Information

Dolby

DOLBY SURROUND PRO LOGIC II

Dolby Surround Pro Logic II Decoder Principles of Operation

by Roger Dressler

Introduction

Matrix surround decoding, the process of deriving several output channels from a two-channel delivery medium, is nothing new. When Dolby Surround Pro Logic decoding was introduced back in 1987, it followed various other surround technologies that had already appeared—and mostly disappeared—in the two decades before. The popularity of Pro Logic increased dramatically through the 1990s, and helped establish the basis for surround sound capability in future consumer digital delivery formats.

The advent of digital formats meant that source content, no longer restricted by the limitations of grooves, multiplexed RF carriers, or tape heads, could expand to 5.1-channel discrete audio as the new benchmark. When introduced, 5.1-channel Dolby Digital established a totally new level of soundfield capability and articulation, far surpassing what matrix surround encode/decode systems could achieve, but it did so using the exact same "3/2" speaker configuration already established by Pro Logic. The widespread adoption of Dolby Digital 5.1 audio on DVD-Video discs helped raise the standard—and expectations—of surround playback in home theaters from that point forward.

Movie producers were the first to embrace discrete 5.1-channel audio for films, which is the de facto standard for current production and release on DVD. Many earlier movies originally released in Dolby Surround have also been reissued on DVD in 5.1 audio, allowing them to be experienced anew with improvements in soundfield spatiality, directionality, and articulation. The transition to 5.1-channel audio is also well under way for digital TV over broadcast, satellite, and cable, while the multichannel DVD-Audio format gives a similar boost to the enjoyment of music recordings.

As more people have come to appreciate the benefits of surround sound playback, they also want nonsurround programs, particularly music, to take full advantage of their playback systems. This desire is not only for home theaters, but for car audio, computers, and even headphone listening. Dolby Pro Logic II was designed with these expanded uses in mind.

Dolby Laboratories, Inc. 100 Potrero Avenue, San Francisco, CA 94103-4813 Telephone 415-558-0200 Fax 415-863-1373
Wootton Bassett, Wiltshire, SN4 8QJ, England Telephone (44) 1793-842100 Fax (44) 1793-842101 www.dolby.com

Why a new surround decoder technology in 2000?
Significant improvements in the way audio/video media is created and delivered to consumers have occurred in the last several years. VHS Hi-Fi is now the standard audio for stereo VCRs and prerecorded tapes, DVD is rapidly becoming the format of choice for movies in packaged media, and digital TV will eventually supersede analog broadcast formats around the world. The ability to deliver high-quality stereo audio has never been better. This also benefits the delivery of surround encoded programs, which are more prevalent than ever on TV, video, and DVD.

These improvements in content delivery, coupled with advancements in surround decoding technology, allow Pro Logic II to set a new benchmark in matrix surround decoding performance, thereby revitalizing the vast array of existing and newly produced Dolby Surround programs.

The challenges for a modern surround decoder therefore are numerous. It must:

- perform with a wide range of movie and music content
- raise the sonic standard to address contemporary "5.1" expectations
- be suitable for home theater, PC, mobile, and headphone playback
- have cost-effective analog and digital implementations
- be simple to use

Pro Logic II meets these requirements. Decoding of Dolby Surround soundtracks retains the fundamental consistency and "rightness" the movie industry has come to expect from Pro Logic, but with a new sense of spatiality, directionality, and soundfield stability that is unprecedented in matrix surround decoders.

For the first time, Dolby is offering a surround decoder equally adept at bringing out the hidden spatial cues in conventional music recordings in a natural, convincing way. The listener is drawn into a three-dimensional space rather than hearing a flat, two-dimensional presentation. This not only helps develop a more involving soundfield, but also solves the narrow "sweet spot" problem of conventional stereo reproduction.

What's inside?
In previous logic decoders, including Pro Logic[1], the control circuit is looking at the relative level and phase between the input signals. This information is sent to the variable output matrix stage to adjust VCAs controlling the level of antiphase signals. The antiphase signals cancel the unwanted crosstalk signals, resulting in improved channel separation. This is called a feed-forward design.

Pro Logic II looks at the same input signals and servos them to match their levels. These matched audio signals are sent directly to the matrix stages to derive the various output channels. Because the same audio signals that feed the output matrix are themselves used to control the servo loop, it is called a feedback logic design.[2]

[1] See Dolby Pro Logic Principles of Operation, available from www.dolby.com.
[2] Patents pending.

