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**AES**

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**AN AUDIO ENGINEERING SOCIETY PREPRINT**

## THE AUDIO SIDE OF THE LASER VIDEODISC

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### 0. Introduction

Since the beginning of the video age the audio part of the program has been treated as a poor hand-maiden. That is, a mere helper to the main conveyer of the program - the video. This philosophy is evident in recording and editing of the program - the audio characteristics of most videotape recorders are dreadful - and reaches its nadir when you examine the audio system of the average television set.

Fortunately, the video renaissance that we are experiencing with the explosive growth of the cable industry, super stations and satellite broadcasting, has brought with it a demand for audio improvement. A generation raised on high fidelity stereophonic reproduction of music is demanding high fidelity in video music as well. The age of "HI VI" has arrived.

As MCA and Philips developed the standards for the laser optical videodisc, they jointly agreed that the medium should offer high quality stereo sound and worked assiduously to achieve that goal.

The laser optical videodisc has been a commercial reality in the United States for four years. It is capable of providing an NTSC compatible television signal and two high quality channels of audio programming for a wide variety of industrial, educational, and entertainment applications. It is the only

consumer video format (tape or disc) to offer the full 4.2 Mhz NTSC video luminance bandwidth with high timebase stability for sharp, detailed video reproduction.

The purpose of this paper is to explain how high quality audio is reproduced from the LaserDisc, the application of the CX noise reduction system and the considerations necessary for optimal tape formatting for typical source materials.

#### 1. Carrier Spectrum Modulation Technique

The NTSC video signal from the 1" C videotape recorder and two separate audio channels are frequency modulated as shown in figure 1. The video carrier is preemphasized, group delayed and frequency modulated with a positive modulation. The main carrier deviation corresponding to video blanking (0 IRE) is  $8.1 \text{ MHz} \pm 50 \text{ KHz}$ . The bottom of synch (-40 IRE) to white level (+100 IRE) causes a deviation of  $1.7 \text{ MHz} \pm 35 \text{ KHz}$  (figures 2 and 3). When the video signal is modulated for the disc, it is clipped at 110 IRE. It is then preemphasized and clipped again to maintain video carrier deviation within specified limits to minimize visible distortion and audio interference.

Frame and time address, and chapter and picture stop information are added during the video vertical interval for player control and random access.

The audio subcarriers are symmetrically double-edge pulsewidth modulated on the main carrier at a level of 20 to 26 db below the unmodulated video carrier (figures 4 and 5). The audio subcarrier frequencies are 2.301136 MHz ( $146.25 \times fH$ ) for channel one (left) and 2.812499 MHz ( $178.75 \times fH$ ) for channel two (right). ( $fH$  = horizontal flyback frequency = 15,734 Hz). These nominal audio subcarrier frequencies are interleaved with the video carrier so that during periods of non-modulation their sidebands cause a minimum of inter-modulation in the video signal, thus reducing visible interference in the picture. The audio signals have a 75 usec preemphasis (figure 6) and a maximum deviation of  $\pm 150$  KHz for short term transient peaks and must have the same modulation polarity.

## 2. Disc Modulation and Mastering

The LaserDisc mastering process is shown in figure 7. First, a glass substrate is polished to produce a flat smooth surface. It is coated with photoresist and baked to form a glass master.

The composite FM signal from the audio and video VCO's modulates an electro-acoustic modulator which rapidly turns a high power laser beam on and off, selectively exposing a spiral of pits into the photoresist on the surface of the spinning glass master starting from the inner diameter out.

The glass master is then developed using techniques similar to those used for film (figure 8). The information on the disc is encoded in one of two formats: CAV (Constant Angular Velocity) - in this format the master disc spins at a constant speed of 1800 RPM. This produces a disc with one complete television frame per revolution. In this mode, all special effects (fast and slow motion, still frame, and full random access) are available (figure 9). In the NTSC television system, every television line is scanned every 1/60th of a second. During vertical flyback, the electron beam is extinguished and then begins scanning the picture beginning with the previously unscanned lines in the vertical interval. During this period, the laser beam in the player may be made to repeat previous tracks for still or slow motion or skip over others for fast motion (figure 10). The linear playing time per side is limited to thirty minutes for a total of 54,000 frames.

A second format, CLV (Constant Linear Velocity) is used to extend playing time to an hour per side. In this mode, linear play with random chapter and running time, search and scan access is available. The CLV track readout velocity is maintained at approximately 35 feet per second. This is accomplished by slowing down rotation of the disc from 1800 RPM at the beginning inside diameter to approximately 600 RPM at the outer diameter.

The developed glass master is plated and a negative image of the master is obtained which may be used to mold finished replicas or may be duplicated via mother/daughter plating techniques similar to LP manufacturing. The stamper is mounted in a large die inside an injection molding machine. The replicas are made of Poly Methyl Methacrylate (PMMA) plastic. The backs of the single sides then receive a vaporized coating of aluminum to become reflective. The unbalance vector of each side is measured and the two sides are bonded back to back with balance vectors opposing to minimize overall disc unbalance.

The discs are then trimmed, inspected and packaged for shipment.

### 3. Disc Playback

In the LaserDisc player a laser beam is directed onto the disc track and reflected back onto photosensitive diodes (figure 11). The laser stylus never physically contacts the disc so the disc never wears out. Since the laser is focused on the reflective layer at the center of the disc, dust and fingerprints on the surface are ignored because they are out of focus. The signal is converted into electrical RF signals which are subsequently amplified approximately 37 db (figure 12.) Following compensation for level differences between inner and outer tracks by the RF correction circuit, audio signals

are retrieved by lowpass filtering of the composite RF signal. The lowpass RF signals are separated via separate bandpass filters which are passed to quadrature frequency detector stages to obtain the two audio channels. The occurrence of dropouts is detected in the FM detector and causes the demodulated audio channels to hold the previous voltage value during the loss of signal. The demodulated audio signals are applied to respective switching circuits under microprocessor and keypad control to provide audio muting and audio channel switching. The audio signals appearing after switching are passed through 75 usec deemphasis circuits before being applied to the CX noise reduction decoder. The outputs of the CX decoder pass through buffer amplifiers and are available as line level signals (650 mV for 100% deviation) or via the NTSC RF modulator for playback over a standard television speaker.

#### 4. Audio Channel Characteristics

##### Signal to Noise Ratio

Typical discs have peak to unweighted peak video carrier to noise ratios (VCNR) between 58 and 63 db, producing a video signal to noise ratio between 38 and 43 db. Peak to peak audio carrier to RMS noise ratios fall between 25 and 35 db. Although the audio subcarriers are at a level of 20 to 26 db down with respect to the video carrier, a 10 db reduction in

noise level is afforded by the narrower bandwidth of the audio channels. With 75 usec deemphasis, a 25 db Audio Carrier to Noise Ratio (ACNR) translates to approximately a 58 db audio signal to noise ratio at the output of the player. ACNR and VCNR vary slightly depending on disc format and the track radius where the CNR is measured.

### Frequency Response

The frequency response of the LaserDisc at different levels is dependent on overall program level limiting, if used, and partially on the 75 usec preemphasis curve. The maximum frequency deviation of the audio subcarriers is limited to  $\pm 150$  KHz deviation after preemphasis and CX compression. The maximum frequency deviation has been established to assure that the audio subcarrier filters in the player pass the audio signals and their significant sidebands with minimum attenuation.

Initially the 0 db reference level on the LaserDisc was defined as a  $\pm 50$  KHz deviation with a 1 KHz input, allowing 6 db of headroom after preemphasis above 0 reference ( $\pm 100$  KHz deviation). Subsequently, the 0 db reference has been redefined as a 40% modulation at 1 KHz ( $\pm 40$  KHz deviation). This increases headroom about 2 db at all frequencies and reduces SNR by 2 db (figures 13 and 14) show audio headroom available on the disc.)



Compare this new frequency response to the response of a typical music cassette, a typical FM broadcast, and LP disc (figure 15.) It can be seen that the LaserDisc compares favorably with other high fidelity media. Any slight loss due to peak clipping in the modulator at high frequencies may be compensated for by careful attention to high frequency peak levels and equalization during tape mastering.

#### Audio Timebase Errors

Any disc system is subject to timebase errors due to disc track eccentricity during the disc replication process. The influence varies from disc to disc and player to player and would be manifested primarily as a 30 Hz frequency modulation of the audio signal if not corrected (figure 16). In the consumer LaserDisc player this FM component is removed by the tangential servo mirror which is also used to reduce first order video timebase errors. Wow and flutter are typically below .1% on all LaserDisc programs.

#### Residual Channel Noise

Another area of concern to audio engineers is the residual audio noise during vertical flyback and the vertical interval. The player relies on several signals to keep the laser beam on the assigned track. One of the signals used in the tangential servo is the color burst at the beginning of each line of video. During the vertical interval and blanking

periods, no color burst is present in the NTSC format. Consequently, there may be present a burst of low level phase modulation of the audio carriers during this period due to radial tracking errors during blanking. After deemphasis, the Fast Fourier Transform of the audio signals during this period would reveal residual modulation energy spikes at 30 Hz and its lower harmonics.

### Distortion

Sibilance on LaserDiscs is distortion usually due to excessive audio levels or distortion products present on the client or release master tapes. This often causes distortion due to overmodulation after preemphasis. A typical narrative soundtrack with high levels of harmonic, difference frequency, or intermodulation distortions can generate excessive audio carrier deviations due to audio preemphasis. The hard clipping in the mastering machine necessary to maintain audio carrier deviation within the player audio FM filter bandpass will sometimes further complicate matters if overall program levels are excessive. This can be eliminated with careful attention to audio levels, equalization, noise gating/filtering techniques, and monitoring audio carrier deviation after preemphasis with peak level detecting LED's in place of PPM or VU meters. Occasional distortion during playback of poor quality discs has been caused by excessive RF carrier level fluctuations and dropouts on the disc.

## Dropouts

Crackle on the audio channels of the disc occurs when uncompensated or partially corrected dropouts of the RF carrier due to disc manufacturing defects cause the audio subcarrier levels to drop below the threshold of the limiter in the FM detector in the player, causing impulse noise spikes. These dropouts are corrected as far as possible by a sample and hold circuit in the player which maintains the audio signals at their levels before a detected dropout began. The ultimate solution to dropouts lies in careful disc manufacturing under clean room conditions. Discs of recent manufacture exhibit considerably fewer dropouts than earlier discs and with the use of CX noise reduction, are almost entirely free of these problems.

