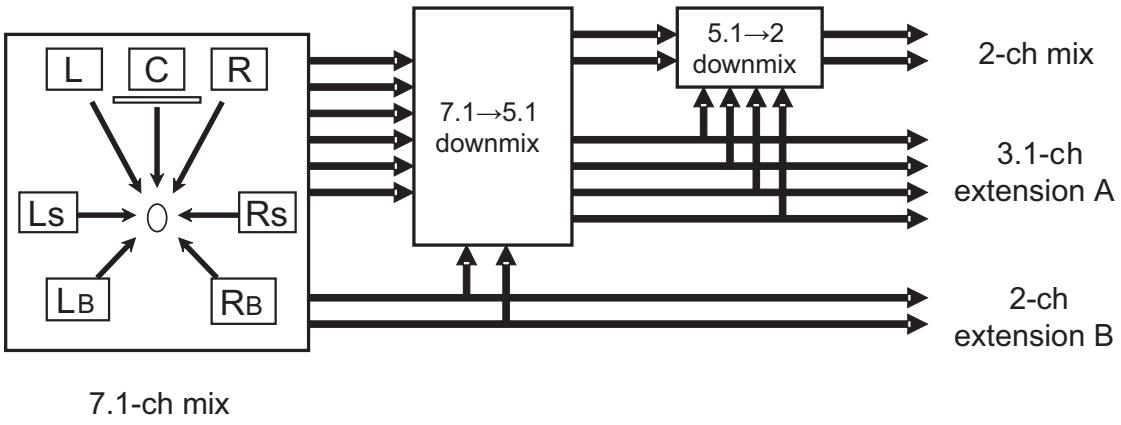


Figure 1 Conventional Multichannel Substream Encoding

The total payload is still 7.1 channels, with preconfigured subsets to create two-, 5.1-, and 7.1-channel presentations. Figure 2 shows how these substreams are used to construct the various 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 above reconstructed 5.1-channel program with the final two-channel extension B substream.

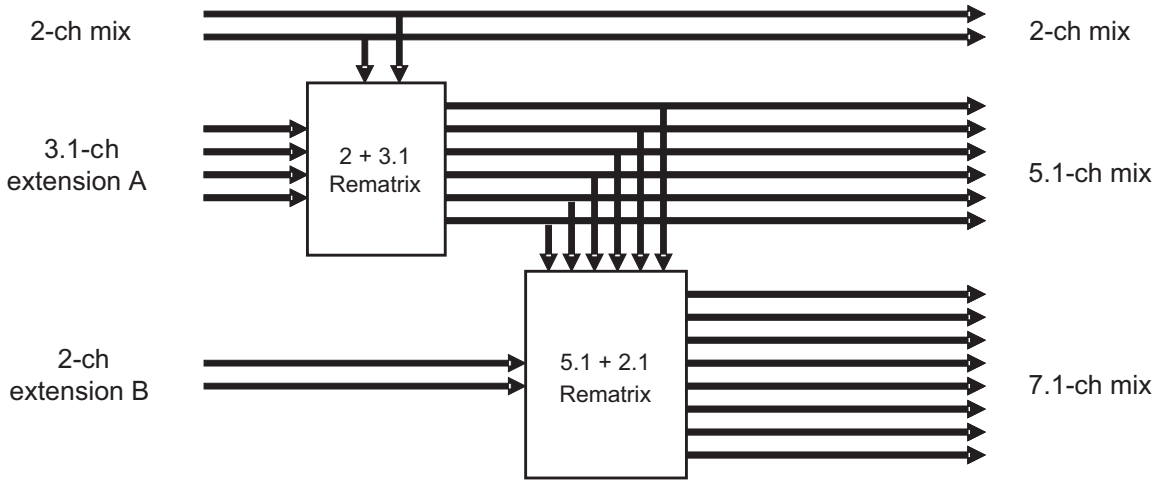


Figure 2 Conventional Multichannel Substream Decoding

It all works nicely—on paper. Rematrixing is itself not a problem, and because it works perfectly with MLP Lossless coding on DVD-Audio, the method was carried over into Dolby TrueHD. But when used with “lossy” codecs that rely on psychoacoustic principles such as noise masking to achieve a desired level of quality, this rematrixing has been demonstrated to reveal coding artifacts that were formerly inaudible. It’s not that the coding artifacts have increased; instead, they become physically separated from the sound that used to mask them. The main sound is redirected to another speaker, whereas the coding artifacts remain behind and thereby take a different acoustic path to the listener. The result is a phenomenon called “coder unmasking.”[3]

