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APPLICATION BULLETIN
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OUTPUT SPECTRUM AND POST-LPF DESIGN OF THE PCM1710

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This application provides an analysis of the PCM1710's output spectrum and data from actual use. In addition, a sample design of a post-low-pass filter for the PCM1710 and test measurements are presented for the user's reference.

INTERNAL LOW-PASS FILTER

The PCM1710 incorporates a low-pass filter to remove oversampled high-frequency spectrum noise. The equivalent circuit of this internal low-pass filter is shown in Figure 1. Figures 2 and 3 show the frequency response of the filter. As can be seen in Figure 3, the filter has no suppression effect on frequencies lower than about 100kHz.

DIGITAL FILTER

The PCM1710 also incorporates a digital filter. The attenuation level of this digital filter is –62dB in the stop-band, and its frequency response is shown in Figure 4.

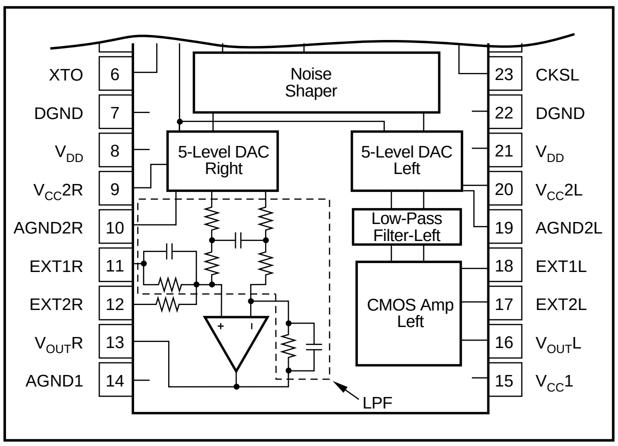

FIGURE 1. Low-Pass Filter Equivalent Circuit.

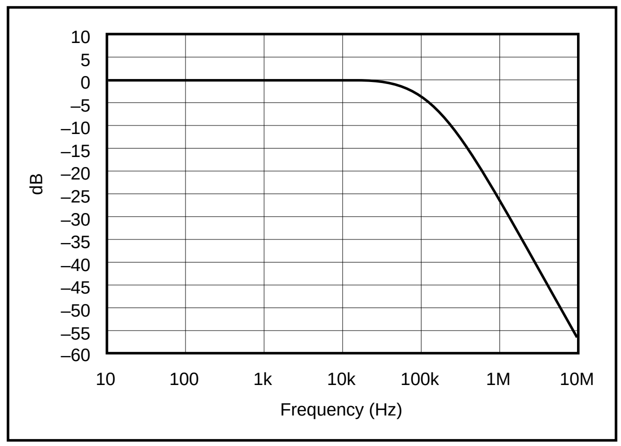

FIGURE 3. Low-Pass Filter Frequency Response (10Hz ~ 10MHz).

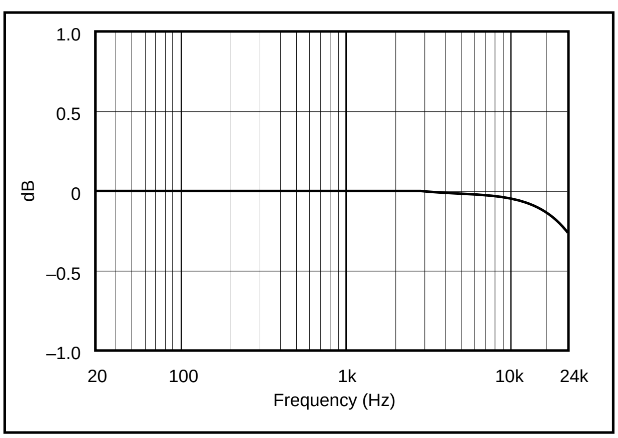

FIGURE 2. Low-Pass Filter Frequency Response (20Hz ~ 24kHz, Enlarged).

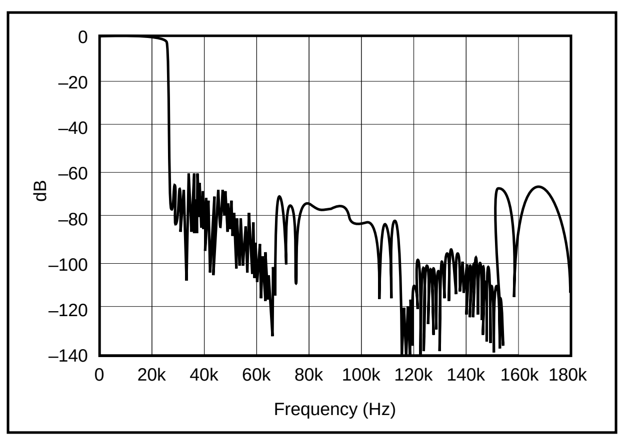

FIGURE 4. Frequency Response (Normal Mode, De-Emphasis OFF).

