and the onset of reverberation from the 224. With the "PRE-DELAY" slider all the way down the displayed delay value will be that value inherent in the particular delay program being used. Refer to Section 3 for the specifics of each program.

SHIFT CONTROL

The "SHIFT" function has been reserved for diagnostics and special functions which will become available to 224 users as they are developed.

2.3 ADVANCED FEATURES OF VERSION 3 (AND HIGHER)

Version 3 (and higher) software allows the interested user to adjust the two subprograms "MODE ENHANCEMENT" and "DECAY OPTIMIZATION". Both subprograms work by altering some of the reverberation parameters as the music is playing. The rate and the amount these parameters are altered are preset by each program when it is loaded, and can be adjusted by the user. "MODE ENHANCEMENT" is set normally with a rate parameter value of 2. This setting produces excellent reverberation while keeping the induced noise low. A slightly more natural sound can be obtained (at the expense of more interaction noise) by setting this parameter to 1. Setting the parameter to 3 or higher reduces the amount of alteration. The parameter is adjusted by using the "SHIFT" button.

To change the parameter, enter the "CALL" mode and select the desired program. Now push AND HOLD both "SHIFT" and program button #7. If you now move the "PRE-DELAY" slider while holding the two buttons the alteration parameter can be set from 1 to 16. The digital display will show the value set. Notice the control must be actually moved to set the parameter. Pushing any of the buttons under the sliders will restore the normal display.

Once the parameter has been changed the new value can be stored along with the program and the slider settings in a register for later use. Calling a register always sets these parameters to the values previously stored. However, pushing the running program button again does not restore the original settings of either "MODE ENHANCEMENT" or "DECAY OPTIMIZATION". The recommended settings are only loaded when a different program is loaded, or if button 7 is switched off and then on. To compare your modified settings with the original it is best to store both an un-modified and a modified version of the program in the registers.

Setting this parameter has been deliberately made difficult. It is not recommended that users adjust "MODE ENHANCEMENT" or "DECAY OPTIMIZATION" unless they are willing to devote considerable time listening for the results.

The "DECAY OPTIMIZATION" parameter is normally 5 for the concert hall programs and 7 for the plates. Again higher parameter values mean less alteration. To set this parameter use the same procedure as for *"MODE ENHANCEMENT", except hold button #8 instead of #7.* Once again the changed program can be stored in a register for later use or comparison. Small values of the parameter tend to make the program sound clearer and less colored in the decay, but at the expense of the evenness. When the parameter is too small there can be a noticeable left-right shifting of the decayed sound, especially with a strong input in one channel only. This effect is reduced by the new level detecting algorithm, which can differentiate between strong bursts of sound and continuous music which stops suddenly. Once again, the *"DECAY OPTIMIZATION" parameter has been deliberately made difficult to* adjust. Users should not attempt to adjust this parameter without careful listening.

2.4 OPTIONAL MEMORY BOARD

Version 3 (and higher) software supports a memory board which plugs into the option slot on the 224. This board (available fall 1980) allows additional reverberation programs, permanent storage of registers preset by the user, and the restoration of the current operating state after the power has been turned off or has failed. See Section 5 for a complete description of this board.

3.0 PROGRAMS

3.1 INTRODUCTION TO PROGRAM OPTIONS

The Model 224 may be ordered with or retrofitted with several different programs.

Each program has characteristics which optimize it for particular applications. Although adjustment of front panel controls can change the sound of a program it can not change the basic character of a program eg. change a chamber to a plate.

It is strongly recommended that the user carefully study the descriptions of each program to select those programs which suit his needs. Development of new programs and revision of old ones is ongoing at Lexicon so that a substantial program library (including programs for special effects) is anticipated. Of course new programs and revisions of old ones will be available to every 224 owner.

In order to receive new and updated programs, it will be necessary to ship the program circuit board (SBC board) module back to Lexicon. Or, if the 224 must remain in operation, it will be possible to either purchase a new module with the new programs installed or to purchase a new set of 2716 Music Program ROM IC's for field installation. Refer to section 6.5.1 for procedures required to install the ROM's. Extra modules can also be purchased in the event that more than eight programs are desired. See section 6.5, Module Exchange Program, for instructions on removing, refitting and shipping the program module.

3.2 OPERATING SYSTEMS

In order to co-ordinate and maintain numerous programs and revisions of programs each different set of programs is assigned an "operating system" identification number. This number has the following format:

V X . Y

where X is the unique number or letter of each operating system and Y is the revision level.

The initial operating system in production is V 1.1. This number will uniquely define what programs are installed in a 224, what revision level they are and what program number on the front panel "calls" a given program.