One way to reduce these exposed artifacts is to increase the coding bit rate so as to reduce the level of the artifacts relative to the audio signal, but this brute-force method reduces codec efficiency without guaranteeing success, as it depends on the nature of the sounds involved and the playback acoustics of a given room.

Dolby Digital Plus was designed to employ an altogether new technique to address the downmix compatibility issue, and is the only perceptual coder thus far to do so. In its “core plus extension” structure, the Dolby Digital Plus core is a complete 5.1-channel mix; the extension contains the new channels, plus any channels that have been modified between the 5.1 and 7.1 renditions. (See Figure 3.)

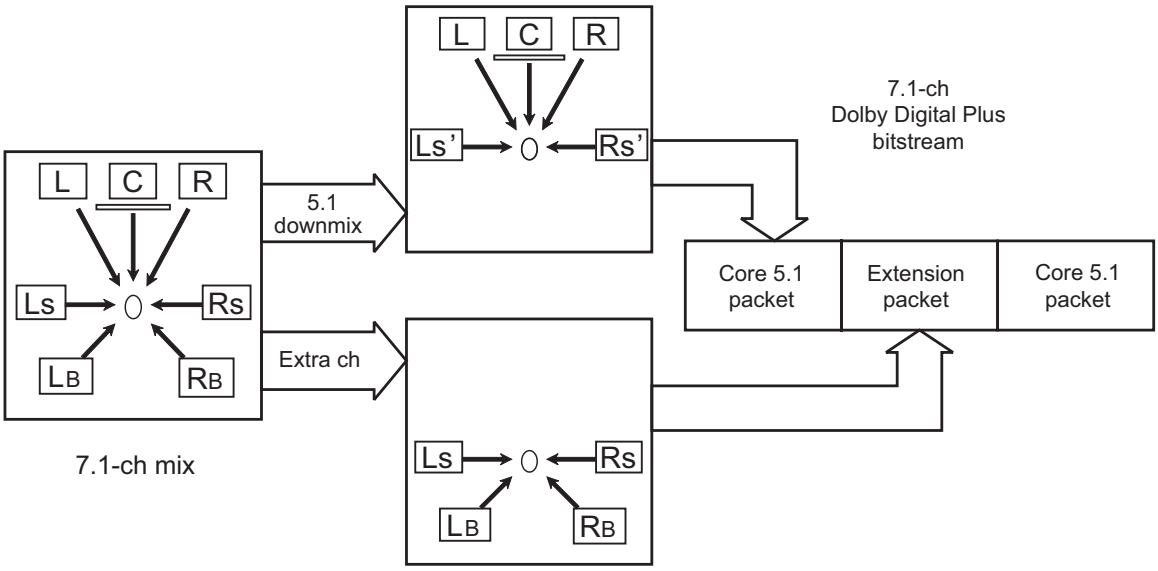


Figure 3 Encoding on Dolby Digital Plus 7.1-Channel Bitstream

For example, referring again to the 7.1-channel soundtrack described earlier, a 5.1 mix is made by downmixing the Left Back and Right Back channels with the Left Surround and Right Surround channels, thus creating the new composite Left Surround/Right Surround channels for the 5.1 version. The 5.1 mix is now complete, and is encoded into its own core audio packets for the output bitstream.

A separate audio extension packet carries the signals that were downmixed, in this case Left Surround, Right Surround, Left Back, and Right Back. To reconstruct the 7.1 mix, the Left, Center, and Right channels of the core packet are used, but the downmixed Left Surround and Right Surround signals are replaced by the four channels from the extension packet. (See Figure 4.)

