SIDE VIEW

Integrating Sony's Audio, Electronic Circuit, and Software Technologies

The World's First Digital Noise Canceling Function

Noise canceling headphones reduce ambient noise such as the low rumbling of the engine in an airplane cabin or subway train and provide a quiet listening environment. Sony has now succeeded, for the first time in the industry, in creating a digital implementation of the signal processing that forms the core of that functionality. What has changed due to this digital implementation? This article investigates this question and introduces Sony's headphone technology.

Introduced at CES International this January

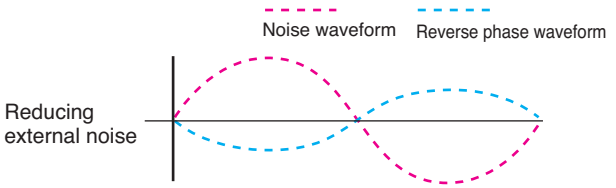
Digital noise canceling headphones "MDR-NC500D"

Main features

- The industry's first digital implementation of a noise cancellation function*1, and reduction of ambient noise by approximately 99%*2
- Sony's AI noise canceling function, which analyzes the ambient noise and automatically selects the optimal noise reduction mode
- Inclusion of a digital equalizer that applies compensation to the playback signal using digital signal processing and creates superb audio quality with realism

*1: According to Sony's research as of March 2008
*2: When comparing not wearing headphones in the Sony stipulated simulated airplane environment to using noise canceling mode A.
A total noise suppression of 20 dB (using Sony's test methods) corresponds to a 99% noise reduction in audio energy.

Figure 1 Principles of Noise Cancellation



The sound at the user's ears is monitored continuously with a detection microphone built into the headphones. This microphone output signal (A) is converted to digital and sent to the DNC software engine (signal processing block). At the same time, after converting to digital, frequency characteristics adjustment is applied to the audio source signal (B) input to the input plug and that signal is input to the DNC software engine. The DNC software engine subtracts the audio source signal (B) from the sound at the user's ears (A). The noise signal that must be cancelled is extracted by taking this difference. The phase of this signal is then inverted and the result is added to the audio to create signal (C). Noise cancellation at the user's ear is then implemented by playing back this signal (C).

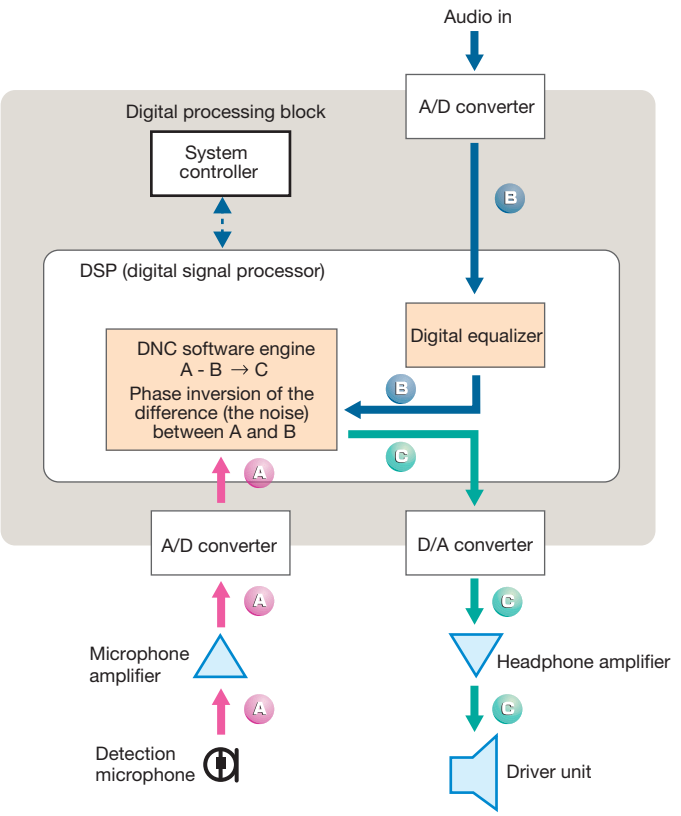


Figure 2 MDR-NC500D Noise Canceling Headphone Internal Block Diagram

DSP Technology has Caught up with Audio Technology

Why had this product not been implemented in digital yet?

Noise cancellation cancels noise by analyzing the ambient noise and generating a reverse phase (inverted waveform) sound. (See figure 1.) The important point here is how quickly and correctly this phase inversion can be performed. For performing these calculations, previous DSPs were unable to exhibit a clear superiority over analog processing. Furthermore, their power consumption was excessive for portable equipment.

The situation has, however, changed. In the context of technological advances such as the increasing functionality of cellular phones, Sony's device technology has evolved rapidly. Equipment in which audio and DSP technologies collaborate has matured. Then, two years ago, we formed a team consisting of audio design, electronic circuit design, and software design engineers and started a full-scale development effort towards digital noise canceling headphones.

Implementation is Possible Because it is Digital

(1) Significant improvement in noise cancellation

Figure 2 shows the internal block diagram of the MDR-NC500D.

