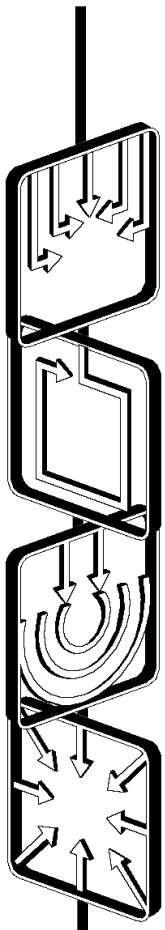

Multi-Channel Music & Cinema Systems

Theory and Design

Lexicon

Acknowledgements

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Introduction

All of the Lexicon home theater surround sound processors have a common goal: to draw you, the listener, more deeply into a musical performance or a film. For music, we use true stereo digital processing to recreate the original recording space or to create a new one of your choosing. For films we incorporate discrete digital multi-channel surround processing for both Dolby Digital (AC-3) and Digital Theater Systems (DTS) formats. For two channel surround encoded films we include our own proprietary 5 and 7 channel implementations of the original Dolby Pro Logic surround decoder. These improvements yield a greatly increased sense of surround and envelopment, as well as spectacular left / right surround effects.

Our processors are flexible enough to satisfy the most critical listeners and yet simple to operate. Essentially, they are signal processing computers that can be custom-programmed for any specific system. The increase in impact of a musical performance or film when heard with Lexicon processing is incredible.

To recreate the experience of being at a live musical performance we have drawn on recent studies of concert-hall acoustics, and applied this research to home listening rooms. Your auditory sense is quite adept at interpreting clues about your physical environment. Even with your eyes closed, it is possible to get a good mental picture of the room or hall you are in by listening to the ambience, or reflected sound energy, in the room. We are not aware of our auditory sense in everyday life because it confirms what our eyes identify as the environment. When we listen to recorded music, however, there are no visual clues and we rely completely on our sense of hearing. The introduction of two-speaker stereo systems over thirty years ago brought dramatic improvement to high fidelity music reproduction. With a carefully-designed system, and good recording, it became possible to produce a good sonic picture of the original event. Unfortunately, our listening rooms do not approximate the acoustics of a good concert hall, an intimate jazz club, or a magnificent cathedral - our ears tell us where we really are. Lexicon processors are designed to overcome this fundamental limitation to two-speaker reproduction and bring us closer to the ultimate goal of transporting ourselves to the original musical event.

Four basic algorithms are utilized: 5 channel or 7 channel Surround, Ambience, Reverberation, and Panorama. These algorithms create effects specifically designed to accurately reproduce any program material in your home. The object is to increase the sideways-moving sound in a room, thus increasing Spatial Impression, or SI. We accomplish this by either extracting it from the original recording, with the Panorama or Surround effects, or by generating a new acoustic environment with Ambience or Reverberation.

The surround effects include our proprietary matrix technology which is capable of extracting 5 or 7 channels from a two channel encoded original in such a way that the left and right channels maintain full separation during music playback. Although matrix decoders have been previously made with more than 4 channels, they all reduce the separation in the rear channels when decorrelated material such as music is being decoded. Our matrix effects maintain full separation and envelopment during the music sections of films, and for music recordings.

The Ambience (Nightclub and Concert Hall) and Reverberation (Church and Cathedral) algorithms transform the listening room into a new acoustic space, letting you choose an environment which matches your music or your mood. Unlike most ambience processors, ours provide full stereo processing, preserving the critical SI information in the recording and expanding upon it. The Ambience algorithm generates the side and rear reflection patterns of idealized rooms and concert halls. The larger spaces add the true depth and realism of a concert hall to classical and popular music, while the smaller spaces are ideal for jazz and rock. The Reverberation algorithm is similar, but places more emphasis on rich, dense reverberant decay than on early reflections. It is especially good for simulating large, highly reverberant spaces such as churches, stadiums, and cathedrals.

When a listener is in the correct spot the Panorama effect provides an almost ideal re-creation of the original recording space. It works by using digital signal processing to cancel the crosstalk between the listener's ears, effectively spreading the sound from the two front loudspeakers in a wide arc in front of the listener. With the optional addition of rear speakers, Panorama can be startling in its realism.

The requirements for processing sound for home theater are somewhat different than those for music and our surround programs meet all of these requirements. Lexicon invented the technology that permits the most accurate reproduction of film sound in the same system that is used for music listening, and our software-based processors are optimized for each of these unique tasks. The Music Surround and Music Logic effects are specifically designed to optimally play conventional stereo music through any system which includes side or side-located rear speakers. Additionally, our processors are able to perform automatic analysis and error correction to compensate for problems in the source material.

The new 5 channel and 7 channel surround decoding allows the stereo music in soundtracks to be reproduced with a full stereo spread, unencumbered by the relatively narrow separation of the front speakers. Left-to-surround and right-to-surround pans are also enhanced. Instead of sound jumping from a front channel to both surrounds, the left and right side speakers can function independently to facilitate smooth and fluid pans. Sounds directed to hard left and hard right (the main left and right speakers) will not appear in the side surrounds.

This technique overcomes the limitation of the monaural surround channel inherent in these formats, while remaining true to the front hemisphere directional cues. The audio imaging tracks the picture image in a way which fulfills the intent of the sound mixer. The drama of this effect is most noticeable with strong stereo music soundtracks, and on films with strongly panned effects.

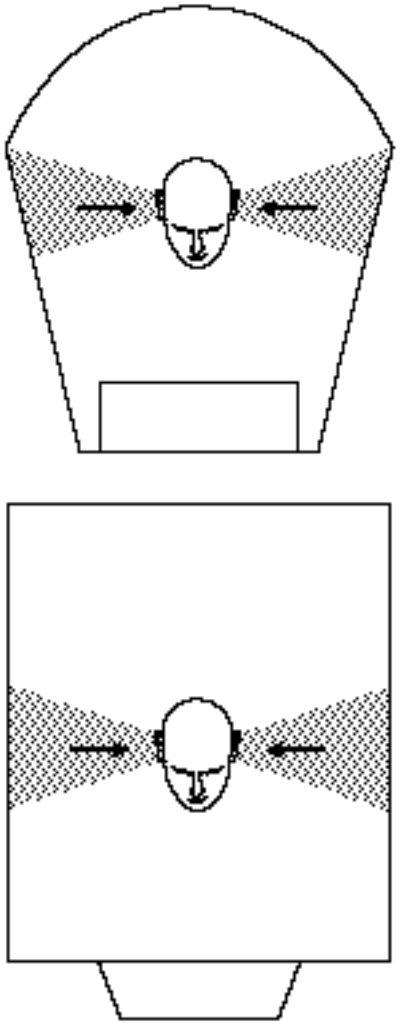
For film viewing, we provide effects for expanding monaural film sound tracks (Mono Logic), general TV viewing (TV Matrix) and, of course, direct two-channel stereo playback (Two Channel).

Our procesors also incorporate Lucasfilm THX Ultra processing, which compensates for the tonal and spatial characteristics of film soundtracks mixed for the cinematic environment. Home THX provides improved reproduction of film soundtracks recorded in Dolby Digital, Dolby Surround, and DTS. The two channel input THX Cinema effect includes a parameter which allows it to utilize the Lexicon 5 channel surround technology, although 7 channel operation is inhibited if dipole speakers are selected.

Lexicon processors equipped with Dolby Digital and DTS are capable of decoding these discrete digital multichannel formats. These “5.1” formats have five completely independent channels, each offering full-range fidelity, and a bass-only effects channel, known as the Low Frequency Effects channel (LFE). Lexicon processors use six of their eight discrete 24-bit D/A converters to decode these 5.1 channel encoded signals. In addition to standard decoding for both Dolby Digital and DTS soundtracks, we also include our proprietary Logic 7 matrix technology to extend the 5.1 standard to seven channels, along with some of the LucasFilm Home THX enhancements. Also included are effects which mix original 5.1 discrete soundtracks down to two channels which will play back with five or seven channels of surround when decoded with our processor.

All matrix decoding algorithms in our processors, (including the original Dolby Pro-Logic effect) utilize a patented, completely digital surround decoder, the only one with automatic correction of inter-channel phase and channel-balance errors (the most common audio problems in currently available video releases of films). The integration of Lexicon’s proprietary digital signal processing with these new technologies results in a home theater experience that is unmatched in the industry.

Lateral Sound



Halls with similar RT_{60} sound very different. The best have large amounts of sideways moving reflected sound.

Concert Hall Acoustics

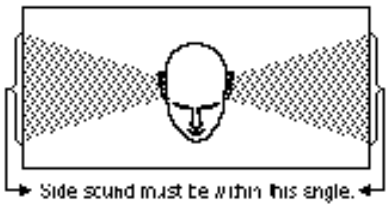
For decades the study of concert-hall acoustics relied on certain basic measurements to characterize halls, principally the time it takes a sound to drop in level (decay) by 60 decibels — referred to as RT60, or "reverberation time". Approximately the time it takes a hand clap to subside to inaudibility, reverberation time is measured as a function of frequency, usually in bands one octave wide, over the range of audible frequencies. Although this measurement is of fundamental importance in predicting the rate at which sound decays, it does not predict how loud or how audible the sound decay will be, and it does not predict the intelligibility of speech or the clarity of music. Other measures are clearly needed to determine hall quality and suitability for a particular function or type of music.

The search for accurate and reliable measures of hall quality has been long and contentious. Measures of intelligibility or clarity were the first to be developed, and many have been proposed. The most common measures, (Clarity or C80, Centertime, Deutlichkeit, etc.) have been shown to be highly correlated in actual halls. They thus are closely related, and have common virtues and faults. None of them appear to accurately predict intelligibility, although they are still useful.

An accurate measure for the quality of reverberance, and for the properties of spaciousness and envelopment, has proved much more difficult. A. H. Marshall and Michael Barron noticed in laboratory experiments that reflections arriving from the side were important to the perception of spaciousness. Although this perception clearly applies equally to both early and late arriving sound, Barron concluded that the early arriving reflections were the most important. This conclusion (which in hindsight is misleading at best) has dominated academic thought on hall acoustics for many years. Fortunately, the best working acousticians gave lip service to the idea, and continued to build halls with a combination of tradition and blind luck.

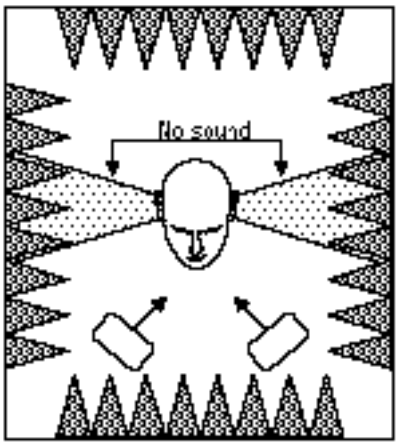
What was really needed was a method to study halls in the laboratory, but under realistic conditions. One step toward this process was provided by Manfred Schroeder. In an effort to answer the question of why some halls sound so much better than others, Schroeder devised a method for comparing them without transporting his subjects from hall to hall. Using a dummy head with microphone diaphragms in place of ear drums, Schroeder made binaural recordings in many halls. These recordings, played back through earphones, gave excellent reproduction of spatial qualities. Unfortunately, the stereo image tended to appear entirely inside the head, spoiling the accuracy of such recordings for some listeners.

