multi media manufacturer

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CONTENTS

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Challenges of MP3 Player Testing

By Steve F. Temme, Listen, Inc.

MP3 players have been the "must-have" electronic gadgets for the past few years. Over 10 million players were sold in 2005, and this is predicted to rise to more than double this by 2010. But how can manufacturers carry out QA tests on the production line, ensure excellent sound quality, and demonstrate their compliance with Sound Pressure Level regulations?

MP3 player testing is challenging because it combines traditional audio analysis techniques with some characteristics unique to MP3 players. Here, I examine the equipment and techniques that MP3 player manufacturers can use to test the sound quality of their products, and advise how to overcome some of the challenges inherent to measuring MP3 players.

WHAT NEEDS TO BE MEASURED?

There are several different aspects of MP3 players that need to be tested. The most obvious is the audio quality—does the signal coming out of the MP3 player sound the same as the signal going into it? It is also becoming increasingly important to measure Maximum Sound Pressure Level (SPL), which is now required in some European countries. Finally, to ensure good user experience, the complete system including headphones and other ancillary components needs to be tested.

CHALLENGES OF MP3 PLAYER TESTING

Measuring MP3 players presents many challenges. MP3 files are by their nature compressed, which makes accurate measurements difficult, particularly at the extremes of the frequency spectrum. The wide dynamic range places some constraints on the hardware that can be used. In addition, synchronization of the signal playback and measurement, jitter, and sampling rate errors result in the necessity for specially designed measurement algorithms. In addition, manufacturers may need to test the complete system including headphones and possibly even a mobile telephone, which require their own set of tests.

HARDWARE AND SOFTWARE

The hardware is an important factor in

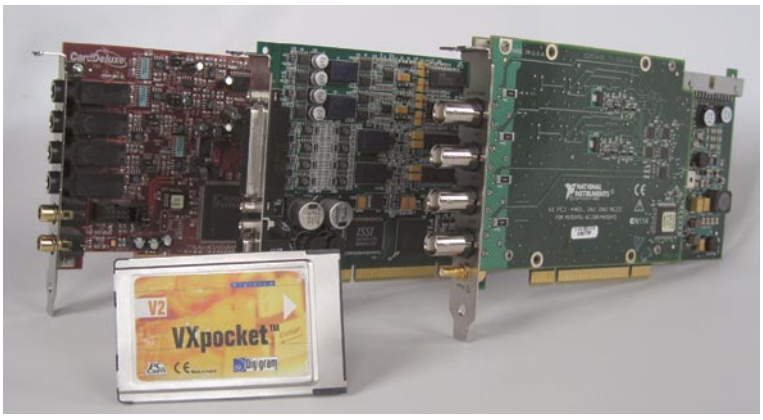

PHOTO 1: Selection of soundcards suitable for MP3 player testing.

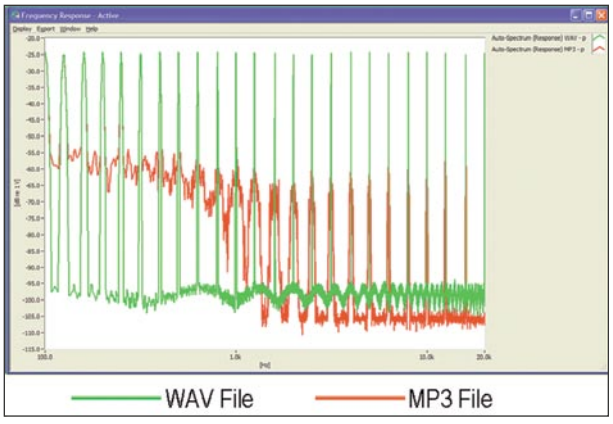

FIGURE 1: Noise floor of MP3 and WAV files.

MP3 player testing. MP3 players have a wide dynamic range because they use at least a 16-bit D/A converter. This means that any measurement system used must offer a dynamic range of at least 96dB. For software-based systems, a high-end sound card or data acquisition card is necessary (***Photo 1***). We have achieved excellent results using DAL sound cards (104dB), Lynx Soundcards (110dB), and NI PXI 4464 data acquisition cards (117dB).

