

Portable Audio: Built on Innovation

By Robert Baum, Senior Engineer, Menlo Scientific

► From transistor radio to Walkman, iPod and beyond . . .

The portable entertainment revolution was started by Sony's pocket radio in 1957, built on what was then state-of-the-art technology: the transistor. The personal audio category was firmly established by the cassette Walkman in 1979, and accelerated by Sony's Discman CD player in 1984, both of which drove sales of tapes and CDs. These products were from an audio/video company founded in the ashes of war-ravaged Japan, by the visionaries Morita and Ibuka. Sadly, Sony lost its way in the portable market in the late 1990s by pursuing the Mini Disc and ignoring the emerging MP3 format, for fear of piracy of their music, leaving the door open for someone else.

Sony has been displaced as the innovator in portable audio by an upstart Silicon Valley computer company, founded by another pair of marketing and technical wizards, Jobs and Wozniak. Personal entertainment hardware was thus reincarnated as Apple's iconic iPod and iTunes service in 2001, which benefited from Apple's three core skills: software, industrial design, and user interface. Apple has knocked Sony from its positioning as the leading consumer electronics lifestyle brand, despite its far weaker distribution and much smaller size. The great success of the iPod family as well as other portable compressed audio players has produced demand for portable speaker products, and this article will discuss these and some of the related enabling technologies and trends, and some speculation as to what the future will bring.

Market Overview

A quick look at the data illustrates the size of this new market—approaching 30 million compressed audio players (mostly flash-based) sold last year, with over 50% growth rate predicted for 2005. Since inception of the iPod product line in fiscal 2002 (10/23/01), Apple itself has sold over 5.7 million iPods. More than 22 million US adults have an iPod or an MP3 player, with men more likely than women to be carrying the digital music devices (Pew Internet and American Life Project, "iPods and MP3 Players storm the market," 2/14/05). That's 11% of the US adult population 18 years old or older, which is substantial market penetration.

This penetration has also caught the attention of accessory

providers. Vern Smith, Director of Business Development at Monster Cable, noted, "At Monster, we recognize the substantial growth in this category. We continue to develop accessories that make these devices easier to use on their own, or connect to speakers and sound systems. We strive to enhance the consumer's experience, while giving retailers the opportunity to offer additional attachments that sell." That sentiment is reflected in one of Monster Cable's latest introductions, the iCruze, which lets consumers play and control their iPod through their existing car stereo.

People are spending more time listening to music; but not on traditional home stereo systems designed to play CDs, cassettes, or LPs (remember those?), which have been eclipsed by home theater. Consumers are looking for systems that operate more conveniently, are portable, or ideally invisible and pervasive—such as hard disk players, flash music players, and portable digital satellite receivers. These products can be carried around or connected to car stereos, PC/laptops, or home networks (both wired and wireless)—as well as on whole-house media servers. Consumers want loudspeaker systems that match the flexibility and power of their new playback devices.

As a result, small and light active (meaning with built-in power amplifier) speaker systems are an established market trend, often in combination with portable players. Several new cost-effective technologies are available to manufacturers to dramatically improve the efficiency and sound quality of these speakers.

New digital technologies and falling prices for DSP (digital signal processing) are an enabling technology, in audio and video playback with improved compression standards, facilitating broad and rapid consumer adoption of DVD, home theater, and portable flash memory/HDD (hard disk drive) players. These go far beyond simple equalization to boost the bass. On the other hand, loudspeaker quality is driven by magnetic



and other loudspeaker materials, which do not follow the DSP silicon advancements of Moore's Law (the doubling of the number of transistors per chip every 18 months).

Until recently, DSP algorithms (software) have not been available to allow the benefits of DSP silicon (hardware) to be applied effectively to redress the acoustic limitations of loudspeaker. In fact, the fidelity of the typical speaker sold today has markedly declined from the glory days of stereo—as manufacturers relentlessly reduce the price and size of speakers, quality has been sacrificed. Some of this can be corrected by DSP.

