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MIPS Chipidea Audio IP White Paper

Audio IP with True Hi-Fi Codecs and Class-D Headphone Amps for SoC Design

Abstract:
System-on-Chip (SoC) designers can now incorporate Hi-Fi Audio codecs and Class-D audio amplifiers in chip designs, eliminating the need for a separate IC, and delivering significant power-savings and cost-savings. Portable consumer electronics, including cell phones and smart phones, media players, cameras, and digital entertainment devices constitute the main target applications.

Introduction

Audio processing is essential to mobile phones, portable media players, digital cameras, camcorders, electronic toys, and a host of other applications where size and power consumption are critical design criteria. Additionally, advanced portable products such as GPS navigation devices and smart phones need to set themselves apart from similar products by adding value with audio capabilities, creating an expanding marketplace for audio processing.

While a few years ago audio functions would have been handled by one or more separate integrated circuits, especially if true H-Fi Audio performance was needed, today's System on Chip can combine what previously required several different ICs onto a single SoC, with quality that matches separate audio ICs. This provides extraordinary space savings, and reduces power consumption for longer times between battery changes or recharges. Most recently, all-digital "Class-D" audio amplifiers have been added to the list of audio functions that can be integrated into an SoC design, with power output up to one watt, which is more than enough for driving headphones, and is enough to drive small speakers.

Considering the enormous pressures to miniaturize products while integrating high quality audio, extended battery life and delivering this at competitive prices, IC designers and end-product manufacturers are finding integration of audio into their SoC designs increasingly attractive. As shown later, the performance of the current state-of-the art in SoC audio is competitive with separate audio ICs.

SoC IC Technology Overview

SoC designers don't need to start from scratch, but can piece together building blocks of already developed designs for signal processing within the SoC. These are called cores, and the intellectual property constituting the plans for creating them is called an "IP core" or just "IP." Chipidea is an eleven-year-old company specializing in audio IP.

SoC fabrication plants, or foundries, offer a variety of ever-shrinking technology nodes. The node is the measure of a single IC junction between different semiconductor materials -- an underlying building block of the chip. Previously measured in micrometers -- or microns -- nodes are now measured in nanometers due to their ever-shrinking size -- a phenomenon known as "Moore's Law."

As technology nodes shrank below 1-micron (1μm), the IC technology was called "submicron," with 0.55μm and 0.35μm becoming quite popular (and still in use today.) Then as it shrank below about a quarter-micron -- or 250-nanometers (nm) -- the term "deep submicron" technology was coined, and that's the era we're in. Today, the 180nm (also called 0.18μm) and 130nm technologies are mature, the 90nm and 65nm are quite popular, and 45nm and smaller are up-and-coming.

Each smaller technology node presents new sets of challenges to IP designers. For example, crossing into the deep submicron zone required development of shallow trench isolation, or STI, to prevent leakage between device components. Providing adequate ESD (electrostatic discharge) protection is crucial. Analog audio signal processing can be especially vulnerable to noise.

Founded in 1997, Chipidea is uniquely experienced in the audio IP industry, having worked through many of these issues years ago, and having a silicon proven track record in millions of consumer devices. Chipidea offers a range of audio IP products to SoC designers. These include audio encoders/decoders (codecs), amplifiers, and other audio functions of particular use to designers of portable equipment. Sometimes, when a single SoC proves impractical, a designer will combine several chips into a McM -- a Multi-Chip Module -- or into an SiP -- System in Package. Chipidea Audio IP can be used with all of these approaches to system design.

Dynamic Range

High dynamic range means low noise. It's the ultimate proof that an audio IC is not "noisy" -- and that's why it's arguably the most important audio spec. The dynamic range of the standard audio CD is 96dB, and this is considered excellent performance for consumer audio systems. For pro-audio applications, standalone audio ICs with dynamic range as high as 120dB are available; however such high performance would represent overkill for a consumer application in which power consumption and small size are important.

