Xilinx High Volume Programmable Logic Applications in Internet Audio Players

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Summary

This paper provides an overview of Internet audio technologies and how Xilinx high-volume programmable devices can be used to overcome some of the significant challenges facing the designers of portable players. The Xilinx device families targeted at these high-volume applications include CoolRunner™ CPLDs and Spartan™ FPGAs. Detailed information describing these families can be found on the web at www.xilinx.com.

Introduction

The flow of this document will start with an overview of this dynamic market covering where it is, where we think it might go, and what are the issues involved in developing products for it. Next there will be an overview of the underlying Internet audio technologies. This will include an overview of the different formats used and how they relate to the most popular, MP3. There will also be a comparison of the various ASSP products that are being used in these products. The next topic to be covered will be an analysis of the first and most successful so far, the Diamond Rio MP3 player. The final topic is the benefits that Xilinx programmable logic can bring to these products and what support materials Xilinx is developing to assist customers in the design-in process.

While this document focuses on applications of these devices in portable audio player applications, the examples discussed illustrate many of the issues found in other portable consumer electronics applications.

What Exactly is an Internet Audio Player Anyway?

In general an Internet audio player is any device or program that supports the playback of music compressed using any one of several audio compression algorithms, the most well known of which is MP3. Internet audio players are available as application programs for Windows and Macintosh PCs. In addition dedicated hardware players in a variety of forms including in-dash automotive players.

This aside, what most people are familiar with, is the portable MP3 players, which resemble a WalkMan or pager. This product category was pioneered by Diamond Multimedia in the form of their Rio PMP-300. Since the introduction of the Rio, a variety of competing products have been introduced by Creative Labs, RCA, Samsung, Sanyo, Eiger Labs, and numerous startups.

Portable MP3 players store the music files in FLASH memory. Players typically come equipped with 32 MB of FLASH, which can be expanded to 64 MB and beyond through the addition of a Compact-Flash card. Music is transferred to the player from a PC using a cable connected either to the PCs parallel port or USB port.

MP3 music files for these players typically come from one of two sources. MP3 files can be downloaded from numerous sites on the Internet including mp3.com. Owners can also compress, or "rip" as it is popularly called, music tracks from CDs using software that is included with all players.

The Market

All analysts predict tremendous growth in the market for portable Internet audio players. This growth is driven by the acceptance of the Internet as a medium for online commerce and music delivery. Currently the Internet currently generates a mere $88 million in annual domestic sales of retail music, or less than 1% of the total. By 2002 analysts expect online music sales to rise to $1.4 billion, or nearly 8% of the total market (Figure 1).

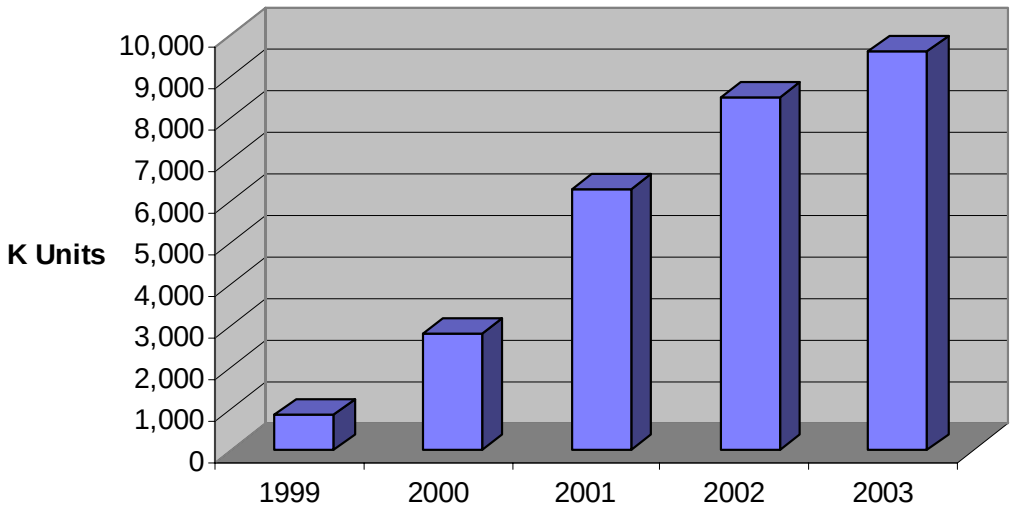

Figure 1: Portable Internet Audio Player Market Growth Projections

In spite of the forecasts for dramatic growth in the overall MP3 player market, there are three key issues that will both limit the rate of market growth and impact the definition of products. The first of these is that of music file format. While MP3 is the dominant format for music download others are emerging. Several of these new formats were designed to provide the copyright protection features that are being demanded by the music industry. The copyright protection issue and the resulting lack of big name media is the biggest issue impeding market acceptance. The third issue is the feature set supported by players.