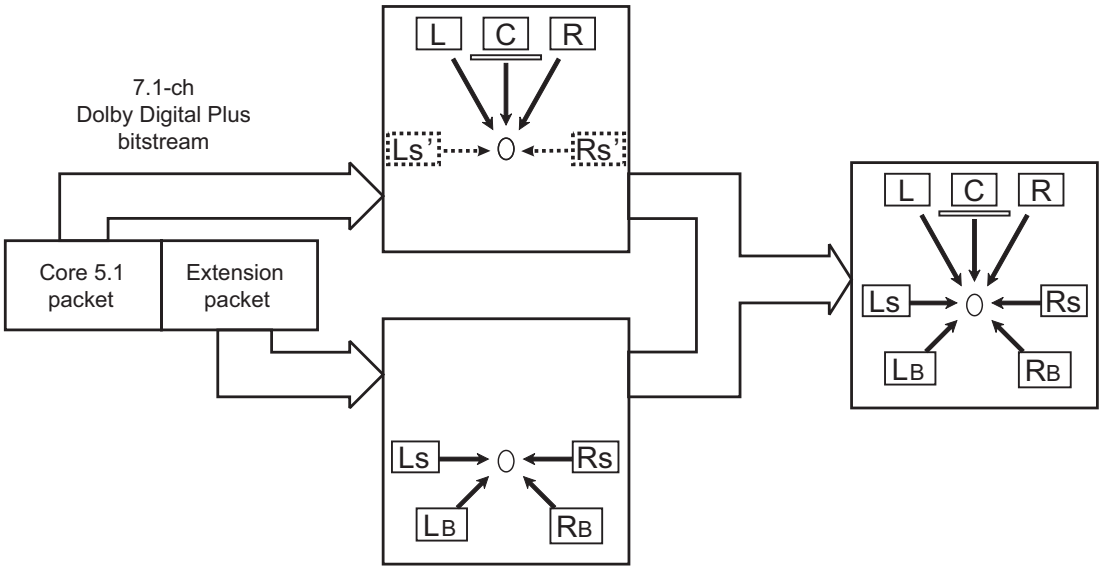


Figure 4 Decoding of Dolby Digital Plus 7.1-Channel Bitstream

The total delivered bitstream payload has thus increased from 7.1 to 9.1 channels in order to support the 5.1 and 7.1 presentations, but the side effects of rematrixing are totally avoided. The high coding efficiency of Dolby Digital Plus—coupled with the large capacity of HD disc formats—means there is no material penalty in employing this method. Dolby Digital Plus can deliver 7.1-channel soundtracks with superb quality at bit rates of 1 Mbps or less.

The ability to implement downmix strategies that take best advantage of the codec's characteristics is made possible by handling the lossy codec independently of the lossless codec. Were they forced to be treated together, as is done by other codecs that use a lossy core paired with a lossless extension, one of the two would inevitably suffer. Either the lossy audio is potentially degraded by rematrixing, as explained earlier, or the lossless audio payload would be materially increased because of the extra channels it carries. The Dolby solution elegantly avoids these compromises by using the optimal method for each codec.

Unique Aspects of Dolby Digital Plus on Blu-ray Disc vs. HD DVD

There is a fundamental difference in the way programs are carried in the two HD disc formats. Like DVD-Video, the HD DVD format carries audio and video signals in the MPEG-2 "program stream" format, whereas the Blu-ray Disc format carries them in the MPEG-2 "transport stream" format, the same manner in which ATSC DTV and DVB signals are broadcast. A result of this otherwise subtle distinction is that there are packetizing differences for the audio bitstreams between the two disc formats. You may recall that DVD-Video is not able to carry Dolby Digital bitstreams of more than 448 kbps. The same remains generally true for HD DVD, although due to finer granularity in the choice of data rates, the actual maximum rate increases slightly, to 504 kbps. In order to support the higher bit rates and greater number of channels offered by Dolby Digital Plus, HD DVD discs will use Dolby Digital Plus bitstreams (which have progressively shorter coding frames as the bit rate increases, thereby always fitting within the defined audio packets on the disc). For example, standard Dolby Digital has a six-block frame, and in that case the Dolby Digital Plus bit rate can reach 0.5 Mbps; a three-block frame can reach 1 Mbps; a two-block frame, 1.5 Mbps; and a one-block frame, 3 Mbps.