To overcome this problem, Schroeder played his recordings through a pair of loudspeakers in an anechoic chamber, using a special electro-acoustic technique (developed by Atal, Schroeder, Damaske and Mellert) to eliminate crosstalk between the listener's ears. Normally each speaker is heard by both ears but Schroeder's system canceled the sound reaching the right ear from the left speaker and vice-versa. Provided that the listener held his head in exactly the right spot, the sound had all the excellent localization properties of earphones but was properly located outside the listener's head.



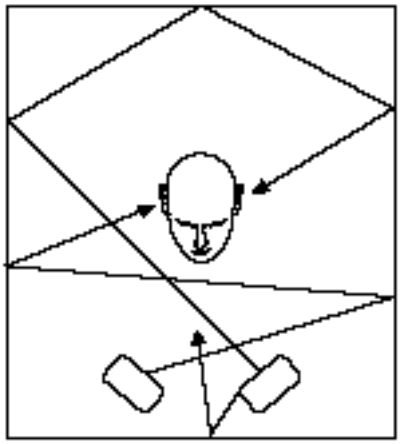
Sound from the side is vital to listener comfort and involvement . . . It must really be from the side!

This technique, generically known as interaural crosstalk cancellation, was found to work well even without the anechoic chamber, and music presented this way can be quite enjoyable. Lexicon incorporated this technique in many products as "Panorama". Dwane Cooper coined the name "transaural reproduction" for similar effects. This allowed the first direct comparisons of specific halls. From these studies Schroeder concluded that the best halls were all characterized by having large differences in the sound between the two ears in the dummy head. Very simply, the best halls gave the most stereo. But there is more to it than that. We have continued laboratory work, using both Panorama and headphones and have utilized our skill in reproducing different types of reverberation to study the effects of reflected energy at all time delays and angles. Our results have shown that differences between the ears are created by sound arriving from the sides, but the optimum angle is a function of frequency. Below 700Hz the optimum angle is completely from the side (or lateral). As the frequency rises the optimum angle becomes a cone centered on a line drawn between the ears. The interior angle of the cone rises from 0° at 700Hz to about 30° at 1000Hz, to about 60° at 2000Hz.

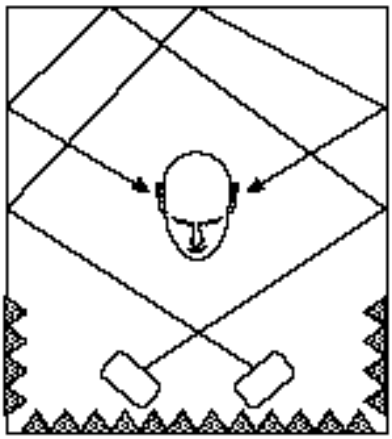


In an anechoic chamber, this sideways sound is missing . . . and music sounds unpleasant.

This angular dependence has some very interesting consequences for the perception of spaciousness, envelopment, and reverberance. Most home hi-fi systems have the front loudspeakers separated by at least ±30°. Such a separation is effective for frequencies above 1000Hz, and the front speakers alone create substantial spaciousness, at least at the frequencies which convey the most speech (and music) information. In the best seats in concert halls the orchestra is at least this wide. The high frequency direct sound is inherently spacious, even without the aid of reflected energy. Yet it is clear that halls increase the spaciousness of the sound. With careful listening both in actual halls and in the laboratory, it becomes apparent that the increased spaciousness is perceived primarily at low frequencies and in the gaps between notes. Hall spaciousness can occasionally also be heard when a note is held, particularly during a brass chord with a little vibrato, but this perception is relatively rare. Spaciousness and reverberance are never heard at the attacks of notes. In the best halls these are always clear and dry.



In an ordinary room, the room supplies these directions, and the sound is cramped, but tolerable. The overall impression, however, may be muddy due to unwanted frontal reflections.

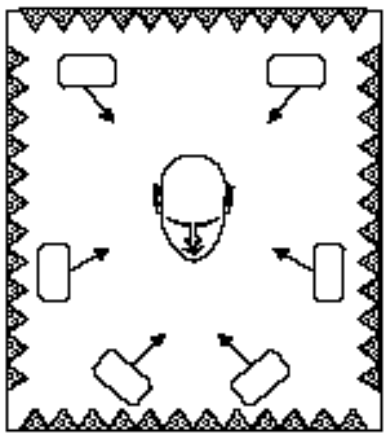


The confusing frontal reflections can be absorbed, leaving the essential lateral ones. This is better, but not ideal.

The reason is simple — music is highly effective at masking its own reflected energy. Most of the time, note follows note with very little space between. It is only in the gaps between notes that our ears have time to perceive the background sound which the hall creates. When that sound has a strong lateral component, a sense of spaciousness is created.

The time delay of the lateral reflected energy turns out to be very important. The ear is relatively insensitive to reflected energy in the first 150ms or so after a note ends, and musical masking increases this dead time to over 300ms. The greater the amount of reflected energy that comes to our ears after this time, the greater the sense of spaciousness and reverberance. Thus, both the loudness of the reverberation (the total energy relative to the direct sound) and the reverberation time are important to our perception. In natural halls the loudness and the reverberation time are linked by the hall volume. In a very large hall the reverberation level tends to be low, but the lack of level can be compensated by an increase in reverberation time. This effect can be clearly heard in an organ concert in a great cathedral. The organ, although often quite distant, is completely clear, yet it is bathed in a marvelous quiet reverberance. Similarly, small rooms with very little absorption can be loud and muddy, but seldom seem spacious or reverberant.

This understanding of the importance of late arriving lateral energy is quite new, and its effect on hall design has yet to be seen. The best halls have high late arriving lateral energy for obvious architectural reasons, such as a long narrow shape with high coffered ceilings. Fan-shaped halls have better sight lines, are more adaptible to multiple uses, and hold a greater number of seats for their total volume than shoe-box halls. However, their greater number of seats increases the total absorption of the audience, and decreases the strength of the later reverberance. These differences can sometimes be overcome. A notable example is the Boston Symphony's fan-shaped Tanglewood music shed. Although it used to be thought that diffraction from the edges of the overhead reflectors provided the needed spaciousness, it is more likely that the high internal volume of the hall and the low absorption at low frequencies combine to make the low frequency reverberance unusually audible for such a hall. Middle and upper frequences are dry unless one is distant from the orchestra.



With Lexicon processing, confusing short reflections can be absorbed; our processors will supply the essential lateral sound — which can simulate a much larger space. The more absorbent the playback room, the better it will sound, and the closer it will sound to a real hall, or larger environment.

In a small playback room, a spacious and enveloping sound can be achieved only if several conditions are met. First, significant energy should reach the listeners from the side. Second, this energy must be *different* on the left and right, i.e. it should be stereo, with excellent separation. Third, at least some of this energy should have a time delay of at least 100ms. These conditions can only be completely satisfied by placing loudspeakers at the sides of the listeners, and then driving those loudspeakers with a stereo signal which contains either ambient information from the original venue, or ambient information synthesized in the processor. Achieving all of these conditions is the guiding principle behind the Lexicon processors.

Lateral Sound in your Listening Environment

In an ordinary listening room, conventional stereo set-ups (with loudspeakers separated by 60° or less) provide a feeling of spaciousness only at upper frequencies. It is the room reflections excited by the speakers which provide low frequency lateral energy. A standard speaker arrangement in the artificial environment of an anechoic chamber is exceedingly detailed and precise, but unpleasant. Some lateral reflections are needed to make the sound musical.

Ordinary two-speaker stereo works as well as it does because sideways-moving reflections can be excited at low frequencies by two loudspeakers if they are placed asymmetrically in the room, or if they are driven with out-of-phase low-frequency information. (Out-of-phase bass is intentionally provided in the best stereo recordings.) Another reason is that most listening rooms have reflective surfaces to the sides of the listener. A popular listening room treatment puts absorptive material at the front of the room, leaving the walls by the listener reflective. This improves the clarity by removing the front reflections, while retaining those from the side. This also explains the appeal of loudspeakers that produce lots of sideways-reflected energy.

Unfortunately, in most two-speaker set-ups the mid- and high-frequency lateral sound is not optimal unless the speakers are unusually widely placed. The listener can hear a little of the original hall, stretched between the stereo loudspeakers, but never really becomes a part of it. What is worse, the lateral sound that exists in most playback rooms has so little delay that the ear can not separate it from the direct sound. The reflections generate some room sound but they also cause coloration and muddiness. Small rooms usually sound better if these reflections are broken up (with wall hangings, furniture or bookcases) or absorbed (with curtains or sound-absorbent panels). When this is done the room becomes quieter and clearer, but not in any way like the original hall.

Lexicon processors resolve this deficiency by supplying appropriate signals to loudspeakers at the sides of the listener. Our processors give the listener a choice: the sideways energy cues of the original recording can be extracted by our processor, or a different hall sound can be generated and supplied from the correct directions.

Low Frequency Management in a Multichannel System

Recent research into low frequency propagation in listening rooms has shown that the use of a single low frequency driver to cover the frequency range of 40Hz to 120Hz is not optimal. Modeling of rectangular rooms and measurements in several rooms both indicate that a single subwoofer (in the front corner of the room) can create a high level of low frequency energy in the area immediately around the subwoofer, but this level can drop substantially and non uniformly for standard listening positions.

When two full range speakers (or two symmetrically placed subwoofers) are used in the front, the level can become more uniform, but the low frequencies do not externalize, that is, they sound as if they are inside the listener's head. This "in-the-head" bass impression is very common in high-end recording studios but is decidedly unnatural. Our research has shown that if frequencies below 150Hz are to be reproduced through more than one loudspeaker, the sound can be externalized and made more uniform by applying a constant phase shift of 60° to 90° between the loudspeakers on the left side and the right side of the listener.

Both theoretical models and room measurements show that the uniformity of the low frequencies (and the externalization) is further increased by using loudspeakers at the sides of the listeners which are capable of response to about 50Hz or lower. Note that many smaller speakers can reproduce usable bass below their rated frequency response.

The Music Logic, Logic 7 and TV Matrix algorithms include the necessary phase shift networks for the Bass Enhance effect. The difference between optimal low frequency bass and that produced by a standard single subwoofer can be easily compared by changing the speaker configuration of the processor. For un-enhanced bass reproduction, turn the subwoofer on, and set all other speakers to Small. For bass reproduction that takes advantage of the Bass Enhance effect, set the crossover to the subwoofer at 40Hz and set the center channel to Small with a crossover setting of 120Hz. Set all of the other speakers to Large, or to Small with a 40Hz crossover. Make sure Bass Enhance is engaged in the Effect Adjust menu. Invariably, the sense of fluidity in the low frequencies will increase and there will be an increased sense of spaciousness.

Bass Split Operation for the Center Speaker

The Music Logic, Logic 7 and TV Matrix algorithms deal with a small center speaker differently than the other matrix effects. Rather than taking the low frequencies which would ordinarily be sent to the center speaker and splitting them between the left and the right front speakers, the new algorithms split these low frequencies between all the side speakers — including the sides and the rears. This is important because in most popular music the low frequencies are monaural, and much of the higher frequency material is also centered. As a result, there is a large amount of low frequency information in the center channel. However, these recordings typically have a strong monaural low frequency component in the left and right channels, and low frequencies reproduced from the center loud-speaker are always perceived as coming from inside the head. Thus, the optimal system uses a Small center speaker setting — whether the speaker is capable of full range operation or not. Ideally, the center speaker should be set to 120Hz crossover.

