

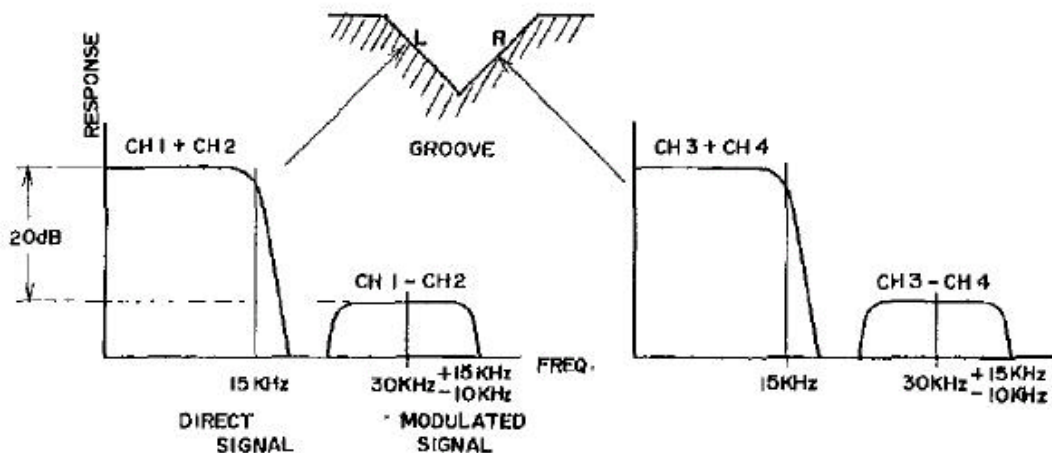
High Performance 2007 CD-4 Demodulator

By
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Installment III

This is the meat and potatoes section of the CD-4 demodulator. It is the 30 KHz sub-carrier recovery and demodulation section. The performance of this section directly affects the overall performance of the CD-4 system. CD-4 uses two 30 KHz sub-carriers. One sub-carrier for each groove wall. Each sub-carrier is modulated with the Front minus Back difference signal for that side. The 30 KHz frequency was chosen to fulfill the Nyquist criteria for signal multiplexing. The term multiplex means to send multiple types of information in the same signal. FM stereo and FM quadraphonic are both multiplex systems, as are all of the television systems world wide.

Being a dual multiplex system that is recorded and played back by electromechanical transducers (2 channel wide band cutting head and 2 channel wide band phono cartridge), mechanical constraints put some interesting design problems in creating the CD-4 system. Figure 10 shows the base band groove layout for the CD-4 system.

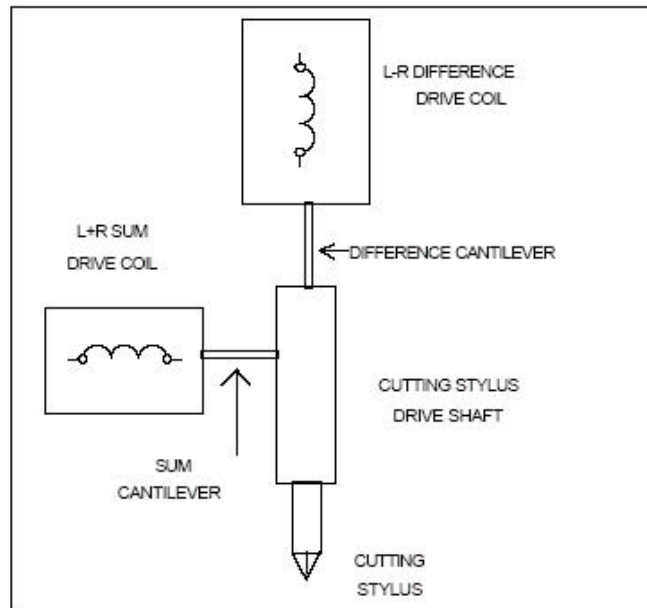


CD-4 Base Band Groove Layout

Figure 10

To meet the information theorem, the CD-4 system has 4 audio inputs, therefore, it must have 4 transmission channels to deliver to 4 audio outputs. Starting out is the orthogonal record groove. This defines shape of the record groove as a V. For the phonograph groove to meet the information theorem, it has 2 signal inputs, 2 transmission channels to deliver 2 signal outputs.

