



Understanding the Recording Process and RIAA Equalization

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2.11 PHONO PREAMPLIFIERS AND RIAA EQUALIZATION

2.11.1 Introduction

Phono preamplifiers differ from other preamplifiers only in their frequency response, which is tailored in a special manner to compensate, or equalize, for the recorded characteristic. If a fixed amplitude input signal is used to record a phonograph disc, while the frequency of the signal is varied from 20Hz to 20KHz, the playback response curve of Figure 2.11.1 will result. Figure 2.11.1 shows a plot of phono cartridge output amplitude versus frequency, indicating a severe alteration to the applied fixed amplitude signal. *Playback equalization* corrects for the alteration and recreates the applied flat amplitude frequency response. To understand why Figure 2.11.1 appears as it does, an explanation of the recording process is necessary.

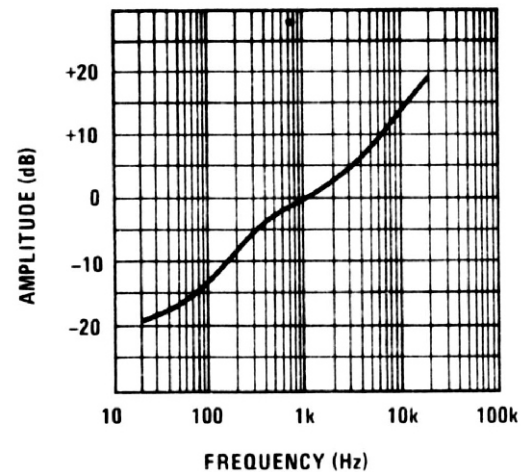


FIGURE 2.11.1 Typical Phono Playback Characteristic for a Fixed Amplitude Recorded Signal

2.11.2 Recording Process and RIAA

The grooves in a stereo phonograph disc are cut by a chisel shaped cutting stylus driven by two vibrating systems arranged at right angles to each other (Figure 2.11.2). The cutting stylus vibrates mechanically from side to side in accordance with the signal impressed on the cutter. This is termed a "lateral"

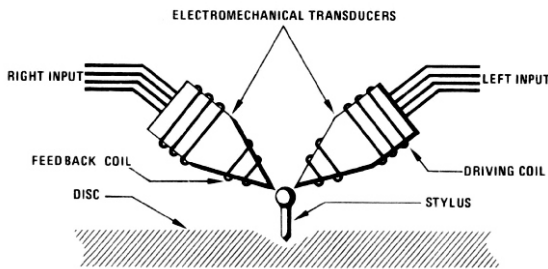


FIGURE 2.11.2 Stereo Cutting Head

cut as opposed to the older method of "vertical cut." The resultant movement of the groove back and forth about its center is known as groove modulation. The amplitude of this modulation cannot exceed a fixed amount or "cutover" occurs. (Cutover, or overmodulation, describes the breaking through of the wall of one groove into the wall of the previous groove.) The ratio of the maximum groove amplitude possible before cutover, to the minimum amplitude allowed for acceptable signal to noise ratio performance (typically 58 dB), determines the dynamic range of a record (typically 32-40dB). The latter requirement results from the grainy characteristic of the disc surface acting as a noise generator. (The cutting stylus is heated in recording to impart a smooth side wall to minimize the noise.) Of interest in phono preamp design is that the record noise

performance tends to be ten times worse than that of the preamp, with typical wideband levels equal to 10uV.

Amplitude and frequency characterize an audio signal. Both must be recorded and recovered accurately for high quality music reproduction. Audio amplitude information translates to groove modulation amplitude, while the frequency of the audio signal appears as the rate of change of the groove modulation. Sounds simple enough, but Figure 2.11.1 should, therefore, be a horizontal straight line centered on 0dB, since it represents a fixed amplitude input signal. The trouble results from the characteristics of the cutting head. Without the negative feedback coils (Figure 2.11.2) the velocity frequency response has a resonant peak at 700Hz due to its construction. Adding the feedback coils produces a velocity output independent of frequency; therefore, the cutting head is known as a constant velocity device (Figure 2.11.2a).