## 5. CX Noise Reduction

While the audio quality of the basic LaserDisc player is sufficient for many applications, there are circumstances where significantly wider dynamic range audio would be most desirable. To this end, several noise reduction systems were studied for their applicability to the noise spectrum of the LaserDisc. The system finally chosen was a modified version of the CBS CX system (figure 17).

The compression and expansion specifications for CX on LaserDisc are discussed in the Appendix. This version of CX

provides a system for wide band compansion which will transmit a high quality program within the noise spectrum and headroom limitations of the audio modulation scheme while being compatible with typical good quality video source material. The resulting CX encoded disc is sufficiently compatible to allow single inventory marketing of discs. In fact, many listeners prefer the bright, compressed sound of the undecoded CX LaserDisc. With the CX noise reduction system and the increased peak modulation specification outlined earlier, high frequency maximum output level where 0 db can be reproduced (before CX decoding) is increased 4K Hz over the earlier deviation standard (figure 14) to 10K Hz. In addition, initial high level transient overshoots present due to the transient attack characteristics of CX compression are transmitted with a minimum of interference to the picture signal. Peak level distortion is reduced due to the lowered deviation levels on the CX compressed disc for most high level signals.

A brief overview of the modified CX encoder/decoder is necessary to understand how it is able to deal with the noise spectrum of the LaserDisc. The compression/expansion ratio which determines the amount of perceived noise reduction is only 14 db due to the fact that few videodisc source materials are available which could tolerate an increase of more than 14 db in the noise floor on a single inventory disc. Secondly, the "knee" at which the compressor reverts

from 2:1 to 1:1 compression was raised from -40 to -28 db below the 0 db reference level to prevent additional noise modulation on playback without a decoder. The cutoff frequency in the control circuit was left at 500 Hz to prevent extraneous noise from the player servos from interfering with the transient tracking characteristics of the CX decoder.

An undecoded CX LaserDisc provides smooth dynamic performance in a manner not obvious with most musical material and no alternation of frequency response whether decoded or not. The time constants of the system alternate between fast and slow operation in response to changes in music dynamics and ignore small changes which could induce modulation distortion.

The block diagram of the CX encoder and decoder are shown in figure 18. The decoder is a mirror image of the encoder, ensuring accurate transient tone burst tracking through the entire noise reduction process. In the encoder, the two audio signals pass through voltage controlled amplifiers. Each channel also has a feedback loop which passes through a 500 Hz high pass filter to a full wave rectifier. Here the AC signal is converted to a DC level. The higher peak outputs of the two rectifiers controls the final gain of the VCA's for both channels.

The signal next passes through a fast attack (1 mS) and decay (10 mS) circuit. Such a circuit, if used alone,

provides good response for rapid transitions but also produces audible noise motion and modulation distortion. To handle these transitions, a multiple-time-constant circuit is used which operates rapidly for large changes in music dynamics and slowly during steady portions of the program.

The multiple-time-constant circuit comprises four filter paths with specially selected time constants. Two of these filter paths,  $F_1$ , the 30 ms low pass, and  $F_2$  the 30 ms high pass, operate only on large increasing forward changes in the control signal and, hence, work on signal attacks. The diodes shown with these filters serve two functions: for forward-biased signals, they provide a dead band which inhibits operation until a large signal change occurs, and for reverse-biased signals, they inhibit operation for all signal levels. Filter  $F_2$ , the 30 ms high pass, allows a rapid response to the attack signal. This attack signal, however, often contains unwanted ripple components associated with small changes in the music dynamics which can produce a modulation distortion. Filter  $F_2$  thus is cut off rapidly and filter  $F_1$  takes over. Because  $F_1$  is a low-pass filter, the unwanted ripple is removed. Since the summation of the outputs of  $F_1$  and  $F_2$  provides the final control, the fast attack is handled smoothly and ripple components are removed after a few milliseconds. While the ripple can be present momentarily, the time is too short for the ear to detect any distortion. This provides clean response to any music transients which occur.

Filter  $F_4$  is continuously in operation, but provides primary control only when no major changes are occurring in music dynamics; its time constant is 2 S. Filter  $F_3$  works only on signal decays, and the reverse-biased diode again serves two functions. Namely, it prevents any response for forward-biased signals (attacks) and it allows response only for large changes in reverse-biased signals (decays). As a signal decays from a loud to a soft level, the ear will readjust its listening after about 200 mS and begin to focus attention on the soft portion of the music. If a fast decay persists after 200 mS, it will continue to adjust the gain rapidly during a time when the music no longer masks any tape or disc noise. This noise change may then become audible as an undesirable breathing or swishing sound. With the CX circuit,  $F_3$  allows a rapid decrease in signal level during the period when the ear has not readjusted to the soft music. After 200 mS,  $F_3$  no longer functions and  $F_4$ , the 2 S filter, handles the remaining decay. Even if noise is now perceived, it will appear as a steady component and undesirable breathing effects will be eliminated from the output signal.

The output of the time constant network passes to the voltage to current converter to provide the final current controlling the two VCA's.

In the decoder, the same control circuit is in a feed-forward configuration to restore the audio signal to its original state.

## 6. Evaluation of Source Media Quality and Audio Processing

One of the challenges of having the wide audio dynamic range of the CX LaserDisc is finding source materials that fully utilize its capabilities. All too often, the limiting audio quality factors of the final disc are the production methods used for the source tape. Optimal audio processing guidelines for most common source media will be reviewed.

It is mandatory that audio noise reduction be used during all analogue tape generations. Any shortcomings of noise reduction aside, there is no arguing that multiple analogue generation noise buildup must be avoided to preserve program integrity on the final disc. Typical audio source media used for videodisc mastering include:

1. Film with magnetic or optical soundtracks.
2. 1/2" four track audio tape synchronized with videotape or computer generated stills.

At the present time, the majority of entertainment programming on LaserDisc is on film. A brief review of the A and B film audio chains is necessary to understand processing of this media for disc (figure 19). If a film will be released in Dolby stereo, Dolby A or dbx noise reduction will be used to preserve dynamic range and prevent noise buildup during each



magnetic film or tape generation. The A chain consists of the microphones and equipment used to record the original dialogue, music and effects.

Dialogue is often rerecorded on a dubbing stage with an automatic dialogue replacement system. At least three rolls of magnetic film are generated for the finished track, one for each audio element. These may be dubbed and mixed from many sources. A stereo film will have stereo music and effects tracks. However, dialogue is almost always mono and fed to the center speaker behind the screen. At this point, a synchronized magnetic master (mono or left, center, right and surround four channel) is produced. If the picture is in Dolby optical stereo, 100 Hz high pass filter and 7 KHZ low pass filter and Dolby B noise reduction are applied to the surround track. The three front channels and the modified surround pass through a matrix encoder to produce a two channel optical printing master. If the picture is released in the 70mm six channel format, the four audio signals are recorded on magnetic tracks 1, 3, 5 and 6, respectively. Low frequency bass enhancement signals are recorded on tracks 2 and 4 to augment bass response in the theatre. The 35mm optical printer records the two audio channels next to the film. This is where the A chain ends.

The B chain begins at the projector solar cell. It provides high frequency compensation for cell slit loss. If it is

Dolby stereo, the output is fed to a head amp equalized for a frequency response to 12.5 KHz (figure 20). It is Dolby A decoded, passes to a Tate Directional Enhancement system used in advanced SQ decoders to produce the four signals with a high degree of separation. The surround signal is delayed, filtered and Dolby B decoded. The delay is used to assure that the signal from the surround speakers arrives at the listener's ears after the signal from the front speakers. The Haas, or precedence effect of human hearing then guarantees that any front to back crosstalk and distortion from the optical track will be largely inaudible to the listener. The four channel outputs pass through equalizers to compensate for auditorium acoustics, power amplifier and speaker response. For mono films, the Academy high and low pass filters are inserted in the power amplifier feeds.

When mastering a soundtrack for videodisc, the printing mag should be used to bypass the distortion and phasing errors inherent in the optical track. If the film was in surround stereo from four track mags, it should be encoded with the Dolby matrix or SQ encoders to preserve the full original soundfield. Some low frequency equalization may be needed to remove buzzing, rumble or other unwanted low frequency noise from the location microphones or ADR system. Low pass filtering at 8-10 KHz may be necessary to remove hiss or reduce sibilant splatter present on most mono tracks due to excessive recording levels. Dropouts and poor edits may be partially masked with judicious use of reverberation.

Videotape programs are subject to all of the poor audio production techniques common to television. In addition to the noise and distortion problems of film, leakage of the video horizontal flyback frequency (15.734 KHz) is often present in the audio and must be notch filtered out to prevent excessive carrier deviation and clipping. Due to the angular orientation of the video head and magnetic particles on 1" videotape, elevated hiss levels are often present in the audio, mandating the use of noise reduction.

Interchannel phase shifts between stereo audio tracks on videotape may exceed 20 degrees with significant phase jitter at 10 KHz. Frequency response errors of more than 3-6 db over the entire audio band are common. Saturation due to excessive record levels is common, as is excessive wow and flutter, harmonic, intermodulation, and twin-tone difference frequency distortion.

The ideal analogue tape format for high quality audio programs is a 15 IPS 4 track tape synchronized via the SMPTE time code on the videotape and on track 4 on the 1/2" tape. Tracks 1 and 2 carry the stereo program with noise reduction. Track 3 is blank to prevent leakage of the time code into the program.

Synchronized PCM audio encoded sources are also frequently used to avoid the distortion, wow and flutter, and other problems associated with analogue systems.

## 7. Conclusion

The NTSC television system standards are sufficient to define a noise-free picture with high resolution, true color, and high quality sound. Our brothers in the SMPTE are assiduous in their efforts to transmit programs of high quality. However, the high quality usually ends at the transmitter. Transmission problems, interference, and cheap television sets degrade the signal so that the received audio visual presentation is a poor replica of the original production. The laser optical videodisc, coupled to one of the high quality consumer monitors that are now becoming available promises a new era of high quality program presentation. Let us hope for a continuing supply of software that will do justice to the medium.