The first stereo cutting heads used a sum and difference technique to create the stereo groove. Using an algebraic sum and difference matrix, L+R and L-R signals are generated from the Left (L) and Right (R) audio signals. These are then fed to the orthogonal cutting head from 2 high power amplifiers. Figure 11 is a block diagram of this type of cutting head and Figure 12 is a picture of an actual head.



INTERNAL CONSTRUCTION OF ORTHOGONAL CUTTING HEAD Figure 11

The L+R signal drives the stylus horizontally and if it is the only drive signal, the groove cut is monophonic. The L-R signal drives the stylus in a vertical direction and if it was the only drive signal, the groove cut would be stereo with the Left and Right channels out of phase. A Left channel only will cut a stereo groove with modulation on the Right groove wall only, and the Left groove wall silent. As can be seen a Right Channel only will be just the opposite, with the Left groove wall modulated and the Right groove wall silent.



ORTHOGONAL CUTTING HEAD Figure 12

Picture Courtesy Neumann GMBH

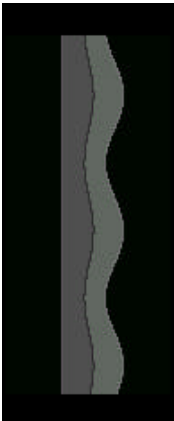
The problem with this type of cutter head is the absolute precision between the vertical and horizontal drive sub-systems. Every parameter, from frequency response, distortion, mechanical compliance, drive power and equalization must be absolutely identical. If all parameters are not the separation between left and right channel degrades. This showed up as loss of high frequency separation which starts at about 6 KHz. Maintaining separation to 50 KHz would be impossible with this type of cutting head.

Since the record groove is a V, some smart engineers at Westrex developed the V angle cutting head also known as a 45-45 cutting head. The 45-45 reference is because the angle between the 2 drive coils is 90 degrees and the stylus drive shaft is placed in the center of this angle, 45 degrees to either drive coil. This

head construction eliminated the precision parameter matching and made the mechanical matching much easier. No sum and difference matrix is required which makes this type of head perfect for the CD-4 system. A left channel only groove illustration is Figure 13 and Right channel is Figure 15. Figure 14 shows the internal construction of the 45-45 cutting head. Figure 16 is a Westrex cutter mounted on a cutting lathe, while Figure 17 is the Neumann cutting head that is used for CD-4 mastering and Figure 18 show the Neumann head mounted in a record cutting lathe.

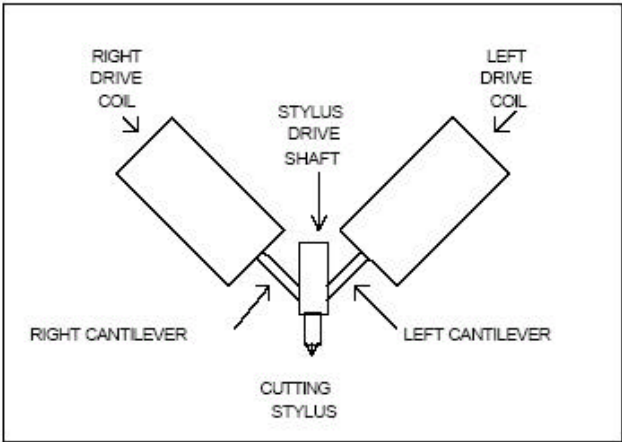
In CD-4 mastering, the biggest problem is ultrasonic heating of the cutting head from the 30 KHz sub-carriers. Most cutting systems use very high power (100 to 500 Watts per channel) to drive the cutting head coils. The first is to control the carrier level to main channel level for each side of the groove wall. Figure 10 shows the level of the 30 KHz sub-carriers to be 20 dB below the maximum level of the main channels.