Internet Audio Formats

Internet audio formats can be classified in two key ways. The first of which is whether the format is targeted at streaming or download applications. Although streaming and downloading are often mistaken as interchangeable terms, in fact they are two very different things.

Streaming refers to the playback of audio in real-time as it is transferred across the Internet. The advantage of this approach is that the user does not have wait for the entire music file to be downloaded before hearing it. The tradeoff is that the music must be highly compressed in order to support the access rates that most users have, typically 28.8 to 56 Kbps. This gives Net users instant gratification but relatively poor playback quality. In addition, streaming audio players do not capture the content, so each time the clip is played it is transferred again.

Downloading, which involves transferring the entire file to the computer before any part of it is accessible, offers better quality since the data rate of the compressed stream does not have to less than the data rate of the internet connection. MP3 for example, is targeted at data rates from 64 to 128 Kbps. The goal of these formats is to provide near CD quality audio.

Another way of classifying Internet audio formats is whether they have copy protection technologies built in. This is a key issue with download formats since once the clip has been downloaded, one can do pretty much whatever anyone wants with it, fueling the piracy scare and a host of copyright concerns (Table 1).

Table 1: Internet Audio Format Summary

Format	Developer	Notes	Type	Secure
Windows Media Audio (WMA)	Microsoft	Supported by Creative Labs NOMAD II	Both	Yes
G2	RealNetworks	Streaming audio market leader	Streaming	No
QDesign Music Codec	QDesign	Ships with Apple's QuickTime 4	Streaming	No
LiquidAudio	Liquid Audio	Based on AAC	Download	Yes
TwinVQ	Yamaha	Incorporated into MPEG-4	Download	No
a2b	AT&T	Based on AAC	Download	Yes
AAC (MPEG-2 AAC)	Fraunhofer Institut	Part of MPEG 2 standard	Download	No
MP3 (MPEG-1 Layer III)	Fraunhofer Institut	Part MPEG 1 and 2 standards	Download	No

MP3 (MPEG Layer III Audio Coding)

The MPEG Layer III audio compression scheme that was defined as part of the International Standards Organization (ISO) Moving Picture Experts Group (MPEG) audio/video coding standard. MPEG-I defined three encoding schemes, referred to as Layer I, Layer II, and Layer III. Each of these schemes uses increasing sophisticated encoding techniques and gives correspondingly better audio quality at a given bit rate. The three layers are hierarchical, in that a Layer III decoder can decode Layer I, II, and III bitstreams; a Layer II decoder Layer II, and I bitstreams; and a Layer I decoder only Layer I bitstreams. Each of the layers supports decoding audio sampled at 48, 44.1, or 32 kHz. MPEG 2 uses the same family of codecs but extends it by adding support for 24, 22.05, or 16 kHz sampling rates as well as more audio channels for surround sound and multilingual applications.

MPEG-2 AAC (Advanced Audio Coding)

AAC (Advanced Audio Coding) is one of the audio compression formats defined by the MPEG-2 standard. AAC used to be called NBC (Non-Backward-Compatible), because it is not compatible with the MPEG-1 audio formats. MPEG-2 also defined another audio format called MPEG-2 Multi-channel or MPEG-2 BC (Backward Compatible), which is compatible with MPEG-1. AAC is more efficient than MP3 (MPEG-1 Layer III) and is the state of the art in audio compression technology. Formal listening tests have demonstrated it is able to provide slightly better audio quality at 96 kb/s than Layer III at 128 kb/s or Layer II at 192 kb/s.

WMA (Windows Media Audio)

Part of Microsoft's Windows Media Technologies, which combines Video for Windows, ActiveMovie, and NetShow into a unified architecture is called Windows Media Audio. A key feature of this architecture is that it automatically downloads codecs for new formats from the Internet as needed. This gives them the ability to support both streaming and download applications efficiently.

G2

G2 is the name of RealNetworks' most recent streaming audio/video CODEC technology. The G2 includes several features targeted specifically at streaming media applications including synchronization with other media types such as video and graphics, and the ability to handle data loss. According to RealAudio, the G2 Music Codec can handle packet loss up to 10-15% with minimal reduction of audio quality.