New Music Programs Added:

In addition, several entirely new programs were introduced with VERSION 2. (See the program lists below and the program description section of the manual.) The new programs and the improvements to the old ones represent a major improvment in the sound of VERSION 2 and VERSION 3 over the original VERSION 1. Lexicon recommends that owners of machines with the original operating systems upgrade them to VERSION 2 or higher software.

Field Hardware ECO Needed for VERSION 2 and higher software:

Upgrades from the original VERSION 1.1 and 1.2 software require a simple field ECO. Refer to section 6.5.2 for details.

VERSION 3 DESCRIPTION (all Rev. Levels)

VERSION 3 software offers easier operation, 32 more storage registers for preset effects, and the new subprogram "MODE ENHANCEMENT". (See section 2 of this manual for descriptions of these new features.)

Upgrades from VERSION 1 should perform the hardware ECO described in section 6.5.2

V3.0 DESCRIPTION

V3.0 is supplied with two programs. They are:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - B	075-01846
5.	PERCUSSION PLATE - A	075-01794
(7.)	MODE ENHANCEMENT (all programs)	
(8.)	DECAY OPTIMIZATION (all programs)	

V3.1 DESCRIPTION

V3.1 is supplied with four programs. They are:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - B	075-01846
3.	LARGE CONCERT HALL - B	075-01847
4.	ACOUSTIC CHAMBER	075-01793
5.	PERCUSSION PLATE - A	075-01794
(7.)	MODE ENHANCEMENT (all programs)	
(8.)	DECAY OPTIMIZATION (all programs)	

V3.2 DESCRIPTION

V3.2 is supplied with six programs. They are:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - B	075-01846
2.	VOCAL PLATE	075-01791
3.	LARGE CONCERT HALL - B	075-01847
4.	ACOUSTIC CHAMBER	075-01793
5.	PERCUSSION PLATE - A	075-01794
6.	SMALL CONCERT HALL - A	075-01790
(7.)	MODE ENHANCEMENT (all programs)	
(8.)	DECAY OPTIMIZATION (all programs)	

3.4 INTRODUCTION TO THE PROGRAM DESCRIPTIONS

Programs in the Lexicon 224 are mathematical algorithms which simulate the sounds of reverberation. Because the time available for computation is finite, it is not possible to exactly duplicate the properties of natural reverberation. The programs differ greatly in both the type of natural acoustics they try to simulate, and in the ways they differ from the ideal. Standard acoustical terminology is not always accurate in describing the sound from the 224. In this section we define the terms we use in the program descriptions both as they apply to natural acoustics and to the 224.

3.4.1 Reverberation Time and Decay

The decay is the reverberation which is heard when the music stops. It is also called stopped reverberation. The reverberation time controls on the 224 set the rate of decay. Decay is usually assumed to be at a constant rate, a certain number of decibels per second. However, in most buildings the initial rate of decay is much faster than the final rate. Churches, where many fine recordings are made, frequently show this type of non-uniform decay. A slower final rate of decay gives a sense of space and depth in a recording, while a quick initial decay can keep the music from becoming muddy. The numbers displayed with the reverberation controls on the 224 usually indicate the effective reverberation time of the first 20 decibels of decay. Lexicon 224 programs differ in the amount of difference between the initial and final rate of decay, and in how the difference varies with the reverberation time setting. The "DECAY OPTIMIZATION" and "MODE ENHANCEMENT" options available with Version 2 and higher software operating systems make the decay rate more uniform on all the programs.

3.4.2 Sound heard before steady decay, or "Initial Sound"

In a concert hall the first sound to reach the listener is the direct sound, followed closely by reflections from the stage floor and walls. Somewhat later the hall walls, floor, and ceiling contribute their reflections. Finally the reflections from the back wall arrive. During all this time it is meaningless to speak of "smooth decay". The smoothness of these initial sounds depends on the size and shape of the hall and the position of the listener. Steady decay is reached only after sound has had time to bounce through the hall several times. Small rooms or chambers achieve even decay much sooner, and the ear perceives these rooms as smaller. The duration and the smoothness of the initial sound is vital to creating a sense of being in a specific acoustic location. The duration of the initial sound is built into the various 224 programs. It can be as long as 200ms in the concert hall programs and less than 50ms in the plate programs. The initial sound is also very important in determining the character of the "running reverberation", or reverberation which is heard while the music is playing.