Figure 13



**GROOVE
LEFT CHANNEL**

Figure 14

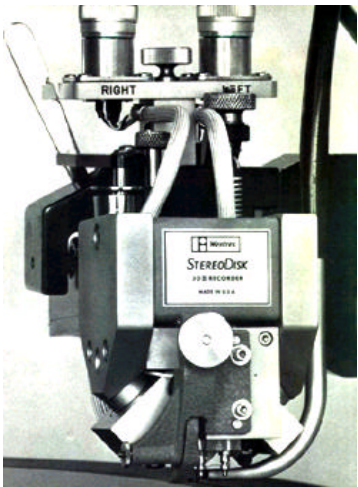


**INTERNAL CONSTRUCTION
OF THE 45-45 V CUTTING HEAD**

Figure15



**GROOVE
RIGHT CHANNEL**



WESTREX STEREO CUTTING HEAD
Picture Courtesy Neumann GMBH

Figure 16

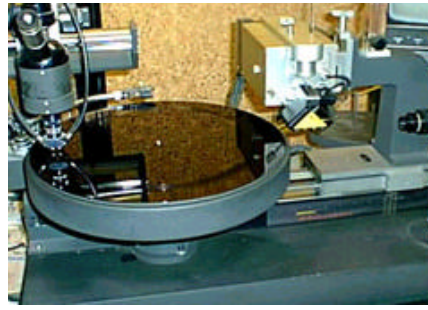
Figure 17



NEUMANN 45-45 CUTTER HEAD

Picture Courtesy Neumann GMBH

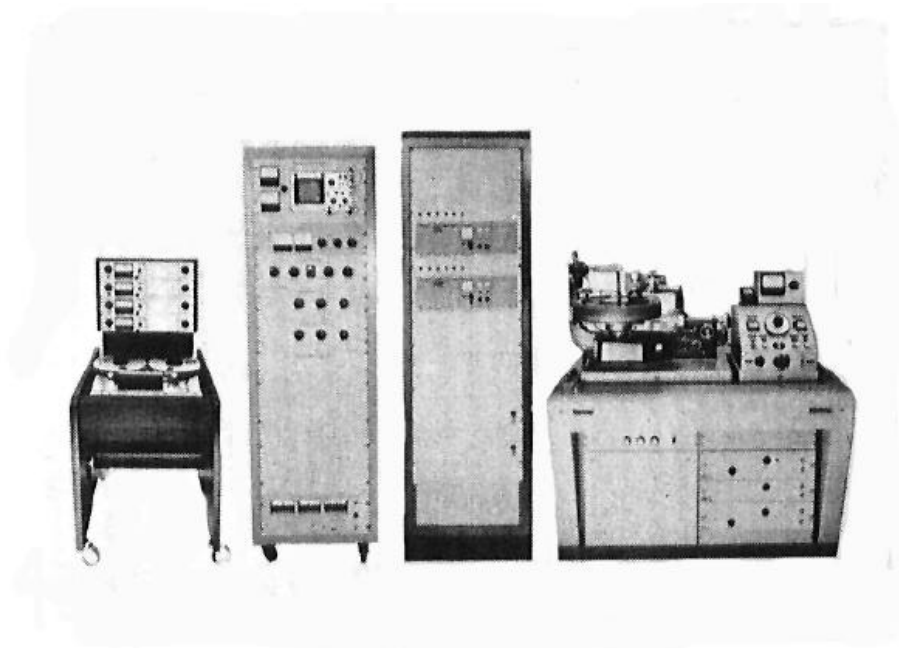
Figure 18



NEUMANN HEAD MOUNTED IN LATHE

Picture Courtesy Neumann GMBH

When the first CD-4 mastering system was built, the frequency response of the Neumann SX-74 cutting head was 24KHz with good separation at that frequency. The phase shift was quite linear to 24 KHz as well. The problem, however, was obvious. How do you record frequencies up to 45KHz with a cutting head that only goes to 24KHz? The answer, reduced speed cutting. When new systems are in design, conservative implementation is the order of the day. Even though the Neumann Cutter is good to 24KHz, not having to record higher than 15KHz would be even better. The first CD-4 mastering systems recorded at 1/3 speed which made the maximum recorded frequency 15KHz and both carrier frequencies 10KHz. During recording the disk rotates at 11.11 RPM. When this disk is played back at 33.33 RPM the carrier frequencies become 30KHz and the maximum frequency is 45KHz. Figure 19 is a photo of the first CD-4 mastering system.