Qdesign Music Codec

Based in British Columbia, Qdesign developed a high quality, streaming audio CODEC. Distributed by Apple as part of their QuickTime media architecture, this CODEC gives excellent quality at dialup data rates.

Liquid Audio

Targeted at download applications, the Liquid Audio media architecture can support multiple audio coding standards. The default codec is based on AAC and includes copy protection features.

TwinVQ (Transform-domain Weighted Interleave Vector Quantization)

This compression technology, targeted at download applications, was originally developed by Yamaha and has been incorporated, along with AAC, into the MPEG-4 specification. The underlying algorithms are significantly different the algorithms used in MPEG Layer III.

Trends in Internet Audio Formats

Indications are that the Internet audio market will not converge on a single standard any time soon, in fact it will probably get more fragmented as it grows. Each of these standards will be optimized for different applications (streaming versus download), bit rates (users with DSL versus modem connections), and the business agendas of the media providers.

As this takes shape users will want players that support multiple standards. A key component of a player is of course the range of music that it makes available to its owner. This trend is already started, the recently announced Creative Labs' Nomad II will be able to support multiple standards and will have the ability to download support for new standards in the future.

Another trend that is emerging is support for "metadata" in the music standards. Metadata is non-music data that is included in the music files, and includes items such as track information and cover art. Another potential use for metadata is advertisements.

Copyright Protection

Copyright protection is the biggest issue hindering the growth of Internet music distribution. MP3 files can be easily distributed across the Internet using web page downloads or email. Since MP3 has no inherent copy protection, once it is made available on the web everyone has access to it at no charge.

The recording industry, headed by the Recording Industry Association of America (RIAA), sees the combination of MP3 and the Internet as a Pandora's box that will result in the widespread piracy of copyrighted material. The RIAA perceives the threat to be significant enough that they took legal action in a failed attempt to block the sale of the Diamond Rio in late 1998. The fear of piracy by mainstream artists and the recording industry has limited the availability of legitimate MP3 material to emerging/fading artists and sample tracks from mainstream artists.

The Secure Digital Music Initiative, SDMI

SDMI was started by the RIAA as a means of establishing a framework for the secure distribution of copyrighted material. SDMI now includes over 150 member companies from both the technology and music industries. To quote the SDMI web page:

> *"The Secure Digital Music Initiative brings together the worldwide recording industry and technology companies to develop an open, interoperable architecture and specification for digital music security. The specification will answer consumer demand for convenient accessibility to quality digital music, enable copyright protection for artists' work, and enable technology and music companies to build successful businesses."*

The goal of SDMI is to establish a technology framework for the secure distribution of copyrighted material. To further this goal, SDMI will be delivering a series of specifications that show how watermarking and encryption technology should be used to achieve these ends. Implementation of these standards will be left up to member companies. Currently Liquid Audio and InterTrust have indicated that they will deliver SDMI compliant technology packages.

Deployment of SDMI technology will be rolled out in phases. This approach was taken as a compromise between the time to market goals of the technology companies and the security concerns of the music industry.

Phase I involves watermarking of material and the deployment of players that can recognize these watermarks and inform the consumer when an upgrade for Phase II technology is available. Phase I devices must be upgraded to play Phase II protected material. Players compatible with the Phase I standard are expected to be available for the 1999 holiday season.

Phase II compliant players will incorporate encryption technology that will provide protection for copyright material. The specifications for this phase are still being developed and the delivery timetable is uncertain.

The big question becomes, what resources need to be included in phase I compliant players to ensure that they can be upgraded to support Phase II features?

Internet Audio Player Feature Flux

The feature set of Internet audio players is another area where there is rapid change. The search for feature differentiation is driven by the fact that, in spite of being a consumer oriented product, a portable player is a relatively expensive item, and that the bulk of the cost structure is driven by a commodity semiconductor, FLASH memory. As a result it will be difficult for anyone to differentiate on a cost basis without simply giving up margin.

As a result, developers of these products will be looking to differentiate themselves through innovative features. In an emerging market, it is difficult to predict what these features will be. Possibilities include enhanced graphical user interfaces; the ability to playback music video clips, games, and day-timer features. This leads to the question; will these devices evolve into specialized PDAs for teenagers?

Internet Audio Player ASSPs

Next the Application Specific Standard Products that are being used to implement portable Internet audio players will be covered. The three products that will be discussed also represent three different approaches to the problem.