SMALL CONCERT HALL - B: (PART NO. 075-01846) REV. 0

Initial sound:		Hall-like - uneven for 200ms
Decay:		Moderately non-uniform
Initial Diffusion:		Moderate - some clicking on an impulse
Coloration:		Low
INPUTS	MONO:	both "LEFT" and "RIGHT" in parallel
	STEREO:	left "LEFT" right "RIGHT"
OUTPUTS	MONO:	either "A" or "C" (plus source)
	STEREO:	left "A", right "C" (plus source)
	QUAD:	left front "B", right front "D" (plus source) left rear "A", right rear "C"
REVERB TIME	BASS:	0.6-70 sec
REVERB TIME	MID:	0.6-70 sec
CROSSOVER	FREQ:	100Hz-10.9kHz
TREBLE DECAY	FREQ:	100Hz-10.9kHz
	DEPTH:	0-71
	PRE-DELAY:	24-152 ms

This program is basically a modification of "SMALL CONCERT HALL - A". In the old program the "TREBLE DECAY" control affected the sound only after the first 300ms. In "SMALL CONCERT HALL - B" "TREBLE DECAY" affects the early sound too, and reduces the decay more rapidly. It mimics the effects of air absorption better than "SMALL CONCERT HALL - A" and sounds more natural.

The "SMALL CONCERT HALL - B" is useful whenever a sense of space and depth needs to be added to music. It is best on classical music or on popular music which has already been mixed, although it can be used to fill-out a vocal or drum track if clicking is not too apparent. All the concert hall programs are intended to put their sound behind the music, not with it. This program produces best results with reverb time settings of 1.5 to 5 seconds. Program 3, "LARGE CONCERT HALL - B" has less coloration and is recommended for long reverb times.

Recommended Settings

When used with "Mode Enhancement" and/or "Decay Optimization" "SMALL CONCERT HALL - B" sounds most natural if the "BASS" and "MID" control are relatively close to the same setting. "BASS" should be usually set somewhat higher than "MID". The "CROSSOVER" control is useful over the entire range. If it is set to 200Hz, the "BASS" will tend to be emphasized. If it is set to 1.5kHz it can be used to change the character of the high frequencies. When the subprograms are not used "BASS" should be set about a factor of two higher than "MID". When neither subprogram is used the setting of the "TREBLE DECAY" control is very important to achieving a natural sound, but the correct position depends strongly on the type of music and the desired reverb time. With chamber music, or for film sound, a short reverb time (1.5 to 1.7 sec.) is useful, and the "TREBLE DECAY" might sound best at 3.0 kHz. A longer reverb time might sound best with a "TREBLE DECAY" of 4.4kHz or higher. If reverb times longer than 3 seconds

As new programs are developed at Lexicon they will be made available for installation in operating systems 2 and 3. Up to seven different programs can be installed on the SBC/BLC board along with the VERSION 2. VERSION 3 holds 6 programs along with the two subprograms on buttons #7 and #8. If more than six programs are desired an extra read only memory board is available which fits in the option slot on the 224 mainframe, providing storage for an almost unlimited number of programs. This board also contains a battery back-up memory to retain the register storage when power is off. The extra programs are called by pushing two program buttons at once (double-digit program numbers.) Only the program buttons which correspond to programs actually installed in the machine respond when they are pushed. All others are inactive. The non-volatile register storage is activated automatically when the optional memory is installed. For more about the option board, see section 5.

The Lexicon 224 varies the time dependence of the initial sound with the depth control. Low depth emphasizes the early parts of the initial sound, simulating a close listening position. Higher positions of the depth control tend to increase the running reverberation without changing the amount of reverberation when the music is stopped. In programs which simulate small environments such as a chamber or plate, "depth" controls the explosiveness of the initial sound by compressing it or stretching it out.

3.4.3 Diffusion

Diffusion is the ability of an acoustic chamber or the 224 to spread a single pulse input into a very closely spaced series of pulses. The best acoustic example is the reflection of a click from an irregularly shaped wall. Very high diffusion causes a click to be spread into a swish of sound. Less diffusion causes a more grainy sound, and low diffusion can produce an obvious series of discrete clicks. Contrary to popular opinion, high diffusion is not always desirable, at least for the first 200ms or so after an impulsive input. In concert halls the floor and stage walls are usually not very irregular. In halls diffusion is a function of time. As sound bounces around the room diffusion builds up. Low diffusion in the initial arrivals contributes to a very clear uncolored sound. Small rooms and echo chambers are designed to produce high diffusion initially, and work well on impulsive material. Such reverberation tends to spread out and color the sound it is applied to, giving it a louder, fatter sound. All Lexicon 224 programs have high diffusion after the reverberation has built up, but they have different degrees of initial diffusion. Symphonic music sounds best with low initial diffusion, vocals with moderate diffusion, and drums with high diffusion.