In contrast, the Blu-ray format has no such packetizing constraint, so one immediate result is the ability to transport Dolby Digital at its maximum 640 kbps rate for the first time. That's slightly higher than the 576 kbps carried on D-VHS.

Another area where the two disc formats differ is in terms of mandatory versus optional use of Dolby codecs. In HD DVD, Dolby Digital, Dolby Digital Plus, or Dolby TrueHD may be used as the sole soundtrack on a disc, because every player will have a decoder that can process any of these three bitstreams.

By contrast, the Blu-ray format mandates Dolby Digital, while Dolby Digital Plus is optional. This means that Blu-ray Disc players might only be equipped with a basic Dolby Digital decoder on board. If a Blu-ray disc carries Dolby Digital Plus (or Dolby TrueHD) bitstreams, there will also be a companion Dolby Digital track to ensure playback compatibility with every player configuration. Rather than transporting a core 5.1-channel Dolby Digital bitstream and a separate 7.1-channel Dolby Digital Plus bitstream on the same disc, the Dolby Digital Plus bitstream will be constructed as a hybrid of a 5.1 Dolby Digital core frame followed by a Dolby Digital Plus extension frame. A basic two- or 5.1-channel Blu-ray player only needs a conventional Dolby Digital decoder IC to play these bitstreams. An advanced player with 7.1-channel decoding capability will include a Dolby Digital Plus decoder that will decode both frames to reconstruct the 7.1-channel program as depicted in Figure 4. Because the Blu-ray

format has no audio packet constraints, Dolby Digital Plus will always operate with full six-block coding frames, just like Dolby Digital. This yields the maximum coding efficiency, and makes the process of decoding core and extension frames easier because they always have identical frame structures. It also means that in those cases where a disc and player permit direct bitstream output over S/PDIF, the core Dolby Digital bitstream can be routed directly to the S/PDIF with no need for conversion.

These differences between the two disc format structures also lead to differences in the maximum bit rates for Dolby Digital Plus. On HD DVD, the maximum is 3 Mbps regardless of the number of channels. The maximum bit rate for Dolby Digital Plus on Blu-ray Disc is 640 kbps for the core audio packet (carrying from one to 5.1 channels) and 1.024 Mbps for the extension packet (carrying up to 5.1 channels) for a total bit rate maximum of 1.7 Mbps. In the future, the bit rate can rise to as high as 4.7 Mbps (a core packet plus up to four extension packets), should the format developers elect to support even more than eight discrete channels.

Unique Aspects of Dolby Digital Plus in Broadcast Formats

Aside from HD disc formats, next-generation satellite and cable broadcast systems are also considering adopting Dolby Digital Plus. In addition to high-bit-rate extensions designed for next-generation optical media, new coding tools enable Dolby Digital Plus bitstreams that are roughly half the data rate of Dolby Digital. These tools include an improved filter bank, improved quantization, enhanced channel coupling, spectral extension, and a technique called transient prenoise processing.[4]

While not limited to broadcast products, this may be the first application to benefit from a new backward compatibility feature. Employing an elegant conversion process, Dolby Digital Plus bitstreams, regardless of their source bit rate, are repackaged into a standard Dolby Digital format at a bit rate of 640 kbps. The conversion process does not decode the signal to PCM and reencode it, and therefore avoids compounding coding artifacts. The converted output maintains the quality of the source bitstream up to the limits of a 640 kbps Dolby Digital bitstream. If the source soundtracks are of sufficient quality, this connection can enable an A/V receiver to sound better than the output of a standard-definition DVD-Video player, which is limited to 448 kbps. Elevating the playback audio quality for legacy A/V receivers is a unique benefit of Dolby technology.[5]

Another new capability of particular benefit for broadcast applications is dual-stream mixing. Broadcasters are increasingly providing services for hearing and visually impaired viewers. This is accomplished by supplementing the main audio soundtrack with an additional (and usually mono) descriptive dialogue track that mixes on top of the main soundtrack. In order to control the final presentation, the dialogue bitstream carries mixing metadata that adjusts the loudness of the program elements to ensure good intelligibility.