Standard built-in PC or laptop soundcards are usually around 80dB and do not offer sufficient sensitivity for MP3 player testing. If you're using a data acquisition card, it is important to ensure that it offers anti-alias filters for spectrum analysis. Whatever input device you use, take care to ensure that the playback and acquisition are at similar levels in order to utilize the entire dynamic range. This is usually done using input attenuators on the signal.

Because an MP3 player has a stereo output, the fastest way of measuring it is with a system that offers at least two channels (a single channel system will work, but will take longer). A system with four channels will enable headphone output and line out to be simultaneously measured, and a six-channel system would enable the complete system (both outputs, and the headphones) to be measured in a single test.

There are both hardware- and software-based systems on the market, and even systems that are a combination of the two. Software systems generally offer considerably more flexibility and a lower initial purchase price than hardware systems. Because they use the processing power of the computer, IT upgrades can make your system run faster, whereas a hardware-based system will offer the same performance over its entire life.

A Windows software-based system offers the added advantage of working directly with WAV files, thus avoiding the additional step (and possible introduction of errors/noise) of having to convert the test signal from the hardware system's native format. The main advantage of hardware-based systems is that they can offer extremely high test accuracy due to the data acquisition device. This can be important for testing some high-precision audio electronic devices, but in our experience, a professional sound card is more than adequate for testing MP3 players.

Another important aspect to consider when selecting a test platform is speed. Will the system be used on a production line, and what is the necessary throughput?

Systems vary in the time taken to run a test and in their ability to be integrated with automated production lines, offer simple pass/fail results, and so on. If high throughput is important, a multi-channel system, although with a higher initial purchase price, may prove less expensive in the long run because more parameters can be measured simultaneously, enabling faster testing. If it is important to you to use the same system in R&D as on the production line to facilitate test development, make sure that it also offers the test design flexibility that product designers will need.

THE INPUT SIGNAL

Most MP3 players are playback-only devices. While some can play WAV files, many can play only MP3 files. Testing using a WAV file is preferable if the player will support this because it makes it easier to more accurately measure the characteristics of the player.

When an MP3 file is made, in addition to eliminating some of the sound information, the noise floor is increased (***Fig. 1***). This increase is more significant at low frequencies (below about 2kHz) because the compression algorithms typically compress sound more in this frequency range because the ear is less sensitive. This makes it

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much harder to accurately measure distortion and noise at low frequencies. If measuring THD+noise is important to you, it is important to use a WAV file as your test signal. The first step in any MP3 player test is to get the test signal into a format that can be read by the player, and loaded onto the device under test.

PLAYBACK SYNCHRONIZATION

In any electroacoustic test, the stimulus (test signal) is played and the response of the device measured. In this case, because the stimulus comes from the MP3 player rather than being generated by the test system, triggering is necessary to make sure you start measuring as soon as you start playing the signal. Even with triggering there may still be some offset between the start of the file and the signal, so it is necessary to compensate for this. We have used a cross-correlation algorithm, which compares the input and output signal and uses this to calculate where the signal really began, with excellent results.

JITTER AND SAMPLING RATE ERRORS

Jitter and sampling rate errors, such as "wow and flutter" in analog audio devices, occur when a playback signal is unstable, for example, in the case of jitter, when a 1kHz signal fluctuates between 999 and 1001kHz. Sampling rate error occurs when the playback is very slightly faster or slower than the encoded frequency.

For example, an MP3 file that is sampled at 44.1kHz is, in reality, played back very slightly faster or slower (say 44.009, or 44.011kHz). This is due to the quality of the crystal. While it is possible to use a very accurate crystal, low-cost consumer goods such as MP3 players tend to use inexpensive crystals, and most of the MP3 players that we have tested demonstrate this frequency shift. In reality, this small shift means that a 10kHz tone may be played back at 10.005kHz.

While the ear does not discern small sampling rate errors or jitter, there is a serious implication for testing. Most MP3 player tests involve comparing the output signal to the input signal. If the sampling rates are different, the difference in phase will cause the results to be meaningless. Generally, any measurement using time averaging techniques is affected by jitter and sampling rate errors.