Ambience Extraction

The Panorama and Surround effects extract the original acoustic cues from the recording and present them to the listener from the correct directions. We call this *ambience extraction*. The Panorama effect can do this even with only two loudspeakers. Panorama uses crosstalk elimination to fool the ear into thinking there is a continuous band of loudspeakers extending all the way to the sides of the listener. Panorama also supplies a delayed and filtered L-R signal to rear speakers. On a good recording this successfully recreates the original recording space, although the ideal listening area may be small.

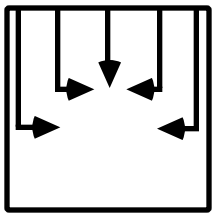
The Music Surround and Music Logic effects also provide ambience extraction. They divide the front energy among the three front loudspeakers and supply an ambience signal to the surround loudspeakers. Because a center speaker is provided, the left and right speakers can be placed far enough to the sides of the listener to directly excite significant spaciousness, and the resulting image is wide but seamless. This setup can sound similar to Panorama, and it works over a large listening area.

Pro Logic, THX Cinema, TV Matrix, Logic 7, and Music Logic also provide steering. Steering works by enhancing the directionality of the loudest sound in a mix; it steers the sound out of loudspeakers where it is not needed and into the ones closest to its direction in the image. In popular music the loudest sound is usually the vocals, which will be preferentially steered toward the center loudspeaker. Some steering is frequently beneficial to music recordings played with a surround speaker arrangement, and it is essential for films. The latest of the surround programs, Music Logic and Music Surround, apply the steering in a special way. In these programs whenever there is no particular loudest sound, the left and right surround loudspeakers mimic the left and right front loudspeakers, but with added delay and frequency contouring. This provides an ambience signal with maximum left and right difference and maximum spaciousness. When there is a strong signal to the left or right this signal is cleanly removed from the rear speakers, and reproduced only in the front. The result is a convincing five or seven channel reproduction of a two channel original recording.

Ambience Generation

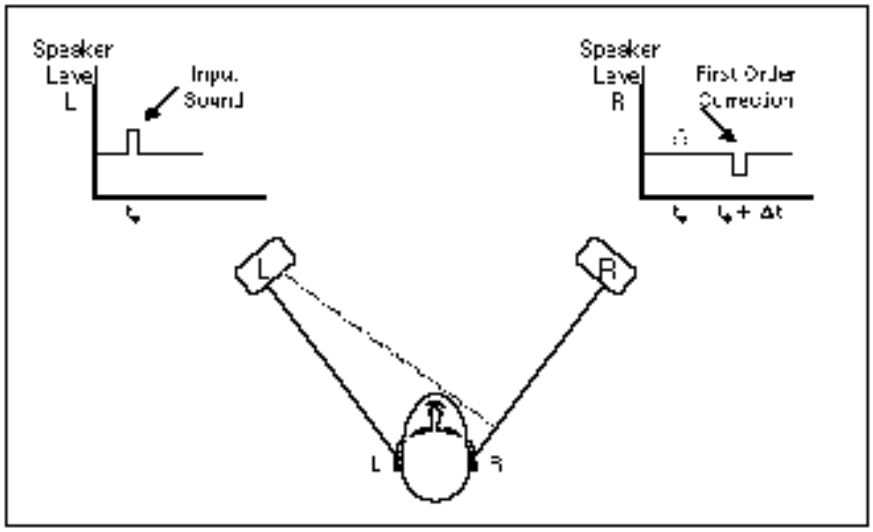
The ambience and reverb effects — Nightclub, Concert Hall, Church and Cathedral — synthesize the side and rear sound of several different acoustic spaces. Rather than extracting the acoustic cues of the original hall from the recording, they generate a new environment, effectively enlarging and improving the acoustics of your listening room. In these effects the original stereo channels are presented basically unaltered to the main loudspeakers, and new signals are generated for the side and rear loudspeakers.

Panorama



Loudspeakers placed on either side of the listening position are the most effective and foolproof way to produce added Spatial Impression. Since it is not always possible to have side loudspeakers, Lexicon processors use crosstalk elimination to simulate them when they can't physically be there. In Panorama the front speakers are driven entirely by the front digital outputs of the processor.

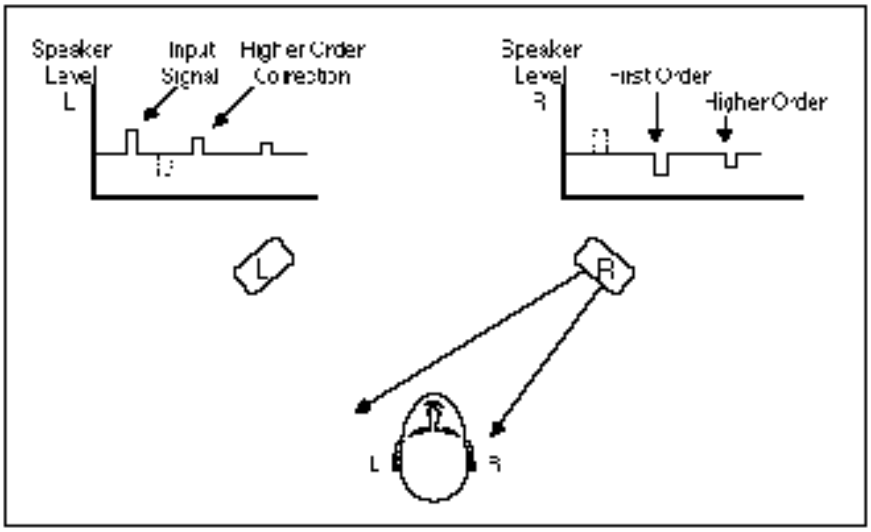
Versions of the Atal / Schroeder / Damaske / Mellert technique mentioned earlier have appeared in several consumer signal processors under various trade names, as well as in a line of loudspeakers that achieved a similar effect acoustically. These have all been what we call "first-order" devices. To see what this means, imagine there is a sound coming from the left channel only. This sound will travel to the left ear of the listener, then diffract around the listener's head and be heard by the right ear. If we take the left-channel sound, delay it just the right amount, invert it in phase and feed it to the right speaker, it will arrive at the right ear just in time to cancel the crosstalk from the left speaker.



First-order correction travels to the left ear, where it will be heard unless canceled by an additional correction. When these higher-order corrections are supplied, accurate cancellation is possible.

The main problem with a first-order device is that the subtracting signal is also heard by the opposite ear. In our example, the canceling signal from the right loudspeaker will diffract around the head to the left ear, interfering with the left-speaker sound and producing a "comb filter" which colors the sound in an obvious and unpleasant way. Furthermore, the listener's head is not well represented by a simple delay line. Both the delay and the amplitude of the opposite-ear sound vary in complicated ways with frequency.

Lexicon's implementation, called *Panorama* , was designed using measured data on sound diffraction around the head to shape the frequency spectrum of the canceling signal. This signal is then itself canceled by a second signal, and so on, so that both the crosstalk and the signal that is canceling it are eliminated.



Imagine a click in the left speaker . . .

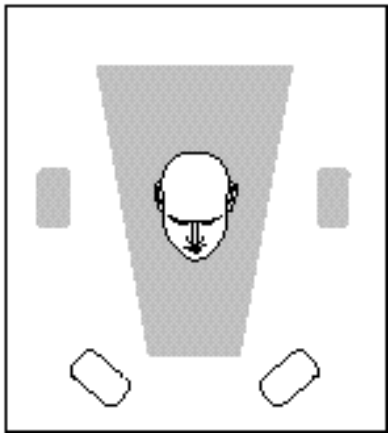
Sound from speaker L travels to the left ear and also to the right ear, a time Δt later.

If we supply a negative delayed signal to the right speaker, this crosstalk can be canceled.

This works extremely well when the room is well damped and the listener's head is correctly positioned. The first order devices described earlier required the listener to sit on the center line between the loudspeakers, and to arrange the angle between the speakers to correspond to the modeled delay. Although the processor provides adjustments to compensate for off-center listening and for varying speaker angles, maintaining a consistent listening position is still important and becomes more so with increasing frequency. With wide speaker angles, a movement of as little as 1 inch can make a perceptible difference. Fortunately, the effect is usually fairly good everywhere within a zone about one foot wide.

To achieve the fullest Panorama effect, your main loudspeakers should have good imaging. The smaller speakers that tend to be used with video systems may have an inherent advantage here but the most important requirement is that the two speakers have identical frequency response and symmetrical dispersion. It is not necessary, or desirable, to turn your listening room into an anechoic chamber but moving the speakers away from the walls can be helpful, as can adding absorption (as provided by carpets, curtains and / or sound-absorbent panels) to reduce the reflectivity of the floor, walls and ceiling.

In a well-damped room with loudspeakers mounted on stands away from the walls, the Panorama effect can be very exciting, giving the closest possible approximation to the actual hall used for the recording. With true binaural recordings (made with a modern dummy head with accurate external ears and proper equalization) the playback can be uncannily realistic. And, unlike previous versions of this technique, the Panorama mode adds virtually no coloration to the original signal.



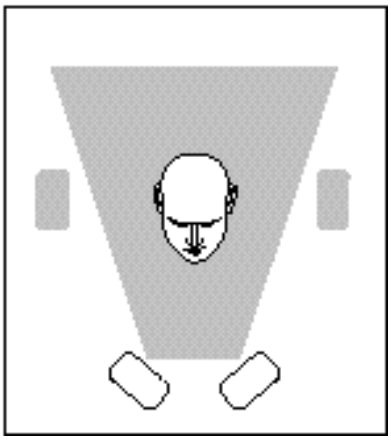
Panorama can be used with music, films, or from within the Reverb and Ambience programs to simulate side speakers if the listener is inside the effective area between loudspeakers.

Panorama is used in two ways. First, it is designed to reproduce as closely as possible the sound actually recorded by the engineer. If the recording has good natural ambience, Panorama will spread that ambience around the listener, giving a true impression of the original hall.

The Low Frequency Width control provides an important adjustment to the bass in Panorama. This control is a simple implementation of a Spatial Equalizer (a function which Alan Blumlein referred to as a "shuffler"). One of the ways ordinary stereo excites SI is through the out-of-phase low frequency energy in the recording. The Low Frequency Width control allows the amount of out-of-phase bass in a recording to be adjusted. Even when the Effect level of the Panorama control is all the way down, the Low Frequency Width control is active, allowing the user to experiment with this property of sound.

Recording engineers have only recently become aware of Spatial Equalization and many older recordings are greatly improved by increasing the low frequency width a little. When the rest of the Panorama mode is not used (by turning down the Effect control) just turning LF Width up a bit can make ordinary recordings quite spacious. The user should exercise caution, however, since some recordings (such as those on Telarc) use microphone techniques which already contain sufficient out-of-phase low frequency energy.

The crosstalk cancellation in Panorama increases the low frequency width as well as the high frequency width of a recording. Recordings in which the engineer deliberately added large amounts of low frequency width will sound too wide and phasey when played with either Panorama Normal or Panorama Wide. Negative values of the Low Frequency Width parameter can bring the low frequencies back in line with the higher frequencies and make the playback with Panorama more effective. The Binaural setting of Panorama greatly increases low frequency width and should only be used with true binaural recordings, which have very little out-of-phase low frequency energy. A few compatible binaural recordings are becoming available, in which the low frequency width has been increased to match the requirements of loudspeaker playback. These recordings may sound best when played with the Normal setting.