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The spectrum from 1FS to 8FS, the result of oversampling, is suppressed by this digital filter, but the output spectrum also includes a residual noise spectrum outside the audio band below –62dB.

OUTPUT SPECTRUM MEASUREMENTS

Figures 5 and 6 show the unfiltered output FFT spectrum measurements of the PCM1710. The output here is of signal frequency 20kHz, at an output level of full scale (0dB), and the measured bandwidth is 100kHz. From this data, one can see the aliasing spectrum at 24.1kHz (44.1k – 20k) and the noise boost curve resulting from noise shaping.

The spectrum level at 24.1kHz is suppressed to the –62dB level by the digital filter.

Figures 7 and 8 show the FFT spectrum analysis of the direct output of the PCM1710, this time with the signal frequency at 1kHz and the output level at –60dB, with a measured bandwidth of 100kHz. From this data, it is apparent that the low-level quantization noise spectrum of the PCM1710 is being distributed outside the audio band.

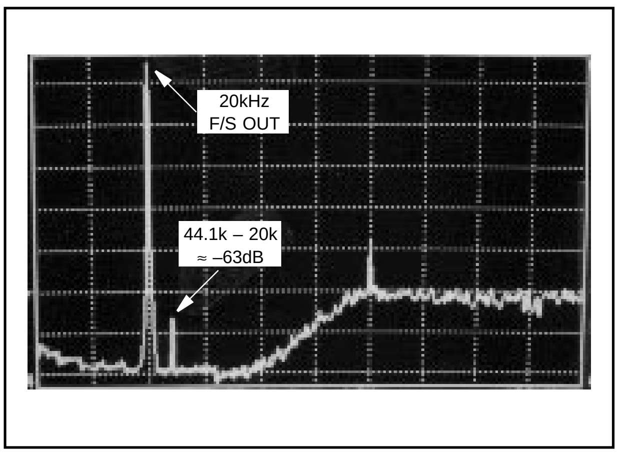

FIGURE 5. Unfiltered 0dB, 20kHz, 256fs Response.

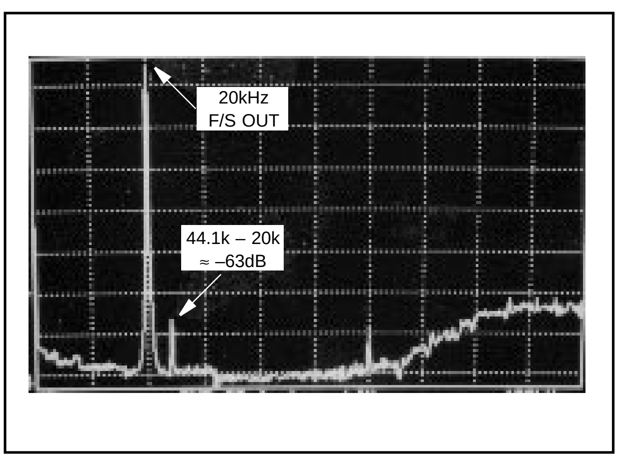

FIGURE 6. Unfiltered 0dB, 20kHz, 384fs Response.

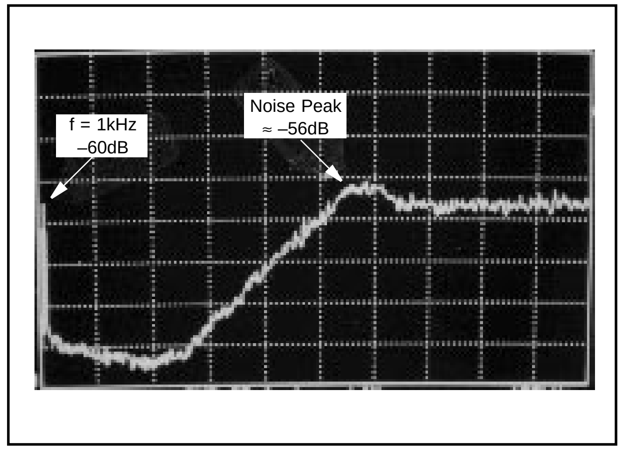

FIGURE 7. Unfiltered –60dB, 1kHz, 256fs Response.