While using separate audio ICs for key functions such as codecs and amplifiers was once almost mandatory for any product aspiring to "hi-fi" reproduction quality, today these functions can be readily integrated into system on chip (SoC) designs, using advanced high performance audio IP.

The Chipidea audio IP cores for Hi-Fi applications deliver full 96dB dynamic range to suit a wide variety of cost, power, and size limitations. They're ideal for mobile phones and portable devices.

For true audiophile-quality applications Chipidea IP enables the SoC designer up to 104dB of dynamic range, without requiring a separate audio IC. While consuming slightly more space and power, the trade-off can be worth it for applications such as high-end cameras and camcorders, digital TVs, set top boxes, etc.

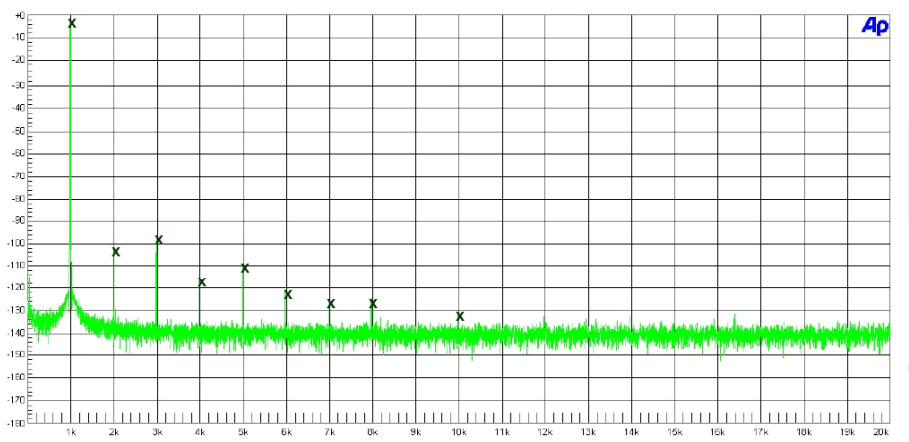

Fig. 1 - Response for a 1-kHz signal output by Chipidea CI7822dl 24-bit Stereo DAC IP core. The strongest harmonic, at 3-kHz (the third "x"), is over 95dB lower than the test signal. Total harmonic distortion (THD) is 90dB, and dynamic range is 100dB.

Advanced Audio Features

Advanced audio features that help system designers save power and improve performance make Chipidea Audio IP unique in the industry. These advanced audio features include:

- **Headphone Check (Electric Jack Insertion Detector)**: Why power an audio headphone amplifier if there are no headphones plugged in? This feature powers down the amplifier when it is not needed, and requires no extra jack connections.
- **Capless Output / Floating Ground:** Capacitors are big external components that many audio codecs require between the IC and the headphone jack. Save space with audio output that connects directly from the IC to the jack.
- **Ground Isolation:** Eliminates noise from a portable device's ground and extends the ground of a connected home stereo.
- **Automatic Level Control**
- **5-Band Audio Equalizer**
- **3-D Sound Enhancer**
- **Reverse Stereo:** Flips the left and right channels.
- **Microphone Bias:** Supplies power to an electret microphone element
- **Digital Sound Effects**

These features, along with standard codec and DAC and mixer and amplifier functions form a family of completely "integratable" Audio IP. Designers can select the features they need for each application.

Lowest Power Consumption
Audio performance and advanced features are complemented by the lowest power consumption in the industry. This makes Chipidea Audio IP ideal for handsets and other portable applications.

Audio playback, for example, iscommonly needed for mobile phones, and Chipidea Audio IP has three implementations that consume less than 10mW, with the lowest at a mere 7.2mW. This is with performance that would have consumed 40mw, or more, in 2005.

Class-D Digital Audio Drivers -- power amplifiers -- offer significant power savings advantages over traditional Class-A/B analog amplifiers. While A/B amplifiers at best are roughly 50% efficient, Class-D amplifiers achieve 80 to 85% efficiency. If you're driving headphones or speakers, that represents significant power savings.

