DENON ALPH

I. **Prologue** In 1972, DENON became the first in the world to develop a practical PCM recorder. Ten years later, the first CD appeared on the market. And today, digital audio has become an indispensable part of our daily lives. In one remarkable instant, a host of problems associated with analog records were solved: noise, phase characteristics, wow and flutter, modulation noise, deviations in frequency characteristics, and so on, have been relegated to history. A new problem, however, occurred. When digital audio signals are recorded onto a CD at their sampling frequency (fs) of 44.1 kHz, the band above fs/2 is cut and the delicate sonic nuances below the LSB are lost because of the 1 6-bit quantization. Rather than attempting to recapture the sound above 20 kHz, DENON engineers have concentrated their energies on solving the problem of quantization noise which affects sound quality within the audible frequency band. In recent years, the recording industry has begun to produce high-bit recordings using 20-bit recorders. The DENON label, too, has already started producing 20-bit recordings of **their own.** Now DENON's hardware engineers have devoted themselves to tackling the biggest challenge in digital audio technology, the minimization of quantization noise. The fruit of their endeavors is the ALPHA processor, which is capable of reproducing 1 6-bit digital audio sources with 20-bit sound quality.

II. **Digital Audio's Destiny** All sound in the natural world is analog. One could say it contains unlimited sampling frequencies and numbers of bits. When this sound is digitized, anything below the lowest levels expressed in the Least Significant Bit (LSB) is rounded off or otherwise processed and lost. The recorded sound can be reproduced only in the form of a staircase

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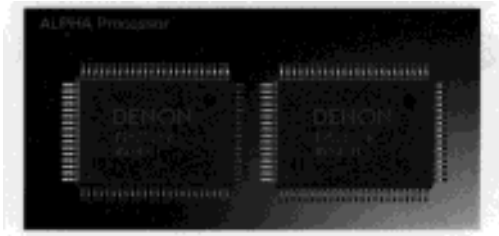
quantization distortion (Fig. 1). When the waveforms for even the delicate low-level signals ("a" in Fig. 2) or the high-level, lowfrequency signals (')" in Fig. 2) are smooth like low-pitched signals, the top and bottom curves of the waveform still take on a staircase form, generating considerable quantization



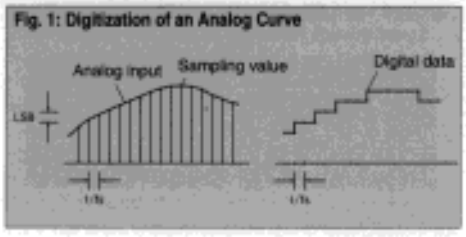


Fig. 1: Digitization of an Analog Curve

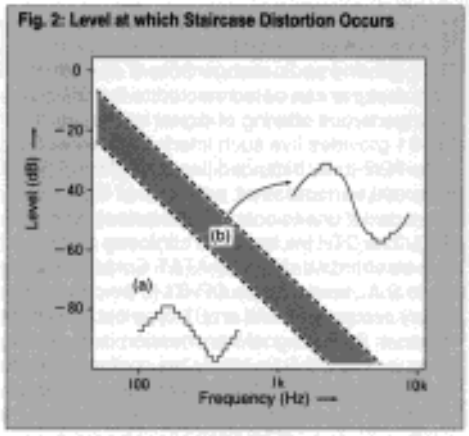


Fig. 2: Level at which Staircase Distortion Occurs

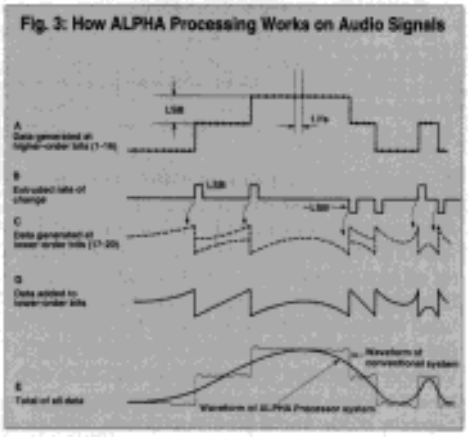
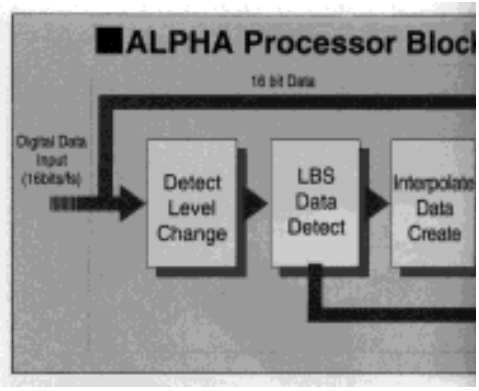


Fig. 3: How ALPHA Processing Works on Audio Signals

distortion.