The first approach involves the use of a fixed function DSP, the Micronas MAS 3507D. The second approach is a standard programmable DSP, in this case a member of the TI C54x family. The third approach is a standard RISC processor with integrated peripherals.

Micronas MAS 3507D

The Micronas MAS 3507D is a fixed function DSP specifically targeted at MP3 decoding applications. The device consists of a specialized DSP core, program memory and serial interfaces for shifting MP3 data streams in; shifting uncompressed audio data out and an I^2C interface for control.

The advantages of the MAS 3507D are low cost at the device level, and the maturity of the product. The device is used in virtually all of the first generation portable Internet audio players.

The key disadvantage of this device is that supports only MP3 audio. This means that support for other formats or SDMI will require additional devices. Another issue with this device is that while the cost of the device itself is low, there is a lot of additional functionality that is needed to implement a complete portable player. We will cover this in more detail later when we discuss the implementation of the Rio.

Texas Instruments C54x DSPs

Texas Instruments is positioning its C54x family of DSPs as a solution for Internet audio decoding applications. TI provides a reference design targeted at this application complete with firmware for MP3, AAC, AC-3, and Liquid Audio's Secure Portable Player Platform (SP3). TI has announced design wins based on this design with e.Digital, and Sanyo.

The advantage of this approach is that since the DSP is fully programmable a wide range of audio formats can be supported and there is no need for a separate microcontroller for system management functions.

The disadvantages of this approach is that DSPs are less programmer friendly than general purpose RISC processors, and while this approach eliminates the microcontroller needed in a Micronas MAS 3507D based design it does not provide the rest of the peripheral support logic needed.

Cirrus Logic EP7209 & EP7211 "Maverick"

Cirrus Logic has taken yet another approach to providing a portable Internet audio player in the form of their EP7209 & EP7211 "Maverick" family of Market Specific Processors™ (MSPs). These devices combine an ARM720T core with a selection of peripherals including FLASH interface, LCD Interface, two serial ports, and a parallel port. Cirrus has created an evaluation platform for these devices that currently does not include any decoders.

The advantages of the Cirrus approach are that since these devices are based on a standard RISC CPU they are flexible and easily programmed. In addition they are highly integrated resulting in a low solution cost.

The disadvantages include the fact that, while it is easy to program a RISC processor it is not as efficient as a DSP in implementing the algorithms used in audio decoders. This may result in higher power consumption at the system level.

Another disadvantage is the flip side of the high level of integration that is intended to reduce cost. The problem lies in whether the ASSP vendor has included the right set of peripherals for the target application. In this case the Cirrus devices implement a variety of peripherals on chip but do not include a USB interface which has become the defacto standard for connecting newer portable players to personal computers. The problem with such high levels of integration is that it makes product differentiation difficult, and as we have previously mentioned this is already a challenge with this class of product.

The Diamond Rio Player

To get a better feel for what goes into a typical portable Internet audio player lets examine the Diamond Rio MP3 player. The Rio represents the first generation of players and supports the playback of MP3 files exclusively. Files are loaded into the player by connecting it to the parallel port of a PC. The fact that a parallel port is used means that Macintosh owners cannot use it. The user interface consists of pushbuttons and a single line alpha numeric LCD. The display is not backlit making it difficult to see under low light conditions.

The Rio uses a Micronas MAS 3507D for decoding and is controller by an 8-bit microcontroller. A one-time programmable FPGA is used to implement the system glue logic (Figure 2).

