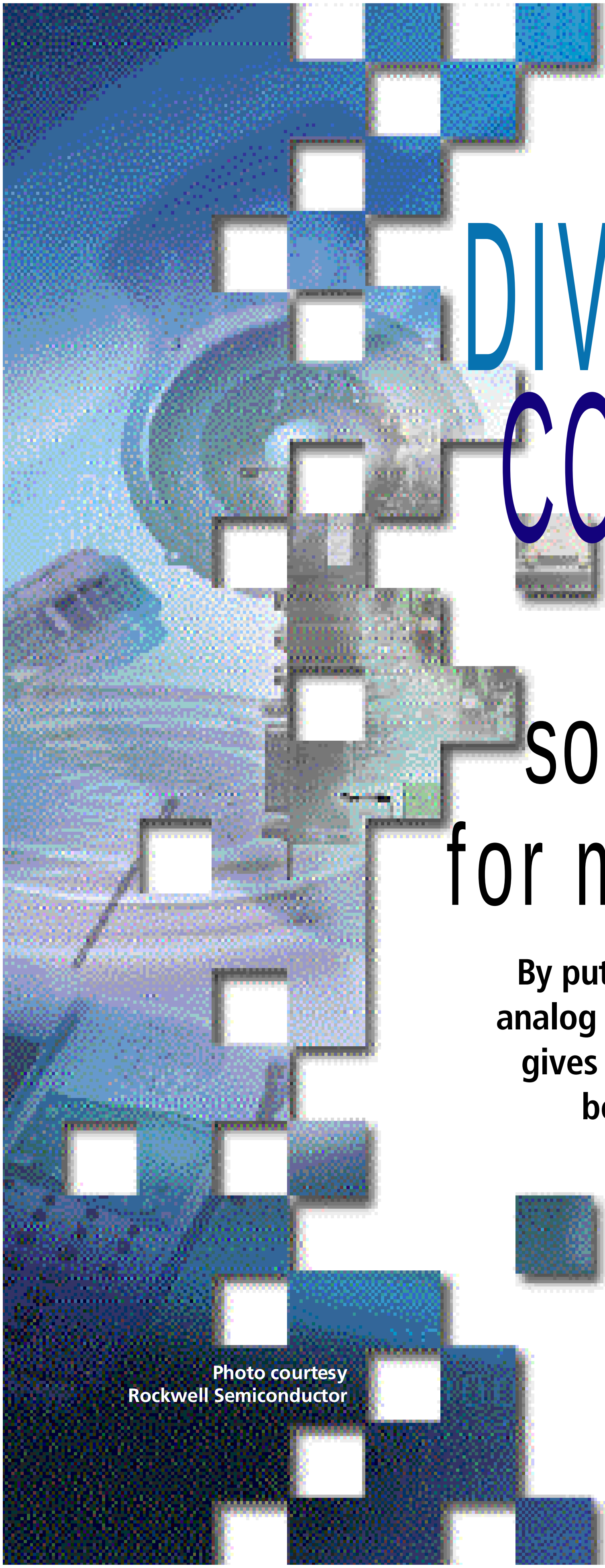


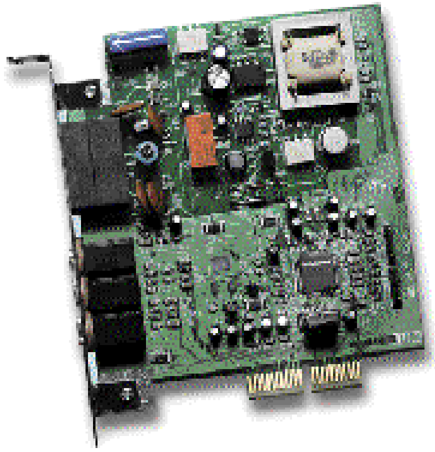
Photo courtesy Rockwell Semiconductor

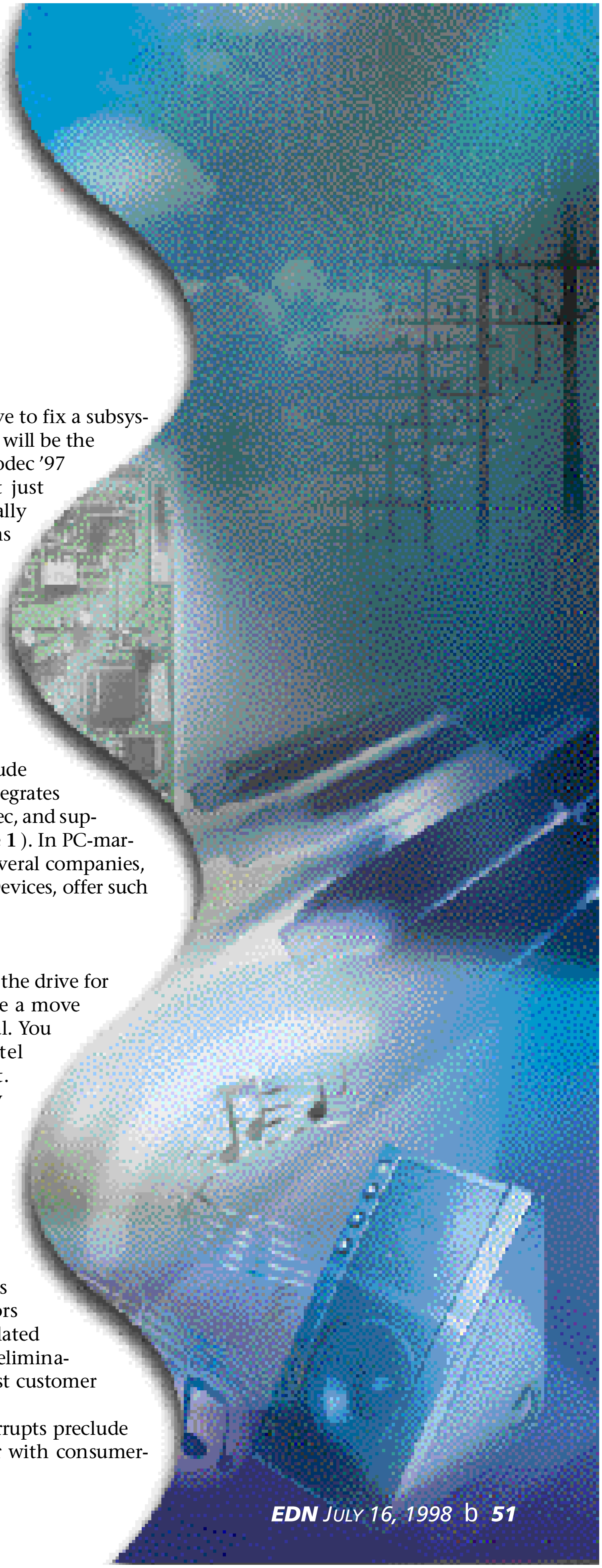
# DIVIDE & CONQUER

## AC'97's sound strategy for multimedia PCs

**By putting audio codecs' digital and analog functions in separate ICs, AC'97 gives PCs better sound quality. As a bonus, it promises to lower costs by integrating audio and modem subsystems.**

*MAURY WRIGHT, TECHNICAL EDITOR*





In computer-system design, sometimes you have to fix a subsystem that's arguably not broken. It appears that will be the case with computer audio. In fact, the Audio Codec '97 (AC'97) specification demands that you not just make changes but also take what's now typically implemented in one IC and split the functions into separate digital and analog ICs. In the short term, AC'97 will increase the bill-of-material costs of the audio subsystem. In the long term, however, AC'97 promises to lower costs by moving audio-processing tasks to the host CPU and potentially integrating the audio and modem subsystems. Within the next year, AC'97 and other PCI audio ICs will provide designers with several options for next-generation system designs.

Today, most desktop and embedded PCs that include audio ICs rely on a single mixed-signal device that integrates an ISA-bus interface, an audio controller, an audio codec, and support for legacy audio registers and a game port (**Figure 1** ). In PC-market volumes, this audio IC sells for around $5, and several companies, including ESS Technology, Cirrus Logic, and Analog Devices, offer such products.