FIRST CD-4 1/3 SPEED MASTERING SYSTEM

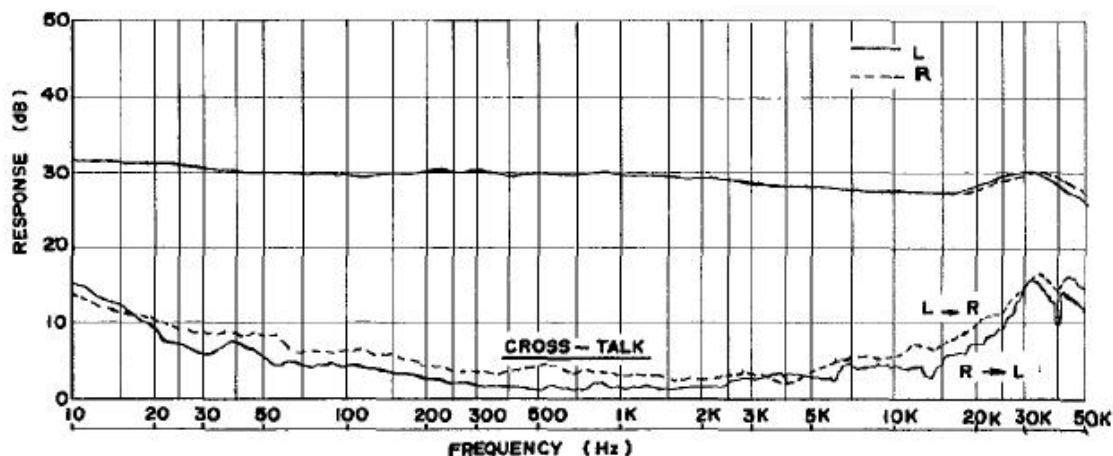
Picture Courtesy JVC

Figure 19

Some significant equipment modifications were required to get this system to work. The R.I.A.A. curve had to be modified for 1/3 speed operation. The diameter eq for the cutting head position had to be modified and the NAB tape playback curve had to be scaled down to 1/3. Fortunately, tape playback speeds were already available on the Ampex 440 four channel playback deck.

Overall system performance involves the differential between a perfect system (theoretical) and the actual system (empirical). The perfect system would have flat frequency response, infinite separation, and unmeasurable distortion. Reality is quite different, but with appropriate circuit techniques, excellent performance can be realized.

Figure 20



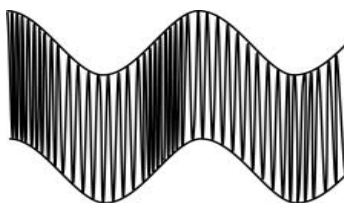
LEFT-RIGHT SEPARATION VS FREQUENCY RESPONSE FOR THE CD-4 SYSTEM

Courtesy JVC

Figure 20 shows the minimum separation of 15dB in the sub-carrier region from 18 to 45KHz,. This cross talk manifests itself as incidental amplitude modulation to the FM demodulator on the opposite channel. There are several types of FM detectors. They include Discriminators, Ratio Detectors, Quadrature Detectors, Pulse Count Detectors, and Phase Lock Loop detectors. CD-4 is considered a wide band modulation versus center frequency system. Of all the detectors mentioned, the ideal for CD-4 is Phase Lock Loop(PLL).