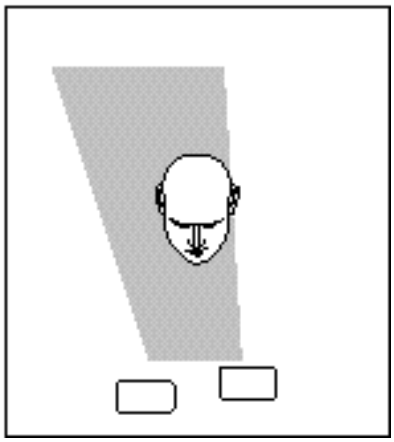


When the front speakers are close together, the Panorama Effect is less precise but more dramatic, and it works over a larger area.

Panorama is capable of simulating side loudspeakers effectively, but cannot mimic sound sources to the rear of the listener. So we have added a delayed Left minus Right signal which can be sent to the side and rear loudspeakers. The delay is adjustable, as is the treble rolloff.

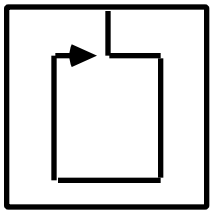
For a listener in the ideal position, Panorama, with surround (side or rear) speakers, gives a nearly ideal re-creation of the original recording area.

Panorama is also used as an element in the ambience and reverb simulation effects, where it can synthesize side loudspeakers which are not present in the installation. In these effects, the stereo inputs to the processor are fed directly to the front loudspeakers, with the digital outputs mixed in according to the setting of the processor's Effect Level control. The Ambience or Reverb side outputs are sent through Panorama before being mixed into the front loudspeakers, so the added sound spreads beyond them and does not interfere with the original material. When side speakers are present, the Panorama Effect parameter is automatically turned down and no mixing occurs into the front speakers.



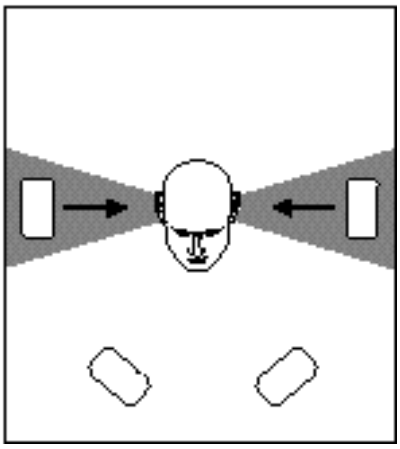
Speaker alignment is important. A 6" difference in the distance to the rear wall can greatly change the effective area, unless compensated for by the LISTENER POSITION parameter.

Ambience



While Panorama recreates the space that already exists in the recording, the Ambience effects actually generate the side and rear reflection patterns of ideal halls. The reflections were determined by computer ray-tracing using architectural data, augmented by Lexicon's decades of experience with digital concert hall simulation.

The ambience simulation is done in stereo. Instead of feeding a monaural signal derived from the combined left and right channel inputs, Lexicon processors have two input points corresponding to instruments placed on the left or right side of the stage. From these, the loudness and delay of the reflections for the side and rear loudspeakers are calculated. By using full stereo for the inputs to the simulation programs, the spread of the soundstage is automatically preserved in the simulation process. This obviates the need for adjustment on every different recording, a chore required for decent results on some other systems.



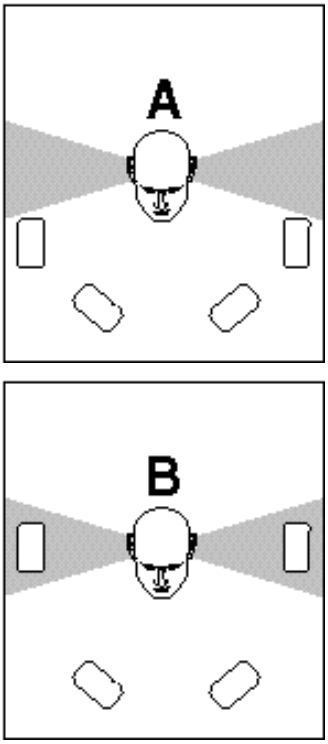
The best way to generate spatial impression (SI) is with appropriate signals from loudspeakers at the side. Reverb, Ambience and the Surround programs can all be used to generate these signals.

Early research with quadraphonics involved extensive experimentation with speaker placement, and confirmed that additional speakers beside the listener sounded better than the conventional approach of putting pairs of speakers in front and behind. Our research into speaker placement with ambience confirmed the previous results of others: The side speakers should be directly to the side of the main listening position, plus or minus about 20°. The spatial impression is greatly reduced outside of this critical angle. The primary reason for this result is the critical importance of the lateral energy at frequencies below 700Hz, which is usually insufficient in playback rooms. Thus, speakers which can reproduce frequencies down to 100Hz or below are recommended for the sides. If tiny speakers with subwoofers are used for the sides, it is best to use a separate subwoofer for each side, and place the subwoofers on opposite sides of the room.

The sides are the most important additional speakers, much more so than the rears. Keep in mind that, although you can use the left and right main speakers to simulate a phantom center speaker, you cannot produce spaciousness with one speaker in the front and one at the rear . (You can perform this experiment for yourself using the Ambience effect: Try the side speakers both in their usual positions and in the front corners. If your listening room has enough absorption to damp its side-wall reflections, the side location will provide much more spatial impression, and will sound substantially better.) The processor mixes some reverberant sound into the front speakers, to create an overall impression.

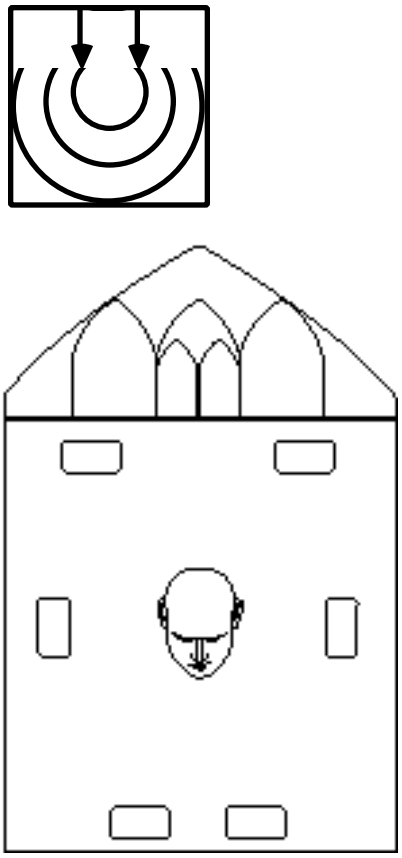
The effectiveness of the ambience simulation is heavily dependent on the source material and the playback room. If the playback room is large and reverberant, its reflections may dominate those generated by the processor. Carpet, drapes and furniture can all be used to break up or absorb undesirable reflections, making it easier to hear the processor's output. The balance between the side, rear and front speakers is also very important. If the channels are set up properly, no single speaker will be audible by itself.

Although the ambience effect in Nightclub and Concert Hall can provide some reverberation (adjustable with the Liveness parameter), for long decay times it is better to use the reverb effects: Cathedral and Church. The Concert Hall ambience is not intended to be used on material which is more appropriate to a smaller ambience, such as a small hall or a club. Highly percussive material is almost always better in Nightclub, which is quite successful in livening and expanding popular music.



Placement of side loudspeakers is critical! Placement B sounds much better than A, especially when the room is well damped.

Reverb



Reverb is very good for simulating a large reverberant space.

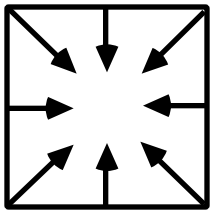
While the Ambience effect simulates the early reflections of real halls, the Reverb effect, used in Church and Cathedral, is more concerned with what happens to the sound after the first hundred milliseconds or so. The first reflections are not intended to simulate any particular hall and no real shape will be audible.

The Reverb effects produce a rapidly increasing echo density that smooths out impulsive sounds. The decay in these effects is unusually smooth and natural and can create the effect of a church or a very reverberant hall. The early sideways reflections are weaker than they are in the Ambience effects. For both reverb and ambience simulation, the stereo input is fed directly to the front loudspeakers. Some of the reverb is also added to the front channels to produce a convincing sense of surround.

Direction is critical to maintaining clarity in the Reverb as well the Ambience effects. The recording engineer has probably put as much reverberation in the recording as the music can withstand. Adding more through speakers located in front of the listener is generally not a good idea, since these effects combine with the sound from the front speakers, making the music muddy.

Delay and reverb in the rear can occasionally be helpful but the ear is not particularly good at distinguishing between front and rear sounds and, as with the ambience effects, it is at the sides that reverb information is most needed.

Surround



The requirements for processing sound for film viewing are quite different than those for music listening. Music demands recreation of the original performance venue, or the evocation of an appropriate setting, as well as the creation of a believable soundstage. When visual images are introduced, not only is strong audio imaging necessary to reinforce the illusion that dialog originates at the screen image, but a diffuse soundfield must be created which envelops the viewer without distracting attention from the screen.

In addition, films are designed to provide an enveloping experience in large, reverberant auditoriums where background noise is a significant consideration, where the screen dominates the field of vision, and where the sound must be as uniform as possible over a large seating area — in short, quite a different environment from your living room.

When all of these factors are taken into consideration, it becomes obvious that no single speaker system or single method of processing is optimal, or even adequate, for all types of music as well as for audio/video material.

Lexicon processors are able to optimize the listening experience of any material precisely because they provide such a wide range of processing options. This flexibility is readily apparent in the variety of Surround effects available to the user, each optimized for maximizing listener involvement in different types of material played on a system whose speakers are laid out primarily for films.

TV MATRIX provides surround effects to enhance television viewing of monaural, stereo and stereo-synthesized programs. This program has the most flexibility in adjustment of any of the Surround effects.

MUSIC LOGIC and MUSIC SURROUND use a unique ambience extraction method which can provide spectacular results with music, as well as providing seven channels.

PARTY (Full Range) allows unprocessed music to be played over all the speakers for background music, or for maximum acoustical output of the system.

MONO LOGIC expands the music and effects on monaural films into the surround channels while leaving dialog in the front center.

PRO LOGIC provides the same decoding used in Dolby Stereo theater systems, using as many as eight speakers for front, center, side, rear and subwoofer channels. All side and rear channels are driven in parallel, or monaural.

THX Effects combine Dolby Pro Logic decoding and the spectral enhancements of the LucasArts Home THX Cinema system. Home THX Cinema enhancements are provided for film soundtracks recorded in the Dolby Digital and DTS formats.

Our own LOGIC 7 effect takes decoding further with the introduction of true seven channel decoding using a stereo surround process. Steered signals are panned to the front, side and rear speakers so that surround information follows the visual movement on-screen. Ambient surround information, such as stereo music in the soundtrack, is reproduced at full bandwidth and in stereo in the rear channels. Sound effects which pan to the left or right of the listener are reproduced with full realism.

DOLBY DIGITAL and DTS effects decode six discrete channels of digital information from encoded soundtracks. Improvements to film sound reproduction include improved dynamic range, superior channel separation, a dedicated subwoofer channel, and discrete sound effects. For each format we include THX enhancements as well as our own music enhancements. The 5.1 2-CHANNEL effects mix 5.1 information down for two-channel playback. Soundtracks can be recorded onto two-channel formats for later playback through a surround effect such as Logic 7, or they can be played back through left and right front speakers.

TV Viewing

Television sound playback presents a challenge simply because of the wide variety of recording and processing techniques used in program production and transmission. Programs and commercials are recorded in mono, stereo, and surround sound, then subjected to compressors, erratic stereo synthesizers, sleepy production interns, and other electronic tortures. Often all of this can be experienced on one channel within five minutes.