But until very recently (late 2007), Class-D audio drivers required a separate IC. Chipidea is the first Audio IP vendor to introduce Class-D audio drivers that are "integratable" into SoC designs. The design offers 1-watt power output (into 4 ohms with THD under 1% THD, or under 0.1%THD at 125-mW into 16-ohms.) Power efficiency is over 80%. And it occupies a compact area -- just 0.7sqmm for stereo (in 180-nm technology).

Smallest Area
While clearly the SoC approach saves space compared with use of discrete ICs, or even the IC-stacking SiP (system in package) approach, within the SoC itself real estate is money. The less space consumed, the less it will cost to manufacture the chip, and the smaller the SoC IC can be.

Chipidea can supply a voice-quality ("VoIP quality") codec suitable for use in toys that consumes a mere 0.5 sq. mm. Such VoIP/Enhanced Voice quality has about 75 to 80 dB dynamic range, and draws just 6mW during playback.

For higher performance while paying close attention to minimizing area and power, Chipidea offers Low Area/Low Power Hi-Fi Audio solutions. These offer 90 to 96dB dynamic range, and require approximately 2.7sqmm area, consuming just 9mW for playback at 48kHz sampling rate.

Area goes up about 40% for Chipidea's groundbreaking 104dB dynamic range Audio IP for applications such as high-end portable audio. At every notch of quality along this scale, Chipidea IP is the most space-efficient in the industry. A full featured Hi-Fi codec takes up a little more area, but is every bit as good as separate audio ICs and directly comparable in capabilities and performance with many leading ICs (see figure 2).

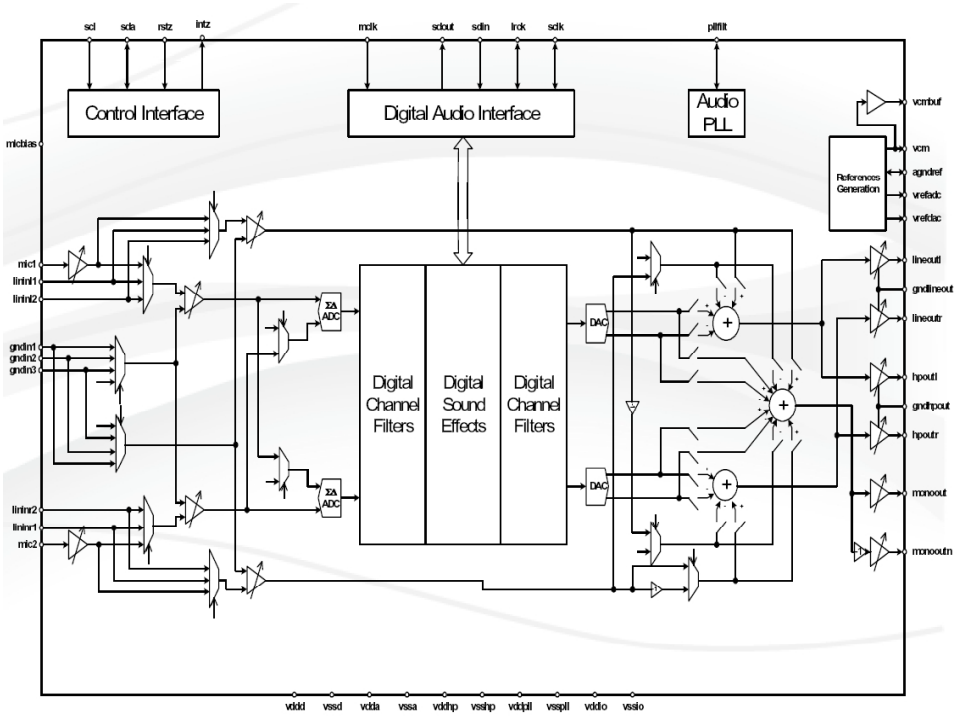

Fig. 2 - High-End 24-bit Chipidea Hi-Fi Audio Solution featuring 96dB dynamic range, 8 to 96kHz sampling, Stereo Sigma-Delta Audio DAC with built in short circuit detection and jack insertion detection, "capless" output, 3 stereo inputs, digital mixing and sound effects.