## Bibliography

IEC Specification for Laservision Videodisc, May 1982

Abbagnaro, Lou: The CX Noise Reduction System, Audio,  
February 1982

Badger, Greg: Advancements in the USQ Family of Multichannel  
Reproduction Systems, AES Preprint #1779 (J-4)

Willcocks, Martin: Transformations of the Energy Sphere,  
AES Preprint

U. S. Patent #3,944,735: Tate Directional Enhancement System

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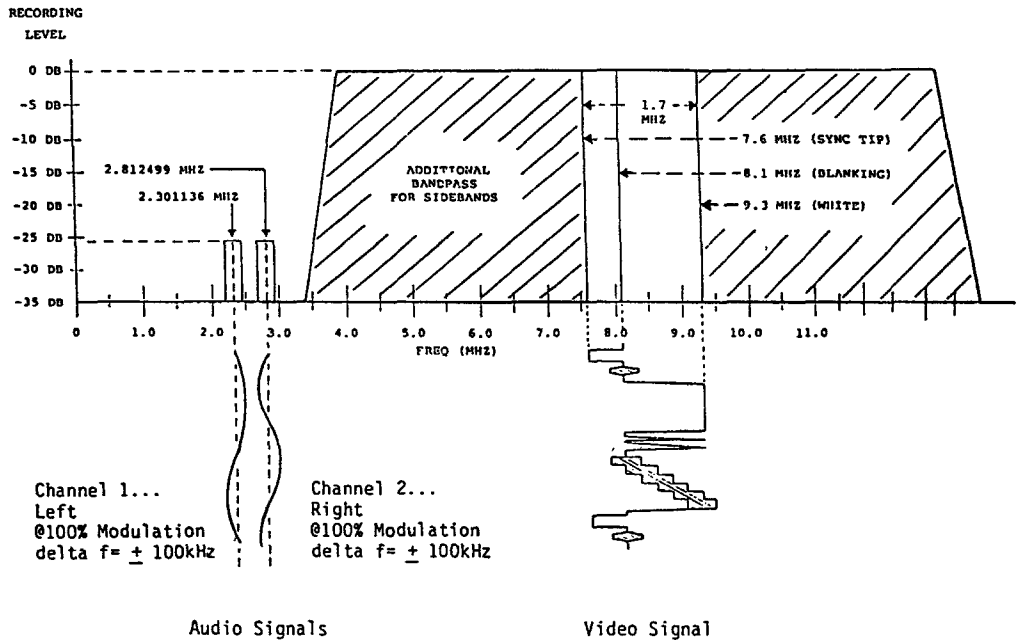
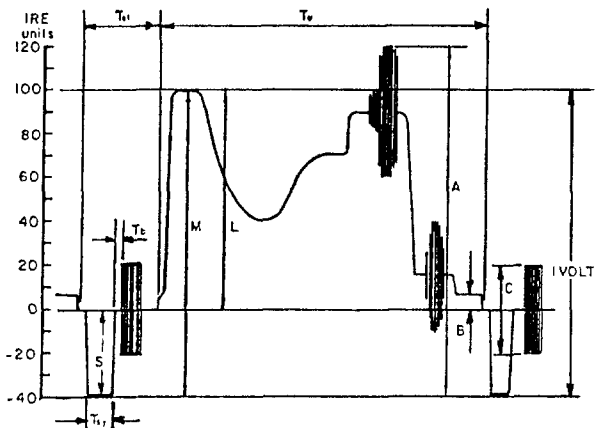


Figure 1. LaserDisc FM Modulation Spectrum.

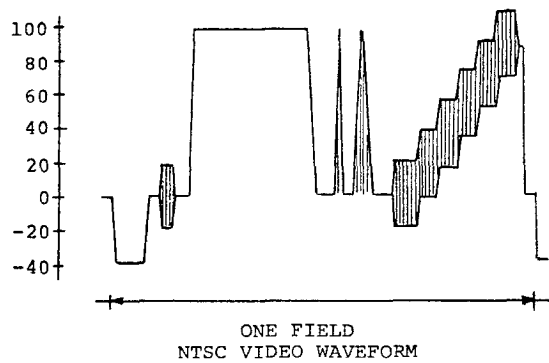


#### WAVEFORM TERMINOLOGY

- A: The peak-to-peak amplitude of the composite color video signal
- B: The difference between black level and blanking level (set-up)
- C: The peak-to-peak amplitude of the color burst
- L: Luminance signal - nominal value
- M: Monochrome video signal peak-to-peak amplitude ( $M = L+S$ )
- S: Synchronizing signal - amplitude
- $T_b$ : Duration of breezeway
- $T_{sl}$ : Duration of line blanking period
- $T_{sy}$ : Duration of line synchronizing pulse
- $T_u$ : Duration of active line period

Figure 2. NTSC Color Video Waveform





- 9.3 Mhz: 100 IRE White Level
- 8.1 Mhz: Blanking
- 7.6 Mhz: Sync Tip

Video Carrier Deviation  
On Disc

Figure 3. NTSC Video Waveform to  
LaserDisc FM Modulation

Recording

Level RE

Video Carrier Level:

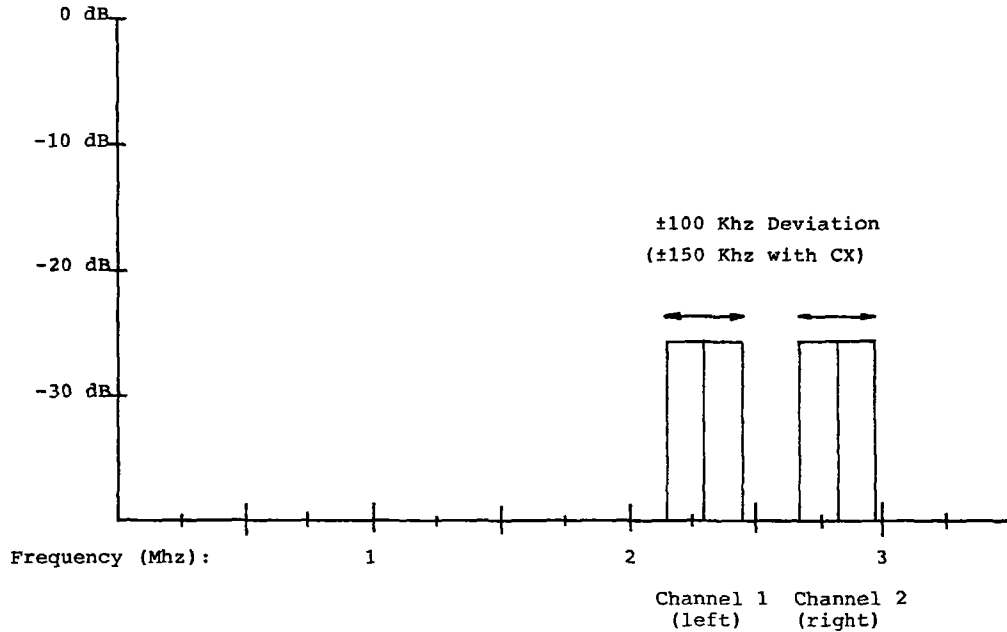
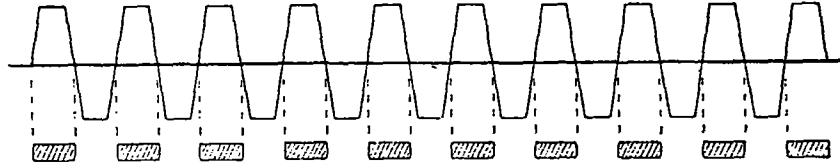


Figure 4. LaserDisc FM Audio Subcarrier Spectrum.

Video Carrier ALONE  
@ some gray level  
8.4 MHz

Pits/Bumps Produced



Video Carrier  
+  
Chan 2 Sound  
Carrier - 2.8 MHz

Pits/Bumps Produced

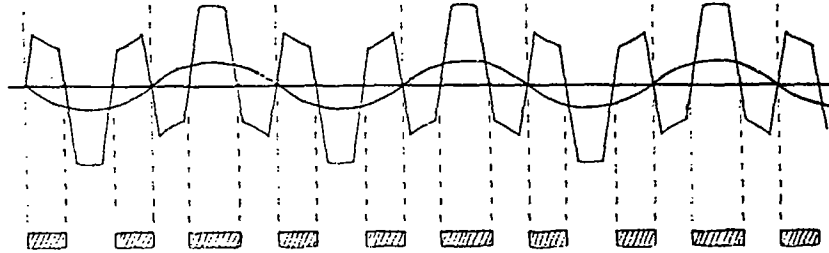


Figure 5. Pulsewidth Modulation Effect on Pit Geometry.