III. **ALPHA Process ng** ALPHA processing is the world's first technical formula for reproducing an analog waveform from the reproduction of 1 6-bit data in 20-bit quality. The ALPHA processor interpolates the digital data recorded on a CD and reproduces it in a waveform that is very close to the way these musical signals would look in a natural analog waveform. We will explain in more detail how this principle works: First of all, the data reproduced from a CD is input as is in its 1 6-bit staircase form to the ALPHA processor, as shown in waveform (a) of Fig. 3. The processor then extrudes the rate of change in 1 LSB, whether positive or negative, from the portions of waveform (a) where a change in the data has occurred and produces waveform (b). Next,



the ALPHA processor uses its lower-order bit data generator to produce data for the four

lower-order bits, 17 ~ 20, that should normally exist below the 16 bits as shown in waveform (c). The result is waveform (d), where lowerorder bit data for each 1/16 LSB point of change is generated. Finally, the higher-order bits of waveform (a) are added to waveform (d), producing the synthesized waveform shown in waveform (e). This waveform thus reflects the smooth 20-bit oversampled data that is reproduced with high sonic clarity. Quantization distortion did not exist in sound reproduced from analog sources. Since this noise includes much high-harmonic distortion, it pierces the ears and can be very damaging. Quantization noise cannot be suppressed by adjusting the cutoff characteristics of the digital filter. It is also impossible to adjust the filter's characteristics based on the frequency of the original signal. Quantization noise is also unpreventable because the number of bits for quantization is

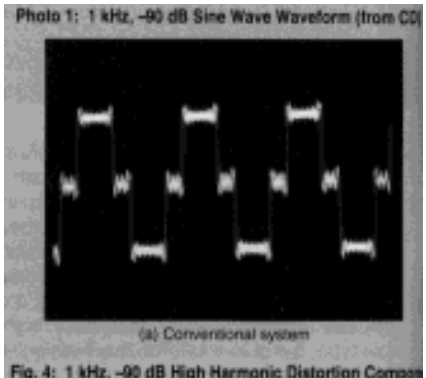


Photo 1: 1 kHz, -90 dB Sine Wave Waveform (from CD

(a) Conventional system

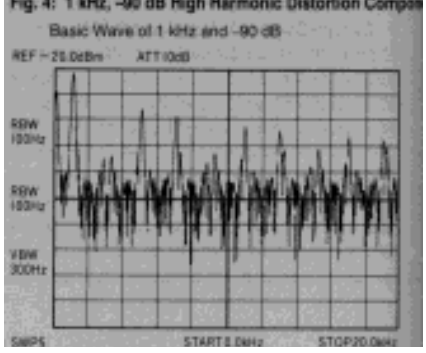
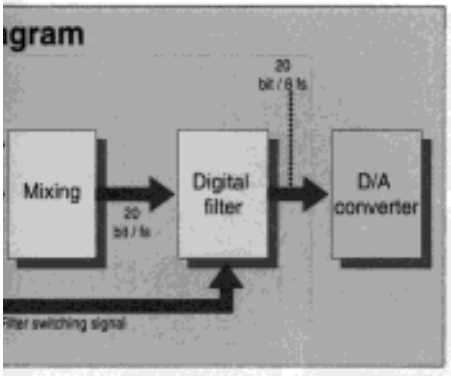


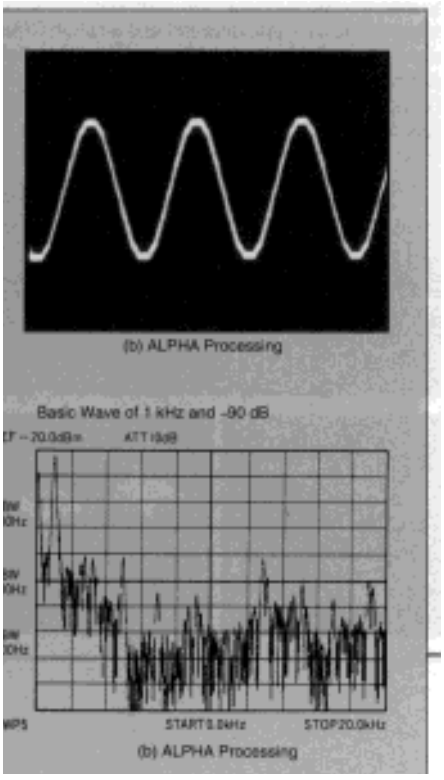
Fig. 4: 1 kHz, -90 dB High Harmonic Distortion Compos

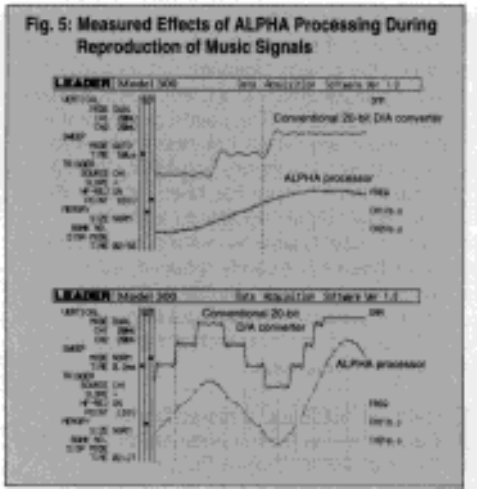
A PROCESSOR



sufficient for low-level and low-frequency signals to oduce a satisfactory S/N resolution. When filter cutoff haracteristics especially are insufficient, modulation oise occurs when image components of greater than /2 make an aliasing.