The Dolby Digital Plus low-bit-rate encoding mode (described below) is particularly beneficial in this application. Because the main and descriptive soundtracks, including the mixing metadata, are delivered in a single Dolby Digital Plus bitstream, it is very easy to produce and handle in the distribution chain. Once received by the set-top box, a single Dolby Digital Plus decoder IC will handle the entire decoder and mixing process, and even handle the final step of converting the mixed signal to Dolby Digital for output on S/PDIF.

To attempt to achieve all these capabilities with conventional codecs would require the set-top box to have two separate audio decoders, a mixer, metadata support, and an encoder to create a compatible 5.1 signal for the S/PDIF output. It is easy to see how this could result in significantly higher MIPS/DSP complexity and a potential for reduced quality. The improved efficiency and support for dual-stream mixing, coupled with the unique ability to provide a compatible Dolby Digital bitstream output via S/PDIF, makes Dolby Digital Plus the ideal audio companion for advanced video codecs in broadcast applications.

Mixing

The same S/PDIF compatibility pathway is available for conversion of HD DVD's Dolby Digital Plus bitstreams into conventional Dolby Digital signals. In contrast, Blu-ray Disc, as already discussed, carries a Dolby Digital packet anytime a Dolby Digital Plus bitstream is present, so no conversion step is necessary. However, a larger issue will overshadow any such bitstream output or conversion options from either of the next-generation disc formats: audio mixing.

Both HD disc formats possess an audio sophistication dramatically greater than that of standard-definition DVD-Video. For example, rather than simply delivering a commentary track on the disc, the new formats might construct a commentary enhanced track using the main soundtrack from the movie, mixed with a commentary track downloaded from the Internet. These elements will be mixed in the player to create the final audio presentation. (See Figure 5.)

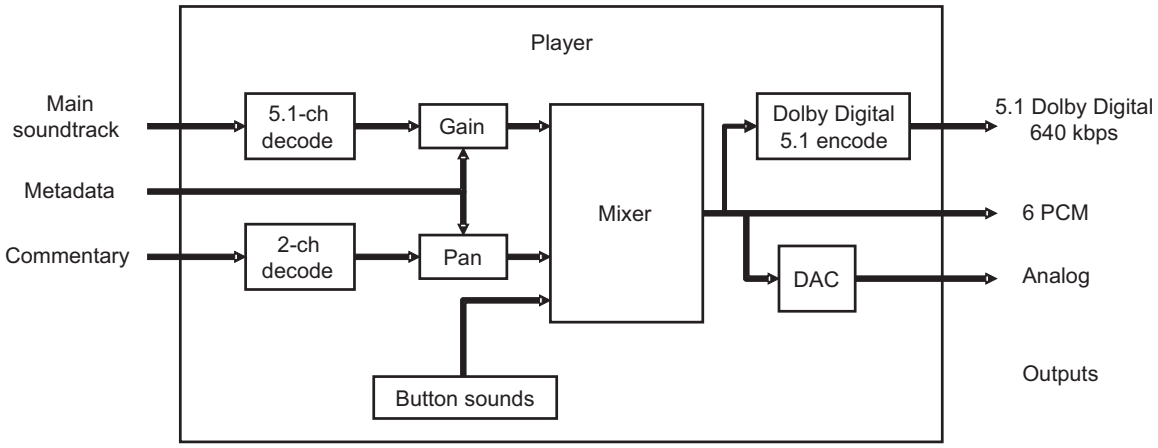


Figure 5 Block Diagram of HD Disc Player Audio Structure

The implications of this are significant. Aside from the obvious aspect that new features can be created for a given title long after the discs have shipped, the fact that players will be mixing the audio internally means that it will no longer be possible to output the raw bitstreams from the player as is customary with DVD-Video. Instead, these players will decode and mix in standard PCM format, and therefore will have the option to output the PCM digital signal either directly, or through DACs as analog signals to the connected audio receiver. It should be mentioned that certain discs and players will indeed support the direct output of encoded audio bitstreams, but this option is the choice of the content maker.