The first company supplying compact, powered portable speaker systems with sophisticated signal processing and class D amps to the mass market was Sonic Impact Technologies. They introduced a product using MaxxBass (discussed later) and back in 2002, and have since sold hundreds of thousands of their speaker systems through mass merchandisers, such as Target. They have licensed Apple, Delphi, and a game peripheral supplier for the Sony PSP (discussed later).

The poster child for portable audio entertainment is clearly Altec-Lansing's inMotion speaker products. These accessories for the Apple iPod effectively saved the company after some tough times supplying multimedia speakers to a large computer brand.

The first inMotion has the defining characteristics of the entire product category:

- Battery powered for portability, typically four AA-size batteries.
- Psychoacoustic bass frequency processing to compensate for the small speaker size and high power efficiency requirements.
- High-efficiency digital switching amplifiers for power efficiency.
- Speaker drivers with aluminum cones and neodymium magnet structures.

Altec's product used Waves MaxxBass to extend the apparent bass response; other products in this category will use simpler and less effective equalization. The original inMotion has spawned a product line, essentially a sub-brand, of portable audio speaker systems for Altec that is sold through Apple's growing collection of retail stores (about 100) as well as online and through the usual channels.

"We recognized several years ago that there was going to be an explosion in portable audio, and we launched our inMotion brand to address that market—first with products designed specifically for the Apple iPod, and more recently with a universal model called the inMotion iM4 that can be used with any brand of MP3 or CD player," said Bob Garthwaite, senior vice president of sales and marketing of Altec-Lansing. "We are now aggressively expanding the line because we expect to see exponential growth in this market over the next few years, not only to amplify the sound for MP3 and CD players but also for other areas such as satellite radio."

Psychoacoustic Bass Frequency Processing

Waves' audio signal processing algorithms are widely used by pros to mix and master music and movie soundtracks. Waves' MaxxBass psychoacoustic bass extension is a new approach to solve a key issue in compact, low power speaker systems: the inability to reproduce bass frequencies. MaxxBass uses the "Phenomenon of the Missing Fundamental" to

allow listeners to hear bass an octave below the loudspeaker's physical limitation. It doesn't break the rules of physics, but sounds as though it does by using the audio equivalent of an optical illusion to fool the ear-brain system into perceiving more bass than there actually is. Waves offers its MaxxBass algorithm either in DSP code or in a low cost, mixed-signal ASIC (Application Specific Integrated Circuit) for use in new portable loudspeaker systems.

In October 2004, Virgin Electronics began shipping two new portable loudspeaker systems—the Boomtube and Boomtube EX—which combine MaxxBass, digital amplifiers, and neodymium speakers with acoustically superior anodized aluminum enclosures. The Boomtube uses two 2" drivers driven by a $2 \times 2W$ digital amplifier with four AA batteries. The Boomtube EX takes performance to the next level with two satellite drivers and two woofer drivers driven by four channels of 15W amplification for over 60W of total power. The Boomtube EX includes a rechargeable Li-Ion battery, further reducing size and weight.

Class D Amplifiers

Two trends have converged to finally make digital amplifiers practical for use in personal audio systems. The first is the constant advancement of integration, particularly mixed signal implementations that include digital and analog systems mixed together. The second includes advancements in processing theories. The basic concepts for switching amplifiers have been around for decades, existing as large discrete applications. The early implementations provided the huge efficiency gains that were expected, but they lacked useful audio performance, so they were used in other applications.

In the mid-nineties, companies such as Tripath Technologies in San Jose began to implement advanced feedback and processing schemes—such as varying the switching frequency based on program content—to overcome the performance limitations and produce audiophile-quality, switching amplifiers that were simple enough to replace traditional class AB amplifiers. There are many other players in the field, including Texas Instruments, Cirrus Logic, Maxim, B&O's ICE, Apogee DDX, National Semiconductor, and so on.