The TV Matrix effect makes use of directional steering to enhance dialog in the center channel and remove it from the left and right channels, while maintaining as much stereo separation as possible. In addition, it contains several interesting variable parameters. In the preset version of TV Matrix these parameters are set for pleasing results with a wide variety of programming, but they can be changed to produce a versatile mode for film sound — and some music as well.

Enjoying Music in Surround

The Music Logic and Music Surround effects are designed to optimally play conventional stereo music through any system which includes side or side-located rear speakers.

Conventional stereo generally relies on the acoustics of the playback room to regenerate the important side, or lateral, energy which is present in nearly all music performance spaces. Speakers which are arranged for film viewing, however, often have the front loudspeakers too close together for optimal reproduction of the spaciousness of the original soundfield. With Lexicon processing, additional speakers located near the sides of the listeners can add to the playback spaciousness. In the ambience and reverb effects (Nightclub, Concert Hall, Church and Cathedral), the processors calculate and generate the ambient sound from a larger room and present this sound through the additional speakers. This works well, but the ambience is generated by the processor — not contained in the recording. In the surround effects (Music Surround, Music Logic, Logic 7 and TV Matrix), surround channel information is extracted from signals encoded on the recording by the sound mixer — the processor does not add anything to the sound.

On films, this surround information is intended to be reproduced in monaural from an array of speakers all around the rear of the listener. Unless there is enough energy accidentally encoded into the surround channel to give significant sideways energy, surround speakers won't contribute very much to the listening experience of ordinary stereo music. In addition, with all speakers except the fronts reproducing the same monaural signal, no directional effects are possible. There may be some sense of the music coming from all around you, but the violins and cellos are equally loud from both sides.

Music Logic and Music Surround solve this problem in a novel way. The side speakers reproduce the left and right front loudspeaker signals with two additions: delay and inverse steering.

The delay serves a simple purpose. Sounds are kept from being localized to the sides by an approximately l0ms delay inserted between the front and side speakers. The center speaker is steered, and its volume can be adjusted relative to the fronts.

Inverse steering acts to remove a strongly steered signal from certain directions. As an example, assume you have a strong signal in the left channel of a film. With normal steering, the processor enhances the level of that signal in the left speaker, and actively removes it from the other speakers. Inverse steering actively removes this signal from the left side speaker, while keeping its level strong in the left front speaker. This signal removal is done cleverly, so the level of any unsteered signal which might be present at the same time (such as music in a film, or the rest of the orchestra in a music recording) is not significantly reduced. The sonic result is a much wider soundstage and a very spacious sound. When music is

played, any loud instrument or sound effect is reproduced from the front speakers, not distractingly located off to the side.

Rear speakers in Music Logic and Music Surround, as in the stereo surround film effects, are driven by a similar signal to the side speakers, but with some additional delay and steering. Thus, in a 7 channel setup when a sound effect is intended to come from the rear, it is reproduced primarily from the rear speakers with deliberate additional help from the side speakers. (In THX Cinema and Pro Logic, the rear speakers and the side speakers are driven in parallel. In the Pro Logic effect, all four side and rear speakers are driven in mono, and in the THX Cinema effect, there is a decorrelation between the left and the right, but the signal being reproduced is the same mono signal used in Pro Logic.)

In the Music Surround effect, the front left and right outputs are attenuated by the volume and balance controls, but are otherwise unaltered by the processor. This absence of main front steering is ideal for playing stereo classical music, where the original stereo signals are reproduced from the front speakers with absolutely no alterations. The Music Surround effect really shines on this material — the center speaker adds a little stability to the front image without being at all obvious, while the side and rear speakers add a tremendous amount of ambience. Adjustments to the Soundstage parameter will emphasize or de-emphasize the ambient information extracted from the recording. For film, the lack of steering of the main speakers is noticeable on dialog, and the Logic 7 effect gives better results.

Music Logic expands on Music Surround by providing increased control of the front soundstage. In addition to Center Level volume control, the Music Logic effect adds Vocal Enhance and Front Steering parameters. Together, these parameters allow you to fine-tune the effect to a specific recording. The Vocal Enhance adjustment adds brightness to the vocal frequencies while simultaneously increasing the volume of this region. This can help a soloist project through a dense mix without altering the volume of the center channel relative to the fronts. The Front Steering parameter is provided to deliver a strong center image at a variety of listening positions, rather than being limited to one centered “sweet spot”. Music Logic is ideal for both pop and classical music.

The Party effect is provided to allow music to be played over your entire system. A High Pass parameter allows you to remove bass from side and rear speakers which might not be able to handle it. Center Level and Subwoofer Level controls are also provided. This effect is primarily useful for large audiences, or background music when entertaining.

Film Surround

The goal of the film surround effects is to maximize viewer involvement and to faithfully reproduce the director's intentions for the soundtrack in your own listening environment. Before explaining the way each of the film surround effects (Mono Logic, Pro Logic, THX Cinema, TV Matrix, and Logic 7) accomplish this goal, it is important to understand something about the way film soundtracks are made and presented in the theater.

In the early 1940's, large movie studios owned their own theaters and took responsibility for their own quality standards. During this period, movie theaters had the best sound reproduction heard anywhere — each major studio had a master sound engineer to ensure that the sound systems in that studio's theaters performed properly. A decade later, the studios were forced to sell off their theater holdings in an anti-trust action, and quality became the responsibility of independent theater owners. Since each theater could choose films from any studio, it was no longer practical, or feasible, for the studios to monitor the quality of each theater. At the same time, the impact of television caused a decline in theater attendance which left little money for individual theater owners to reinvest in their facilities. As a result, sound technology in theaters froze. Despite the advances being made in recording and in home music systems during this period, film sound remained essentially unchanged through the 50's and 60's. In fact, by the end of the 1960's the average teenager had a music system at home which was considerably superior to theater systems.

This situation began to change in the 1970's with the introduction of Dolby Stereo. This technological breakthrough, which allowed four channels of sound to be recorded onto the two available optical soundtracks of a 35mm movie print, yielded spectacular results — and created a demand for improved film sound tracks, and for better-sounding theaters. Theaters that upgraded their sound systems were rewarded with larger audiences. Over the next decade, Dolby Stereo became an established standard for film sound recording — but theater sound systems, although improved, varied in their ultimate accuracy.

In the 1980's a new movie theater sound system was created under the name THX. This system addressed, for the first time, the design of a theater speaker system which could faithfully reproduce the film director's intentions. The THX Sound System complemented and enhanced the playback of Dolby Stereo, and encompassed standards for power amplifiers, speakers, and the acoustics of theaters themselves, to assure the best possible reproduction of movie soundtracks. By 1998, this system was available in over 1600 theaters across the country. The increased availability of film on video tape, laser disc, DVD and broadcast, has led to a demand for home audio / video systems which equal the best theater sound. The Home THX Cinema system was designed to address this need.

Research at Lexicon has taken the possiblities of THX decoding to a further level with the introduction of true 7 channel decoding using a stereo surround process. This option is available via the Surround Effect parameter in THX Cinema, and is further refined in the Logic 7 effect. A variety of surround film effects allows you to have the highest possible sound quality for video material — whether you select classic monaural movies or the latest releases with all of their special effects — simply by changing effects.

Recent advances in film sound include discrete digital surround formats such as Dolby Digital AC-3) and Digital Theater Systems (DTS) digital surround. Unlike analog matrix-encoded formats such as Dolby surround, with its mono, band-limited surround channel, these formats have two completely independent surround channels. As a result, film sound engineers can implement true stereo surround effects, providing theater audiences with an expanded sense of depth, localization and overall realism. Today, films with Dolby Digital and DTS soundtracks can be found on digital media such as the laserdisc and DVD formats. As the acoustics, equalization curves and speaker arrays used in mixing are the same, whether mixing a four-channel analog matrix soundtrack, or a 5.1 digital soundtrack,. Dolby Digital and DTS 5.1 channel soundtracks played back through Lexicon processors have more spatial realism, and a more cinematic presentation.

Monaural Films

The problem of mono-to-stereo conversion is an old one. One time-honored solution is to break the incoming signal into frequency bands, sending some to one channel and the rest to the other. When the filters are complementary (when the sum of the two output channels equals the original input channel) this solution can give stereo spread without ruining the tonal balance. When the filters are non-complementary, they can produce an unpleasant fake stereo effect.

Some effort has been made to design filter pairs for film sound which leave voice frequencies unchanged while spreading out the music. More recent designs have gone in another direction, using digital or analog delay lines to produce a comb filter effect. So far, these attempts have not been very successful.

The principal element of film sound is dialog and the principal rule in reproducing it is to assure that it appears exclusively in the center channel. Broadcasters, who have an interest in converting mixtures of dialog and music to synthesized stereo, have built circuits designed to turn off the stereo synthesizer when voice appears. Unfortunately, the switch from mono to stereo is often abrupt and the chances of dropping into mono by mistake during music are high. One basic problem with films, especially modern ones, is that music or background effects which should be spread out into the side speakers frequently appear at a low level beneath the dialog.

During the early days of film stereo, dialog was sometimes mixed (by "panning" the monaural dialog track) to come from the same part of the screen as the image of the actor. Subjective reactions to this technique were varied, and technical problems with some magnetic sound tracks helped to discourage the practice, so modern movies are seldom mixed with panned dialog. In a home system with a good Pro Logic decoder, however, the effect can work quite well; examples of releases with panned dialog include "Yellow Submarine" and "Superman I." In most films though, all dialog comes from the center channel.

The Mono Logic effect electronically identifies certain properties of film speech and removes it from the stereo synthesis. This allows music and effects in the dialog to be spread out while leaving the dialog centered. The remaining music and effects are directed to the input of a room simulation mode that creates a space the size of a large room or small theater. The room simulator has outputs for left, right, side and rear surround speakers.

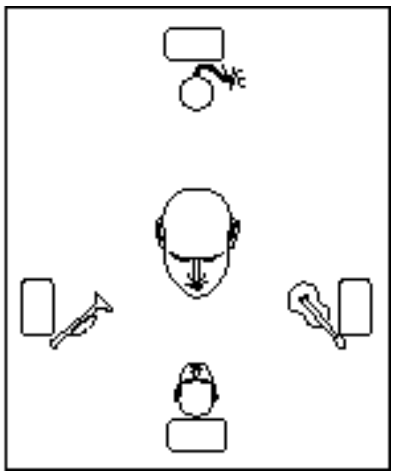
The monaural input sound from the film is unchanged in the center speaker, so that all the dialog and music that the director expected to come from the screen still does — with no modification or reverb. Partly because of the acoustical character of the room synthesizer, the result is often so successful that switching from Mono Logic to Pro Logic or THX may make a surprisingly small difference.

The most critical adjustment in Mono Logic is the Effect Level. Ideally the film's music and effects should appear to come from the front but with the added sense of a large space surrounding you. The side and rear speakers should not be individually audible.

High frequency attenuation is provided via the variable Treble Rolloff parameter and the Academy Filter On / Off parameter, which recreates the proper tonal balance of older, monaural films which were recorded with a much narrower and brighter frequency response than current films.