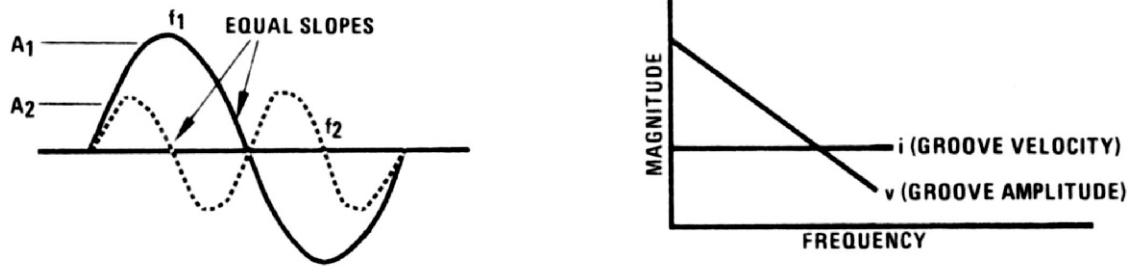


FIGURE 2.11.2A Constant Velocity Recording

Figure 2.11.1 appears as it does because the cutting amplifier is pre-equalized to provide the recording characteristic shown. Two reasons account for the shape: first, low frequency attenuation prevents cutover; second, high frequency boosting improves signal to noise ratio. The unanswered question is why is all this necessary? The not so simple answer begins with the driving coils of the cutting head. Being primarily inductive, their impedance characteristic is frequency dependent. If a fixed amplitude input signal translates to a fixed voltage used to drive the coils (called “constant amplitude”) then the resulting current, i.e., magnetic field, hence rate of change of vibration, becomes frequency dependent (Figure 2.11.2b); if a fixed amplitude input signal translates to a fixed current, i.e., fixed rate of vibration, used to drive the coils (called “constant velocity”) then the resulting voltage, i.e., cutting amplitude, becomes frequency dependent (Figure 2.11.2a). With respect to frequency, for a given input amplitude the cutting head has only one degree of freedom: vibrating *rate* (constant velocity = current drive) or vibrating *distance* (constant amplitude = voltage drive).

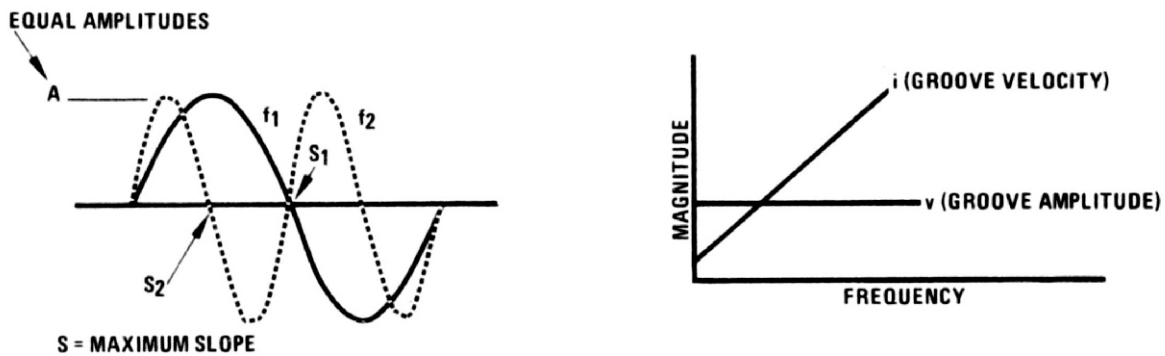


FIGURE 2.11.2B Constant Amplitude Recording

The terms constant velocity and constant amplitude create confusion until it is understood that they have meaning only for a *fixed amplitude input signal*, and are used strictly to describe the resultant behavior of the cutting head as a *function of frequency*. It is to be understood that changing the *input level* results in an *amplitude change* for constant amplitude recording and a *velocity change* for constant velocity recording *independent* of frequency. For example, if an input level of 10mV results in 0.1 mil amplitude change for constant amplitude recording and a velocity of 5cm/s for constant velocity recording, then a change of input level to 20mV would result in 0.2 mil and 10cm/sec respectively - independent of frequency.

Each of these techniques when used to drive the vibrating mechanism suffers from dynamic range problems. Figures 2.11.2a and 2.11.2b diagram each case for two frequencies an octave apart. The discussion that follows assumes a fixed amplitude input signal and considers only the effect of frequency change on the cutting mechanism.