Home theater enthusiasts with established audio or video systems will need to shop carefully to select players with the right type of outputs for their existing equipment. Table 1 shows some examples of the types of connectors and output signals these next-generation optical players could deliver:

Connector	Signal
Line output	Two-, six-, eight-channel analog
S/PDIF	Two-channel PCM, Dolby Digital
HDMI 1.1	Two-, six-, eight-channel PCM, Dolby Digital
HDMI 1.3 (future)	Two-, six-, eight-channel PCM, Dolby Digital, Dolby Digital Plus, Dolby TrueHD

Table 1 Possible Output Connections and Signals from HD Disc Players

Next-generation optical players may have one or more of these output connections, and each connector type may support one or more possible signal types. It will be necessary to select a next-generation player for its specific output configuration and for the signals the playback system needs from it. No longer can a consumer assume that every player will work with every A/V receiver.

Many advanced A/V receivers and processors manufactured today have six (or even eight) channels of external analog audio input for high-resolution DVD-Audio or SACD playback; these will work equally well for multichannel analog-equipped HD disc players, and enable consumers to take advantage of the full-bandwidth audio performance available in next-generation formats without having to upgrade their A/V systems. A growing number of A/V receivers include HDMI™ (1.1) inputs, providing a direct digital connection for the new optical disc players. This ensures not only that the full quality of the HD formats will be available, but that any digital postprocessing—such as bass management, room compensation, speaker equalization, Dolby Pro Logic® IIx processing, and others—can be performed in the A/V processor directly on the source audio without any extra analog and digital conversion steps along the way.

If your A/V receiver has neither of these latest multichannel discrete inputs, but does have a S/PDIF input and includes a Dolby Digital decoder, then all you need is an HD player with an onboard Dolby Digital encoder that will take any output from the internal mixer and provide a compatible Dolby Digital bitstream.

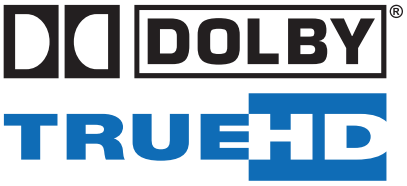
Through use of the variety of available connections, and by offering the proper signal types, HD disc players can ensure complete compatibility with any existing A/V system, and ensure that every system attains the highest audio performance it was designed to achieve, without compromise.

One additional consequence of the above rapidly becomes apparent: there will be no particular reason or benefit to decoding native audio bitstreams in the A/V receiver. This means A/V receivers with HDMI digital inputs or analog-to-digital converters for their analog inputs will be able to use their DSP resources to postprocess full-bandwidth audio from the players, rather

than being required to also handle core bitstream decoding duties. (Such postprocessing is often done at a sampling rate of 96 kHz, thereby demanding at least double the DSP horsepower of conventional postprocessing done at 48 kHz.)

Low-Bit-Rate Mode
Another unique feature of Dolby Digital Plus is relevant to the download feature mentioned earlier. It is important that these files be as compact as possible for storage in the player's internal memory, and also so that they can be downloaded from the Internet rapidly. Therefore, the bit rate must be as low as possible. Because this is typically a commentary track, the content being downloaded is primarily voice, which is mixed on top of the disc's high-fidelity soundtrack. The commentary track can usually be mono, and it can be coded at a reduced audio bandwidth. These aspects alone enable a dramatic reduction in download file size.

Aside from the variety of new high-efficiency coding tools already mentioned that are part of Dolby Digital Plus, one additional tool senses when the commentary has paused, reduces the bit rate to a mere trickle during the ensuing silence, then resumes the normal rate when the commentary continues. Tests have confirmed a downloaded file can be reduced by nearly 40 percent using this method without impacting audio quality at all. This variable bit rate mode is a unique feature of Dolby Digital Plus in HD disc formats, and can be used to similar benefit for descriptive services in broadcasts.



Dolby TrueHD
The capacious HD disc formats have finally made it possible to complement the pristine HD video picture with sound quality previously heard only on high-resolution DVD-Audio recordings. The combination will set unprecedented levels of quality that no other A/V consumer format has ever attained.