**Tech-support costs drive move from ISA**

With a proven low-cost audio design in place, why the drive for a significant change? Several factors combine to force a move away from ISA-based audio and the ISA bus in general. You might want to blame the normal culprits—Intel (www.intel.com) and Microsoft (www.microsoft.com)—for the coming demise of ISA. Intel certainly stands to benefit each time a legacy interface falls by the wayside, because the demise forces users to buy new systems that also happen to include the latest mP. In the case of ISA, however, Microsoft and leading system vendors want to eliminate the legacy bus because of the technical-support costs of ISA devices. Despite a somewhat-shaky start, PCI-based plug-and-play cards generate far fewer technical-support calls than ISA cards. Moreover, system and software vendors can successfully and more quickly dispatch PCI-related calls than they can ISA-related calls. Presumably, the elimination of the ISA bus will lower support costs and boost customer satisfaction.

ISA also hampers audio quality. Constant ISA interrupts preclude today's systems from providing audio quality on par with consumer-electronics gear. The PCI bus, conversely, can carry a number of consumer-quality audio streams using DMA transfers. More robust music and game sounds will require a move to PCI. (For examples of coming audio advancements, see **sidebar** "Incredibly realistic audio moves out of labs.") Other applications, such as AC-3 audio for digital-versatile-disk (DVD) soundtracks will also benefit from the change. In what's obviously the simplest transition, companies may simply develop the PCI equivalent of their ISA single-chip offerings.

Intel, meanwhile, along with spec-development partners, such as Yamaha, Rockwell, Analog Devices, National Semiconductor, Creative Labs, ESS Technology, and others, is pushing for a more radical change with the AC'97 initiative. Revision 1 of the AC'97 spec debuted two years ago and defined an analog-only codec IC with two standard pinouts. Presumably, the standard pinouts would allow multiple vendors to offer compatible ICs. The spec also demands a codec that can provide a 90-dB SNR, attempting to provide consumer-electronics-quality sound. The AC-link time-division-multiplex (TDM) serial interface connects the codec with the AC'97 digital-controller IC, sometimes called a DC'97 audio controller (**Figure 2**). The AC-link carries audio with a fixed sample rate of 48 kHz. Intel and its partners chose that rate so that compliant systems could play AC-3 audio without down-sampling or degradation of the sound quality. DC'97 devices that need to play sounds with lower sample rates implement a sample-rate converter to up-sample to 48 kHz.

With AC'97 Revision 2.1 published on May 22, Intel and its partners added a number of capabilities and made significant changes. First, the AC-link now supports as many as four target codecs in addition to the single digital controller. The spec also allows the link to use extra TDM slots to optionally carry 96-kHz streams. Rather than depend on sample-rate conversion, the new spec requires a variable-rate codec that can match the sample rate of streams carried by the AC-link. The spec is also moving away from the notion of pin-compatible codecs from multiple vendors. Audio-only AC'97 implementations can still use the standard pinouts, but Revision 2.1 of the spec also allows the combination of audio and modem codecs into one audio-modem-codec '97 (AMC'97) IC with seven data converters. Differences in modem algorithms and data-access-arrangement (DAA) designs make pin-

## @ a glance

- PC audio is finally moving off the ISA bus to PCI.
- AC'97 puts analog and digital functions on separate chips but merges audio and modem capabilities.
- Eventually, Intel will use AC'97 to move audio and modem processing to a computer's main processor.

## *INCREDIBLY REALISTIC AUDIO MOVES OUT OF LABS*

PC sound has come a long way from the ubiquitous serial-interface-driven speaker. With each new generation of sound cards, users' experience gets better, and they can't imagine going backward: A user with a good wavetable engine wouldn't appreciate a step back to FM synthesis. However, two new technologies—physical modeling and real-time multigigabyte sampling—are poised to move audio to a point at which reproduced sounds are virtually indistinguishable from the real thing. The techniques take entirely different approaches to the audio problem and leverage different advances in computer architecture. Moreover, they will likely find usage in different types of applications and possibly coexist in next-generation systems.

