Film-Tech

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Dolby Digital

The sound of the future—here today.

DOLBY®

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Dolby Digital audio technology has been providing multichannel digital sound in cinemas since 1992, was launched in two-channel DBS applications in 1994, and first reached consumers via multichannel laser discs in early 1995. It has also been selected to provide multichannel surround sound with digital TV broadcasts in the U.S., and is the standard multichannel audio format for DVD in countries utilizing the NTSC television standard (optional in other areas).

As its many applications attest, Dolby Digital is unusually versatile. Not a single rigid scheme, it is a flexible process allowing parameters such as bit rate and number of channels to be tailored to particular applications. All variations, however, are based on the same advanced perceptual coding technique, Dolby AC-3, which ensures both compatibility among formats and adaptability to future needs.

Most significantly, Dolby Digital combines high audio quality with remarkable data rate efficiency. For example, it enables multichannel surround sound at a lower bit rate than is needed for just one channel on compact disc. Yet sound quality remains fully consistent with listener expectations, thanks to Dolby Laboratories' more than 30 years of experience developing signal processing systems based upon how sound is perceived.

Dolby Digital in the cinema

In the late 1980s, Dolby Laboratories undertook to apply digital audio technology to 35 mm film sound in response to growing interest from the film industry. In order to retain an analog track so that release prints could continue to play in any cinema, it was decided to place a separate new Dolby Digital optical track between the sprocket holes (Figure 1). It was also decided to provide "5.1" channels, which by then had been documented by various film industry groups as best satisfying the requirements for theatrical film presentation (Figure 2).

Because of the limited space available for the new digital track, Dolby Laboratories developed a form of perceptual digital audio coding that makes it possible to store and transmit multichannel audio in less than one-tenth the space needed for standard digital audio. Being the third such digital audio coding system developed by Dolby Laboratories, the technical name given the new development was Dolby AC-3, better known to the public simply as Dolby Digital.

Since the debut of Dolby Digital in cinemas, the release of hundreds of films and the equipping of thousands of cinemas in 50 countries have confirmed that prints with both digital and analog tracks can be manufactured economically, that such prints can play in any cinema, and that the Dolby Digital track provides high audio quality with extraordinary resistance to wear and tear.

Much like Dolby's analog film sound formats, Dolby Digital in the cinema has provided a springboard for consumer formats, starting with NTSC laser discs with Dolby Digital soundtracks in 1995, followed by DVD, cable TV and DBS systems, digital TV broadcasting in the U.S., and a variety of multimedia applications. That film sound has been the starting point for Dolby Digital has enabled the accumulation of invaluable experience in mixing, recording, and distributing multichannel digital audio. It is also fostering a library of program material immediately available for consumer release, and has facilitated the development of cost-efficient IC decoder technology.

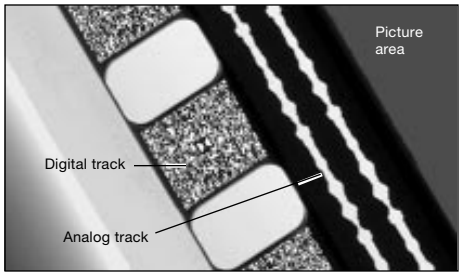

Figure 1. Dolby Digital 35 mm print.

Dolby Digital in the home

The consumer equivalent of Dolby Digital film sound forms the final link from multichannel program producer to home listener. Like the film format, it provides separate channels for left, right, and center speakers at the front; two surround speakers at the sides; and a subwoofer at the listener's option (Figure 3).

Unlike analog Dolby Surround with its single band-limited surround channel (usually played over two speakers), Dolby

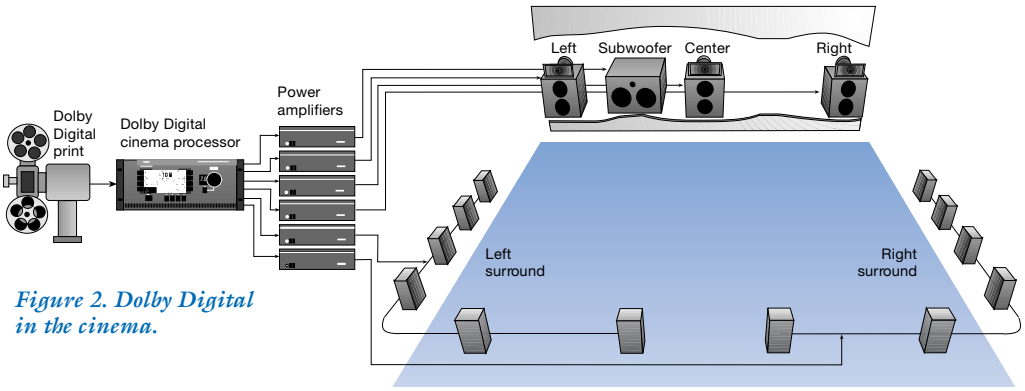

Figure 2. Dolby Digital in the cinema.