To describe the processing simply, first the sound (A) that arrives at the user's ear is subtracted from the audio source signal (B) to extract the noise signal that leaks into the inside of the headphone from the outside environment. With this signal, a reverse phase sound has been created and cancellation is achieved by playing back this signal along with the audio signal.

However, since there is a time lag between the signal created for cancellation and the audio source signal, if the reverse phase sound is simply issued, feedback (a sound with a peak due to resonance) will occur. Therefore a filter circuit is used to remove the sound in the high-frequency band that is the cause of this feedback.

There were, however, problems with the filtering precision when analog circuits were used. When several types of filtering circuits were combined to increase the precision, the circuit was saddled with the problem that inversely, noise increased. By replacing the filter circuit with the Sony DNC (digital noise cancellation) software engine, Sony was able to achieve precise filtering and increase performance significantly.

(2) Achieving a balanced sound

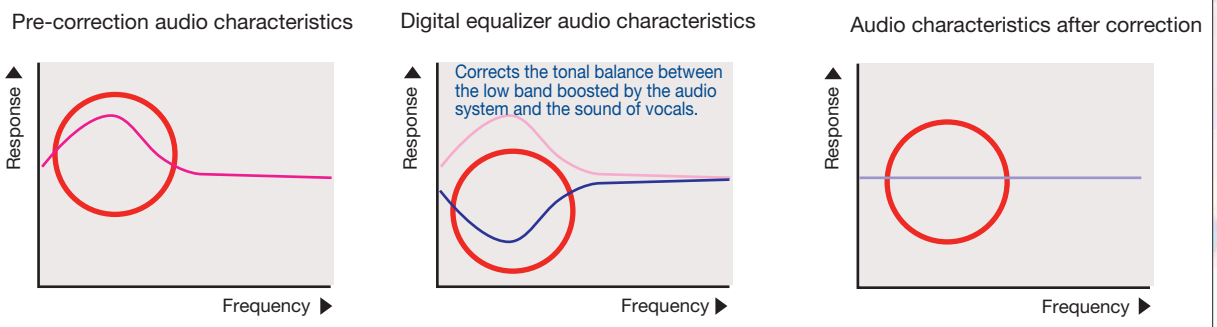
What sort of sound do we perceive as "noise"? For example, consider a bus driving over a bump with a thud. The chassis is distorted, pressure changes occur within the bus itself, and the riders feel pressure and vibration. Actually, this is the noise that should be cancelled.

While this is also the case when an airplane experiences sudden pressure changes, these changes in sound pressure (air pressure) in the low-frequency band are 10 to 100 times greater than the sound pressure level changes in the audio signal itself.

Without the power required to push back against these high-amplitude low-frequency signals, that is, if the sound pressure cannot be created, we could not hope for a pleasant listening experience. Therefore, noise canceling headphones are tuned to have high sensitivity (electric to audio conversion efficiency) in the low-frequency band. This is a major difference compared to normal high-fidelity headphones.

There is, however, a problem. Since the sound to be reproduced from the audio source does contain these frequencies, there is a tendency

Figure 3 Audio Compensation that Suppresses Low Band Expansion



for the low-frequency range to be emphasized. This can result in an unbalanced sound in which, for example, the vocals can be pushed into the background and the bass seems to be out in front. To resolve this issue, Sony implemented a digital equalizer in the first stage of the noise canceling block. This results in a signal-to-noise ratio that would not be possible with an analog equalizer and provides precise equalization to create a natural tonal balance. (See figure 3.)

(3) Handles a wide range of noise environments – AI noise cancellation function

Sony also focused on the fact that the noise cancellation effect differs depending on the noise environment. Sony isolated representative noise environments ((1) airplane cabins, (2) trains and buses, and (3) offices) and, through extensive research, succeeded in developing three types of noise cancellation optimized for each of these environments. With just a press of a button, the MDR-NC500D analyzes the noise in the current environment and automatically selects the optimal mode.

Our Strength was Our Company-Internal Resources

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It is well known that most of the noise in our world is low-frequency noise. In particular, ultralow frequencies of 100 Hz and below are dominant and these are often perceived as a sense of pressure or vibration.

Actually, though, it was through the development of the MDR-NC500D that I first became aware of these sensations. When the low-frequency noise is cancelled, not only does the environment become quiet, but the feelings of oppressiveness and vibration also disappear. This renewed my confidence in the performance of these digital noise canceling headphones.

It was about 15 years ago that I first saw a company internal prototype of a digital noise canceling headphone set. Although this unit was research based, I remember that the audio quality has been superb ever since that time. That demo, however, was a large system that consisted of 3 or 4 racks mounted on a cart.

It is, of course, due to the increasingly high performance of electronic devices that these degrees of miniaturization, weight reduction, and even further improvements in noise cancellation performance have been achieved. In addition to those factors and the miniaturization and increased speed of electronic circuits, the elegant high-performance processing that is now possible in software is another large factor. It turns out that the people who were in charge of the areas related to the digital signal processing were engineers who have previously specialized in designing high-fidelity audio amplifiers. This is one of Sony's great strengths: that when one wants to accept the challenge of new theme, there will be solid resources available within the company.

