How Noise-canceling Headphones Work

Unfortunately for music lovers, many types of ambient sounds can interfere with or even block the sounds coming through their headphones. If you have ever tried to listen to a CD or MP3 player on a plane, then you know the problem well: The roar of the engines makes it difficult to hear what's being piped through the speakers -- even when those speakers are situated in or on your ear. Fortunately, noise-canceling headphones can provide a more enjoyable listening experience.

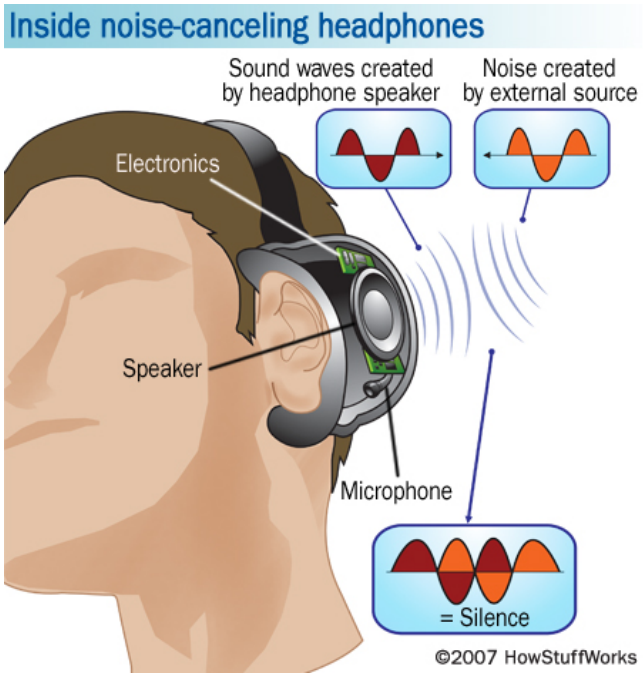
Noise-canceling headphones come in either **active** or **passive types**. Technically speaking, any type of headphone can provide some passive noise reduction. That's because the materials of the headphones themselves block out some sound waves, especially those at higher frequencies. The best passive noise-canceling headphones, however, are circum-aural types that are specially constructed to maximize noise-filtering properties. That means they are packed with layers of high-density foam or other sound-absorbing material, which makes them heavier than normal headphones. The tradeoff of all that extra weight is a reduction in noise of about 15 to 20 decibels (dB). But considering jet engines create 75 to 80 dB of noise inside the aircraft cabin, passive models have some serious limitations. That's where active noise-canceling headphones come in.

Keep Reading Below

Active noise-canceling headphones can do everything that passive

ones can do -- their very structure creates a barrier that blocks high-frequency sound waves. They also add an extra level of noise reduction by actively **erasing** lower-frequency sound waves. How do noise-canceling headphones accomplish this? They actually create their own sound waves that mimic the incoming noise in every respect except one: the headphone's sound waves are 180 degrees out of phase with the intruding waves.

If you look at the illustration below, you can see how this works. Notice that the two waves -- the one coming from the noise-canceling headphone and the one associated with the ambient noise -- have the same amplitude and frequency, but their crests and troughs (compressions and rarefactions) are arranged so that the crests (compressions) of one wave line up with the troughs (rarefactions) of the other wave and vice versa. In essence, the two waves cancel each other out, a phenomenon known as **destructive interference**. The result: the listener can focus on the sounds he wants to hear.



Of course, several components are required to achieve this effect:

- **Microphone** - A microphone placed inside the ear cup "listens" to external sounds that cannot be blocked passively.
- **Noise-canceling circuitry** - Electronics, also placed in the ear cup, sense the input from the microphone and generate a

"fingerprint" of the noise, noting the frequency and amplitude of the incoming wave. Then they create a new wave that is 180 degrees out of phase with the waves associated with the noise.

- **Speaker** - The "anti-sound" created by the noise-canceling circuitry is fed into the headphones' speakers along with the normal audio; the anti-sound erases the noise by destructive interference, but does not affect the desired sound waves in the normal audio.
- **Battery** - The term "active" refers to the fact that energy must be added to the system to produce the noise-canceling effect. The source of that energy is a rechargeable battery.