Digital features two completely independent surround channels, each offering the same full-range fidelity as the three front channels. As a result, true stereo surround effects can be achieved for an expanded sense of depth, localization, and overall realism. And because Dolby Digital maintains complete separation of the channels, it is as suited to music-only recordings and broadcasts as it is to video formats. Thus it has the potential to open up new worlds of multichannel sound reproduction.

Special features

Dolby Digital incorporates a host of special features to satisfy a wide range of listening circumstances, from the uncomplicated to the uncompromised. It is recognized that listeners may have anything from small, monophonic products up through full home theaters, so it is necessary to make sure that each listener gets the best results possible from his or her system.

In the past these differences were addressed by the delivery formats themselves. Television audio has limited dynamics, VHS tapes have moderate dynamics, and laser discs have full theatrical dynamics. The problem is that sometimes people with a normal television, as opposed to a full home theater system, want to watch a laser disc, and the dynamic range is too much. The Dolby Digital solution is to deliver the same unrestricted multichannel audio content to every system, and have the decoder optimize the sound for that particular listener.

Techniques to satisfy these and other needs have been designed into Dolby Digital from the beginning:

- Audio Format. Data identifying each program's original production format—mono, stereo, matrixed or discrete surround—can be sent to eliminate confusion at playback or reception.
- Dialogue Normalization. Additional code can be added to program material when it is originally mixed so that subjectively constant, dialogue-keyed loudness is maintained as the listener switches between program sources. No alteration of audio dynamics is involved, only the setting of the appropriate playback volume for the duration of the program.
- Compatible Downmixing. Decoders can be designed to provide optimum downmixes from multichannel programming, such as a matrix-encoded two-track mix for analog Dolby Surround decoding, a conventional stereo mix, or even mono (Figure 4).
- Dynamic Range Control. When programs with wide dynamic range, such as movie soundtracks, are played at low volume or from smaller speakers, the system can apply appropriate compression to preserve low-level content and prevent dramatic passages from getting too loud. The degree of compression can be made to vary according to need.
- Bass Management. The listener can program the Dolby Digital decoder to route non-directional low bass only to those channels in the system which have wide-range speakers or subwoofers.

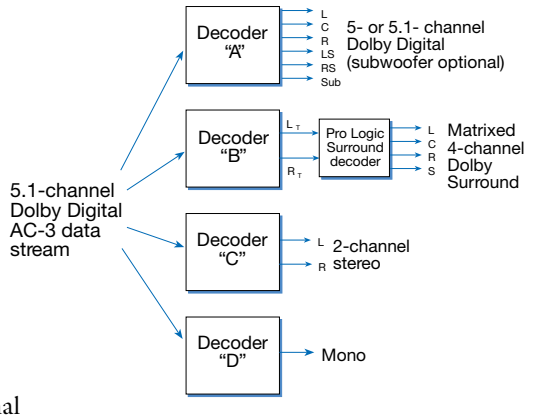

Figure 4. Compatible downmixing feature.

All these features can be previewed, and usually controlled, by the engineers preparing the audio for consumer release, so there are no surprise alterations to the artistic intent.

Dolby Digital offers a dramatic step forward in listener involvement and excitement. It provides producers, directors, recording engineers, and performers unprecedented creative opportunities. And it offers remarkable media adaptability within a single, far-reaching technological framework.

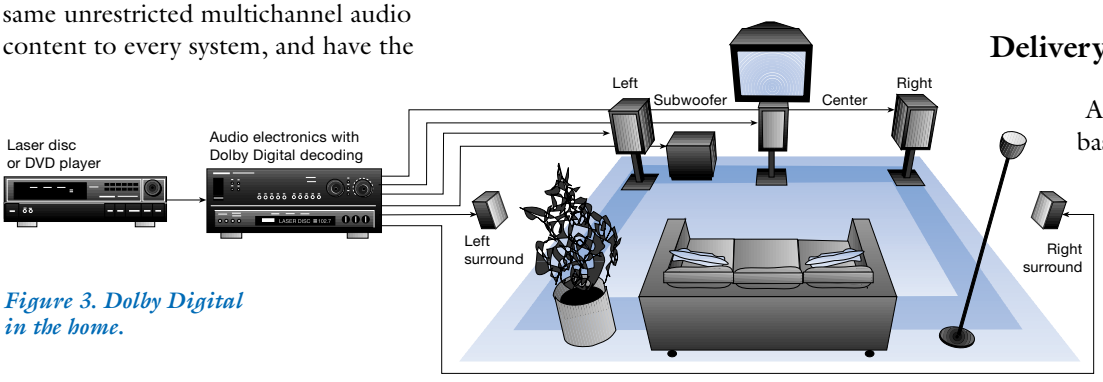

Figure 3. Dolby Digital in the home.

Delivery formats

A wide variety of Dolby Digital-based formats is technically feasible, and several have already made their commercial debut:

- The ATSC digital TV standard now adopted by the FCC for the U.S. uses Dolby Digital for both

HDTV and standard-resolution TV broadcasting. This system is also being evaluated for use in several other countries.