3.4.4 Coloration

The word coloration can be used to describe almost anything. We will use it in the program descriptions to refer to a "bathroom-y" quality which tends to occur whenever the initial diffusion is high. Programs with low initial diffusion are usually uncolored, although coloration can become noticeable at the very end of the decay unless "MODE ENHANCEMENT" or "DECAY OPTIMIZATION" is used.

3.5 Control Settings

Frequently the programs will sound most natural only within a subset of the possible settings of the 224 controls. In general there is no good way to set these controls from a knowledge of acoustical theory. Different types of music may require very different settings of the controls. The settings given with program desriptions (which load automatically with version 3 and higher software) are only a starting point.

are desired, "LARGE CONCERT HALL - B" might give a more natural sound.

We have also found that equalizing the return from the 224 (adding about +3dB below 200 Hz) can add to the richness and naturalness of the reverb. This effect cannot be achieved with the reverb time controls. Boosting the reverb time of the "BASS" excessively makes the bass reverberate too long without increasing richness.

The pre-delay display reads a minimum of 24 ms with this program. Actually there is some output before this time, building to a peak at about 27 ms in the left channel and 20 ms in the right. The time difference in the pre-delay for the two channels can make a pleasant spread in the sound of a mono source. However, with a mono feed solo instruments or voice will sound stronger on the right. If the soloist appears on the left in the mix it may sound more natural to reverse the returns from the 224.

BASS:	3.0 sec
MID:	2.0 sec
CROSS OVER:	540 Hz
TREBLE DECAY:	4.4 kHz
DEPTH:	10 to 40
PRE-DELAY:	24 to 60 ms

In both stereo and quad the feeling of spaciousness is enhanced by using a stereo feed, either similar in placement to the source or reversed. Reversing the returns may decrease the apparent width of the reverb. In stereo or mono operation the outputs "A" and/or "C" should be used as the main echo returns and summed with the source (through a mixer). For quad operation outputs "A" and "C" should be sent directly to the rear, not the front. The "DEPTH" control affects only outputs "A" and "C" and should be set from 0 to 10 for Quad, providing a strong early delay to the rear channels. The outputs "B" and "D" should then be summed with the source at the front.

NOTE: Outputs "B" and "D" are not as satisfactory as "A" and "C" for purposes other than quad.

3.3 OPERATING SYSTEMS LIST

V1.1 DESCRIPTION

V1.1 is the original operating system released by Lexicon in April 1979. It consists of four music programs in the following order:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - A	075-01790
2.	VOCAL PLATE	075-01791
3.	LARGE CONCERT HALL - A	075-01792
4.	ACOUSTIC CHAMBER	075-01793

Pre-delay inherent in each program is not displayed so that the "PRE-DELAY" display only shows the amount of pre-delay added to the inherent pre-delay of each program. This operating system contains no diagnostics. Changes to pre-delay occur in 1 ms steps and will create some artifacts if modified during use.

V1.2 DESCRIPTION

V1.2 contains the same four music programs as V1.1 but with some minor changes in operating characteristics.

The displayed pre-delay is the actual amount used rather than the incremental value as in V1.1.

Changes in pre-delay will cause a controlled sweep from the original delay setting to the new one selected. This "sweep" through time will cause pitch shift to be heard while delay is changing.

V1.3 DESCRIPTION

V1.3 is identical to V1.2 with the exception that two music programs are provided instead of four - they are:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - A	075-01790
2.	VOCAL PLATE	075-01791

V2.0 DESCRIPTION

V2.0 is supplied with two programs. They are:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - B	075-01846
5.	PERCUSSION PLATE - A	075-01794
(8.)	DECAY OPTIMIZATION (all programs)	

V2.1 DESCRIPTION

V2.1 is supplied with four programs. They are:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - B	075-01846
3.	LARGE CONCERT HALL - B	075-01847
4.	ACOUSTIC CHAMBER	075-01793
5.	PERCUSSION PLATE - A	075-01794
(8.)	DECAY OPTIMIZATION (all programs)	

V2.2 DESCRIPTION

V2.2 is supplied with six programs. They are:

PROGRAM #	PROGRAM	PART #
1.	SMALL CONCERT HALL - B	075-01846
2.	VOCAL PLATE	075-01791
3.	LARGE CONCERT HALL - B	075-01847
4.	ACOUSTIC CHAMBER	075-01793
5.	PERCUSSION PLATE - A	075-01794
6.	SMALL CONCERT HALL - A	075-01790
(8.)	DECAY OPTIMIZATION (all programs)	

PLATE: (PART NO. 075-01791) REV. 1

(The original "PLATE PROGRAM" - now called "VOCAL PLATE")