There are various ways to minimize the effects of such errors. The most effective is to use an algorithm that re-samples the recording to match the output signal to enable a comparison of the other characteristics of the output. If, however, your test system cannot accommodate this, there is a variety of methods that you can use to ensure accurate results, including using power averaging rather than complex averaging because it is not affected so much by the two signals being very slightly out of phase (in complex averaging the different phases may cancel each other out), using a flat top window or broad filter, or using short time averages. The particular method chosen depends on the extent of the jitter and sampling rate errors.

COMPLETE SYSTEM TEST

There are many parts of an MP3 system that may need to be tested. MP3

players often have two outputs—headphone and line out. Because the two often have different high-pass filtering and output impedances, they need to be measured individually.

In addition, an MP3 player is usually part of a system that includes headphones. The overall user experience is, therefore, a function of both the MP3 player and the headphones. Generally speaking, the quality of the headphones is the limiting factor because headphones typically have much worse frequency response and distortion than the electronics themselves.

Headphone testing has its own measurement techniques and industry standards that need to be considered. These include what kind of artificial ear to use, how exactly the headphones are positioned on the artificial ear, and how to apply the free-field correction curve to the results. This is a detailed area for discussion, and a subject for a future article.

In addition to testing the complete system for sound quality, it is also necessary to test maximum SPL. You can play MP3 players at very high SPL (some over 110dB) which, together with the tendency of people to listen to MP3 players for long periods of time, can lead to high sound exposure levels. In France there is a law restricting portable audio devices to a maximum SPL of 100dB, and in the US at least one lawsuit has been filed against a manufacturer for hearing damage caused by an MP3 player.

The industry has not yet agreed on what is an acceptable maximum SPL and sound exposure level (SEL). So far the only known standard for measurement is the British standard "BS EN 50332 Headphones and earphones associated with portable audio equipment—Maximum sound pressure level measurement methodology and limit considerations." Although it is more specifically a headphone test requirement, it applies to portable audio equipment so MP3 player manufacturers are wise to ensure compliance. ***Figure 4*** shows the test setup that is recommended by this standard. This requires additional hardware such as a head and torso simulator (usually an expensive system component), which is important to also consider when specifying an MP3 player test system.

It is also worth ensuring that your test system is compatible with testing any other products that may be integrated with your device, such as mobile phones. Mobile telephone tests include measuring additional parameters such as loudness rating, linearity, echo delay, magnetic field for hearing aid coupling, and testing to TIA standards. Although most test systems that can measure MP3 players can also measure mobile telephones and, of course, headphones, there are advantages to choosing a system that does these well and from a company that also has ex-

HOW IS AN MP3 FILE DIFFERENT FROM A WAV FILE?

An MP3 file is significantly compressed to be smaller. It is made by "ripping" the wav file of the test signal using the software supplied by the MP3 player manufacturer. Different manufacturers have their own algorithms or "codecs" for doing this, but essentially the principle is the same. The sound file is sampled digitally at a predetermined frequency and, based on psychoacoustic models, information in the sound signal that you would not hear is removed to make the file size smaller.

Typically, an MP3 compression algorithm would remove higher harmonics above about 17-18kHz (the threshold of human hearing). In addition, masking curves are used to determine recorded frequency content that would be inaudible due to its close proximity to similar tones of greater amplitude. Low frequencies tend to be compressed more because the ear is less sensitive below about 1kHz.

Some files compress more than others when turned into MP3 files; for example, pink noise does not compress much at all because it has less energy at high frequency. ***Figure 2*** *shows the high-frequency cutoff of an MP3 file compared to a WAV file, and* ***Fig. 3*** *shows how a masking curve is used to eliminate "unheard" sounds.* ■

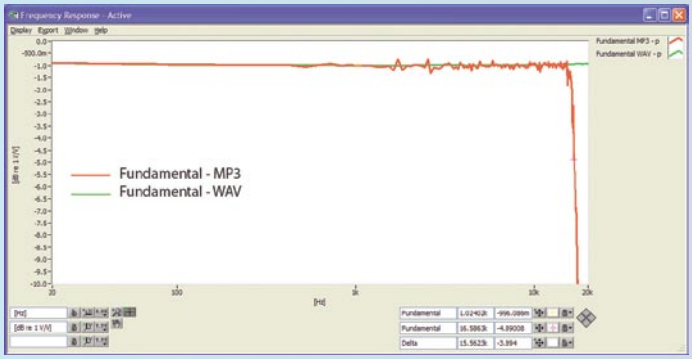

FIGURE 2: High-frequency cutoff of an MP3 file compared to a WAV.

