

*An Advanced Brain Technologies White Paper*



## **The Next Generation Medium For Music-Based Auditory Stimulation:**

**A review of the design and capabilities  
of Apple's iPod and related audio file formats**



Gregory R. Lawrence, Audio Engineer  
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Any comments relating to the material contained in this document may be submitted to:

Advanced Brain Technologies  
5748 South Adams Avenue Parkway  
Ogden, Utah 84405  
United States

Or by email to:

[info@advancedbrain.com](mailto:info@advancedbrain.com)

## Overview

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iListen® is the next generation medium for implementation of The Listening Program® (TLP), the Music-Based Auditory Stimulation™ method developed by Advanced Brain Technologies (ABT). iListen takes the high quality, psychoacoustically modified music found in the Level One and Level One Nature kits (among other products) and puts it in an equally high quality format compatible with Apple's iPod.

Listeners of ABT's line of potential maximizing music can now have it all contained in a single, hand-held player - all accessible with a simple scroll and click! This solution further increases the portability of TLP, improving program compliance and greatly increases the appeal to young listeners. It also removes the issues of inevitable wear and tear that occurs with compact discs, such as scratches and cracks, and removes the possibility for lost discs.

## Choosing a Next Generation Medium

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The selection of a medium that would take ABT's music to a new level in ease of use and effectiveness was guided by the same basic principles on which the company was first founded. For any device to be considered, it must effectively maintain purity and accuracy in the audio signal chain with the same high standard for which TLP has become renowned.

The iPod meets these standards through the same means that a high quality CD player meets them, by incorporating only the highest grade components in their design. The vital points of conversion are in fact fundamentally identical in both the compact disc format and storage-based formats such as the iPod. Each of the formats must faithfully translate the 1's and 0's of binary digital data back into the analog form of electrical pulses. These pulses then need to be amplified to a level sufficient for driving the cones of speakers, which in turn create oscillations in the air for us to perceive as sound.

The iPod's digital to analog converter (DAC) is capable of translating digital

code up to 24 bits in length.<sup>1</sup> This ability exceeds the digital audio standard of 16 bits set by the Compact Disc technology. Once in analog, the signal is then amplified to a maximum output of

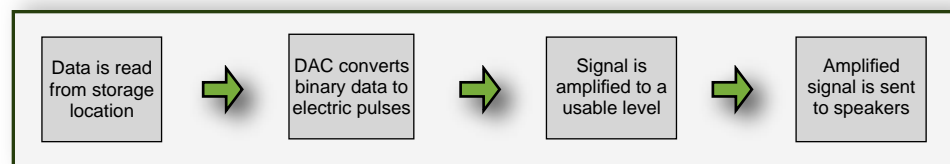


Fig. 1: Basic signal chain for both CD and iPod formats

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<sup>1</sup> Quirk, G. A. *Find out what's really in the iPod.* [www.commsdesign.com/showArticle.jhtml?articleID=177105035](http://www.commsdesign.com/showArticle.jhtml?articleID=177105035). Retrieved April 24, 2008.

30 milliwatts per channel (60ms total).<sup>2</sup> This power output, when coupled with a high quality set of headphones with an appropriate impedance rating, is highly capable of accurately reproducing the full spectrum of sound found in TLP.

## Maximizing the Capabilities of a High Quality Medium

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Ensuring that the iListen® system realized its full potential required that a high quality medium be coupled with a high quality file format. Digital files are created through a sampling technique known as Pulse Code Modulation (PCM), and are communicated in the form of binary code.<sup>3</sup> The common file-types ‘.wav’ and ‘.aiff’ are referred to as uncompressed PCM files. These file types are considered relatively large for use on storage-based players because of limitations relating to the manner in which such files are distributed by content providers and utilized by the end user.