Initial sound:	Explosive - decay starts within 50ms
Decay:	Uniformity depends on Reverb Time settings
Initial diffusion:	Moderate to high - good for vocals
Coloration:	Low to moderate

INPUTS MONO:	both "LEFT" and "RIGHT" in parallel
STEREO:	*left "LEFT" right "RIGHT"*
OUTPUTS MONO:	mix "A" and "C" equally (plus source)
STEREO:	left "A" or "D", right "C" or "B" (plus source)

REVERB TIME BASS:	set by ear - display only for reference
REVERB TIME MID:	0.6-70 sec
CROSSOVER FREQ:	100Hz-10.9kHz
TREBLE DECAY FREQ:	100Hz-10.9kHz
DEPTH:	0-71
PRE-DELAY:	*20-127 ms*

The "VOCAL PLATE" sounds like a plate, but with less initial diffusion. As a consequence it has a clearer, brighter sound. It is useful for most popular music, but it can sound slightly grainy on drums. Again the "BASS" can be set higher than the "MID" if the two subprograms are not desired. Some plates emphasize the treble, and you may want to experiment with that. You may also want to try equalizing the return for more high treble. The "VOCAL PLATE" is not *as good as the percussion plates at very low decay settings, and is* not as good as the hall programs at very long settings. Try:

BASS:	2.0 sec
MID:	2.0 sec
CROSS OVER:	1.0 kHz
TREBLE DECAY:	8.8 kHz to 10.9 kHz
DEPTH:	0 to 30
PRE-DELAY:	to taste

The indicated reverb time for "BASS" is not accurate in this program so that users should rely on their ears more than the panel settings when adjusting the "BASS" parameter. Note that it is possible to cause internal feedback by setting the "BASS" control much higher or lower than "MID". The "DEPTH" control affects the first "reflection" in settings 0-40, making it progressively less pronounced. In settings 50-71 it progressively emphasizes later "reflections". The outputs of this program are identical pairs: "A" is the same as "D" and "C" is the same as "B". This program is recommended for use with stereo inputs since the reverb is more natural and interesting than it is in mono. However sharp transients will sound best if panned to the middle. With stereo input the apparent width of the reverb may be altered on some material by reversing the 224 outputs so that "C" goes left and "A" goes right.

PERCUSSION PLATE - A: (PART NO. 075-01794) REV. O

Initial sound:	Explosive
Decay:	Moderately non-uniform
Initial diffusion:	Extremely high - becomes rapidly very dense
Coloration:	Moderate
INPUTS MONO:	both "LEFT" and "RIGHT" in parallel
STEREO:	left "LEFT" right "RIGHT"
OUTPUTS MONO:	mix "A" and "C" equally (plus source)
STEREO:	left "A" or "D", right "C" or "B" (plus source)
REVERB TIME BASS:	set by ear - display only for reference
REVERB TIME MID:	0.6-70 sec
CROSSOVER FREQ:	100Hz-10.9kHz
TREBLE DECAY FREQ:	100Hz-10.9kHz
DEPTH:	0-71
PRE-DELAY:	0-107 ms

"PERCUSSION PLATE - A" is ideal for adding to drums and vocals at short reverberation times. It has very high initial diffusion, and a very smooth sound on transient material. Coloration is noticeably greater than the vocals plate, although this sound can be desirable. Coloration increases at the end of the decay unless "MODE ENHANCEMENT" or "DECAY OPTIMIZATION" are used. As with the "VOCAL PLATE" a stereo input is provided, and may be interesting on some material. For best diffusion the two inputs should be driven in parallel. It may also be useful to equalize the return for more brilliance on drums. Try:

BASS:	2.0 sec
MID:	2.0 sec
CROSS OVER:	1.0 kHz
TREBLE DECAY:	8.8 kHz to 10.7 kHz
DEPTH:	0 to 30
PRE-DELAY:	to taste

The indicated reverb time for "BASS" is not accurate in this program so that users should rely on their ears more than the panel settings when adjusting the "BASS" parameter. Note that it is possible to cause internal feedback by setting the "BASS" control much higher or lower than "MID". The "DEPTH" control affects the first "reflection" in settings 0-40, making it progressively less pronounced. In settings 50-71 it progressively emphasizes later "reflections". The outputs of this program are identical pairs: "A" is the same as "D" and "C" is the same as "B". This program is recommended for use with stereo inputs since the reverb is more natural and interesting than it is in mono. However sharp transients will sound best if panned to the middle. With stereo input the apparent width of the reverb may be altered on some material by reversing the 224 outputs so that "C" goes left and "A" goes right.