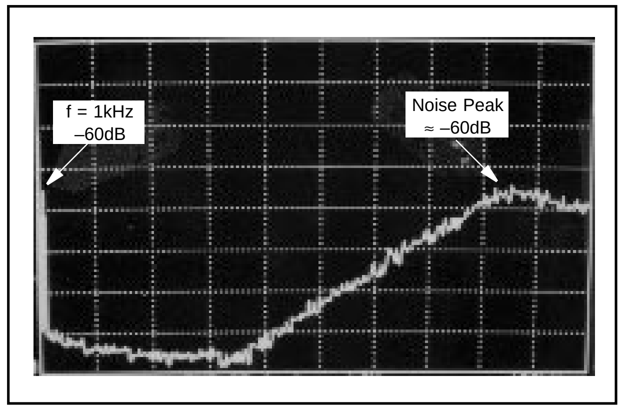

FIGURE 8. Unfiltered –60dB, 1kHz, 384fs Response.

POST LOW-PASS FILTER CONSIDERATIONS

In an actual application, the PCM1710 requires a post low-pass filter to suppress the noise spectrum outside of the audio band. The response of a post low-pass filter directly affects overall THD+N versus signal frequency response. Ideally, the aforementioned 24.1kHz spectrum should be suppressed by more than 96dB by the low-pass filter, but in actual practice, the low-pass filter response is ultimately determined by the policy of the designer with respect to sound quality and cost. (However, the guaranteed THD+N values for the PCM1710 data sheet are obtained using an 11th order 20kHz low-pass filter.)

Next we show examples of post low-pass filter circuits derived from a third-order active filter in Figure 13, and a gain-adjustable second-order active filter in Figure 19. It is impossible to suppress a 24.1kHz spectrum with these low-pass filters, but they are effective in suppressing the component outside the audio band generated by noise shaping. With these filters, it is possible to obtain a better THD+N versus signal frequency response than are obtainable with direct output.

The overall response of a third-order low-pass filter is shown in Figure 14, and Figure 20 shows the overall response of a gain-adjustable second-order low-pass filter.

OUTPUT SPECTRUM MEASUREMENTS

Third-order active low-pass filter

Figures 9 through 12 show measurements of the output spectrum using a third-order low-pass filter. The conditions for each measurement are the same as for Figures 5 through 8. From these we can see the suppression affect on the out of audio band noise.

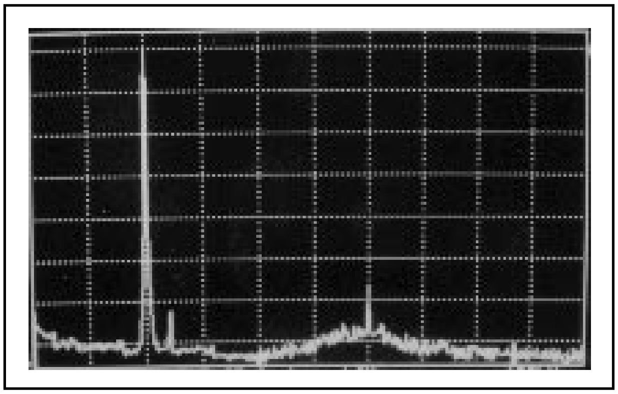

FIGURE 9. 0dB, f = 20kHz, 256fs Third-Order Low-Pass Filter ON.

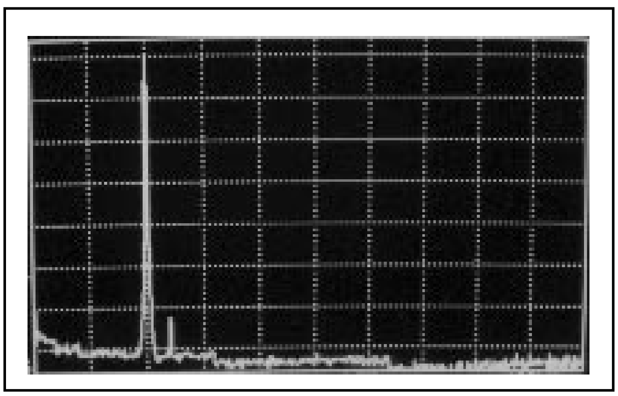

FIGURE 10. 0dB, f = 20kHz, 384fs Third-Order Low-Pass Filter ON.