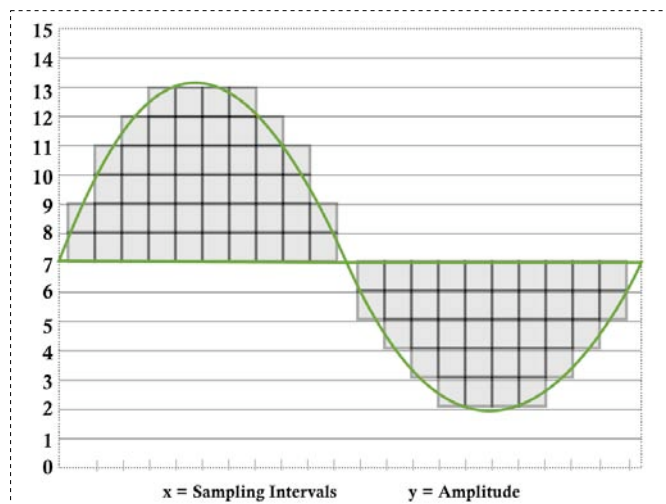


Fig. 2: A visual representation of the PCM sampling process.

iListen incorporates an encoding process known as ‘data packing’ to minimize the amount of storage space required for each file without compromising any of the audio’s integrity. Data packing is commonly referred to as ‘Lossless Encoding’, and the result of such encoding is a bit for bit identical copy of the original PCM file once decoded. This greatly differs from a ‘lossy encoding’ technique such as that used to create the popular ‘MPEG1 Audio Layer 3’ (MP3) file type, which permanently removes selected bits of data.

The lossless data packing scheme employed in iListen first identifies groups of binary data in the PCM code with identical values, such as the seven 0’s at the beginning of the following hypothetical code;

**0000000101100011**

Rather than passing all seven bits, the encoder keeps the first and last 0 plus one bit that marks how many 0’s are in between (in this case five). This method of encoding results in the packed code only requiring three bits of data to send the same information originally covered by seven.

<sup>2</sup> *iPod Frequency Asked Questions*. <http://docs.info.apple.com/article.html?artnum=60920>. Retrieved April 24, 2008

<sup>3</sup> Pohlmann, Ken. *Principles of Digital Audio*. McGraw-Hill, 1995

The decoder then reads the three packed bits and knows to replace the single marked bit with the original 5 in between the first and last, resulting in a bit for bit identical PCM code ready to go to the DAC.

## The Pursuit of Noise-Free Listening

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iListen® provides a major leap forward in the pursuit of noise-free presentation of psychoacoustically modified audio. The 5th generation iPod video (or ‘Classic’) uses a hard disk drive (HDD) means of storing digital audio files, which utilizes a magnetized head to read and write data to a ferromagnetic plate.<sup>4</sup> Reading data using this technology offers dramatically increased isolation of the signal content from unwanted noise that can be introduced at this stage in the signal chain.

This is most evident when comparing the HDD process to that used in other formats such as the CD player, which uses a near-infrared laser to read micro indents on a plastic disk.<sup>5</sup> This laser inherently creates a ‘hum’ noise during scanning that can become introduced into the audio signal.

The 3rd generation iPod Nano (currently used for iListen) uses a flash-based solid state drive (SSD) technology for storage. SSD drives have no moving parts, but rather apply values to cells laid out in a grid by applying voltages assigned for each value (1 and 0 ).<sup>6</sup> No moving parts mean virtually zero noise.

## Confirmation through Analysis

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To confirm that the iListen® system could accurately reproduce the content of The Listening Program® and other ABT music products, testing was performed using a spectrogram for highly accurate frequency analysis. Input fed directly into the spectrogram from iListen is output as a graphical image where black represents zero frequency presence/power and increasingly bright color corresponds to increasingly greater presence/power.

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<sup>4</sup> Hayes, Brian. *Terabyte Territory*. [www.americanscientist.org/template/AssetDetail/assetid/14750](http://www.americanscientist.org/template/AssetDetail/assetid/14750). Retrieved April 25, 2008

<sup>5</sup> Marshall, Brian. *How CDs Work*. [www.howstuffworks.com/cd.htm](http://www.howstuffworks.com/cd.htm). Retrieved April 25, 2008

<sup>6</sup> Armstrong, Lee. *Solid State Drives*. [www.pctechguide.com/31HardDisk\\_SolidStateDrives.htm](http://www.pctechguide.com/31HardDisk_SolidStateDrives.htm). Retrieved April 25, 2008

Figure 3 shows the spectrogram image of an audio signal run through iListen compared to the same signal sent through a high quality CD player. The iListen signal actually maintains a more faithful power response in the high frequencies as compared to the CD's slightly weaker response (as marked by parenthesis). Additionally, the laser hum can be clearly seen at approximately 20 kHz in the CD signal.