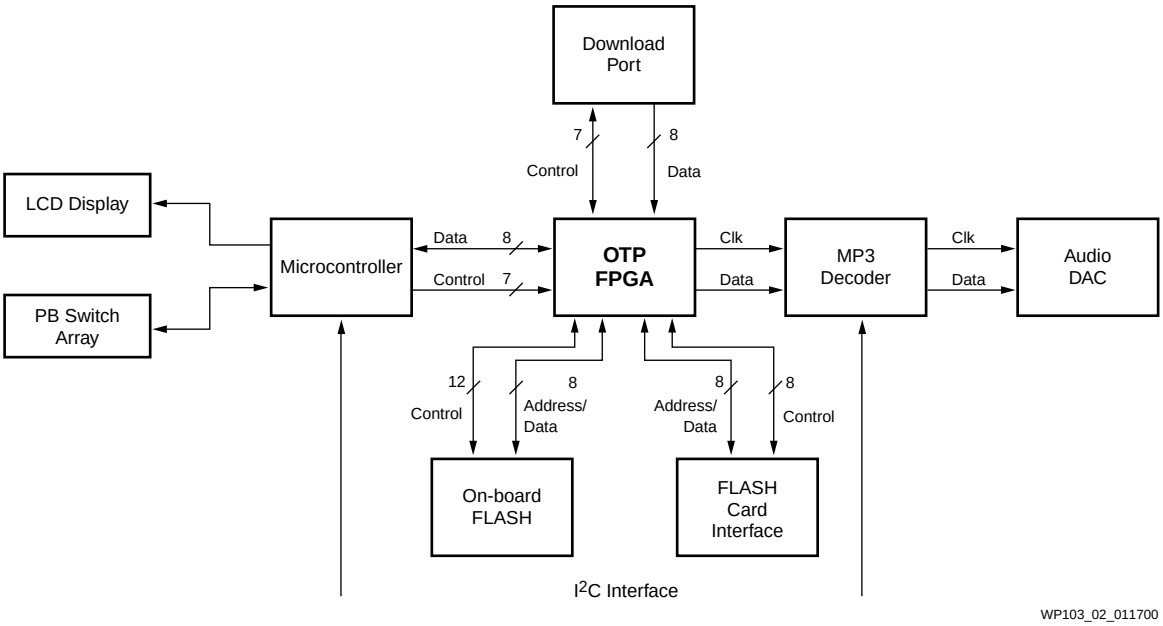

Figure 2: Rio Player Block Diagram

The hardwired approach employed in the design both from the standpoint of the decoder and the system glue logic limit field upgrade capabilities to microcontroller firmware. The Rio has no SDMI upgrade capability.

Figure 2: Rio Player Block Diagram gives an overview of the Rio architecture. The FPGA is used as system level glue, interfacing the microcontroller to memory, the parallel port and the Micronas decoder. Since the FPGA is a one time programmable, there is no ability to change the interaction between these blocks in order to accommodate feature enhancements or bug fixes.

In analysis of the Rio's bill of materials (BOM) shows that the bulk of the cost of this device, greater than 60%, is the FLASH memory used to store the MP3 files (see Table 2). This dominance of the BOM by FLASH cost is likely to continue since it is likely that users will by players with more FLASH as the price comes down. In fact the cost shown in the BOM is for 32 MB of FLASH and most of the new players 64 MB of FLASH.

Table 2: Rio Semiconductor BOM

Item	Qty	Manufacturer	Part Number	Description	Volume	Unit Cost	Ext Cost
1	4	Samsung	KM29U6400T	Flash, 64MBit	1M/yr	$10.00	$40.00
2	1	NEC	uPD78P064	Microcontroller/ LCD controller (ROM version)	10K/m	$2.95	$2.95
3	1	Rohm	A40MX04-VQ80	OTP FPGA	10K/m	$4.50	$4.50
4	1	Micronas	MAS 3507D	MPEG Audio Decoder	10K/m	$10.29	$10.29
5	1	Micronas	DAC 3550A	DAC, Stereo Audio	10K/m	$2.74	$2.74
6	1	Maxim	MAX1705	DC to DC step-up converter	10K	$2.81	$2.81
7	1	TI	HC157	Quad 2-input multiplexer	10K	$0.22	$0.22
						Total:	**$63.51**

Given that a commodity whose cost is dominates the BOM pretty much the same for all players, the challenge becomes how to add value and differentiate.

Xilinx Internet Audio Solutions

Xilinx is addressing the Internet audio market from two standpoints, and has the collateral to support design-ins.

First, Spartan represents an excellent solution for low cost, flexible, system level glue, and peripheral implementation for customers that are using any of the non integrated ASSP solutions (Micronas or C54x). Use of Spartan for this application brings the advantages of quick time to market, easy differentiation, and field upgrade capability. The MP3 NG application note describes this application.

Next, the Xilinx CoolRunner CPLDs provide a low cost, low power solution to implementing the system logic in an Internet audio player. Use of the CoolRunner CPLD in conjunction with the Micronas ASSP MP3 DSP allows for rapid product deployment at competitive price points. Because the CoolRunner CPLDs are programmable in-system, different players based upon different feature-sets can be readily created and delivered to market.

MP3 NG Application Note

The MP3 Next Generation (NG) application note illustrates the use of Spartan FPGA and an IDT RC32364 RISC controller in a hand held consumer electronics platform. Specifically the target application is an MP3 audio player with advanced user interface features. Figure 3 MP3 NG Block Diagram shows the architecture of the player.