Constant velocity recording (Figure 2.11.2a) displays two readily observable characteristics. The amplitude varies inversely with frequency and the maximum slope is constant with frequency. The second characteristic is ideal since magnetic pickups (the most common type) are constant velocity devices. They consist of an active generator such as a magnetic element moving in a coil (or vice versa) with the output being proportional to the speed of movement through the magnetic field, i.e. proportional to groove velocity. However, the variable amplitude creates serious problems at both frequency extremes. For the ten octaves existing between 20Hz and 20KHz, the variation in amplitude is 1024 to 1! If 1KHz is taken as a reference point to establish nominal cutter amplitude modulation, than at low frequencies the amplitudes are so great that cutover occurs. At high frequencies the amplitude becomes so small that acceptable signal to noise ratios are not possible - indeed, if any displacement exists at all. So much for constant velocity.

Looking at Figure 2.11.2b, two new observations are seen with regard to constant amplitude. Amplitude is constant with frequency (which corrects most of the ills of constant velocity), but the maximum slope varies directly with frequency, i.e., groove velocity is directly proportional to frequency. So now velocity varies 1024 to 1 over the audio band - swell! Recall that magnetic cartridges are constant velocity devices, not constant amplitude, so the output will rise at the rate of +6dB/octave. (6dB increase equals twice the amplitude). To equalize such a system would require 60dB of headroom in the preamp - not too practical. The solution is to try to get the best of both systems, which results in a modified constant amplitude curve where the midband region is allowed to operate constant velocity.

The required RIAA (Record Industry Association of America) playback equalization curve (Figure 2.11.3) shows the idealized case dotted and the actual realization drawn solid. Three frequencies are noted as standard design reference points and are sometimes referred to as time constants. This is a carryover from the practice of specifying corner frequencies by the equivalent RC circuit ($t=RC$) that realized the response. Conversion is done simply with the expression $t = 1/2\pi f$ and results in time constants of 3180uS for f_1 , 318uS for f_2 , and 75uS for f_3 . Frequency f_2 is referred to as the *turnover* frequency since this is the point where the system changes from constant amplitude to constant velocity. (Likewise, f_3 is another turnover frequency). Table 2.11.1 is included as a convenience in checking phono preamp RIAA response.

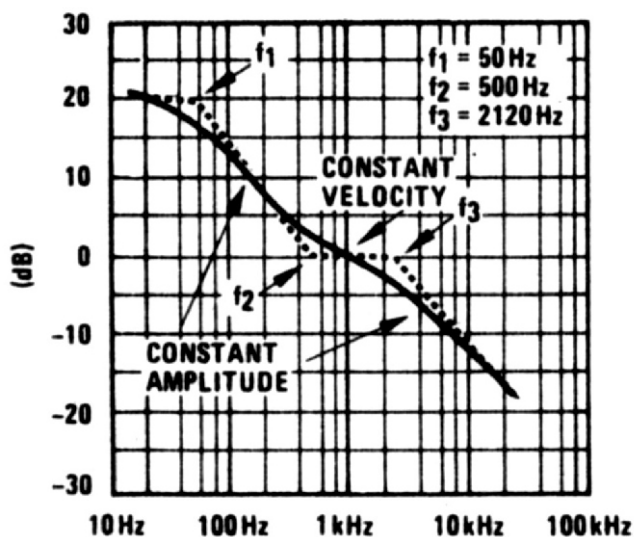


FIGURE 2.11.3 RIAA Playback Equalization

Hz	dB	Hz	dB
20	+19.3	800	+0.7
30	+18.6	1k	0.0*
40	+17.8	1.5k	-1.4
50	+17.0	2k	-2.6
60	+16.1	3k	-4.8
80	+14.5	4k	-6.6
100	+13.1	5k	-8.2
150	+10.3	6k	-9.6
200	+8.2	8k	-11.9
300	+5.5	10k	-13.7
400	+3.8	15k	-17.2
500	+2.6	20k	-19.6

TABLE 2.11.1 RIAA Standard Response

2.11.3 Ceramic and Crystal Cartridges

In contra-distinction to the constant velocity magnetic pickups, ceramic pickups are constant amplitude devices and therefore do not require equalization, since their output is inherently flat. Referring to Figure 2.11.3 indicates that the last sentence is not entirely true. Since the region between f_2 and f_3 is constant velocity, the output of a ceramic device will drop 12dB between 500Hz and 2000Hz. While this appears to be a serious problem, in reality it is not. This is true due to the inherently poor frequency response of ceramic and restriction of its use to lo-fi and mid-fi market places. Since the output levels are so large (100mV - 2V), a preamp is not necessary for ceramic pickups; the output is fed directly to the power amplifier via passive tone (if used) and volume controls.