As the name implies, physical modeling uses a mathematical model to represent a sound source. The model can be quite complex. For example, a car-engine model includes a number of small submodels for each mechanical subsystem. The mathematics of each submodel must match the sounds, such as explosions inside a number of cylinders, the exhaust system, and every other mechanical subsystem. The host CPU or, perhaps, a DSP executes the math algorithm to reproduce sounds.

The concept of physical modeling isn't new, but PCs have lacked the power necessary to execute the inherently complex signal-processing algorithms. Moreover, no tools have existed to allow relatively straightforward generation of models. Today, however, Pentium II processors offer the needed MIPS. And start-up Staccato Systems has developed both a Windows-based CAD-like tool, SynthBuilder (**Figure A**), for model development and an algorithm engine, SynthCore, that runs on Pentium processors under the Windows DirectX application-programming interfaces. The host-based software works with any audio codec. Staccato (a spin-off of Stanford) has rights to physical-modeling patents developed at the university over many years.

The SynthCore algorithm is several hundred kilobytes in size but is loaded just once on the host. Each sound (or "voice" in wavetable lingo) model varies in size from 6 to 20 kbytes based on complexity and requires approximately double the host MIPS as does a wavetable voice. Each sound model also requires a few bytes of input parameters that are essentially filter coefficients to customize sounds. Game developers can use the physical-modeling approach because they can ship Synth-Core on the CD with a game. Moreover, the variable filter parameters allow interactive sound control. Even Internet authors can use the technology because they can download SynthCore and use it as a browser plug-in. The runtime bandwidth requirements are modest.

Unfortunately, the printed page can't demonstrate the realism of Staccato's technology. You can go to the company's Web site and download some physically modeled samples of wind and string instruments—instruments that sound notoriously bad when you use wavetable audio or FM synthesis to reproduce them. The car-engine model in **Figure A** is nothing short of amazing. Parameters include the number of cylinders and valves, as well as settings such as engine timing. The model accurately reproduces hot rods to motorcycles, including those that need a tune-up or a better muffler. Unfortunately, the car engine isn't available on the Web site, but the company is demonstrating it at game-related trade shows. Other impressive demos include a sword model and a door model with an amazing number of creaks and closure sounds.

Staccato is still building a business model and is unsure how many ways it will ultimately sell the technology. The company has game developers working on titles, including one that will use the car engine. The unnamed game company will ship the Staccato-based game around the end of the year. Staccato will provide free demo software and will likely license authors, such as game developers, on an indicompatible AMC'97 ICs virtually impossible. You can also connect separate audio and modem codecs to the AC-link. The limit of a single digital controller, however, means you must integrate audio and modem control functions if you plan to use the AC-link to carry audio and modem data. Despite the changes and additions, AC'97 Revision 1 codecs will work with newer controllers. You can download the AC'97 spec and a number of white papers from www.intel.com/pc-supp/platform/ac97.

The publicly stated driving factors behind AC'97 include:

- elimination of ISA in the audio subsystem;
- a simplification of motherboard design because PCI stub-length requirements make it difficult to locate and route printed circuits for single-chip, mixed-signal audio ICs;
- the need for higher quality codecs capable of 90-dB SNR to meet consumer-grade-audio expectations;
- elimination of the need for a mixed-signal device and the ability of manufacturers to build low-cost AC'97 ICs using mature, 5V semiconductor processes;
- the integration of symbiotic modem and audio subsystems that have similar data-rate requirements and that must work together in applications such as full-duplex speakerphones;
- the ability of system vendors to design a single scalable motherboard that they can customize during building with different stuffing options;
- ultimately, the realization of lower costs resulting from audio-modem integration and a move to host-based audio and modem control.

Upon closer review, you will also find that Intel has a lot to gain once AC'97 gains wide adoption. In 1999, the company intends to integrate the DC'97 capability directly into the core-logic south bridge (**Figure 3**). In all probability, Intel will do little more than add a few buffers and the AC-link interface. In turn, the company will move all audio and modem processing to the host—finally completing what it started in 1994 with the native-signal-processing initiative. In fact, Intel is becoming desperate to find new tasks that can require users to buy faster processors. It's hard, if not impossible, to find an everyday office application that can obsolete a 200-MHz Pentium µP.