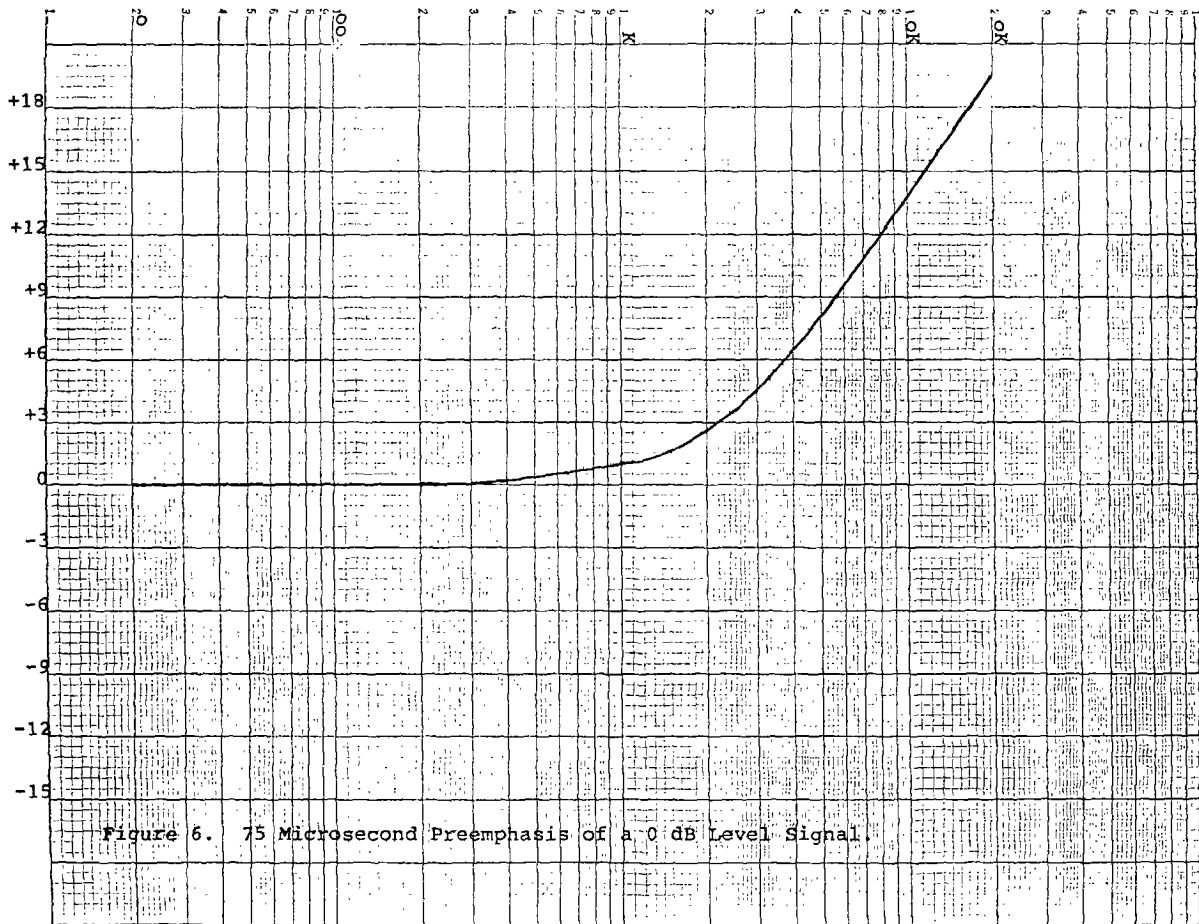


Figure 6. 75 Microsecond Preemphasis of a 0 dB Level Signal.

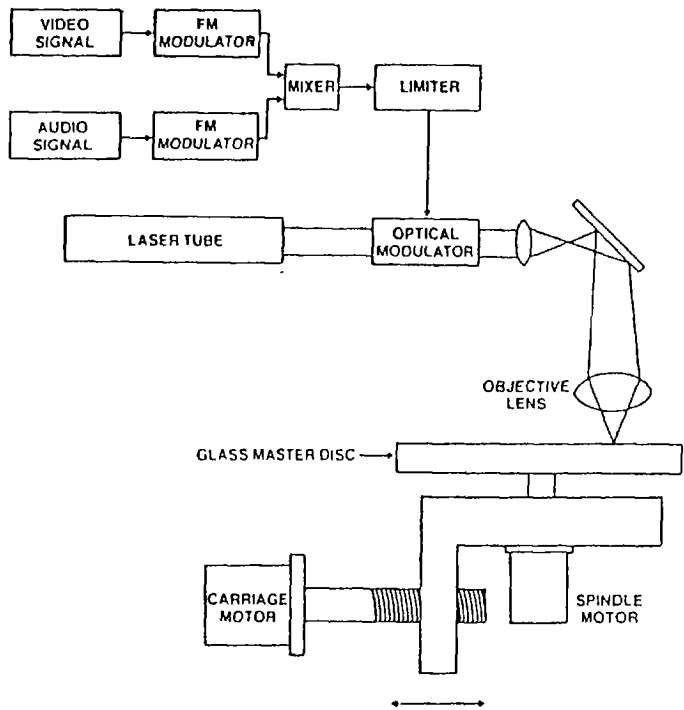
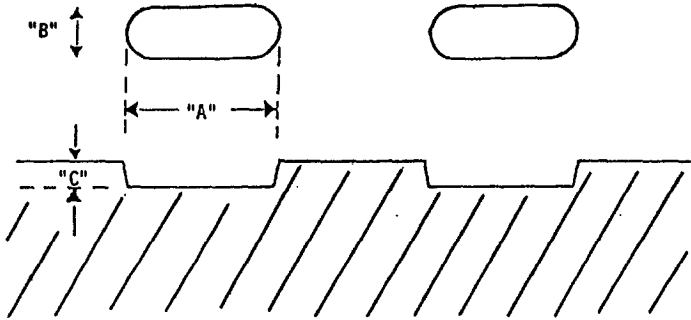


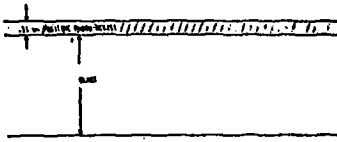
Figure 7a. LaserDisc Mastering Process.



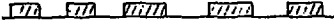
Typical pit dimensions for CAV with 50% duty cycle

DIMENSION	FREQUENCY MHZ	LENGTH ( $\mu\text{m}$ ) RAD. = 55mm	LENGTH ( $\mu\text{m}$ ) RAD. = 145 mm
"A" LENGTH	9.3 (WHITE)	0.55	1.40
	8.1 (BLANKING)	0.64	1.69
	7.6 (SYNC. TIP)	0.68	1.80
"B" WIDTH	ALL	0.40	0.40
"C" DEPTH	ALL	0.11	0.11

Figure 7b. LaserDisc Pit Geometry.



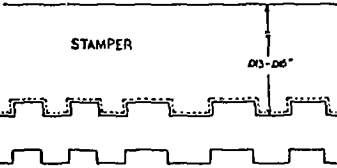
Glass master coated with a positive photoresist in preparation for MASTERING



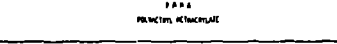
After exposure and development. Missing areas were under laser beam.



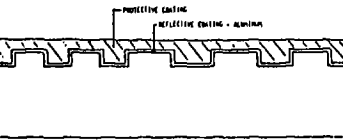
After depositing a thin layer of nickel to allow conduction during plating.



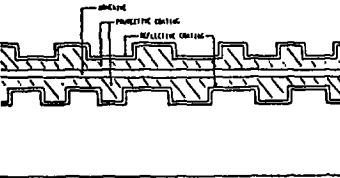
After plating for several hours the nickel stamper is separated from the master.



Injecting hot molten PMMA in cavity creates a 1x disc.



Application of an aluminum reflective layer and protective coating.



Two 1x sides are bonded together information surface to information surface.

Figure 8. Disc Replication Process.

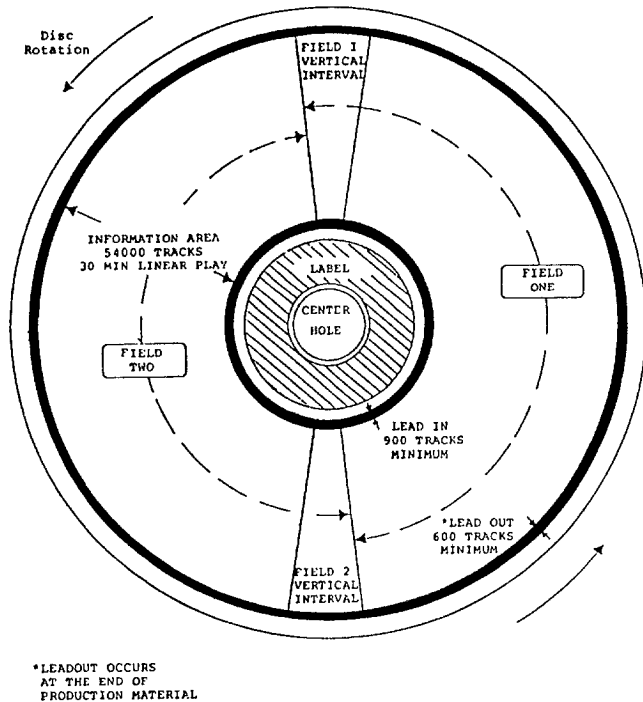


Figure 9a. Constant Angular Velocity (CAV) Disc Format.



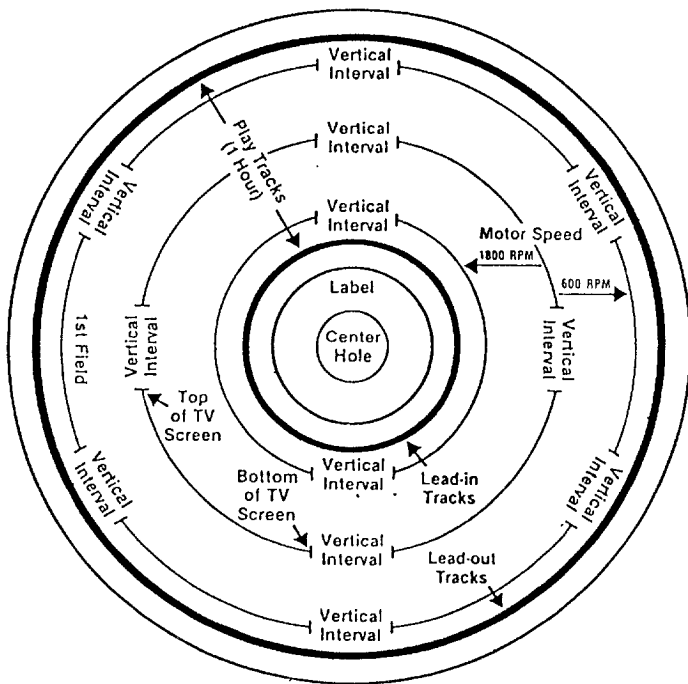


Figure 9b. Constant Linear Velocity (CLV) Disc Format.