One thing that works to our advantage here is that due to the extensive market penetration of digital music players, such as the Sony "Walkman"* over a long period, there is a strong awareness in the market that the audio quality changes greatly when one switches headphones. It seems that an increasing number of people have become aware of noise canceling headphones while searching for headphones that provide audio quality that matches their preferences. I am hopeful that interest in digital noise canceling headphones will continue to increase in the future.

*: "Walkman" is a registered trademark of Sony Corporation.

What music do we enjoy, and where do we enjoy it? We have accumulated technology and experience by responding to a wide range of needs.

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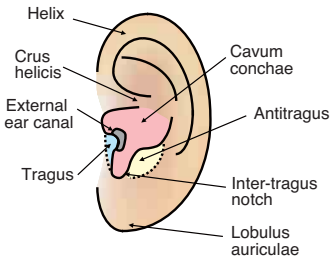
Parts of the Auricle
(The outer parts of the ear excluding the ear canal)



For in-ear headphones, how well the headphones stay in the ear is greatly influenced by the size and shape of the antitragus, by the thickness of the inter-tragus notch, and other aspects of the ear.

Cross section of ear casts showing the inserted state of in-ear headphones (the lower figure shows a closed type in-ear headphone)

What sort of headphones do DJs need?

Once, when a certain record company agreed to use our headphones for monitoring in the recording studio, it took us three years to create the sound. With headphones for listening to music, normally, the headphones are "tuned" so that the sound seems to be coming from the position of the speakers, that is, so that the audio image is distant from the listener. For studio monitoring, however, we were told that it was important that the sound appeared to be close at hand and was heard directly. Rather than creating clarity in the vocals and providing a small amount of reverberation, they wanted first of all to hear the original sound clearly. We learned a lot about the impression of distance in audio from that work. Even within this monitor headphone area, however, DJs have their own specific needs. To smoothly connect two records, they placed the most importance on feeling the beat. This is because they synchronize the beats of the two records to switch over to the second one. Therefore the headphones needed to be tuned to emphasize the low frequencies. Still, if the emphasis was extended too far into the low region, the beat would, inversely, become muddy and harder to hear. Therefore we emphasized through a certain section and then cleanly cut off the frequencies below that. To what extent can the customer's subjective sensory expressions be translated into technological adjustments? This is the point, whatever the type of sound we are trying to create.

We may be something like actors. We have to listen to the same music our customers listen to, and in the same environments. We must ask with what feelings and emotions the customer will listen to this music and adjust our own sensitivities to match. When we do that, we get a hint as to what would be the best sort of sound.

When we were developing the DJ headphones, I went to a club in the trendy Shibuya section of Tokyo every Friday. I suppose I was "clubbing". We would stay up until morning listening to music with the DJs, being introduced to new songs, and having them try our prototypes.

Towards a world of sounds that have not yet been achieved

I am a "second generation ear cast artisan" and now our fifth generation is collecting ear casts. When I find a person with ears whose size or shape is distinctive, I ask them to allow me to take a cast. By now, I have collected over 500 ear casts, although that includes many that are ear hole casts taken for hearing aids.

While the reason for this is to verify how well headphones fit using these ear casts, it turns out that the structure of the headphone ear pad not only affects how the headphones feel, but also is deeply related to the perceived audio quality. If the sound leaks outside the headphones, the low-frequency region will become weaker. Also, while it is presumed that the ear pads themselves cut the high-frequency noise somewhat, since the cancellation signal is generated mainly in the low-frequency region, any instability in the way the ear pads fit can adversely affect the noise cancellation performance.

While the team members who would seem to have the most interest are selected to be ear cast artisans, all audio engineers have an almost excessive interest in ears. If you overhear their conversations, for example "Considering the line of the crus helicis, I think we should make this dimension slightly longer", or "When the antitragus is small, it tends to fall out", and "It is hard to insert since the inter-tragus notch is so narrow", you will find it a world that is incomprehensible to the rest of us.

Between members of a group like this, there will, of course, be no disagreements on sound creation. They are not concerned with what their own favorite sound is, but rather they share the approach of considering what sort of sound would be preferred by this sort of customer, or what sort would be preferred by a teenager. I also enjoy the music teenagers listen to. I learn a lot from the channels my son and daughter listen to. There is also the need for the type of sound in which the singer seems to be murmuring at your ear for the generation raised on the "Walkman". Some users also listen to music as background music for games along with the sound effects. Which is to say that the number of ways of enjoying music is becoming increasingly varied.

I think that there are still many audio areas that cannot be reproduced well on headphones and so I hope to expand the world of headphone sounds while working with many customers. Digital noise canceling headphones could also be used to improve concentration on work or study by cutting the noise present in factory and home environments. I hope to be able to propose a wide range of uses for this technology that we have nurtured, not only in the completed form of the headphone, but in many other forms as well.

We have been collecting ear casts for about 30 years. Yet this represents just one part of the range of possible shapes.
We verify how well a headphone set stays on by attaching our prototypes to an ear cast. For in-ear type headphones, we can cut the ear cast and see where the headphone contacts the ear. We also attach microphones to the ear casts and measure the sound.