The concept of feedback control has long been a mainstay of sophisticated analog control systems such as Dolby noise reduction, where it improves accuracy and optimizes dynamic characteristics. Incorporating global feedback around the logic steering process brings similar benefits in steering accuracy and dynamic behavior.

How it works

To understand the decoder, it is useful to see how four original source audio signals are encoded into the two program channels which eventually feed the decoder. These signals are called Lt and Rt, for left-total and right-total. ("Total" means they contain all the encoded audio channels, not just left and right.) See Figure 1.

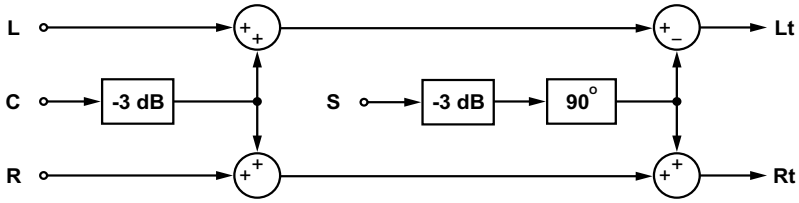

Figure 1. Simple four-input encoder concept

In this case, there are four "cardinal" input signals: Left, Center, Right, and Surround (L, C, R, S). The L and R inputs go straight to the Lt and Rt encoder outputs without modification. The C input is divided equally to Lt and Rt with a 3 dB level reduction (to maintain constant acoustic power in the mix). The S input is also reduced by 3 dB, but before being divided equally between Lt and Rt, the signal has 90-degree phase shift applied relative to L, C, and R. Finally, the S signals are carried in Lt/Rt with opposite polarities (note the "–" sign in the summing stage feeding the Lt output).

The simplest form of surround decoder subtracts the Rt signal from the Lt, as shown in Figure 2. If only an S signal is present at the encoder, the signals in Lt and Rt are identical but of opposite polarity. When these signals are subtracted in the passive decoder, they create the surround output signal as desired.

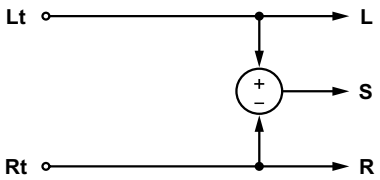

Figure 2. Simple passive surround decoder concept

If only a C input signal is present at the encoder, the signals in Lt and Rt are identical. When subtracted in the passive decoder, they cancel each other completely, leaving only silence at the S output, which is again the desired result. This shows that there is very high channel separation between C and S, even when using a passive decoder.

If the Lt and Rt signals are random (not purely C or S), the Lt–Rt process will produce the difference signal at the S output. As a result, it is impossible for any sounds panned away from dead center to be removed from the S output. The channel separation between front and surround signals can be as low as 3 dB in a passive decoder.

The job of an active decoder like Pro Logic or Pro Logic II is to keep a dominant signal such as dialogue from leaking from the surround speakers whether it is directly in the center channel, slightly off center, or even panned all the way to the full left or right of the soundstage. For example, if dialogue is placed "half right" (at the same levels into the C and R inputs of the encoder in Figure 1), the passive L–R decoder will not cancel all the dialogue in the surround output because the level of dialogue in Lt is lower than the level in Rt.

To make full cancellation occur in the S output, the amounts of dialogue in Lt and Rt feeding the S channel decoder need to be made equal. This can be done by putting VCAs into the Lt and Rt signals feeding the subtraction stage, and adjusting their gains in opposite directions from a common control signal as shown in Figure 3. As the gain rises in one VCA, it falls in the other. By adjusting this control precisely, the leakage of any dialogue signal panned anywhere between L and R (including C) can be completely eliminated from the S output.

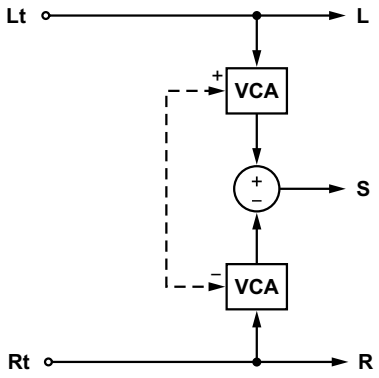

Figure 3. Decoder with VCA balancing

To automatically maintain the balance of the two signals feeding the subtraction stage under dynamically changing signal conditions, a feedback "servo" circuit compares the levels of these two signals after full-wave rectification (FWR), and adjusts the VCA control to force them to be equal (see Figure 4).