- The new CD-sized DVD video disc provides Dolby Digital audio as standard in NTSC territories like North America and Japan, and is fast becoming the *de facto* multichannel standard in other countries. Dolby Digital is also being used on DVD ROM discs for games and other interactive titles.
- In the U.S., the major cable operators and equipment suppliers have reached agreement on a digital cable standard that utilizes MPEG-2 video and Dolby Digital audio, and will be compatible with the ATSC DTV standard.
- The laser disc, long the ultimate quality source of movies on video for home theater, became the first consumer format to offer Dolby Digital multichannel sound (1995). A Dolby Digital AC-3 bitstream substitutes for one of the AFM audio channels, leaving the stereo PCM digital audio and a mono AFM track intact for compatibility with all existing players.
- DBS systems also benefit from Dolby Digital's unique combination of spectrum efficiency, quality, and multichannel capability. In 1994, the first DBS system to utilize Dolby Digital began transmitting 60 stereo music channels via a single transponder for use by business establishments. Additional DBS consumer television services are scheduled for launch in the near future.

Integrated circuits

A major step in the progress of Dolby Digital was the 1994 introduction by Zoran Corporation of the first single-chip DSP capable of Dolby Digital decoding. This was soon followed by a lower-cost IC that combined Dolby Digital and Pro Logic decoding for consumer products. Other ICs, including two-channel chips for such applications as cable TV set-top decoders, DVD players, and PC sound cards, are now available from various suppliers. More than 70 semiconductor manufacturers and algorithm developers have undertaken Dolby Digital IC development.

How Dolby Digital works

The digital audio coding used on compact discs (16-bit PCM) yields a total dynamic range of 96 dB from the loudest sound to the noise floor. This is achieved by taking 16-bit samples 44,100 times per second for each channel, which is often too much data to store or transmit economically, especially when multiple audio channels are required. As a result, new forms of digital audio coding—often known as "perceptual coding"—have been developed to allow the use of lower data rates with a minimum of perceived degradation of sound quality.

Dolby Digital utilizes Dolby AC-3, the first perceptual coder designed specifically to process multichannel digital audio. It also benefits from the development of two other successful perceptual coding systems, Dolby AC-1 and AC-2, and from the development of what are in essence *analog* perceptual coding systems: the full gamut of Dolby professional and consumer noise reduction systems. Indeed, Dolby Laboratories' unique experience with audio noise reduction is essential to Dolby Digital's data rate reduction, as the fewer the bits used to describe an audio signal, the greater the quantizing noise that can exist.

Dolby noise reduction works by lowering the noise when no audio signal is present, while allowing strong audio signals to cover or mask the noise at other times. Thus it takes advantage of the psychoacoustic phenomenon known as auditory masking. Even when audio signals are present in some parts of the spectrum, Dolby NR reduces the noise in the other parts so the noise remains imperceptible. This is because audio signals can only mask noise that occurs at nearby frequencies.

Dolby Digital has been designed to take maximum advantage of human auditory masking. It divides the audio spectrum of each channel into narrow frequency bands of different sizes optimized with respect to the frequency selectivity of human hearing. This makes it possible to sharply filter coding noise, so that it is forced to stay very close in frequency to the audio signal being coded. By reducing or eliminating coding noise wherever there are no audio signals to mask it, the sound quality of the original signal can be subjectively preserved. In this key respect, a perceptual coding system like Dolby Digital is essentially a form of selective and powerful noise reduction.

With Dolby Digital, bits are distributed among the filter bands as needed by the particular frequency spectrum or dynamic nature of the program. A built-in model of auditory masking allows the coder to alter its frequency selectivity (as well as time resolution) to make sure that a sufficient number of bits are used to describe the audio signal in each band, thus ensuring noise is fully masked.

Dolby Digital also decides how the bits are distributed among the various channels from a common bit pool. This technique allows channels with greater frequency content to demand more data than sparsely occupied channels, for example, or strong sounds in one channel to provide masking for noise in other channels.

Dolby Digital's sophisticated masking model and shared bit pool arrangement are key factors in its extraordinary spectrum efficiency. Furthermore, where other coding systems have to use considerable (and precious) data to carry instructions for their decoders, or to carry the same audio in separate channels for compatibility reasons, Dolby Digital can use proportionally more of the transmitted data to represent essential audio, which means inherently higher sound quality.

Technically speaking, Dolby Digital can process at least 20-bit dynamic range digital audio signals over a frequency range from 20 Hz to 20 kHz. The bass effects channel reproduces 20 to 120 Hz. Sampling rates of 32, 44.1, and 48 kHz are supported, while data rates range from as low as 32 kb/s for a single mono channel to as high as 640 kb/s for multiple channels, thereby covering a wide range of requirements. Typical applications include 384 kb/s for 5.1-channel Dolby Digital consumer formats, and 192 kb/s for 2-channel distribution.

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