Efficiency gains are extremely important for portable audio; using a switching amplifier can double the battery life. Equally important is the ability to provide power without bulky heatsinks, which require space and add weight. Parts such as Tripath's TAA2008 provide up to 12W per channel and efficiency up to 89%, can be implemented without a separate heatsink, and require less than 1.5 in² of board space. When you compare class D products, efficiency, as well as idle current and sound quality, counts.

Yet another factor is the recent research published by Vanderkooy and also Keele in the *AES Journal* on the symbiotic relationship between high motor force (high "Bl") speakers in sealed boxes and class-D switching amplifiers. Increasing Bl dramatically increases the driver's true efficiency at all frequencies but radically decreases nominal power efficiency in the bass range. Traditional design methods based on nominal power transfer efficiency disguise the very beneficial effects of dramatically raising the driver's Bl product (Keele,

“Comparison of Direct-Radiator Loudspeaker System Nominal Power Efficiency vs. True Efficiency with High-BL Drivers,” AES Preprint 5887, 115th Convention, 2003). Aurasound’s underhung neo voice coil magnetic system topology is an ideal realization of this sort of high BL high linearity transducer.

Second, new speaker materials and designs are now enabling small speakers with relatively high sensitivity, wide frequency range, and low distortion. All these factors combine to yield real-world performance beyond what Hoffman’s Iron Laws would seemingly limit.

Back in the mid-1960s Anthony Hoffman of KLH (Kloss/Lowe/Hoffman) derived an equation predating Thiele’s circuit analogies for predicting speaker performance. Box volume, low-end response, radiating area of the woofer, and efficiency were locked together. This law says the efficiency of a bass system is directly proportional to its enclosure volume and the cube of its cutoff frequency. You can get bass out of small boxes, but at the price of efficiency. Bandpass woofers trade bandwidth for efficiency, but they typically do not sound or measure well (especially in the time domain).

Amplifier output stage/speaker interaction was not considered, neither was psycho-acoustics. Bob Carver used sheer power to blast through these limitations with an enclosure envelope just barely large enough to fit the components and used 2.5kW nominal (about 600W RMS) to get deep bass and a lot of output from a very small enclosure. But thinking out of the box with high BL speakers and switching amps makes effective use of the reflected power bounced back to the amp from the speaker, and when combined with MaxxBass signal processing, enables high sensitivity sound systems with low power and tiny speakers with satisfying bass. Perhaps not a solution for studio monitors, but for a portable sound system this is a viable and innovative solution.

“Advanced psychoacoustic signal processing and digital amplifiers are enabling product designers and OEMs to develop and build small, portable, high-quality loudspeaker systems that were not previously technically possible,” observed IdaRose Sylvester, IDC senior consumer semiconductor analyst. “The market success of new portable audio players and other portable devices will continue as companies make advancements that

Table 1: Compressed Audio Players by Storage Media.

Source: CEA, 2001, In-Stat/MDR, 8/04

	1999	2000	2001	2002	2003	2004	2005
Solid State, units (flash memory)				2090	6,945	17,850	28,500
HDD, units (hard disk drive)				755	2,110	10,420	14,855
Percentage Solid State				73%	77%	63%	66%
Percentage HDD				27%	23%	37%	34%
Total Market (Units, 000)	500	1,200	1,800	2,845	9,055	28,270	43,355
% Growth		140.0%	50.0%	58.0%	218.3%	212.2%	53.4%

Table 2: MP3 Player Sales to Dealers.

(Includes all portable, compressed audio players: Flash and HDD based)

	2000	2001	2002	2003	2004	2005
Portable Player Sales (Units, Thousands)	510	724	1737	3031	6952	10056
Portable Player Sales (\$ Millions)	\$80	\$100	\$205	\$424	\$1,204	\$1,653
Portable Player (Average wholesale price)	\$157	\$138	\$118 (Estimate)	\$140	\$173 (Projected)	\$164 (Projected)

Source: “US Consumer Electronics Sales & Forecasts, 2000-2005.” Page 15. CEA Market Research, Jan 2005

give consumers the quality audio experience they expect from the living room, but with the portability they now demand.”