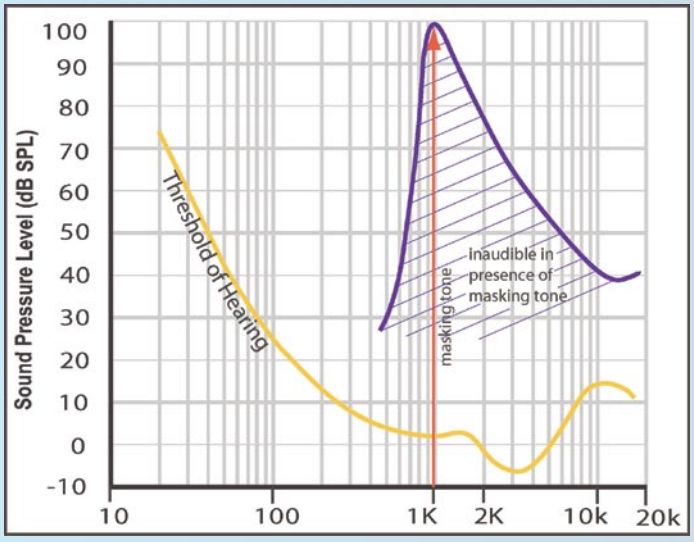

FIGURE 3: A masking curve is used to eliminate "unheard" sounds.

pertise in these products.

CONCLUSIONS

MP3 player testing presents many challenges because it requires fast throughput, accurate testing, and manufacturers need to be able to carry out a wide range of tests that may also include testing headphones and mobile telephones. A thorough understanding of how an MP3 player works and the characteristics that MP3 players display (jitter, sampling rate errors, and so on) is necessary to develop tests that quantify these errors. However, with careful test system selection and awareness of the testing challenges, it is possible to accurately characterize the performance of MP3 players and the associated system components.

Steve Temme is Founder and President of Listen, Inc., a manufacturer of software-based measurement systems for testing electroacoustic and audio electronic products. Prior to founding Listen, he worked for many years as an acoustic test and measurement applications engineer for Brüel & Kjær, and also as a loudspeaker design engineer for Apogee Acoustics. He has authored numerous papers on acoustic testing and lectured extensively throughout the world. www.listeninc.com.

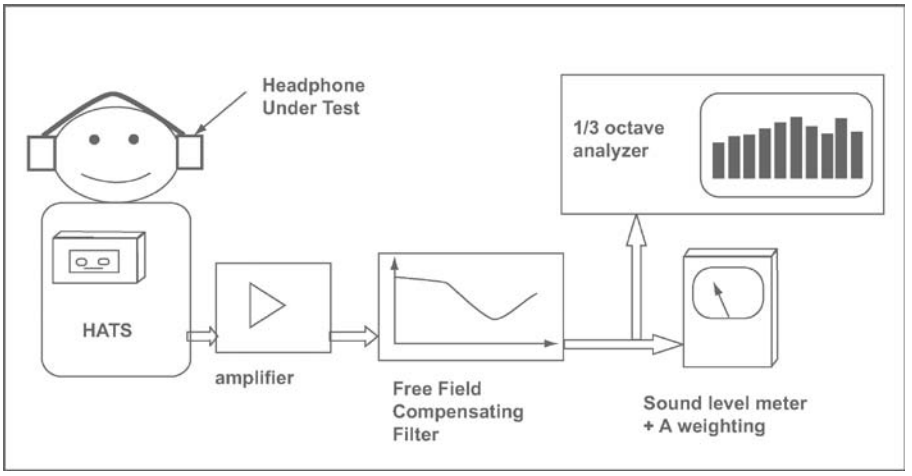

FIGURE 4: Test configuration for British Standard BS EN 50332.