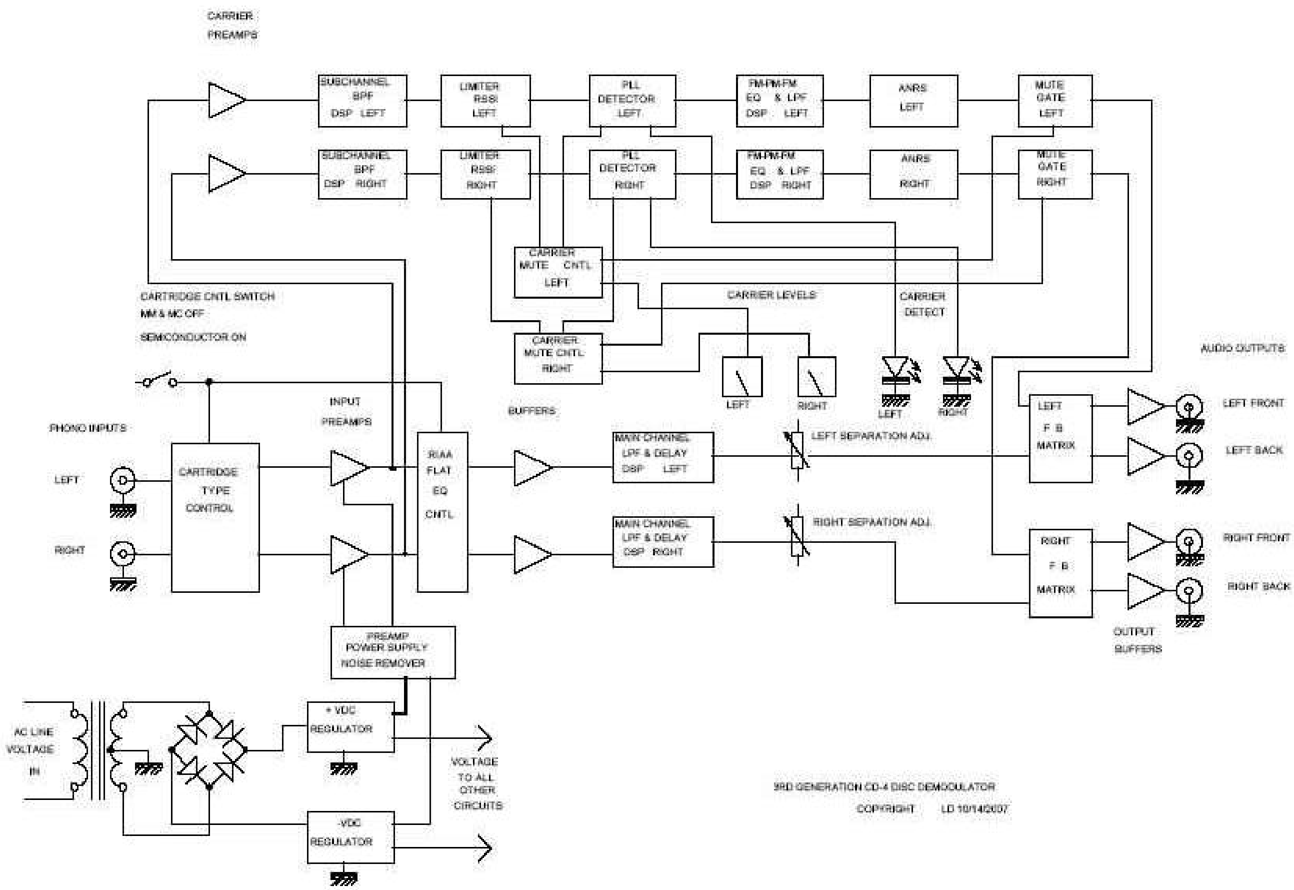
High Performance 2007 CD-4 Demodulator

By
Lou Dorren

It has been 33 years since the last CD-4 demodulator I designed. Sparked by the Quadraphonic Quad forum, I thought it an interesting idea to see how much of an improved demodulator could be designed with today's vastly improved technology. This is not just a paper exercise, but a full blown project to possible limited production. Now, off to the beginning. Figure 1 is the block diagram of the new demodulator. A larger version is on the last page.



Block Diagram of the New CD-4 Demodulator Fig. 1

One of the most critical subsystems in a CD-4 demodulator is the input preamplifier. Several important parameters are at play. First is dynamic range. The difficulty is the R.I.A.A. equalization curve which can be considered frequency dependent pre-emphasis (record) and de-emphasis (playback). This curve has gain at very low frequencies (20Hz) and loss at very high audio frequencies 18KHz.

For all of you numbers fans, the formula to obtain the original RIAA playback curve (courtesy R.I.A.A):

$$N = 10\log_{10}\left(1+4\pi^2 f^2 t_1^{\,2}\right) - 10\log_{10}\left(1+\frac{1}{4\pi^2 f^2 t_2^{\,2}}\right) - 10\log_{10}\left(1+\frac{1}{4\pi^2 f^2 t_3^{\,2}}\right)$$

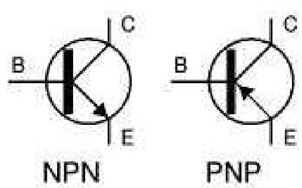
Where:
N=level in dB
f=frequency
t1=treble time constant, 75uS
t2=medium time constant, 318uS
t3=bass time constant, 3180uS

Here is a graphical representation of both the R.I.A.A. record and playback curves (courtesy R.I.A.A.).

R.I.A.A. Record and Playback Curves Fig. 2

As you can see there is a 40 dB dynamic range on the curve itself. Added to this are the dynamics of the recorded content, with cautions for extreme levels that might cause groove kiss (a condition where adjacent spirals on the record disk may overlap).