Expect new products incorporating these innovations—Class D, signal processing, innovative transducers—to migrate to other product categories, such as sound systems to accompany flat panel monitors, mini-compos, premium table radios, console gaming sound systems, and satellite radios.

The Weak Link: Speakers

Consumer electronics have made huge advances in audio and video convenience and quality as media has transitioned from analog to digital formats. For instance, storage capacity has ballooned with new media (CD, SACD, DVD, DVD-A, and inexpensive disk drives), video and audio compression standards (MPEG2/3/4, Dolby Digital), displays (LCD, plasma, DLP), audio converters, and digital amplifiers. However, loudspeakers continue to be the weak link in most systems due to marketing pressures for small size, cost, and weight, the quality of loudspeakers remains marginal in many consumer products. The typical speaker systems used in products in this category have metal cones and neodymium magnet structures.

Harman has been a supplier to Apple of audio systems with very impressive industrial design the last few years, such as the three-piece see-through Harman-Kardon Soundsticks (using four aluminum cone 1” drivers per side) and matching transparent 6” subwoofer, and the aptly named “Creature” three-piece set. Some of their more recent products for the iPod include the JBL On Stage, which uses four aluminum domed transducers, neodymium magnets, and for signal processing, proprietary equalization and compression.

Aurasound’s patented neo-radial technology magnets are incorporated in a range of products, from 18” pro sound subwoofers to micro speakers, all delivering low magnetic distortion and high linearity. Their compact Cougar and Whisper speakers (models NSW-1 and NSW-2, respectively) are premium drivers.

What’s Next?

Perhaps the next step in this portable entertainment process



Table 3: Apple iPod Data. Source: Apple 2004 Annual Report

Fiscal Year (End of September)	2002	2003	2004
iPod sales (\$ Millions)	\$143	\$345	\$1306
iPod unit sales (Thousands)	381	939	4416

is to add visuals—beyond merely the still photos of the iPhoto. Expect to see more portable satellite radio. Sony still has a strong brand name, and will certainly try taking back the “cool gadget” crown from Apple, leapfrogging the audio-only iPod with its new PlayStation Portable (PSP) gaming device, which offers far more than games: movies and music, for starters.

PSP should be on sale in the US by the time this article is published, priced about the same as the iPod Mini, \$250. PSP comes with a small 1.8 GB optical drive (Universal Media Disc), 16:9 widescreen aspect ratio (480×272; 4.3” diagonal), USB 2.0 and WiFi, and may well be a comeback product for the firm. Perhaps Sony has learned some hard lessons, because the PSP will play MP3 files, unlike their prior compressed audio players.

It will be interesting to see whether a very focused and well-executed “fashion” style product such as the iPod can hold out more general-purpose devices such as the PSP. Expect to see a supporting ecosystem of accessories for the PSP, as these competing products slug it out. In the background is the struggle of business models, the iPod/iTunes closed-system purchase model versus Microsoft’s “all you can eat” open subscription service to music that will play on many different devices (and in the future, music videos, games, and movies). Recent announcements by Nokia and Microsoft, and Apple and Motorola, make it clear that music and visuals will be available on cell phones this year.

In 1981 MTV played its first music video, “Video Killed The Radio Star.” For the next 20 years, that had been the case. With the assistance of some of the new personal audio technologies touched on in this review, such as the iPod—as well as portable satellite receivers—personal audio will continue its rapid comeback.

It remains to be seen whether the iPod’s killing of the Walkman is the harbinger of a more fundamental shift in the market, where traditional consumer electronics firms, used to selling isolated boxes—such as Sony and Matsushita—are replaced by, or driven into strategic alliances with, PC and software firms that truly understand software, ushering in an age of networked convergence devices consumers will actually buy. **VC**

Robert Baum is a senior engineer at Menlo Scientific, who can be reached at rob.baum@audioXpress.com.