Stereo Films

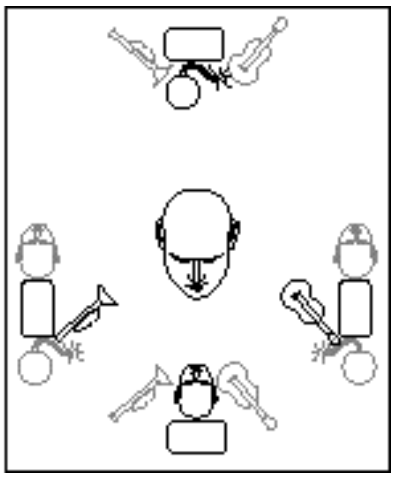
A Dolby Stereo film sound track has four basic components: left and right channels, a center front channel and a surround channel. The first three are fed to speakers arrayed behind the movie screen, while the surround sound goes to speakers on the side and rear walls of the theater. The four channels are recorded on separate magnetic tracks and are combined by the Dolby Stereo matrix encoder into two stereo channels called Lt and Rt (left total and right total) during the final mixing process. The original left and right channels go directly onto the left and right channels of the Dolby Stereo mix. The center channel is fed equally to both channels, in phase, and the surround track is fed equally to both channels, but 180 degrees out of phase. (It's actually a little more complex than that, but the the end result is essentially the same for this discussion).



Films originally have four channels: one for dialog and three for music and effects. To make a Dolby Stereo film, these are combined to two.

The center channel contains the most energy, including the dialog; music is normally mixed so that it appears to come from the front, with reverberation or ambience coming from the surrounds. The surround channel ambient information is a powerful tool for the film sound mixer. It is this information that helps us believe that the scene in the film is real. For special effects, music can be encoded to come from all around the listener or even from behind. In any case, with music and ambient effects there is almost always a substantial spread across the front of the loudspeaker array.

Sound effects can come from any direction around the listener and it is the job of the decoder to duplicate as closely as possible the film mixer's placements.



With conventional surround any sound comes from at least three directions.

When the movie is shown the two Dolby Stereo tracks must be decoded and separated into the original four. The basic Dolby Surround decoder does this in a rather rudimentary way: it supplies a signal to the center channel which is just the sum of the two input channels. This signal contains the dialog. However, the left and right signals still contain dialog too, so the dialog is spread out among the three front speakers. Similarly, the Dolby Surround decoder takes all out-of-phase signals and sends them to the surround speakers, while leaving the original out-of-phase components in the left and right front speakers.

The basic Dolby Surround decoder has high channel separation between left and right decoded audio, and between center and surround. The separation between left or right and center, or between left or right and surround, however, is only a few dB. The simple Dolby Surround decoder does pretty well with music (although sometimes the center channel is too loud) but, because any sound will be reproduced in at least three loudspeakers, effects are smeared and often unconvincing .

A Pro Logic decoder, like the professional Dolby Stereo cinema processor, both enhances the dialog in the center and removes it from the left and right, while maintaining as much stereo separation as possible. This is a form of directional steering. Properly done, steering prevents the dialog from appearing in the other channels and enhances its plausibility.

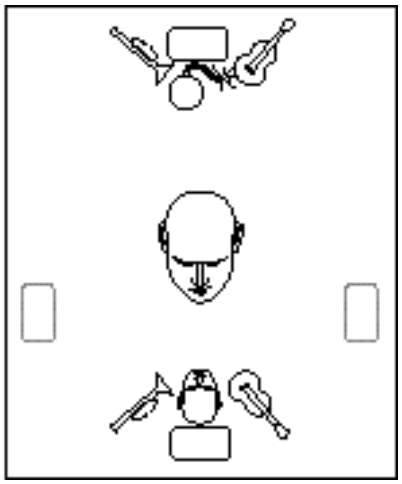
The Importance of Dialog

The requirements for film sound are quite different from those for the playback of music. The most important track in most films is the dialog (assuming you aren't watching 10,000 Years BC or Quest For Fire...). When the two stereo channels are played back through two speakers with no decoder, dialog will appear to come more or less from the center, but only for those listeners on the center line of the main stereo pair.

The situation is similar with music and sound effects. For example, if the sound was intended to be in the left, the decoder will remove it from the center and surround channels. If it was intended to be halfway between left and center, the Pro Logic decoder presents it equally to the left and center speakers and removes it from the right and surround channels.

The Pro Logic decoder can give good stereo spread and precise control over front-to-back perspective. But the real strength of Pro Logic decoding emerges when music and dialog occur at the same time. When dialog is present, the center channel information must be removed from the left and right channels without reducing the spread or loudness of the music.

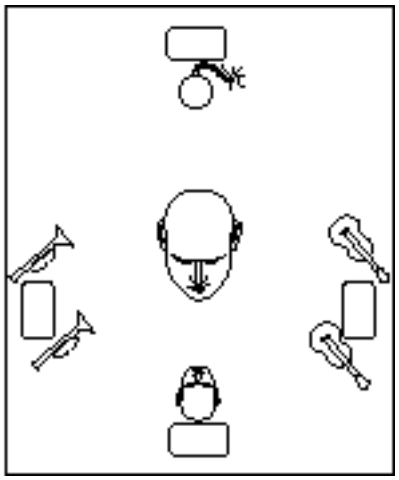
Pro Logic decoders sense both the direction of the loudest sound and the difference in level between it and any ambient information. They then use this information to direct the steering. The accuracy with which this is done is even more important in a home decoder than in a professional model, because the small size of the playback room makes decoding errors more audible than they are in a theater. The level detection must be very fast, and the matrix must adapt very quickly or there will be a time lag between the audibility of a sound and its correct steering. Since phase relationships determine how the sound is steered, Pro Logic decoding puts unusual demands on the accuracy of the phase and balance of the input channels. Other Pro-Logic decoders have a front panel control for adjusting input balance and for best results a user should carefully adjust this for each mode. But what if the channel balance varies during playback?



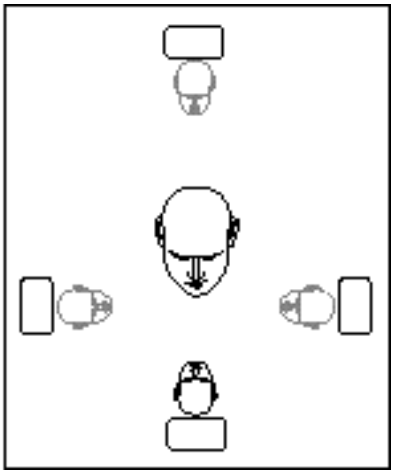
Simple logic decoders turn down the left and right speakers during dialog. This seriously affects music and effects.

The manual balancing procedure does nothing to correct azimuth errors. During the preparation of the master for a video tape or disc, misalignment of the playback heads or skewing of the film produce small time differences between the two channels. Azimuth is poorly controlled in both professional video recorders and optical film chains. In the final product, which has been through many generations, it can easily be wrong by 50 microseconds or more, and may vary as the tape or disk is played. At middle and high frequencies it doesn't take much misalignment to generate large inter-channel differences in phase, which are just what the decoder uses to do its steering.

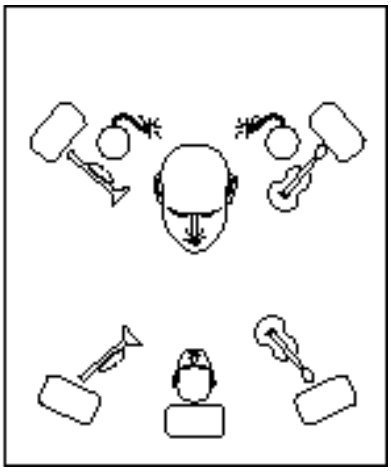
The Dolby encode / decode system deals with this problem by reducing the treble in the surround, so the out-of-phase sibilants in the film do not splatter annoyingly from the rear. This does not, however, reduce the sibilants in the side speakers. Some non-Pro Logic decoders reduce these side-channel sibilants by narrowing the spread of the front channels in the presence of dialog; this compromise is unnecessary in Lexicon processors.



Pro Logic decoders remove dialog from the left and right channels, while maintaining stereo as much as possible.



Pro Logic requires phase accuracy. Common azimuth errors cause ghost dialog in all channels unless the azimuth error is corrected.



Auto Azimuth and Auto Balance features allow accurate decoding of matrix surround.

Lexicon decoders are unusual in a number of ways. First of all, our processors are entirely digital. (Most surround decoders advertise that they are digital because there is a digital delay line for the surround channel but the matrix and the logic decoding are done in analog.) Because our processors are all digital, we can use some of the digital memory to delay all the output channels by 10 milliseconds — about the same as the acoustic delay you get in the front row of a theater. (The surround channels are delayed by an additional 15 to 30 milliseconds.) This delay allows plenty of time to determine the direction of sounds and adjust the matrix before the sounds are sent to the amplifiers. This substantially improves dialog and effects cancellation, as is immediately apparent from the spread of ambient material or music, even in the presence of dialog. Lexicon processors can also sense and continuously correct both balance and azimuth errors in the incoming material. All the time the film is playing, the processor is checking balance and azimuth, keeping the dialog perfectly centered. The result is superior steering. An added benefit is thatLexicon processors need no front panel input balance control; the user need not bother with this adjustment. You can check the quality of the balance and azimuth in a tape or disc if you wish by turning the Auto Azimuth / Balance parameter off and observing any changes in the location of dialog and effects.

The film industry continues to move from a 4 channel audio standard to a 5.1 channel standard. The new standard is similar to the old, but has two surround channels instead of one, and an additional low frequency effects channel for subwoofer playback. Once one has heard some good examples of stereo surround channels the mono surround channel of Dolby Surround is no longer satisfying. As most of the information in the surrounds is ambient information and music, stereo significantly increases listening enjoyment. As listeners become accustomed to placing the surround speakers out to the sides instead of behind them, stereo surrounds become even more important.

The decorrelation circuit required in previous THX decoders overcomes some of the limitations of the mono surround channel. While it does not give directionality to the signal, it at least increases the sense of spaciousness and reduces the tendency of the surround speakers toward localization. Artifacts from the decorrelation itself are usually mild. However, when an event is specifically steered to the surrounds the decorrelation can diffuse the signal too much. For example, if a jet flies from the front to the rear, the sound should not sound sharp and well localized in the front, and then disappear into a diffused mush in the rear.

Lexicon has developed Logic 7 technology for decoding a stereo surround signal from a standard matrix encoding. This yields a 4-2-5 encoding / decoding process. If a 5 .1 channel soundtrack is recorded onto a 2-channel medium-such as HiFi VHS tape or mini-disc using our 2-Channel downmixing effect, the resulting two-channel mix will be encoded with all 5.1 channels, which is much closer to the original. When played back through a matrix decoder using Pro Logic, a four-channel signal is presented, including all the surround information and low frequency informa-

tion of the original. When played back through a Lexicon processor running our Logic 7 effect, surround information is maintained in stereo, and 5-2-5 or 5-2-7 encoding / decoding is possible, and the match to the original soundtrack can be very close indeed.

The decoding works by combining very high quality standard Pro Logic decoding with the technology of the Music Logic program. The front channels (left, center, and right) are decoded in a way similar to Pro Logic, but with the addition of an adjustable delay for the center channel. The two rear channels operate in a dual mode. When the film surround content is primarily music or ambience, the rear channels maintain full stereo, reproducing the left and right front channels with the addition of frequency contouring and delay. (In the TV mode the contouring is adjustable — allowing full bandwidth surround if desired.) When the front hemisphere contains steered information, such as dialog or sound effects, these signals are cleanly removed from the stereo surrounds. Thus, dialog and all on-screen sound effects remain in the front where they belong. The new decoding depends critically on our ability to remove unwanted sound from the stereo surrounds, and this would not be possible without the accuracy afforded by our Auto Balance and Auto-Azimuth circuits.