The trade-offs between chip real estate and quality are clear, and with Chipidea IP system designers can specify the best solution for their particular requirements

Have IP Customized "Your Way"

It's inefficient -- in cost, chip real estate, and power -- to include unneeded functionality in a system on chip design. A distinct advantage of Chipidea's Audio IP is that it enables designers to specify precisely those functions -- and at what quality level -- they need.

This can be crucial for the viability of extremely BoM sensitive consumer products -- inexpensive electronic toys, for example, where the entire product might sell for just a few dollars. With class-D audio power amplifiers integrated in the SoC, today's system designers have unprecedented audio capabilities in the creation of low-power, low cost custom SoCs.

For system designers who don't need a full codec, Chipidea also licenses IP for audio drivers, DACs, and ADCs to provide precisely what's needed and nothing more. If a designer needs a 44.1kHz PLL (phase locked loop), for example, Chipidea has it

available -- and it is optimized for 44.1kHz (the CD audio sampling frequency), not just a generic design! Embeddable audio analog front ends, output amplifiers, and everything in between are available.

The availability of audio IP in popular deep submicron technology nodes -- including 0.18µm, 130nm, 90nm and 65nm -- and having each of these covered by Tier 1 foundries such as TSMC, UMC, Tower, Samsung, Captive, SMIC and Chartered means system designers hit the ground running with reliable, silicon proven performance.

Roadmap for Chipidea Audio IP

In terms of CMOS process technologies and foundries, Chipidea's roadmap is clear, moving codecs, ADCs, DACs and Class-D amplifiers into 65nm and then 45/40nm with TSMS and other leading fabs.

New features being introduced soon by Chipidea include "True Ground," which will improve on the Phantom Ground for consistently lower noise, and a power saving feature that adjusts the headphone amplifier power supply based on the "crest factor" -- the ratio of big peaks to the RMS average. The net effect will be even lower power consumption.

While reduced power consumption is absolutely essential for portable devices, it's also an increasingly important requirement for AC powered consumer devices as well, including TV sets, PCs, set top boxes, game consoles, DVD players/recorders, etc. SoCs for these markets will benefit from the "green" advantages of Chipidea Audio IP.

Adding Value while Clients Look (and Sound) Better

When a designer specifies an off-the-shelf audio IC, credit goes to the IC manufacturer for the product's audio. When you incorporate Audio IP into an SoC design, the SoC gets the credit for superb sound. You're adding value to the custom SoC.

Which is why Chipidea Audio IP is inside many well-known and highly acclaimed consumer products, some of which are household words. But the bragging has to stop there, because Chipidea doesn't get the credit. Chipidea Audio IP has helped dozens of SoC designers bask in the glory of superior audio performance.

Additionally, SoC designers gain control over their own supply chain by integrating audio. Of course, they could also get that benefit by designing the audio for SoC from scratch, but it would add significant time and would result in inferior performance. Chipidea delivers more than Audio IP to its customers, by providing world famous support. Chipidea has a dedicated team working on audio IP, and nothing else, with industry-leading expertise in analog and digital audio signal processing. Ultimately, Chipidea's customers are not just licensing Audio IP, but complete audio solutions -- systems that work together to effectively satisfy all the audio requirements.

Conclusion

Whether designing audio for a cell phone handset, a high-performance media player, camera, or inexpensive toy, Chipidea Audio IP can help design engineers do it faster and

better. Silicon proven solutions in all popular technology nodes assure designers of quick, reliable, consistent results. Hi-Fi Audio requirements that previously could only be satisfied by separate ICs, including efficient Class-D amplifiers capable of driving headphones and small speakers, are now achieved in SoC designs using Chipidea Audio IP.

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