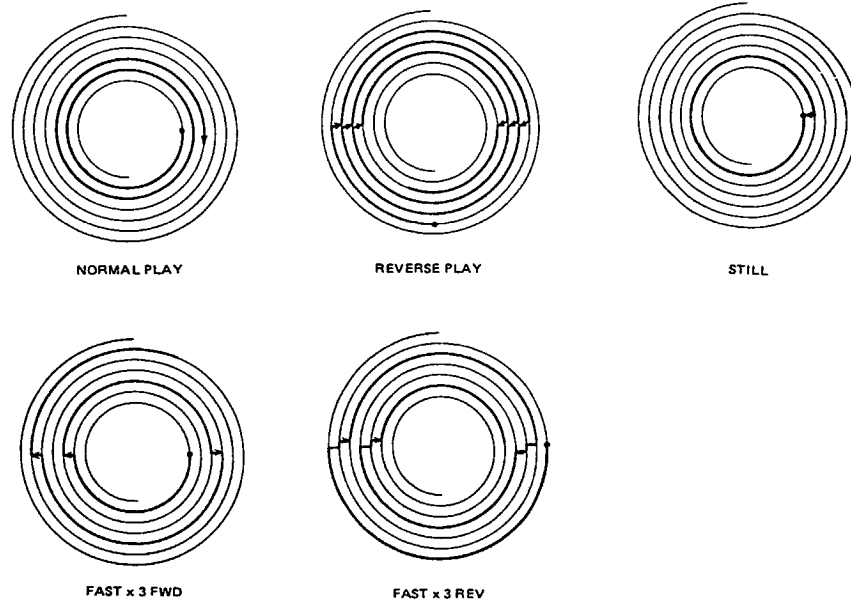


Figure 10. CAV Special Effects.

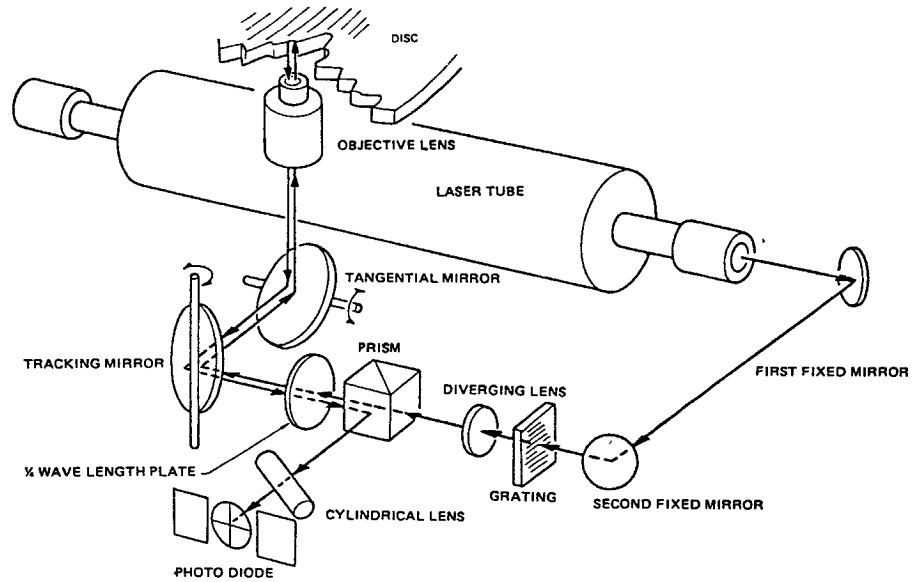


Figure 11. LaserDisc Playback Optical Path.

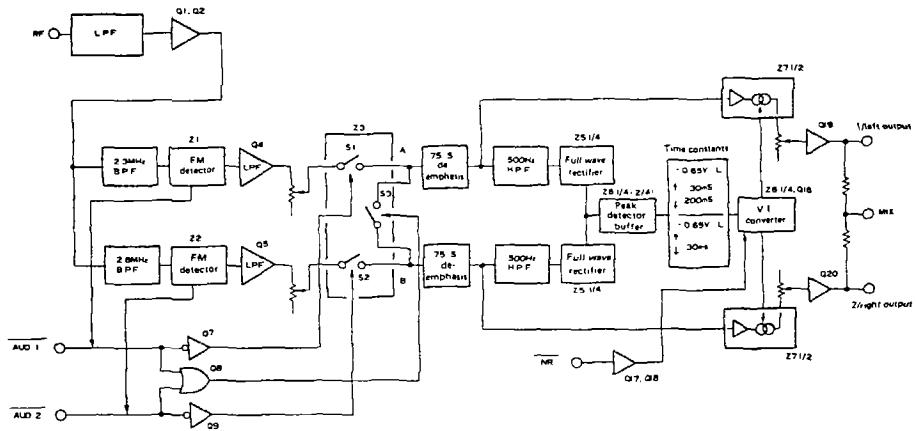


Figure 12. Player Audio System Block Diagram.

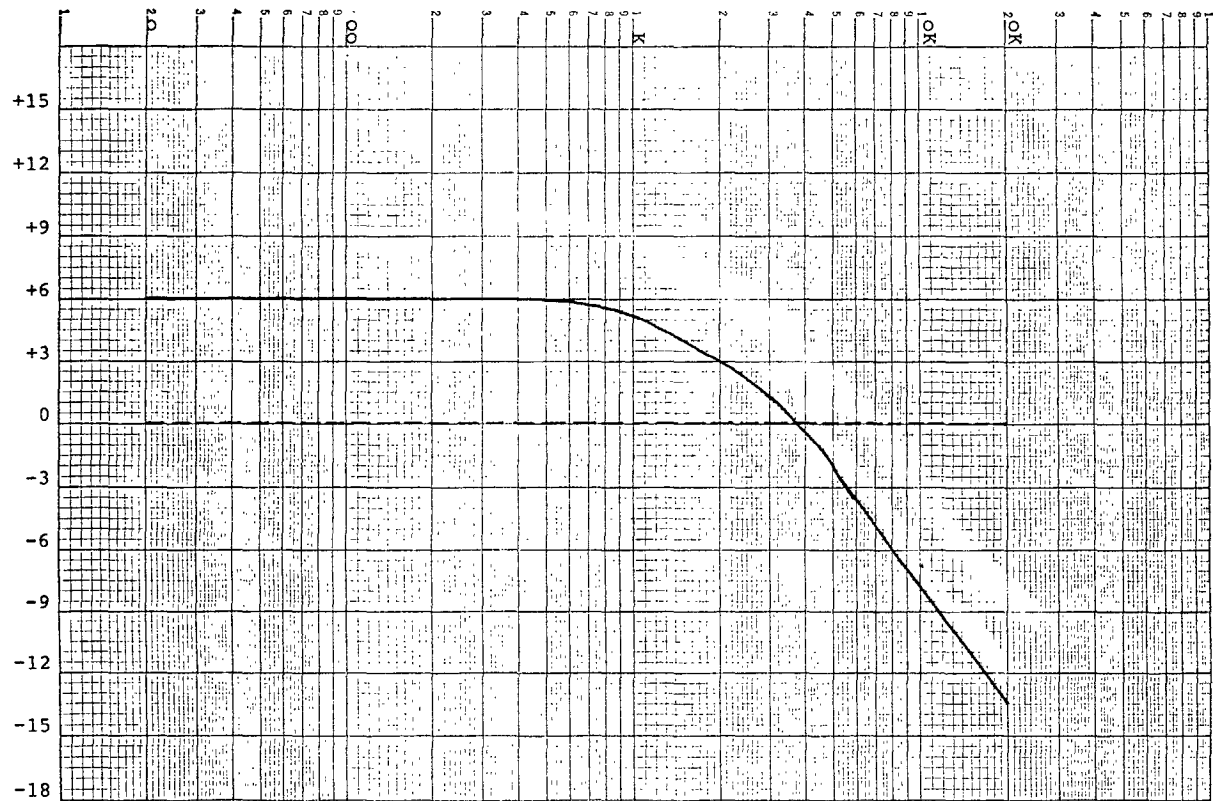


Figure 13. Maximum Audio Output Level for steady-state tones with 75 usec preemphasis, input limiting at +6 dB, and peak clipping after preemphasis at  $\pm 100$  Khz deviation. 0 VU reference level at 1 Khz =  $\pm 50$  Khz deviation.

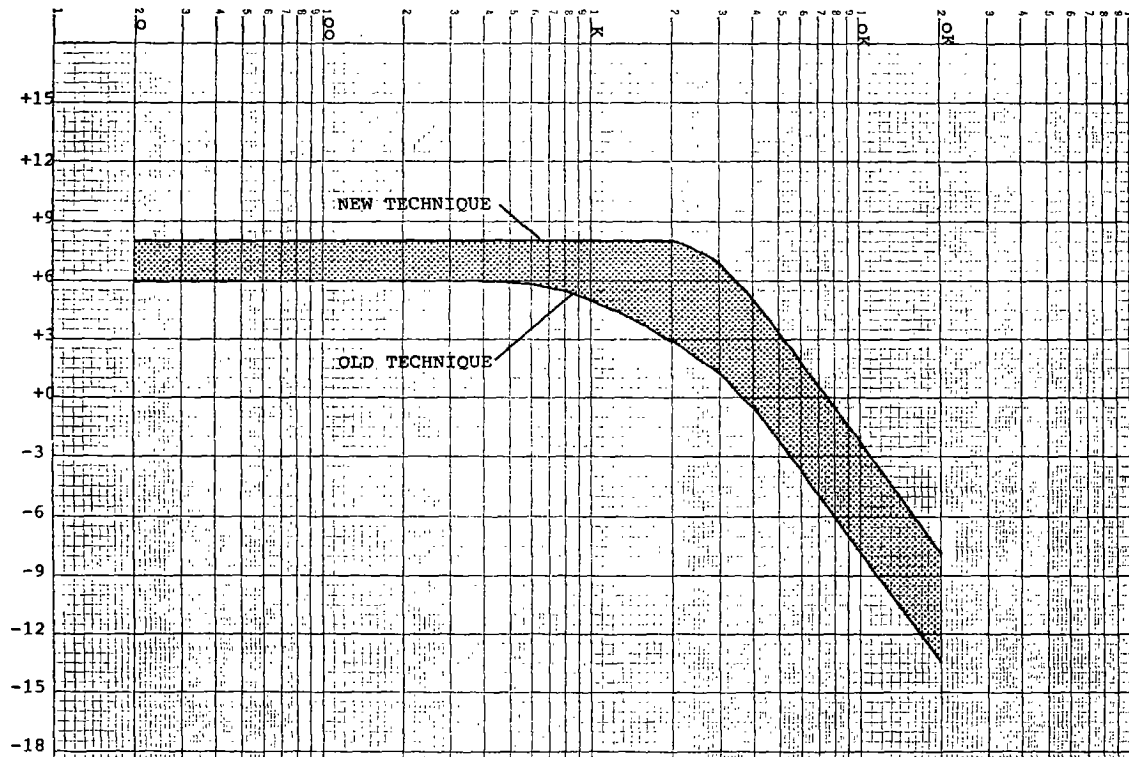


Figure 14. Maximum Audio Output Level for steady-state tones with 75 usec preemphasis, input limiting at +8 dB, after CK compression and peak clipping after preemphasis at  $\pm 150$  Khz deviation, 0 VU reference level at 1 Khz =  $\pm 40$  Khz deviation.