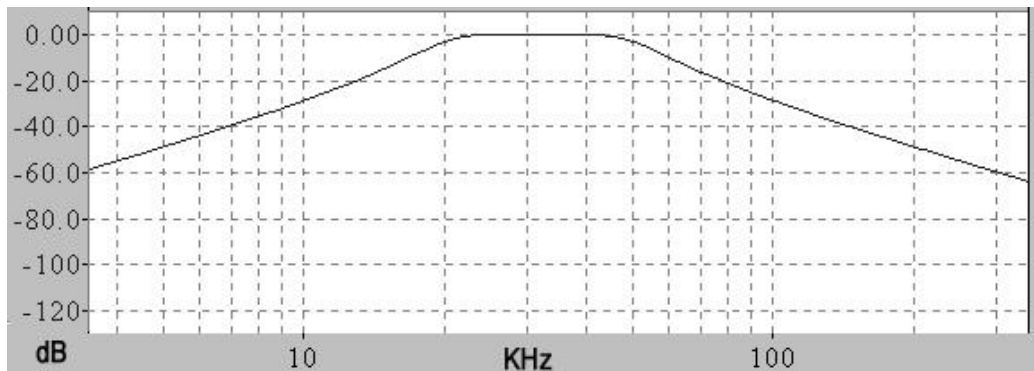
A PLL detector is just another FM detector. It's major advantage over discriminators, Ratio Detectors, and Quadrature Phase Detectors is that it is more linear (lower distortion) than the others. All of these detectors suffer from the same problem. They want a constant carrier level with no variations (incidental Amplitude Modulation). Figure 21 illustrates a main channel signal, a sub-carrier signal and the signal that comes out of the CD-4 pickup cartridge, pictorially exaggerated for clarity. The actual carrier level is 20 dB below maximum level of the main channel signal.

Figure 21



CD-4 CARTRIDGE OUTPUT OF 1 CHANNEL

This signal is the one that is fed to the sub-carrier recovery and demodulation section. Looking at the block diagram in Figure 1, this signal is first fed to a band pass filter. In 1974 the only cost effective way to create a 30 KHz band pass filter, was to use passive components. This means inductors and capacitors. No transistors, op amps, or other active circuitry. To keep the costs down, the filter performance had to be a compromise. Figure 22 shows the filter performance that was used with the QSI5022. Notice that the stop band slopes (stop band are the unwanted frequencies) are very broad and do not attenuate quickly.



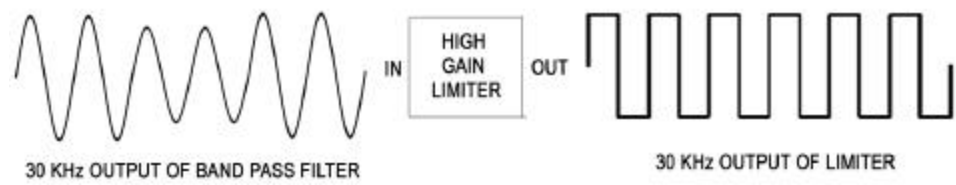
QSI5022 CD-4 30KHz BAND PASS FILTER (1974) Figure 22

The new CD-4 demodulator uses state-of-the-art-processing techniques to deliver an ideal 30 KHz band pass filter. The new technology eliminates inductors and capacitors, which also removes parameter drift due to temperature change. The stop band slope of the filter yields main channel to sub-channel isolation. Figure 23 is a graph of the performance of the filter.



NEW CD-4 DEMODULATOR 30KHz BAND PASS FILTER (2007) Figure 23

The output of the 30KHz band pass filter is the sub-carrier and all of it's side bands which also include amplitude variations of the sub-carrier itself, created by the record surface and playing diameter. In Figure 24, the illustration shows some carrier variation after the band pass filter.



LIMITER INPUT OUTPUT WAVEFORMS Figure 24

After the limiter the signal level remains absolutely constant. This signal feeds the Phase Lock Loop detector with a full quality FM-PM-SSBFM signal.

Well that is it for this installment. Next one will describe the Phase Lock Loop and the ANRS sub-systems. If any of you have questions, please post them. Enjoy!

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