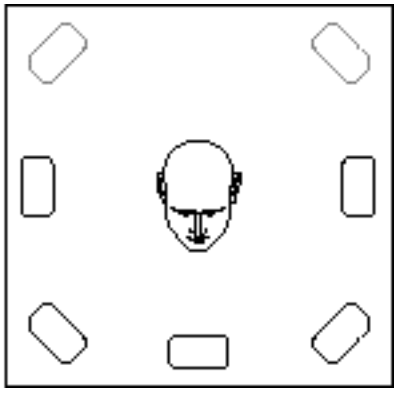
As sound effects move toward the rear, the processor decodes differently. Effects which move from left to rear pan smoothly from the left front loudspeaker to the left side, and then from left side to both left and right rear loudspeakers. The steering between the side and rear speakers is accomplished through a shelf filter rather than with level. In the Logic 7 algorithm, there is a 3dB decrease in the treble content of the side speaker when sound is steered moderately to the rear, but the low frequency content of the side and the rear speakers remains equal. As sound pans further to the rear the shelf filter in the side is lowered, so the treble is further reduced. When the sound is fully to the rear, there is a 6dB per octave low pass filter in the side speakers, with the 3dB point at about 400Hz.

The result is that the low frequencies are never eliminated or reduced in the side speakers. This is important because it is the side speakers which are most capable of delivering fully spacious and strong bass to the listening area. The action of the decoder has been extensively tested both at Lexicon and at Lucasfilm to ensure the intent of the film director is accurately reproduced.

Many listening rooms place the favorite listening position on a sofa along the side or rear wall of the room. It is not generally possible to place speakers behind this piece of furniture — particularly because they would be likely to be directly behind the heads of the listeners. However, it is well known that sounds which come from far behind the listener (at least 150 degrees from the front) are perceived as more psychologically exciting than sounds which come merely from the sides.

The 5 Speaker Enhance effect uses Head Related Transfer Functions (HRTF) to simulate seven channel performance in five speaker systems. It is

possible to make sound which comes from speakers at the sides of the listeners appear to come from behind the listener by applying a notch filter which has the frequency characteristic of the notches in natural hearing which occur at about 150 degrees. This process is possible because sound which arrives from the side is remarkably free of notches in natural hearing. We can add an appropriate notch without having to remove one which is inappropriate.



5 Speaker Enhance simulates 7 channels of surround in 5-speaker setups.

Engaging the 5 Speaker Enhance setting inserts these notches when sound pans from the fronts to the sides and then to the rear. The result is that sound moving around the listener appears to move smoothly from the front to the side, and then behind the listener. This occurs even if the side / rear speakers are at 90 degrees relative to the front. (However the ideal position for these speakers is at about 120 degrees from the front.)

Although films have not yet been deliberately mixed to take advantage of the capabilities of the new decoding, the improvement on standard films can be dramatic. The improvement in spaciousness with music and ambience is obvious. On films with aggressive sound effects the combination of surround steering and localization can convince listeners they are listening to a true discrete surround mix.

Dolby Digital and DTS

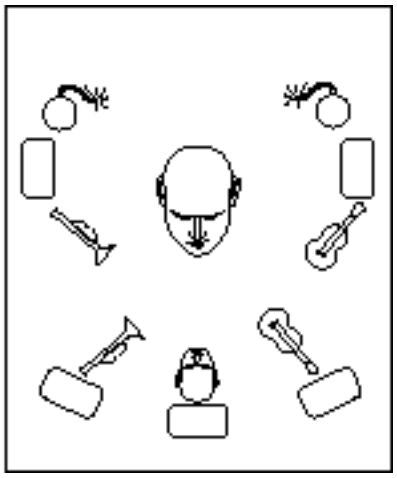
Discrete digital formats such as Dolby Digital and DTS provide six discrete channels of information. Five channels: Left, Center, Right, Left Surround and Right Surround are full-range (3Hz to 20,000Hz). The sixth channel is called the Low Frequency Effects (LFE) channel. It can contain additional bass to emphasize the impact of scenes such as explosions or crashes. Because the LFE channel has a limited frequency response, it is often referred to as the ".1" channel. When added to the five full-range channels, these surround formats are commonly referred to as having "5.1" channels.

As all channels are discrete digital tracks, channel separation and dynamic range are greatly improved over analog surround sound. One advantage is a dramatic improvement in localization of dialog. In addition, full-range surround effects can be independently directed to left surround or right surround speakers for a heightened sense of realism. Another benefit is increased dynamic range, which allows subtle audio cues to be more easily heard while giving loud effects, such as explosions, life-like impact.

The LFE channel delivers deep bass information for special effects and music soundtracks, but is not always used. Recordings made without the LFE channel are referred to as "5.0" soundtracks.

THX Enhancements

Home THX Cinema is designed to present film viewers with the same audio impressions perceived by the film director on the "dubbing stage" — the studio in which the final mix of the soundtrack is established. These stages feature a large screen for viewing the picture and a massive audio console for controlling every aspect of the soundtrack. THX attempts to precisely reproduce the experience intended by the director in a home environment. In general, this requires not only considerations of the characteristics of a small room (as opposed to a large dubbing stage), but many specific system performance requirements. A complete THX system for accurate translation of dynamic motion picture soundtracks requires a specific array of speakers which are designed to produce the soundtrack's full frequency response and dynamics without distortion, amplifiers which meet exacting specifications for distortion, noise, stability and dynamic power, and a surround decoder with electronic enhancement.



THX with Lexicon Stereo Surround 5-channel decoding combines full Pro Logic decoding with stereo surrounds.

Lucasfilm now offers two levels of THX certification. THX Ultra is the highest level of THX certification, and all Lexicon controllers meet these stringent requirements. All references here are to the THX Ultra standard.

As a complete discussion of the theory of THX design is beyond the scope of this booklet, we refer you to LucasArts for detailed information on all aspects of the Home THX Cinema system. (THX Division, LucasArts Entertainment Company, P.O. Box 10327, San Rafael, California 94912 Telephone: 415-492-3900) Here, we will limit our discussion to the advantages of our processors when used as a THX controller.

The main requirements of any THX controller are:

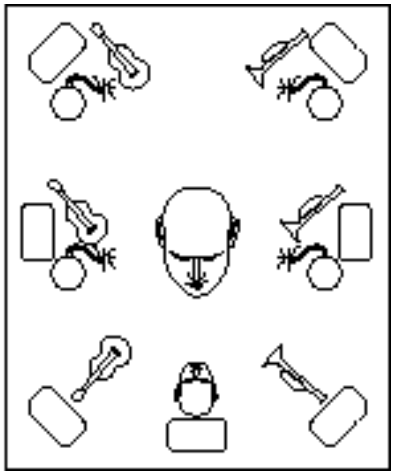
Dolby Pro-Logic Surround decoding
Subwoofer Crossover
Re-equalization
Surround Decorrelation
Surround Timbre-Matching

Dolby Pro-Logic decoding is not only necessary to decode soundtracks which are encoded in a matrixed surround sound format such as Dolby Stereo or Ultra*Stereo, but enables all motion pictures (including the more than 5000 made in matrix stereo) to be reproduced as they were heard in the film studio dubbing stage — no matter what delivery system is used. Lexicon processors are completely digital, Dolby Pro Logic decoders with patented automatic correction of inter-channel phase and channel-balance errors. With this technology, home theater speakers not only reproduce the appropriate audio information, but correct errors which occur in the multiple re-recording processes of most video software releases.

The Subwoofer Crossover feature enables the subwoofer speaker to reproduce only frequencies in the low bass range, leaving the front, center, sides, and rears to reproduce frequencies above 80 Hz. Dolby Digital and DTS add another challenge to bass reproduction in home theaters, as bass frequencies can be mixed into all five channels, as well as the LFE channel. Adapted for these discrete formats, this multichannel crossover is designed to blend

low frequency information from the front and surround channels with the LFE channel. This facilitates optimum placement for imaging and smoothness, protects smaller speakers, and uses amplifiers more efficiently.

Re-Equalization is provided as a control to compensate for the fact that the soundtracks in films sound "bright" when listened to in a home environment. This results from a combination of the way we perceive sound in large halls vs. small rooms, and the theater equalization which has become standardized throughout the movie industry. This problem can be more pronounced with discrete soundtracks due to the addition of three full-range channels in the mix (Center, Left Surround and Right Surround). The re-equalization control restores the sound to its natural balance, and reduces listening fatigue dramatically by reducing excessive high frequencies.



In Logic 7, stereo surround 7 channel decoding features full-range stereo effects in side and rear speakers.

As the surround channel in a Dolby stereo film is monaural, the signal is neither spacious nor enveloping. In a theater, the quantity and placement of surround speakers compensates for this; in the home, arrays of 12-18 speakers are generally impractical. To diffuse the perceived sound, the processor (in the decorrelated mode) provides a decorrelation algorithm which, after the monaural signal is split in two, alters the phase / time relationships between channels slightly. This eliminates the mono effect from the rear channel and creates an enveloping soundfield. When the "Stereo Surround" parameter is selected, the rear channels become stereophonic, and the decorrelation is unnecessary. This setting is recommended.

Although Dolby Digital and DTS have discrete surround channels, not all of the surround information on these channels is stereophonic. Rear channel information is often mono. Raindrops, for instance, are typically recorded in mono. When played back through the array of surround speakers in a theater, there is no need for left channel and right channel raindrops, as the speaker system presents this sound as an enveloping environmental effect. The Home THX Adaptive Decorrelation circuitry is active when surround channel information is predominanatly mono. When stereo effects are present, decorrelation is not used. The result is consistently spacious surround sound and dramatic stereo effects.

Timbre Matching compensates for the difference in characteristics of sounds coming from different locations. In real life, timbre differences help us differentiate sounds which originate from the sides and rear from those originating from the front. Some people, however, find that these natural changes in timbre are undesirable in a film. Timbre-Matching provides equalization to the surround channels, reducing the perceived change in character of sounds which are panned from the screen into the surrounds.

Lexicon 5.1 Enhancements

5.1 Logic 7 and DTS Logic 7 effects combine the re-equalization, subwoofer crossover, and adaptive de-correlation enhancements of 5.1 THX with Lexicon's Logic 7 matrix technology. 5.1 Logic 7 and DTS Logic 7 differentiate between the side and rear speakers with a combination of delay and directional steering. For soundtracks with music or effects such as wind noise or applause, this creates a more spacious and enveloping soundfield and has a large effective listening area. For sound effects that pan to the side and rear of the listener, the result moves more convincingly through the sides and into the rear speakers. These seven channel effects produce the most exciting, and at the same time the most natural reproduction of 5.1 channel encoded material.

The 5.1 Two Channel and DTS Two Channel programs provide a means for mixing the 5.1 channels of a discrete digital soundtrack into two stereo channels while preserving all the original directional effects when the mix is decoded through Logic 7 or TV Matrix. These effects include a parameter for surround level, for adjusting the level of surround information folded into the two channel mix. There is also a parameter for reducing the level of the LFE channel.

Speaker Placement

To some degree, speaker placement will depend on whether your priorities lean more toward music listening or film viewing. Fortunately, the goals are the same for both listening situations: stable localization (imaging) in the front, and diffuse, enveloping surround sound from the sides and rear.

The placement of speakers will be somewhat restricted in your home by the need to have the sound closely associated with both the screen and your seating area. Within this limitation, however, there are many possible variations, for example in the height, angle and distance from the walls. These choices, again, will depend on the type and number of speakers you are using, as well as the physical characteristics of your room. Some of the general effects caused by room reflections are explained in the section "The Listening Room."

CAUTION: Speaker magnets can distort the TV image. If you see any picture discoloration in the area closest to the speaker, the speaker is too close to the screen.