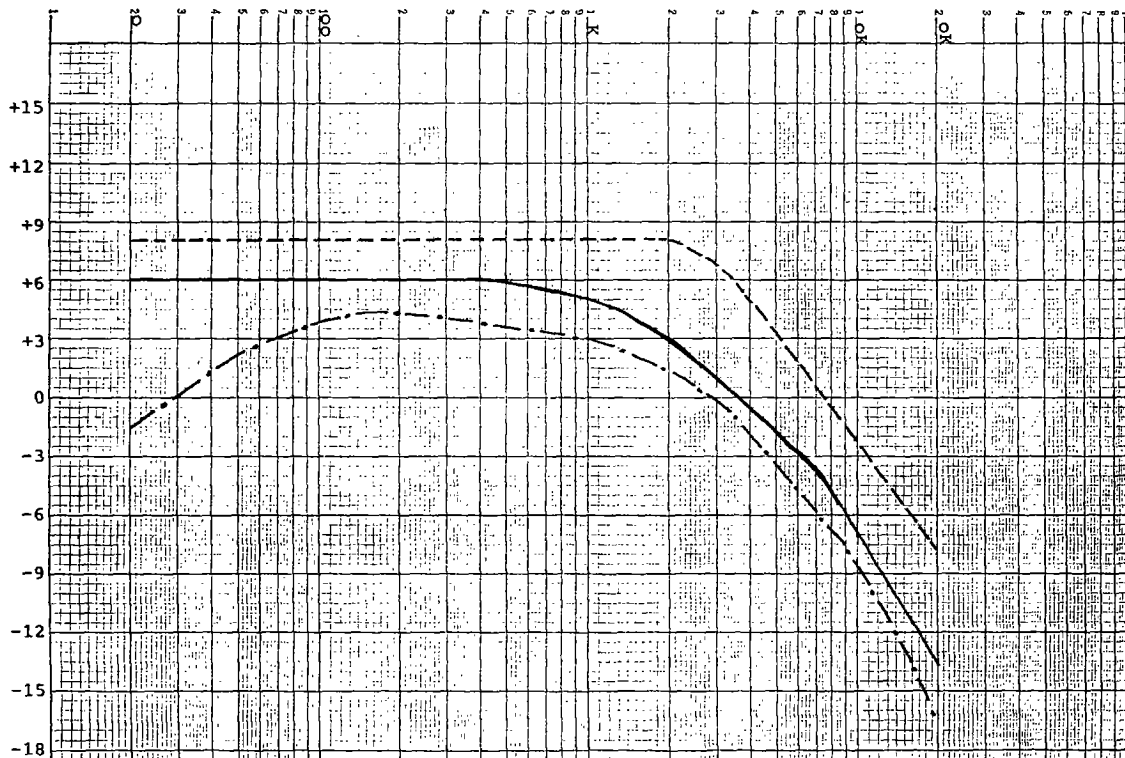
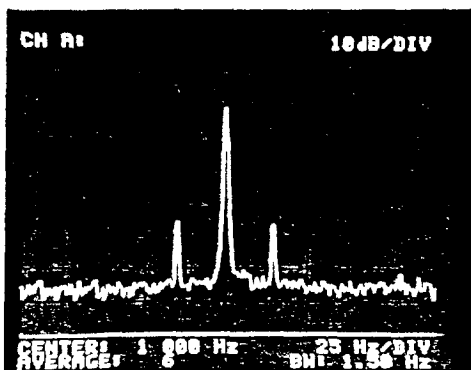
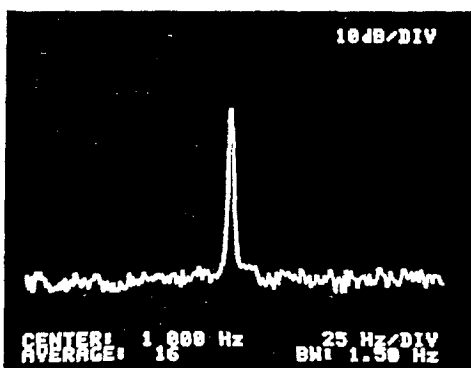


Figure 15. Frequency Response (Maximum Output Level) of Various Media.

- - - LaserDisc (after CX compression)
- FM Broadcast
- · - High Bias Cassette (maximum output level for 3% distortion and tape saturation)



before compensation



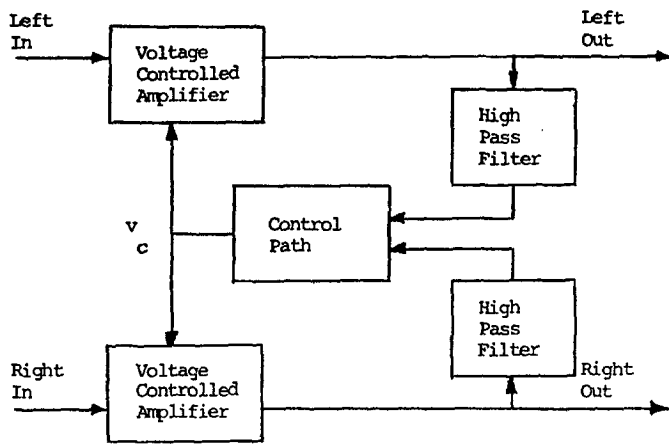
after compensation

Figure 16. Effect of Disc Track Eccentricity on Audio Signal.

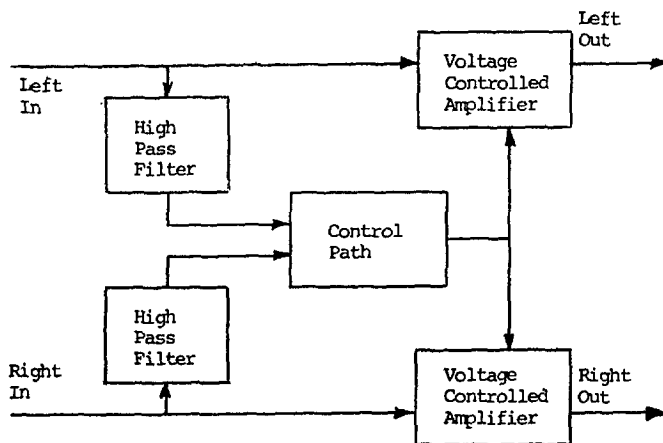


	Standard CX-20 for LP	LaserDisc CX-14
	<hr/>	<hr/>
Maximum compression and expansion ratio:	20 dB	14 dB
Knee level where the 2:1 compression changes to 1:1 (re 0 VU):	-40 dB	-28 dB
Low frequency filter cut-off (-3 dB) in compressor/expander control circuit:	100 Hz	500 Hz

Figure 17. Modifications to LP CX System for LaserDisc Applications.



Encoder



Decoder

Figure 18a. CX Encoder and Decoder Block Diagrams.

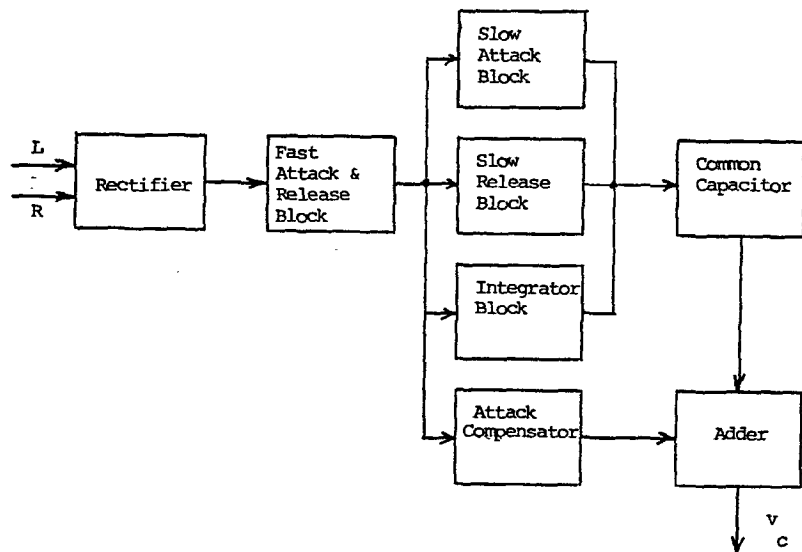


Figure 18b. CX Encode/Decode Control Path.