The C output is created by adding (instead of subtracting) the same two balanced VCA output signals.

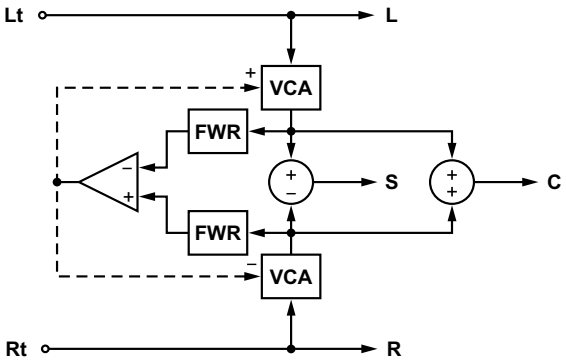

Figure 4. Decoder with VCA balancing servo

Since the L and R signals are being adjusted by the VCAs, this is known as the decoder's Left-Right axis. There is also a Front-Back axis in the decoder, operating orthogonally to the Left-Right axis, which uses the same basic technique to servo the L+R (front) signal versus the L–R (back) signal to reduce crosstalk in the L and R outputs.

By creating a feedback system around the logic steering process, certain benefits can be attained:

- The antiphase signals feeding the output matrix are able to be matched to the unwanted crosstalk signal levels with high precision and low circuit complexity, thereby ensuring high channel separation.
- The steering logic control time constants are within a feedback loop, so as the loop gain changes, so does the response time. Dynamically, there is a greater "speed to smoothness

ratio" than is possible in a feed-forward system, leading to an ideal balance between fast action and stable operation while using relatively simple circuitry.

In Pro Logic, the Front-Back and Left-Right axes are controlled by a single slow/fast circuit. If either axis wants to steer fast, they both go fast. Only when both want to go slow can the logic decoder switch to the slow mode. In Pro Logic II, each axis operates independently, so they decide how fast to go based on their individual conditions. Also, the logic speed range is continuously variable in Pro Logic II, rather than having two fixed rates as in Pro Logic.

These are just some of the more obvious aspects of the new decoder design principles. The end result is that the Pro Logic II decoder can process any kind of source material without changing the core logic steering parameters. Since movies often contain music to a significant degree, a decoder needs to handle dialogue, music, and effects equally well without creating side-effects.

Decoder functions and features

Table 1 shows how Pro Logic II compares with Pro Logic.

Feature	Pro Logic	Pro Logic II
Source content	▪ Dolby Surround programs	▪ Dolby Surround programs ▪ stereo music recordings
Output modes	▪ "3/1" surround ▪ "2/1" with phantom center ▪ "3/0" 3 stereo	▪ "3/2" surround ▪ "2/2" with phantom center ▪ "3/0" 3 stereo Pro Logic emulation mode: ▪ "3/1" with filtered surround
Surround channel BW	7 kHz	unlimited
Panorama mode	no	yes
Dimension control	no	yes
Center Width control	no	yes

Table 1. Comparison of key decoder features

Pro Logic II can be implemented as a "one mode for all programs" decoder, as may be ideal for simpler products. The "Movie" mode shown in Table 2 works very well in that application. The Movie mode is very similar to the Pro Logic mode, with the main difference being that Pro Logic has a 7 kHz surround filter and a mono surround output, while the Movie mode has no surround filter and stereo surround outputs. The Pro Logic emulation mode included in the technology package is as robust as the original Pro Logic decoding mode without having to provide separate decoding circuitry in the product.

The Movie and Pro Logic modes both use sufficient delay in the surround channel(s) to ensure the sounds from the front speakers arrive at least 10 ms before the sounds from the surround speakers. This creates the Haas precedence effect, which helps ensure dialogue and other frontal sounds intended to relate with the on-screen action are actually perceived as originating there.