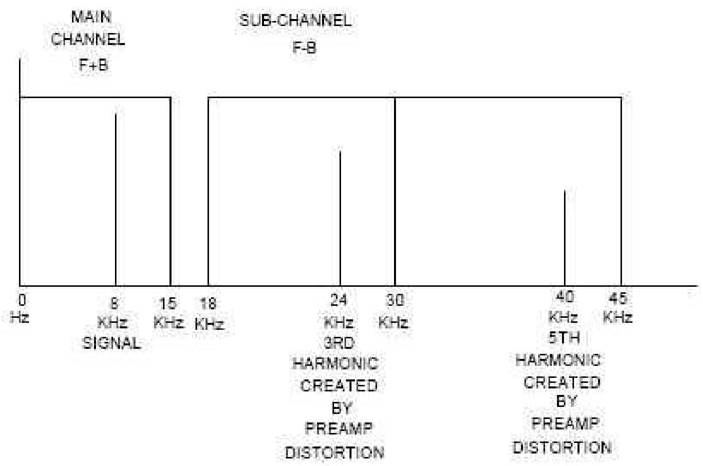
The second parameter is noise or signal–to-noise ratio of the preamplifier and the third is the total distortion (harmonic, inter-modulation, transient inter-modulation). Back in 1974, when Jerry O'Keefe and I were designing the **QSI5022**, analog semiconductor technology was in it's infancy. IC chips are generally made up of large numbers of transistors. In the 1970's these were all a Bi-polar type structure. Bi-polar transistors have two polarity types, NPN and PNP.



Schematic Symbols for Bi-polar Transistors Fig.3

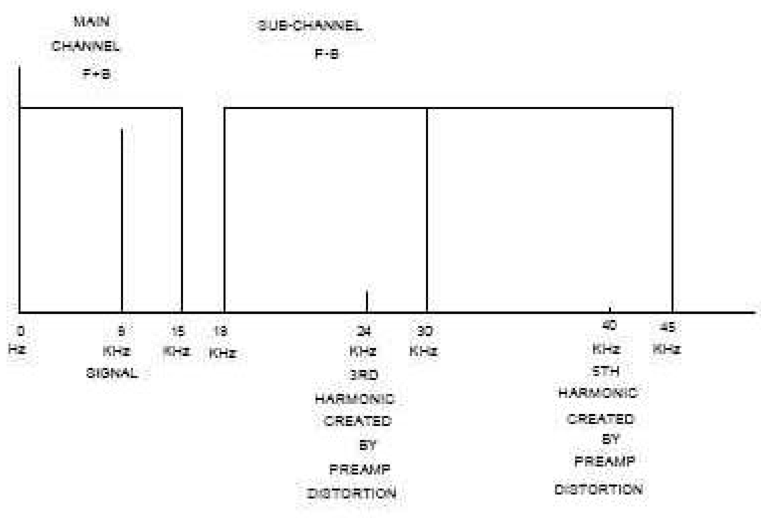
In circuit design, this can be very helpful because of the complementary nature of these types. Unfortunately, in the 1970's NPN type transistor performance was very good, but PNP type was extremely poor. This problem had a great effect on good amplifier design with the parameter affected worst being distortion. The **QSI5022** had the best performing phono preamplifier in the industry with distortion at .03%. The result was the best CD-4 demodulator at that time (SH-400, Heathkit, Southwest Technical Products).

Distortion in the preamplifier causes main channel to sub-channel cross talk. This is because the harmonics generated by the distortion end up in the sub-channel frequency range.



CD-4 Frequency layout for Left Channel .03 Distortion (Right channel identical) Fig.4

Figure 4 shows an 8 KHz signal in the main channel with .03% preamplifier distortion. The resulting



Frequency layout for Left Channel .00003% Distortion (Right channel identical) Fig.5

harmonics end up in the sub-channel, with the third harmonic at 24 KHz and the fifth harmonic at 40 KHz. This is interference in the sub-channel, by distortion products in the main channel. A good FM demodulator will reduce some of this interference, but not eliminate it. Here we are in the year 2007, and integrated circuit technology has improved by several orders of magnitude (order of magnitude = X10 up and /10 down). PNP transistors are now as good as NPNs, so that complementary designs are now implementable. The new CD-4 demodulator has a pre-amplifier with a distortion of .00003%. Figure 5 shows the harmonic content of the new CD-4 demodulator preamplifier.

Even though most amplifier chips have extremely good common mode rejection (the ability of the amplifier to reject common noise on the power supply lines), this is not enough in a CD-4 phono preamplifier. In the new demodulator, the preamplifier power supply line uses noise cancellation amplifiers to reduce the noise to a level of –140dBV(100 nano Volts). This when coupled with the amplifier's common mode noise rejection(100 dB) makes any power supply line noise unmeasurable(10 pico Volts).

The input to the preamplifier comes from the phono cartridge control unit. This selects the input network for the cartridge. For semiconductor strain gauge type, a DC bias voltage is applied to both channels and one of the channels is phase-inverted 180 degrees. This is done because the DC bias voltage can only be applied in one polarity, which makes the left and right channels out of phase. For the moving magnet and moving coil type, the DC bias voltage is removed as is the inversion.

Most phono preamplifiers use active R.I.A.A. feedback networks to get the proper curve. The problem with this technique is that the curve varies from chip to chip and with chip temperature. This variation can affect the CD-4 Front to Back separation. In the new demodulator, a passive R.I.A.A. network is used with temperature compensation to insure consistent Front to Back separation. The network is isolated from the low pass filter and delay stage by a low noise buffer amplifier which also adds some voltage gain to the main channel.

Well, that's it for the first installment. If any of you have questions, please post them. Enjoy!

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