The prospect for additional channels being introduced by D-cinema provided an ideal opportunity to update MLP Lossless technology for its new role as a movie soundtrack codec on HD discs. Aside from a variety of technical revisions and extensions made to the technology, we have also taken this opportunity to distinguish this enhanced version from the MLP Lossless technology used in DVD-Audio by means of a new name: Dolby TrueHD. Dolby TrueHD is your assurance of 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 has been in use longer and more widely than any other lossless audio technology, proving itself to consumers and industry experts alike.

In essence, Dolby TrueHD is a lossless PCM audio format built around the following techniques:[6]

- Lossless matrixing: reduces data rate by taking advantage of interchannel correlations, also used for downmixing
- Decorrelation: Takes advantage of the predictive nature of audio
- Huffman (entropy) coding: 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 to smooth 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—as well as support for all the new channels introduced in SMPTE 428M. (Both HD disc formats are currently defined to carry a maximum of 7.1 channels.)

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 only needs to decode the number of channels it can output, thus enabling more economical DSP decoder designs. (Figure 1 shows the conceptual substream encoding structure.) 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. This is largely due to the characteristics of high-complexity 5.1-channel music, which is continuous and harmonically rich. A movie soundtrack, on the other hand, exhibits extended periods of significantly less complexity, periods of dialogue only, or even periods of silence. Because dialogue is the primary storytelling element, music and surround effects are complementary aspects of the soundtrack, and as such are not always present. All of the unoccupied spectrum or channels increases the effective compression efficiency.

Depending on the complexity of the original soundtrack and the sample rate and word lengths of the digital master, Dolby TrueHD achieves compression ratios in the range of 2:1 to almost 4:1, putting it on par with some lossy compression technologies in terms of disc space, but with perfect audio quality. This level of performance will enable content providers to include Dolby TrueHD soundtracks as demanded by enthusiasts, while still leaving ample capacity for additional high-quality alternative-language tracks or bonus features encoded with Dolby Digital Plus without impacting picture quality or limiting the ability to include a variety of value-added features on the disc.

The high compression efficiencies of Dolby TrueHD and Dolby Digital Plus permit the incorporation of separate lossy and lossless soundtracks with no resulting penalty in disc space compared to other audio coding systems which are required to encode the lossy core and lossless extension as a single bitstream. In fact, the ability to keep these elements

separate (aside from other advantages described earlier) means that either bitstream can be changed during the production process without requiring a QC check of the other, a benefit for content creators.

Dolby's extensive work in D-cinema standards has influenced the development of Dolby Digital Plus and Dolby TrueHD. Both audio codecs are purposely designed to deliver elevated 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.

Conclusion

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

No longer restricted to 448 kbps, Dolby Digital Plus—and Dolby Digital—will bring enhanced quality from a highly sophisticated perceptual audio coder while concurrently enabling content providers to include multiple surround audio streams on the disc without impacting the data needed for high-quality video or added feature content.

The broad, complementary capabilities of Dolby Digital Plus and Dolby TrueHD exemplify Dolby's ongoing commitment to delivering the highest performance and value in audio solutions.

The next-generation HD disc formats will be able to offer the right player to get the maximum capability from every existing digital A/V surround system, and those with high-resolution multichannel inputs will be able to enjoy the full sonic benefits that the new audio formats can deliver, without compromise.

(Endnotes)

[1] Middle Tennessee State University Film Sound History web page (1940s): *www.mtsu.edu/~smpte/forties.html*

[2] SMPTE 428M (replaces RP 226) D-Cinema Distribution Master, Audio Channel Mapping and Channel Labeling, 2005

[3] AES Preprint 3867, Nielsen, Søren H.; Stoll, Gerhard; van de Kerkhof, Leon, January 1994

[4] AES Preprint 6196, Andersen, Robert L.; Crockett, Brett G.; Davidson, Grant A.; Davis, Mark F.; Fielder, Louis D.; Turner, Stephen C.; Vinton, Mark S.; Williams, Phillip A., October 2004

[5] AES Preprint 6196, ibid

[6] AES Paper, Gerzon, M. A.; Craven, P. G.; Stuart, J. R.; Law, M. J.; Wilson, R. J., J. Audio Eng. Soc., Vol. 52, No. 3, March 2004