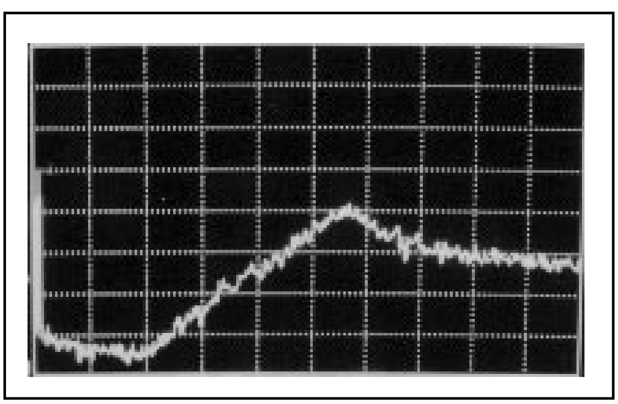

FIGURE 11. –60dB, f = 1kHz, 256fs Third-Order Low-Pass Filter ON.

Gain-equipped Second-order Active Low-Pass Filter

This low-pass filter has a gain of 10k/5.6 ≈ 1.78x, which will increase the 1.13Vrms (3.2Vp-p) output of the PCM1710 1.78 times to approximately standard 2Vrms output.

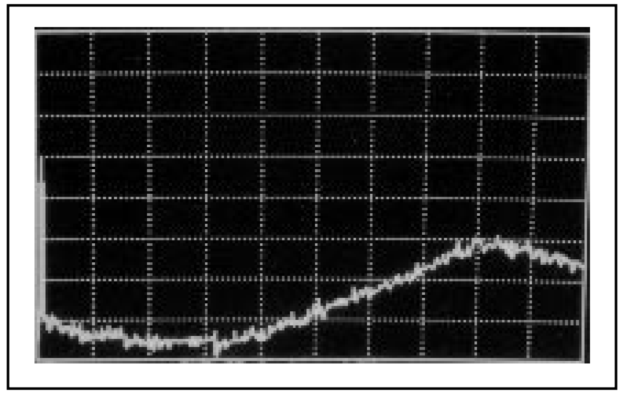

FIGURE 12. –60dB, f = 1kHz, 384fs Third-Order Low-Pass Filter ON.

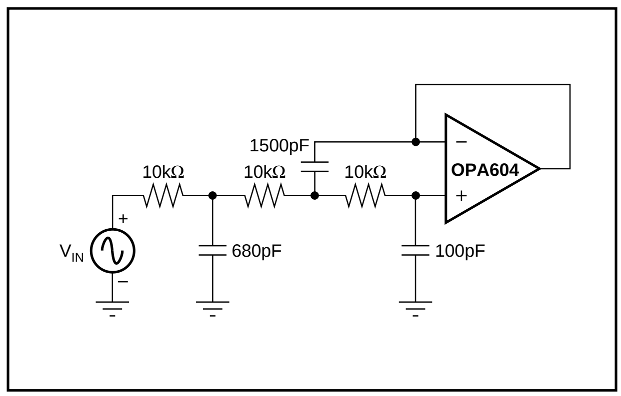

FIGURE 13. Three Pole Low-Pass Filter Schematic.

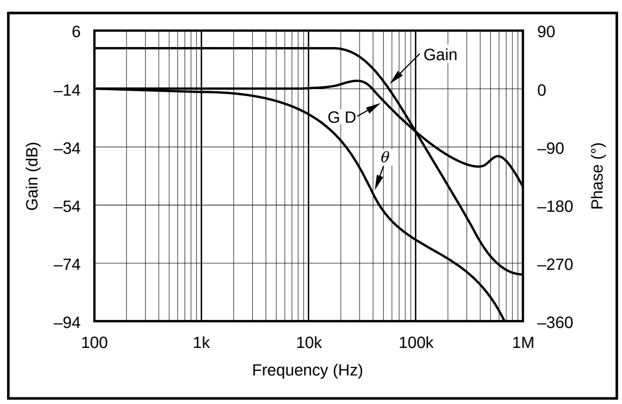

FIGURE 14. Three Pole Low-Pass Filter, Temperature = 27.

Figures 15 through 18 show the output spectrum using the gain-adjustable second-order active low-pass filter. The measurement conditions for each are the same as previously stated.