Fig. 3: iListen vs. CD spectrogram comparison

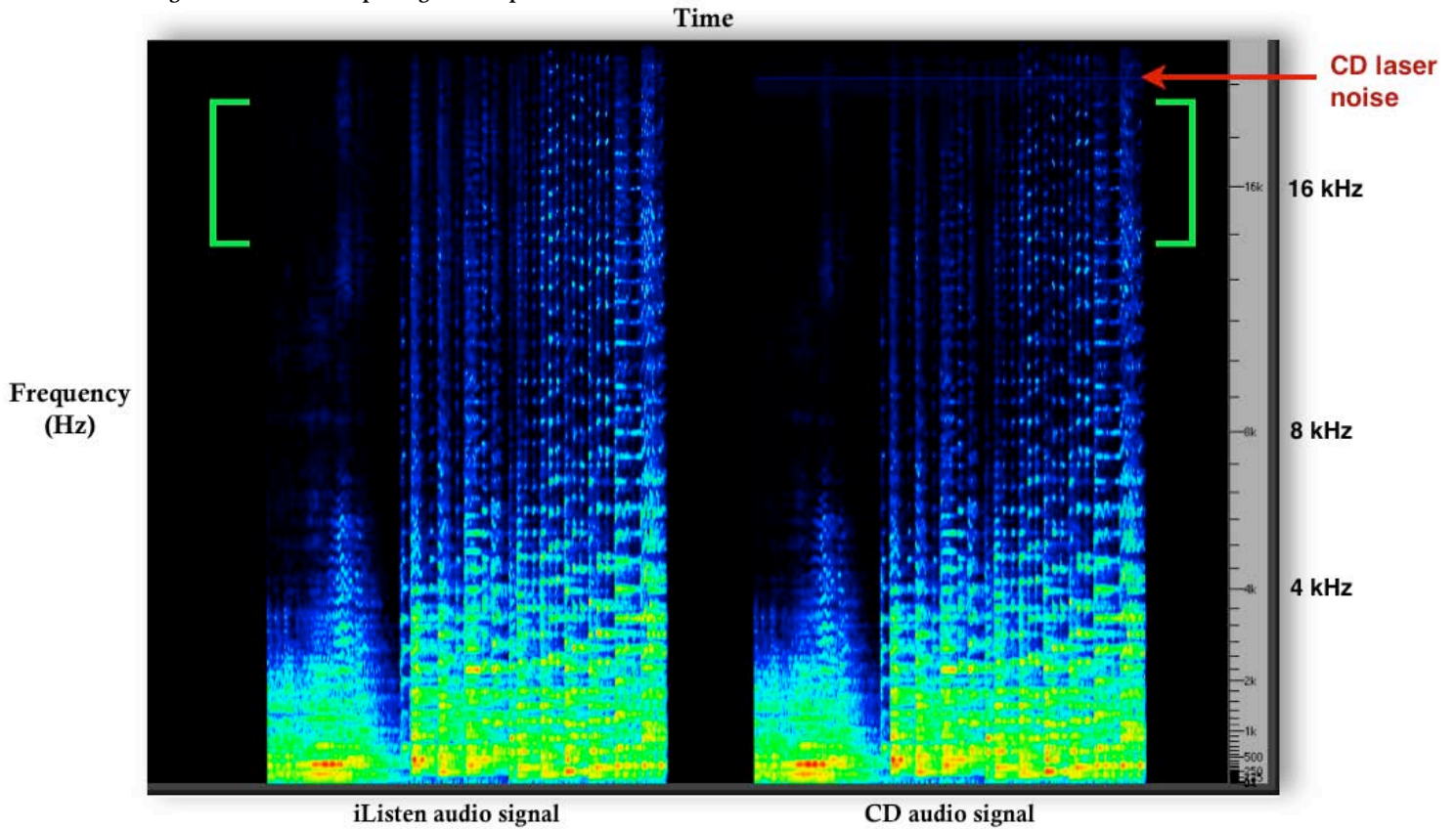


Fig. 4: Encoded file comparison

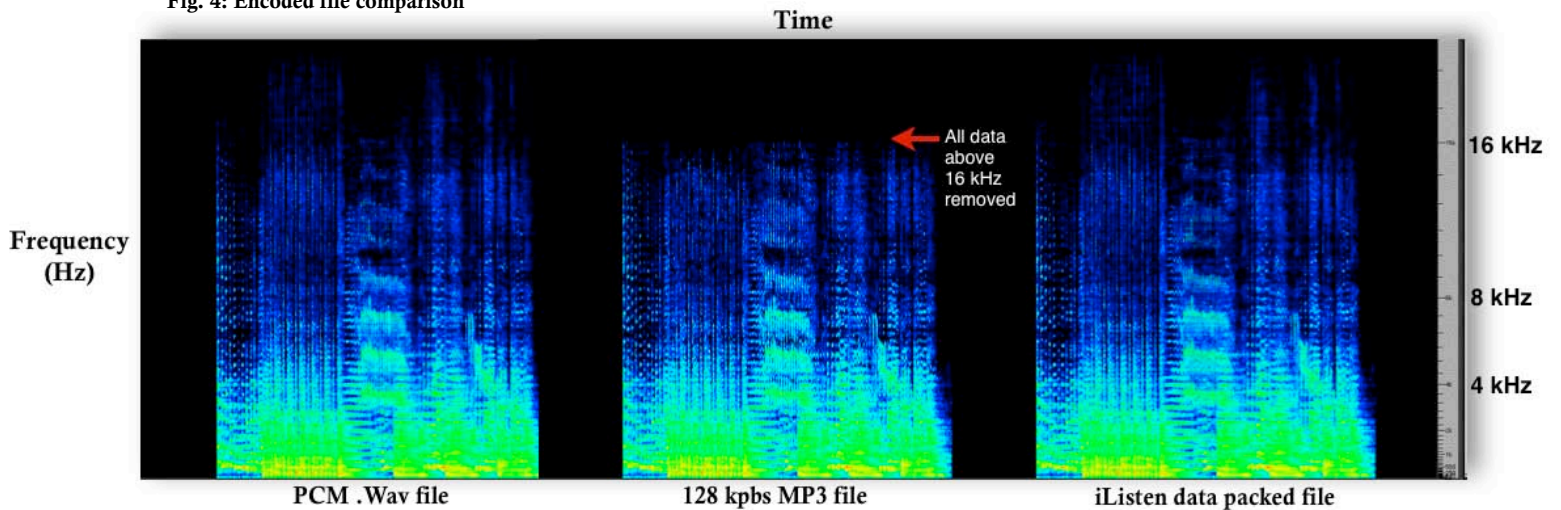


Figure 4 compares the spectral analysis of an unaltered PCM .wav file against a 128 kbps MP3 file (utilizing data compression) and an iListen file (utilizing data packing). The most obvious loss incurred by the data compression encoding is the permanent removal of all information above 16 kHz. Whereas the data-packed iListen file is seen to be identical to the original PCM file.

## Conclusion

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The iListen® system offers major advancements in portability, flexibility, product life, and above all, purity of audio playback. Through these advancements, listeners can now more fully realize the benefits of The Listening Program® using this next generation medium.

## About The Listening Program

The Listening Program® (TLP) is a Music-Based Auditory Stimulation™ method that is an affordable, effective approach for enabling individuals with a broad range of challenges and abilities to achieve even more. To learn more visit [www.thelisteningprogram.com](http://www.thelisteningprogram.com).

## Advanced Brain Technologies

Advanced Brain Technologies (ABT) is a neurotechnology company that develops and distributes interactive software and music-based programs for the improvement of memory, attention, listening, academic skills, sensory processing, brain health, peak performance and more. ABT was founded in 1998 and is located in Ogden, Utah.

Our family of products includes an extensive line of interactive software and music programs including: The Listening Program®, BrainBuilder®, Sound Health®, Music for Babies™, Shelly's Interactive Computer Learning Series™, Spatial Surround® HD, ABT Bone Conduction System™, and iListen®.

In addition we offer professional training, certification and continuing education opportunities to health, therapeutic, education and music professionals as providers of The Listening Program. Our international network includes providers implementing ABT products in home, school, clinic, hospital, and corporate settings on six continents.