Feature	Movie	Pro Logic	Music
Surround filter	no	7 kHz LPF	shelf
Surround delay	yes	yes	no
Panorama mode	off	off	opt
Dimension control	off	off	opt
Center Width control	off	off	opt
Autobalance mode	on	on	off

Table 2. Description of Pro Logic II decoder features

There are well-known characteristic differences between movie soundtracks and music recordings. For example, movies (and Dolby Surround TV shows) are mixed and monitored in a calibrated multichannel environment, so the desired end result when listening at home can be obtained from a similarly calibrated home theater system. Stereo music, on the other hand, is not monitored through a surround system when being mixed, so it is not really known at that time how it will sound when played on a surround system. For this reason, the Movie mode of Pro Logic II has preset characteristics to ensure consistent results. The Music mode, however, can be user-adjustable, assuming the decoder manufacturer decides to offer any of the following three optional controls. These controls may be used in any kind of decoder to allow optimization of the soundfield as desired, but are especially effective in automotive applications due to seating and speaker positions.

- Dimension control. Allows the user to gradually adjust the soundfield either towards the front or towards the rear. This can be useful to help achieve a more suitable balance from all the speakers with certain recordings.
- Center Width control. Allows variable adjustment of the center image so it may be heard only from the center speaker, only from the left/right speakers as a "phantom" center image, or various combinations of all three front speakers. With this control it is possible to create a balanced left-center-right stage presentation for both the driver and the front passenger. For home users, it allows improved blending of the center and main speakers, or to control the sense of image width, or "weight."
- Panorama mode. Extends the front stereo image to include the surround speakers for an exciting "wraparound" effect with side wall imaging.

There is a mild high-frequency shelf filter provided in the surround channels for the Music mode. It results in a more natural, believable soundfield, since ambient sounds normally have a high-frequency rolloff induced by room reflections and absorption.

The goal for music playback is to have the sounds from all the speakers arrive at the listener at the same time, which is known as *coincident arrival*. In case the surround or center speakers are closer to the listener than the main left/right front speakers, a compensating delay will be applied in the decoder. This helps prevent any smearing or combing of the sounds as they combine from the various speakers.

Lastly, the autobalance is turned off in Music mode, considering vocalists are sometimes deliberately placed off center in the mix.

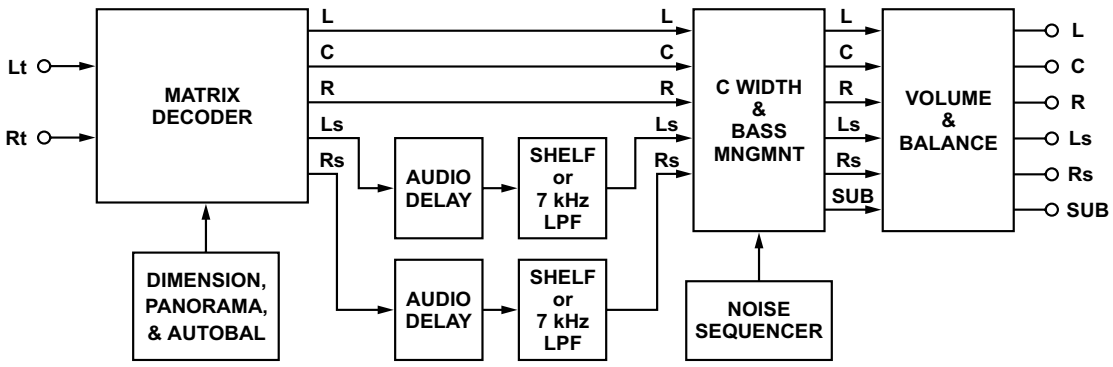

Figure 5. Basic decoder system block diagram

Pro Logic II has a decoder structure basically identical to Pro Logic except for the stereo surrounds, as shown in Figure 5. Since the time Pro Logic was originally introduced, the concept of bass management and the use of subwoofers has become commonplace. Pro Logic II includes a bass management feature to derive a proper subwoofer feed or to allow bass to be reproduced from the main speakers, as appropriate for the application.

Conclusion

A new generation of Dolby Surround Pro Logic decoding is available to take advantage of improved content delivery formats, and to meet higher consumer expectations for enriching surround sound wherever they are listening. Pro Logic II achieves advanced performance from an elegant solution that can be implemented equally well in either analog or digital forms.