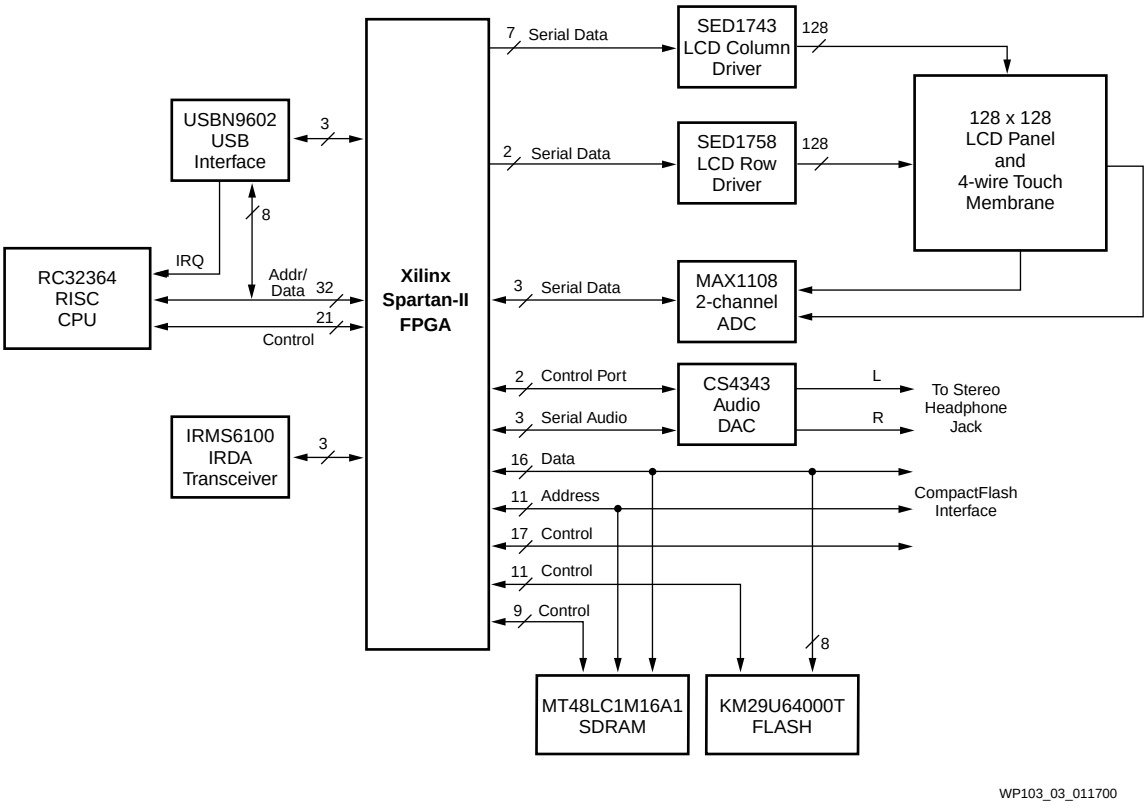

Figure 3: MP3 NG Block Diagram

In this application the Spartan device is used to implement the complex system level glue logic required to interface and manage the memory and I/O devices. The RC32364 implements the MP3 decoding functions, the graphical user interface, and various device control functions.

CoolRunner MP3 Application Note

The CoolRunner MP3 application note (XAPP328) provides a very detailed description of a minimum feature-set Internet audio player based upon the Micronas 3507D MP3 decoder ASSP and the CoolRunner XCR5128 low-power CPLD. The CoolRunner CPLD is attractive for Internet audio applications because of its combination of both low power and cost. In this application note, the CPLD implements all system logic outside of the MP3 decompression enabling a minimal device count, low cost player.

Conclusion

While it is clear that the Internet audio market is rapidly growing, it is not clear which decompression and encryption algorithms will persevere. With over eight different audio formats currently gaining different portions of market share coupled with five different encryption formats, each with their own acceptance, it is evident that products based on supporting only a single format stand the risk of becoming easily obsolete.

With the advent of high-volume FPGAs and CPLDs, it is now possible to develop and ship an internet audio player using programmable logic that has sufficient flexibility to accommodate changes both to the product design as well as audio and encryption formats.

Revision History

Date	Version	Revision
01/17/00	1.0	Initial Xilinx release