Additional information relevant to your particular system should be available from your speaker manuals. THX speakers in particular are designed for specific placement and the manufacturer's recommendations should be followed for best results. With that in mind, here are some general guidelines:

If only two speakers are used, the user is free to experiment. The standard ±30° speaker positon works quite well in many cases for both music and film. For a single listener you may want to try placing the speakers relatively close to the sides of the screen. With this configuration and a single listener, the Panorama effect should be used for both music and films. Be sure to adjust the speaker angle parameter in the Setup menu to correspond to the actual angle between the speakers.

With multiple speakers, the main front speakers can again be ±30° if you are comfortable with occasional sound effects which extend beyond the screen. Spreading the speakers further apart provides a wider, more exciting soundstage, and most people readily accept an auditory sound field which is wider than the visual field. If you wish to put the main speakers close to the screen, the processor will make up for the lost spaciousness in both music and film. The front speakers should be placed at equal heights and at equal distances from the front wall. Try angling the speakers in toward the listening position (toe in) and keep them away from the side walls.

A center speaker is so important for realistic dialog placement that, if it is not possible to have a center speaker, it is frequently better to plug the Center output of the processor into the audio input of your video monitor and use its built-in speaker (if it has one) than it is to run the dialog through the main loudspeakers. (We provide a control for this setup which splits bass out of the center channel and directs it to the left and right speakers.)

The Center speaker should be located directly beneath or above the screen (shielded.) Turning a speaker which is designed to be used vertically on its side will significantly alter the soundwave patterns it is intended to produce.

Right, Left and Center speakers should be positioned at equal heights and at equal distances from the front wall. Depending on their height, they should be tilted to aim vertically at the listening area-they should not necessarily be angled in from the side walls toward this area. In most setups, although the left and right speakers are about the same distance from your listening position, the center speaker is often closer to you, causing sound from the center speaker to reach you earlier than sound from the left and right. The Speaker Distance Adjustment in the Set Up Menu electronically compensates for differences in the distance of all speakers from the listener position. Equalizing the path length (the distance from the speaker to your ear) assures that the sound from each speaker will arrive at the listening area at the same time. Calibrated properly, dialog is more intelligable, and the overall clarity of the system can be substantially improved.

Optimum side speaker placement depends on your room and listening position, the type of speakers used, whether you are primarily interested in film sound or music, and aesthetics (which we'll leave to you). If you have THX-type surround speakers, follow the manufacturer's recommendations for placement. If you are sitting within six to seven feet of the main speakers, place the side speakers directly to the sides of the listening area. If you normally sit further away from the main speakers, the sides should be somewhat forward of the listening position, preferably angled back towards it. A bit of experimentation will prove very helpful. The goal is to blend the side speakers' energy with the main speakers; you should not be distinctly aware of the output of the side speakers.

Side speaker height should be near the level of the ear. Placement near the ceiling / wall boundary may help disperse the sound, and will reinforce the bass response of the speaker, but very high placement can reduce the spaciousness that our true stereo processing provides. If pedestal or wall mounting proves impractical, ceiling-mounted speakers will suffice. Place them far apart and equidistant from the listening area.

Rear speaker placement is somewhat less critical. Here the main goal for both film and music is to produce a diffuse and enveloping soundfield. The height of rear speakers will depend on both room size and furnishing. In general, placement of the rear speaker(s) above the listening area can be very effective. Note, however, that placing these speakers too high in a narrow room, or at the ceiling, may reduce the spaciousness of the sound. For maximum envelopment the rear speakers should be widely spaced — preferably near the side walls.

Subwoofer placement is less critical, but in some positions in your room may cause standing wave patterns and / or a rattling of furnishings. Refer to "The Listening Room" section, and specifically to your subwoofer manual for recommendations. The Subwoofer Output is a monaural signal created by summing the left and right inputs, then filtering out frequencies above 80 Hz at a rate of 24dB per octave. For the tragically technical, this is a Linkwitz-Riley LPF -6dB at 80Hz.

The Listening Room

If you are using THX speakers, be aware that they have significant design differences from standard (non-THX) speakers. Extensive information is available from the manufacturer on their design and on maximizing their effectiveness in a room. Although not contradictory to those recommendations, the following guidelines are intended as a generalized reference for those using *standard* speakers. Most manufacturers assume that THX systems will not include separate side and rear speakers. In our experience, however, adding a pair of widely spread rear speakers to a five channel THX system makes a very significant improvement to the sound. Such a system allows the full benefits of Logic 7, 5.1 Logic 7 and DTS Logic 7 to be heard.

The physical characteristics and furnishings in your listening room will affect the way sound is reflected and dispersed through the room. A great deal of research has been done in the field of room acoustics and a superb environment can be constructed with this research in mind. In this discussion, however, we will limit ourselves by assuming that your room is already built, and that your goal is to get the best sound possible from *your* system in *that* room. Even within this limited scope, there are many factors which may affect the quality of sound. Fortunately, where there are problems, there are also some relatively simple solutions.

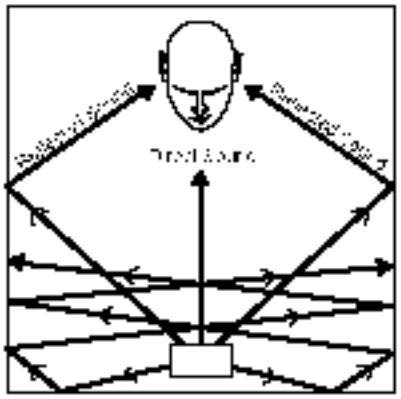
All rooms have acoustical characteristics determined by their dimensions and structural materials. The hard surfaces of the room reflect sounds back and forth in patterns which are likely to interfere with the sounds generated by your system. The nature of these reflections, and their effects, is dealt exhaustively in the wealth of material available on Room Acoustics — here we will simplify by stating that the first general goal is to dampen or diffuse these echoes — to create an acoustically neutral room which doesn't interfere with the environment your system creates. The most obvious way to do this is to add absorbent material to those surfaces from which the most offensive reflections arise, and to break up undesireable reflective patterns with uneven surfaces. Fortunately, furnishing the room with carpets, drapery and furniture goes a long way toward accomplishing this. (Absorbent materials can be commercially-available acoustic panels, fiberglass, dense foam, drapes, or upholstered furniture. Diffusive materials can be commercially-available panels, or irregular furniture, such as bookcases.)

Now, what we really want to do is "tune" the room to maximize the clarity of dialog within a localized front soundstage, and to create a diffuse, non-localized soundfield for effects. This can often be done by adjusting speaker placement, by altering room furnishings or by some combination of both, but to do this effectively, we must look briefly at the kinds of interference you may encounter. Following are some basic problems and suggested solutions.

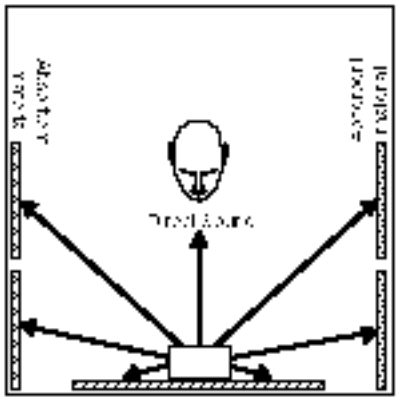
Room reflections

Room reflections cause blurring of the image of a localized front soundstage. Sounds which are ideally perceived as coming from the screen, reach the listener from other directions, spoiling the illusion. These unwanted reflections can be eliminated by placing absorbent or diffusive material at the point of reflection. To maximize the localization of the soundstage, an attempt should be made to deaden the area immediately behind and adjacent to the front speakers.

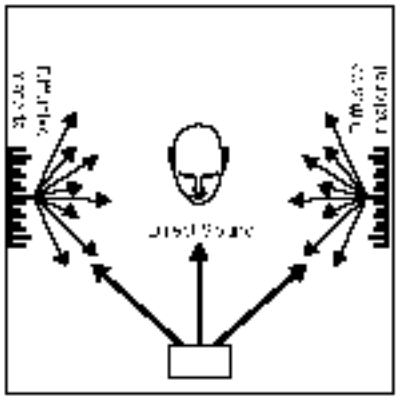
Speaker alignment is important. If front speakers are placed at unequal distances from a wall, the tonal balance between the two speakers will change. This is particularly important in placement of speakers in the front of the room where sounds should pan realistically. Care should be taken to place speakers the same distance from the front wall. An attempt should also be made to achieve approximate symmetry in the distance between each of these speakers and the side walls. In addition to being placed consistently with regard to room surfaces, the front speakers should be placed well away from side walls.



Room reflections interfere with the image of a localized front soundstage.



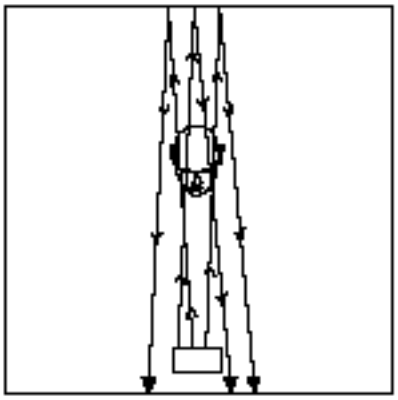
These unwanted reflections can be either absorbed …

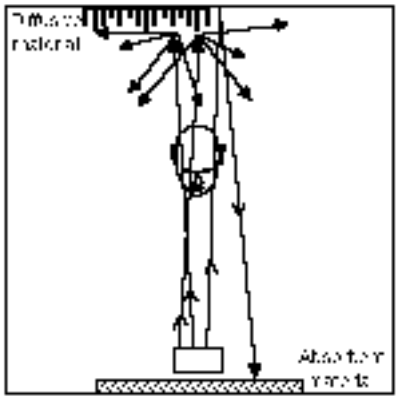


…or diffused.

Room echoes

Room echoes cause interference which results in an unnaturally “bright” sound. These echoes can also be absorbed or diffused. Use heavy insulating drapes over large expanses of glass.





Irregular bass response

Bass frequencies have long wave lengths — these may be as long as one of the dimensions of your room. This can cause over-emphasis of some frequencies and cancelling out of others. This effect is most noticeable in rooms which have two or more dimensions which are equal (for example, length and width). This type of room will exhibit irregular bass response in different parts of the room. Keep in mind that this effect is worst in nearly empty rooms. Large pieces of furniture will break up the reflections between parallel surfaces quite nicely. Moving speakers further in from the walls can also make a noticeable improvement.

Note that speakers placed against a solid wall can alter the bass and mid-bass response of your system — making it sound bass-heavy. Placing a speaker in a corner (where 3 surfaces meet) will make any speaker not designed for such placement sound muddy. Very thin walls will allow some of this amplified bass energy to escape, reducing the effect. Moving the speakers in from the walls also works nicely.

Use of the Bass Enhance adjustment can compensate for inconsistent bass response in the listening room. In addition to improving the quality of bass reproduction, Bass Enhance will help provide even bass response over the entire listening area.

Structural resonance

Structural resonance (pictures and windows rattling. etc.) can be caused even by desireable bass frequencies. If the bass response of your system is at the desired levels, these rattles can be eliminated by putting felt on picture frames, or around window cracks.

Maximizing the effect of the surround soundfield

The listener should not be able to pinpoint the source of surround effects, therefore output from the surround speakers should not be aimed directly at the listening area. This is easily accomplished by raising the surround speakers. Although surround speakers require some reflected sound to be effective, these reflections should be diffusive — providing randomized reflections in many directions. Bookcases and other irregular surfaces provide this sort of diffusion, as do some commercially-available acoustic panels.

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