MEASUREMENTS OF THD+N VERSUS SIGNAL FREQUENCY

Figure 23 shows THD+N versus signal frequency response for the following conditions:

- Direct output, THD meter, 30kHz Low-Pass Filter ON
- Third-order low-pass filter output/THD meter, 30kHz Low-Power Filter ON
- Gain-adjustable second-order low-pass filter output/THD meter, 30kHz Low-Pass Filter ON
- Eleventh-order, 20kHz low-pass filter output (EIAJ method)

The reason the measurements differ for each set of conditions in Figure 23 is due to the size of the +N (out of audio band noise) component of the THD+N measurement. Figures 21 and 22 show the spectrum for condition set (d).

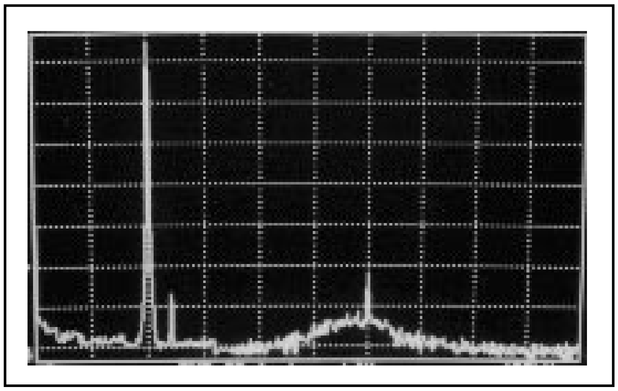

FIGURE 15. 0dB, f = 20kHz, 256fs, Second-Order Low-Pass Filter.

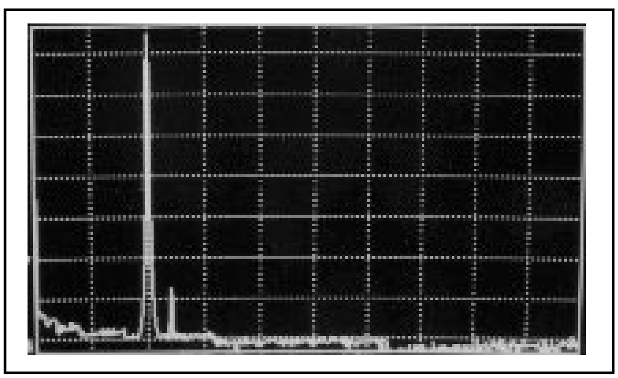

FIGURE 16. 0dB, f = 20kHz, 384fs, Second-Order Low-Pass Filter.

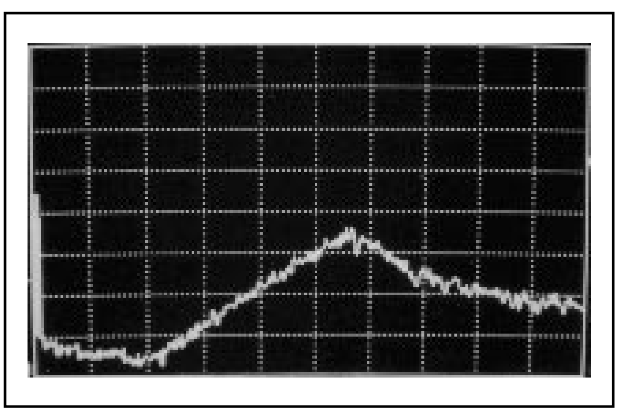

FIGURE 17. Second-Order Low-Pass Filter, –60dB, 1kHz 256fs.

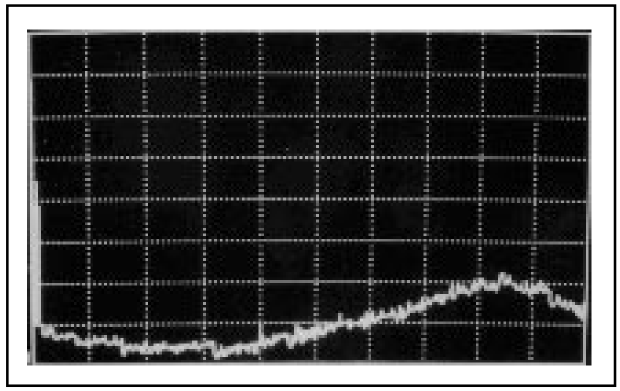

FIGURE 18. Second-Order Low-Pass Filter, –60dB, 1kHz 384fs.