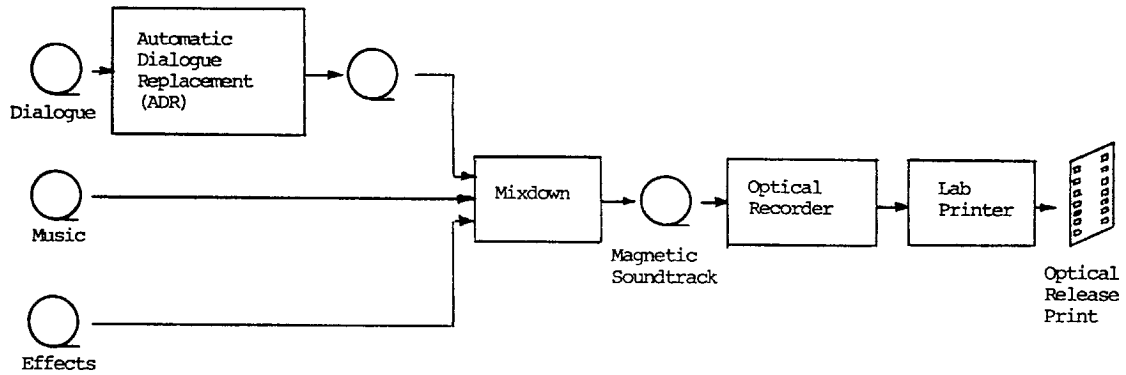


Figure 19a. 35mm Optical A Audio Chain

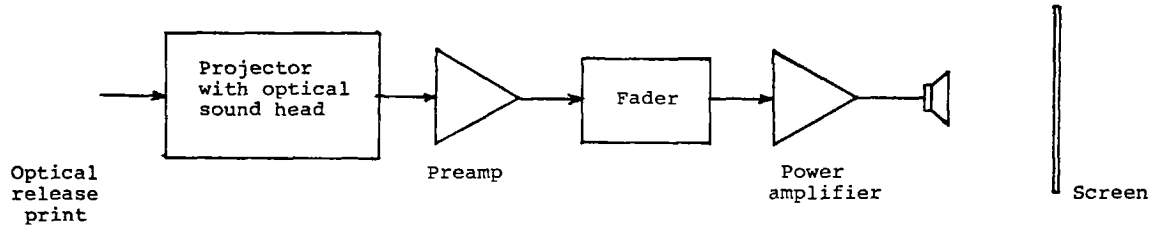
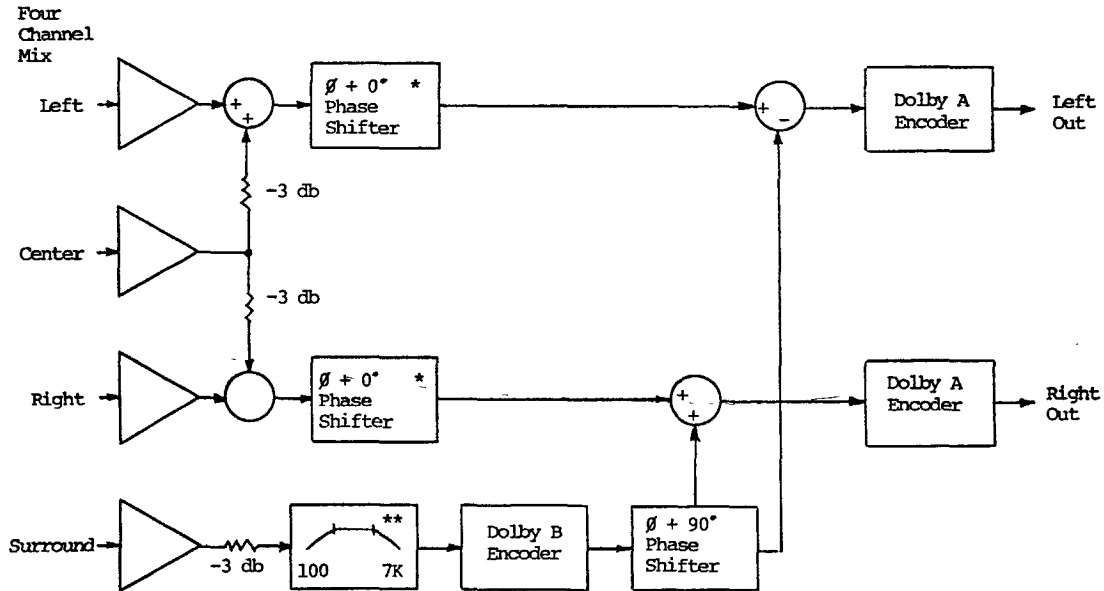


Figure 19b. 35 mm Optical Film B Audio Chain



\*All-pass phase shift network. Phase shift is equivalent to phase shift produced by bandpass filters and Dolby B encoder.

\*\*100 Hz high-pass and 7 KHz low-pass filters.

Figure 20a. Dolby Stereo Optical Encoding System

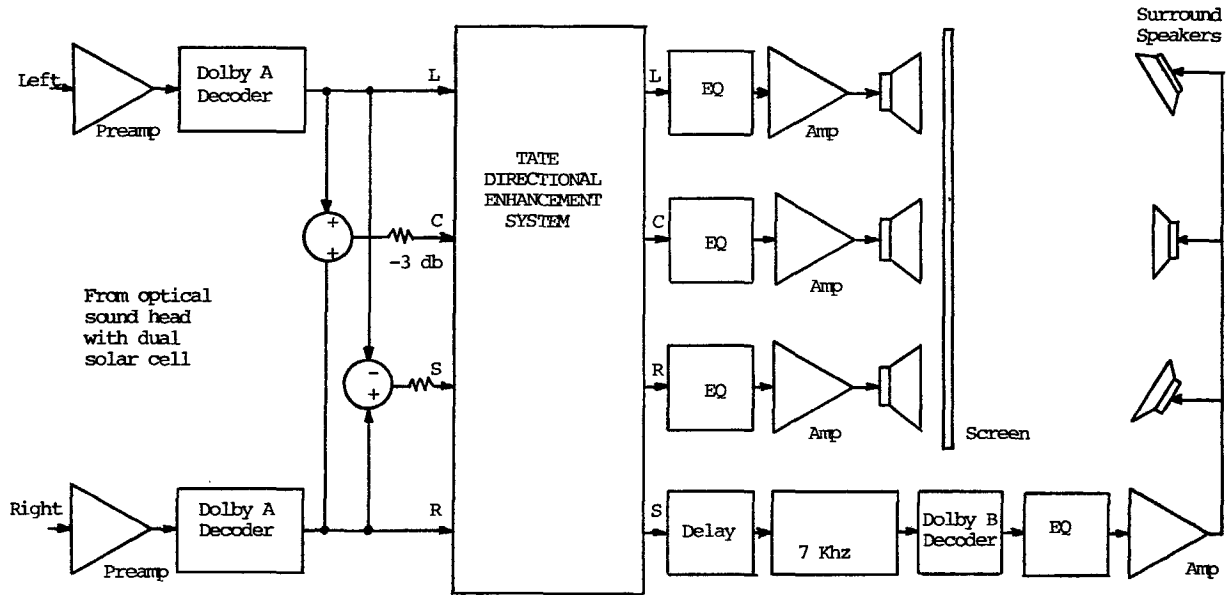


Figure 20b. Dolby Stereo Optical Playback

## APPENDIX

### CX CX COMPRESSION SPECIFICATIONS FOR LASERVISION VIDEODISCS

#### General

To improve the dynamic range of the audio program on the laser optical videodisc, an optional companding technique is recommended. This technique has been developed by the CBS Technology Center and is known as CX. Use of this system for videodisc players or discs is only permitted if a license has been executed with the CBS Technology Center. The version of CX for LaserDisc has been modified from the standard CX for LP's or other videodisc formats, and those CX encoders/decoders will not yield optimum results for LaserDisc. The technique is compatible in that the program, if encoded in the CX format, can be played back on a decoding player or a non-decoding player. If played on a decoding player the full benefit of 14 dB noise reduction will be achieved. Playback on a non-decoding player will be completely satisfactory but will not yield noise reduction improvement.

To assure optimum compatibility between disc and player, it is essential that all disc manufacturers encoding discs for the CX process use the same reference level parameters to ensure a specific correspondence between the static compression curve of the encoder and the modulation level of the audio carriers on the videodisc. Similarly, all player manufacturers incorporating CX decoders should arrange operating levels to match the prescribed disc characteristic.

#### Encoding Characteristics

##### 1. Statics

The static encoding characteristic of the CX system, optimized for LaserDisc use is shown in Figure 1. The figure describes the static gain relationship between the input signal level to the encoder, in dB, referenced to standard operating level, and the audio subcarrier modulation in dB re 100% modulation. Note that the modulator gain should be adjusted such that standard 0 db operating level at 1 KHz produces 40% modulation  $\pm$  0.5 dB ( $\pm$  40 KHz deviation) and at the limit, + 16 dB input will produce 100% modulation ( $\pm$ 100 KHz deviation)  $\pm$  0.5 dB.

The diagram also indicates that the "knee", the point on the compressor characteristic curve below which a 1:1 gain correspondence exists between input and output, should occur 28 dB  $\pm$  0.5 dB below standard operating level.



## 2. Dynamics

To ensure compatibility between encoding and decoding it is also necessary to match the dynamics between compression and subsequent expansion. These parameters are defined with reference to Figure 2A (encoder block diagram) and Figure 3, a simplified circuit diagram of the control portion of the CX system. These parameters are:

1. Control High Pass Filter (C25, R81):  $f_c = 500 \text{ Hz} \pm 5\%$
2. Fast Rectifier Attack Time (C27, R100):  $= 1 \text{ msec} \pm 5\%$
3. Fast Rectifier Release Time (C27, R99 + R100):  $= 10 \text{ msec} \pm 5\%$
4. Slow Rectifier Attack Time (C29, R105):  $= 30 \text{ msec} \pm 5\%$
5. Slow Rectifier Release Time (C29, R107):  $= 200 \text{ msec} \pm 5\%$
6. Low Level Integrator (C29, R106):  $= 2 \text{ sec} \pm 5\%$
7. Attack Compensator Decay Time (C28, R108 + R109):  $= 30 \text{ msec} \pm 5\%$
8. In order to ensure proper transitions between different time constant attack and decay times, a fixed relationship should exist between diode forward voltage drops and the audio operating level. This relationship is established by providing the proper control path gain for specific diode types. With the application of a 1 KHz standard operating level signal, the DC control voltage (at TP-1, Figure 2) should be  $3.85 \pm 10\%$  times greater than the forward voltage drop of the diodes CR 12, 13, 14.

### Engineering Practice

1. In order to prevent overloading of either audio transmission channels or the control voltage, a headroom of 16 dB should be maintained above "0" operating level.
2. At no time should the peak modulation level be allowed to exceed 150% times (+ 150 KHz). A hard limiter should be used after the preemphasis network in the mastering machine to accomplish this objective.
3. The purpose of the CX process is to prevent the deterioration of the program noise floor due to noise contributions from the videodisc process. For this to be effective, the signal to noise ratio of material presented to the CX Encoder should be at least 70 dB with CCIR 468-2 and ARM metering.

## CX EXPANSION SPECIFICATIONS FOR LASERVISION VIDEODISCS

### 1. Statics

The static decoding characteristic of the CX system optimized for videodisc use is shown in Figure 4. The figure describes the static gain relationship between the output of the audio demodulator in dB referenced to the level at 100% modulation and the output of the decoder after deemphasis in dB referenced to standard operating level. Note that the knee, the point at which the decode characteristic switches to linear operation, occurs at an audio demodulator output 22 dB below the 100% modulation reference point ( $\pm 1$  dB).