V. **Improvements in Performance from ALPHA Processing** In Photo 1, the improvement from the staircase waveform of conventional systems to the smooth waveform produced by ALPHA processing is clearly visible. In the 1 kHz example, a sine wave can be produced even with a—90 dB waveform. Next, as shown in Fig. 4, 1 kHz distortion in the FFT data has been improved. High-harmonic distortion has been reduced to less than onetenth the level of conventional systems. Audio signals which have been reproduced as conventional 1 6-bit data and which could only be output in 1 LSB staircase envelopes are now

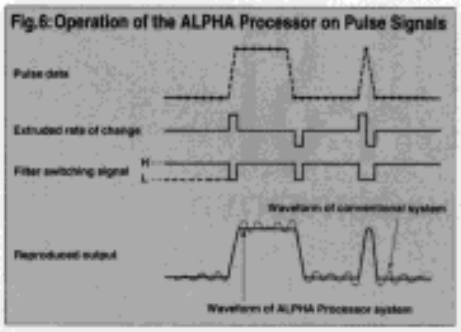


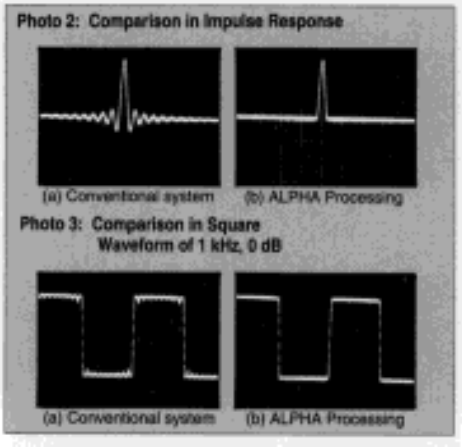


reproduced in smooth waveforms as though they were originally from 20-bit data. Of course, the difference between conventional and ALPHA processed signals is very audible. The annoying quantization noise has been reduced, and the sound that is reproduced is quiet, free of audible distortion, and enjoys a superior S/N ratio. Low-pitched signals, too, sound rich and exhibit considerable resilience. The reduction in quantization distortion thanks to ALPHA processing is in sufficient evidence even when combined with dither and error feedback signals that have been added to a recording.

V. **Data Examination Function to Search Out and Reproduce the Original Signal** The ALPHA processor has one more intelligent capability, namely a function that attempts to identify the type of signal-either pulse or musical-recorded on a CD. During recording, the unneeded band above fs/2 is cut, and in the case of musical data, this band is shut out. Since the original source must be correctly interpolated when it is reproduced via the D/A converter, it passes through an ideal low-pass filter (a sharp roll-off filter) that decreases sharply. In the case of pulse data recorded on test CDs whose signals are digitized without passing through an A/D converter, the signals are reproduced without the use of a filter. In other words, even if a CD which has been recorded using a different method is played, the ALPHA processor includes an Automatic LowPass Filter Harmonic Adjustment feature-the world's first of its kind-which is able to identify the type of incoming signal and automatically select the shut-out band. Because the filter automatically varies according to the incoming data, reproduction of musical data is remains flat very close to the super-high frequency of fs/2. And in the case of pulse data reproduction, the pass band is widened so that the impulse

response can be reproduced as intended without ringing (Fig. 6 and Photo 2). The DA-ST's digital filter incorporates a device (an SM-5824AP by NPC) that is capable of multi-bit input, in order for the ALPHA processor to process data for 20-bit quality reproduction. The amount of attenuation at 8 fs is-117 dB and the ripple within the pass band is +/-0.00002 dB. Only digital filters for professional recording use enjoy such specifications.





VI. **Epilogue** The audible result of ALPHA processing is truly breathtaking; it conveys an awe-inspiring sense of presence, as though the instruments were actually there in front of you, though invisible. All musical components sound smooth and supple, even with the volume raised. A low-level sound of-90 dB, for example, would be the fading resonances of a piano note after it had been struck, or the higher harmonics heard around the sound of a violin being played. They are all heard with a striking realism at all volume levels. Twenty years following the advent of the first practical PCM recorder, the ALPHA processor brings us the world's first technical solution to the reproduction of analog-quality waveforms from digital sound sources. Thanks to ALPHA processing, digital recordings sound as natural as the analog recordings did, only this time with the attendant noise removed.