Using these components, noise-canceling headphones are able to provide an additional reduction in noise of 20 decibels. That means about 70 percent of ambient noise is effectively blocked, making noise-canceling headphones ideal for airline and train travel, open office environments or any other location with a high level of background noise.

While noise-canceling headphones do a good job distinguishing between the audio a wearer wants to hear and the background noise he or she wants to keep out, some people say that they compromise sound quality by muffling sounds. Users can also experience a change in air pressure, although ports built into the ear cup are meant to vent air trapped behind the speakers.

In spite of these tradeoffs, many people would never go back to normal audio headphones. That's because noise-canceling headphones do more than reduce noise. They also help alleviate fatigue when traveling, which can result from exposure to low-frequency noise for an extended

period of time. You can even use noise-canceling headphones if you don't want to listen to another audio source but do want to cancel out background noise. And a little bit of quiet can be music to anyone's ears.

For lots more information on noise-canceling headphones and related topics, check out the links on the next page.

At some point in his or her academic career, a student learns the difference between pure and applied science. Here's the classic definition: Pure science is a method of investigating nature by the experimental method, while applied science is the application of pure science to some practical human purpose. This was an interesting article because it embodied the very essence of applied science. The pure science involves the structure and function of sound waves. The applied science involves how to take that fundamental knowledge and use it to solve a specific problem -- in this case, blocking unwanted noise.

Bose, of course, is a pioneer in developing innovative audio systems. In many ways, Bose could be described as a company dedicated to the pursuit of applied science. Amar Bose, an MIT scientist, founded the company in 1964, taking observational data about sound -- and people's perceptions of sound -- and turning it into useful products. The first of these products was the 901 Direct/Reflecting speaker system, released in 1968. Noise-canceling headphones came later, but they evolved in a similar way, moving from the laboratory bench to the retailer shelf. In fact, as the article explains, Amar Bose first conceived of noise-canceling headphones while on a noisy commercial flight. That image -- of a classically trained scientist trying to solve an

everyday problem, scribbling his thoughts on a cocktail napkin at 35,000 feet (10,668 meters) -- stayed with me throughout my work on this article.

Sources

- Bose Learning Center http://www.bose.com/controller?event=VIEW_STATIC_PAGE_EVENT &url=/learning/index.jsp
- Dennis, Johnnie T. "The Complete Idiot's Guide to Physics." Indianapolis: Alpha Books, 2003.
- Gundersen, P. Erik. "The Handy Physics Answer Book". Canton, MI: Visible Ink Press, 2003.
- Holt, J. Gordon. "Audio basics: A is for ampere," Stereophile. March 1991. http://stereophile.com/reference/62/
- Encyclopedia Britannica 2005, s.v. "headphone." CD-ROM, 2005.
- Encyclopedia Britannica 2005, s.v. "noise." CD-ROM, 2005.
- Fischetti, M. "Reducing a roar," Scientific American. Exclusive online issue. October 2006. http://www.sciamdigital.com/index.cfm?fa=Products.ViewIssuePreview &ARTICLEID_CHAR=4A46FA21-2B35-221B-6561015527D8F570
- "A quick guide to headphones." HeadWize. http://www.headwize.com/articles/hguide_art.htm
- Sems, Marty. "How noise-canceling headphones work," Smart Computing. January 2004. Volume 15, Issue 1.

Stuff You Need to Know:

● Sound waves are similar to water waves. They have compressions that correspond to crests and rarefactions that correspond to troughs.

● Noise-canceling headphones come in either active or passive varieties. Passive noise-canceling headphones use high-density foam or other sound-absorbing material to prevent sound waves from reaching the listener's ears.

● Active noise-canceling headphones add an extra level of noise reduction by actively erasing lower-frequency sound waves. They do this through destructive interference -- creating sound waves that have the same amplitude and frequency as the ambient noise, but are 180 degrees out of phase.

● Good noise-canceling headphones provide a noise reduction of about 80 decibels, enough to block jet-engine noise inside an aircraft cabin.

Now, test your knowledge with these quizzes!

- Noise-canceling Headphones Quiz
- Portable Media Centers Quiz
- Video Glasses Quiz

Check out these image galleries!

- Essential Gadgets Pictures
- Audio Tech Pictures
- iPod Pictures