### 2. Dynamics

The time constants associated with the circuits which control the dynamics of the decoding process must agree with the time constants employed in the encoding process. These time constant specifications referenced to Figures 2B (the decoder block diagram) and Figure 3 (the CX control logic) are as follows:

1. Control High Pass Filter (C25, R81)  $f_c = 500 \text{ Hz} \pm 5\%$
2. Fast Rectifier Attack Time (C27, R100):  $= 1 \text{ msec} (\pm 15\%)$
3. Fast Rectifier Release Time (C27, R99 + R100):  $= 10 \text{ msec} \pm 15\%$
4. Slow Rectifier Attack Time (C29, R105):  $= 30 \text{ msec} \pm 15\%$
5. Slow Rectifier Release Time (C29, R107):  $= 200 \text{ msec} \pm 15\%$
6. Low Level Integrator (C29, R106):  $= 2 \text{ sec} \pm 15\%$
7. Attack Compensator Decay Time (C29, R108 + R109):  $= 30 \text{ msec} \pm 15\%$
8. In order to ensure proper transitions between different time constant attack and decay times, a fixed relationship should exist between diode forward voltage drops and the audio operating level. This relationship is established by providing the proper control path gain for specific diode types. With the application of a 1 kHz standard operating level signal, the DC control voltage (at TP-1, Figure 2) should be  $3.85 \pm 10\%$  times greater than the forward voltage drop of the diodes CR 12, 13, 14.

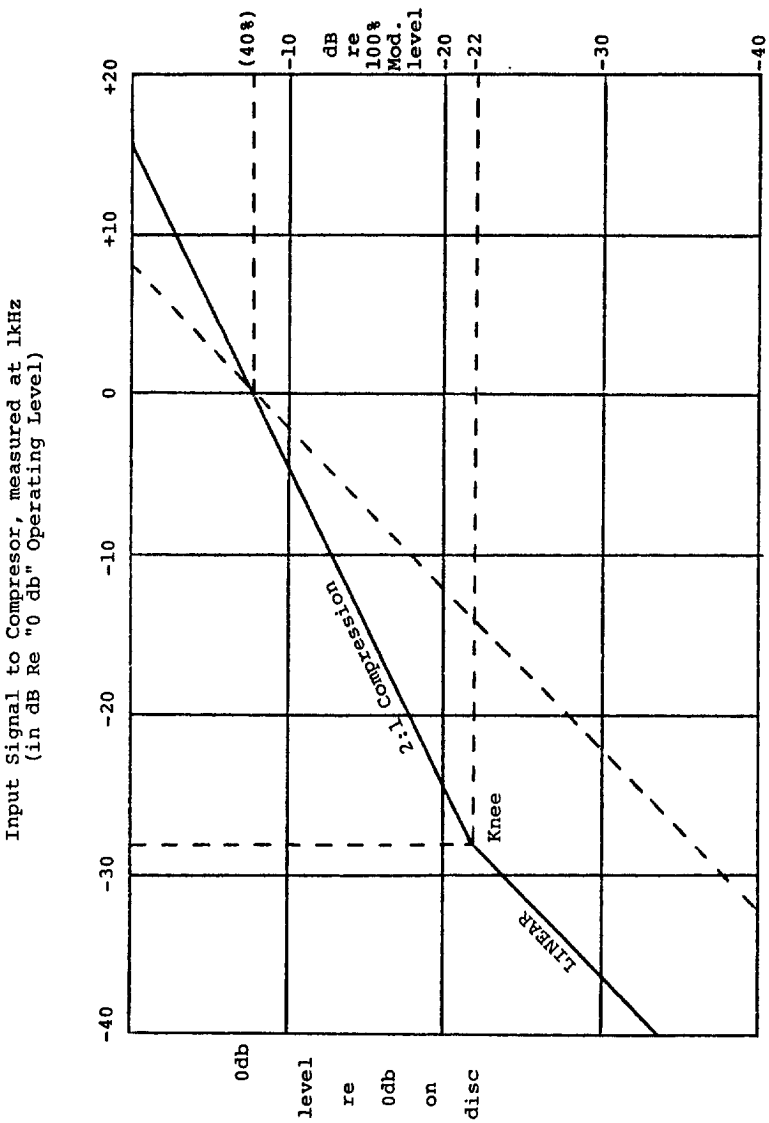


Figure 1 CX Static Encoding Characteristics Appendix

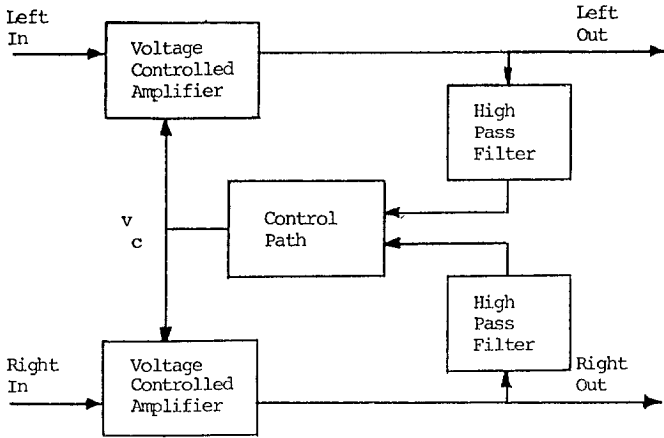


Figure 2A Block Diagram of Encoder Appendix

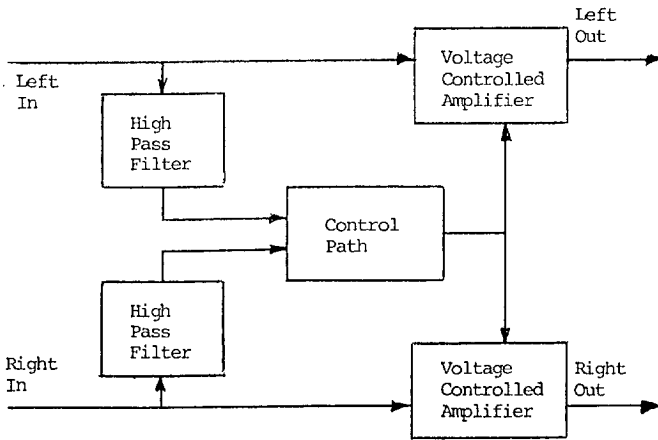


Figure 2B Block Diagram of Decoder Appendix

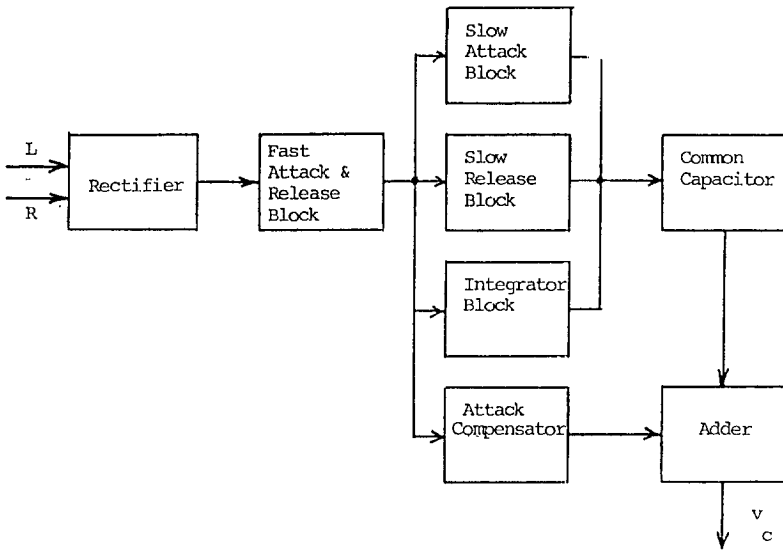


Figure 3 Block Diagram of Control Path Appendix

Audio Demodulator Output  
(dB Re 100% Modulation)

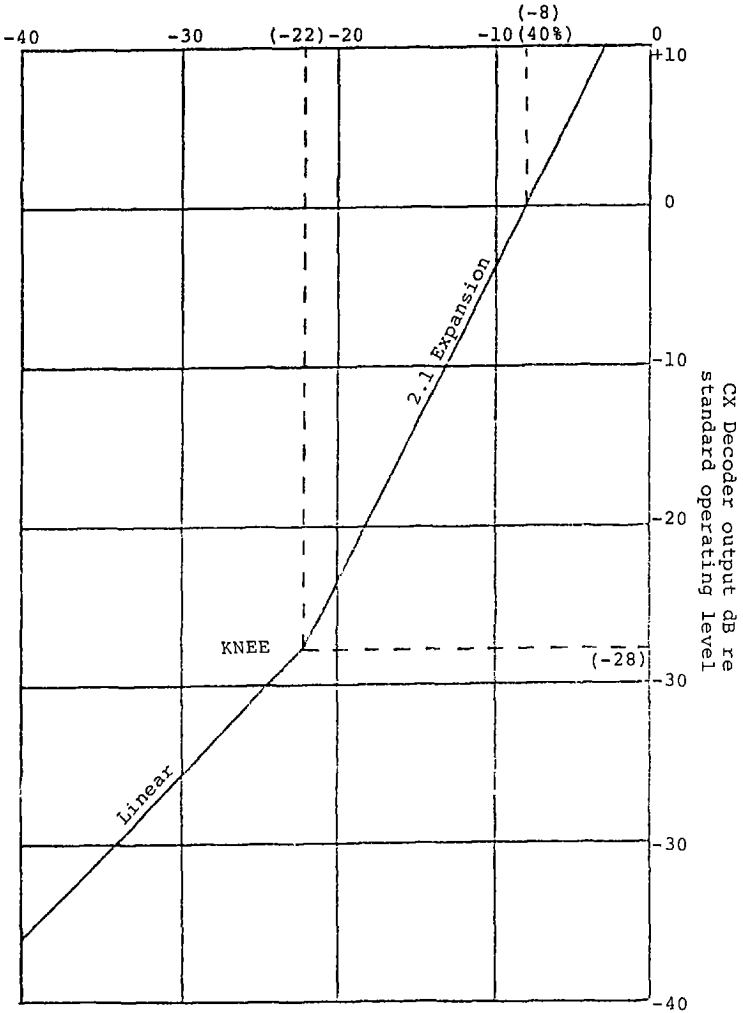


Figure 4. CX Decoding Gain Characteristic Appendix