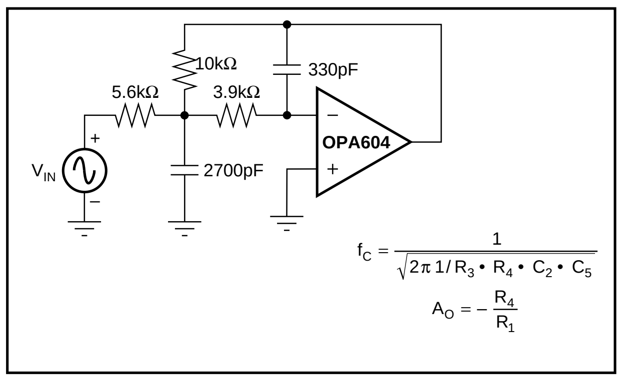

FIGURE 19. Second-Order Low-Pass Filter Schematic.

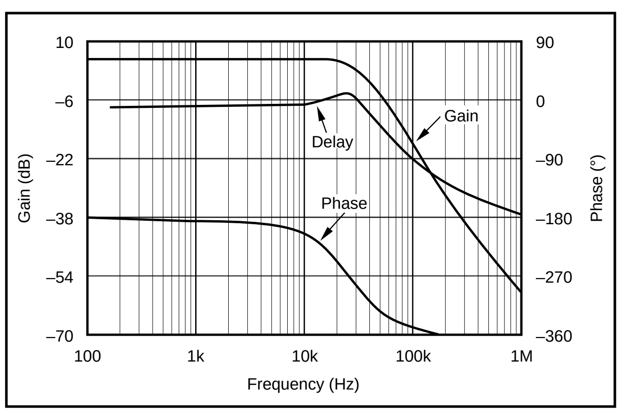

FIGURE 20. Two Pole Low-Pass Filter, Temperature = 27.

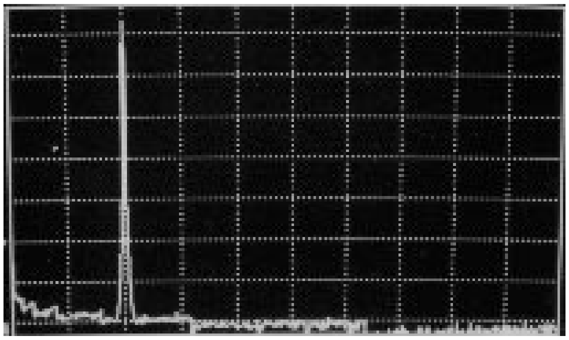

FIGURE 21. 0dB, f = 20kHz, 256/384fs, 20kHz Low-Pass Filter.

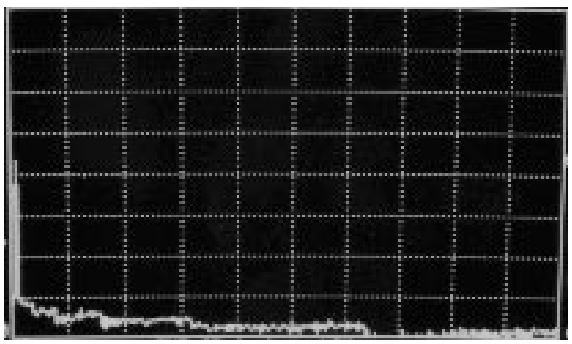

FIGURE 22. –60dB, f = 1kHz, 256/384fs, 20kHz Low-Pass Filter.

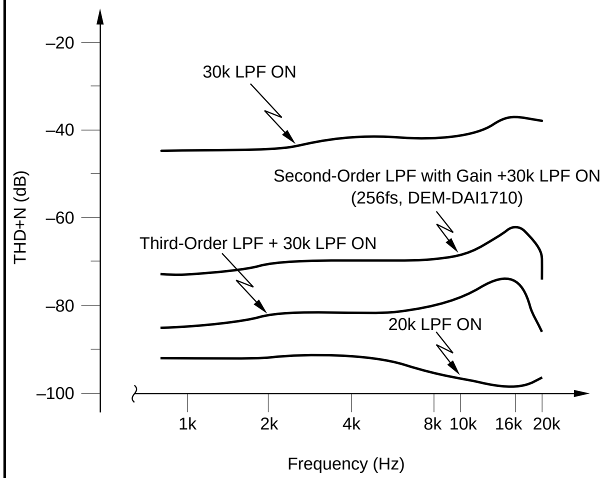

FIGURE 23. THD versus Low-Pass Filter Performance.