Intel also long wanted to capture the modem function on the motherboard, but two roadblocks stood in the way (**Reference 1**). First, system manufacturers never wanted to commit to a motherboard-modem technology with the industry constantly moving to new and faster standards. The signal-processing head room that a 400-MHz Pentium II affords, however, means that system vendors can ship a host-based modem that you can likely upgrade even to digital-subscriber-line (DSL) speeds and standards. Second, system

vidual basis. The company also recognizes, however, that applications such as Internet audio may require a lower cost, shrink-wrapped authoring kit and plans to develop a way to provide such access.

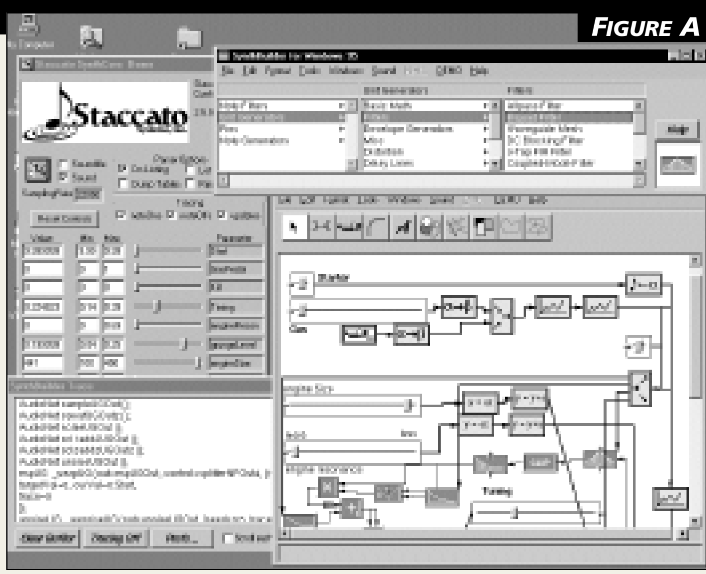
**Large sample sets**

Meanwhile, NemeSys Music Technology has taken a different tack for skirting the limitations of wavetable synthesis. The number and quality of available samples limit the quality of wavetable or follow-on waveguide audio technology. Typical sound cards use a small ROM-based sample set. Even advanced systems that download sounds from a larger sample set have still been limited in accurately producing all instruments.

NemeSys addresses the limitations with gigabytes of samples that include accurate reproductions of everything from a specific baby grand to numerous types of guitars. The GigaSampler software streams samples in real time directly from the hard disk, so the number of samples available to an author is limited only by disk size and the budget to acquire sample libraries. The NemeSys software uses Rockwell's Endless Wave technology, which Brooktree (San Diego) developed before Rockwell acquired the company. Brooktree was first to market with a software-based wavetable product, WaveStream.

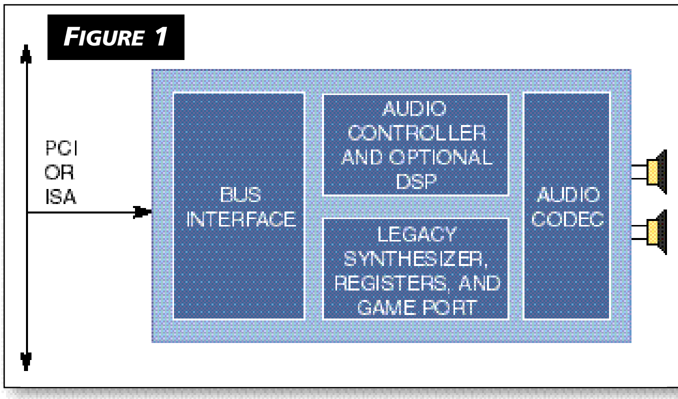
NemeSys targets professional audio developers working on soundtracks and other compositions. The GigaSampler package sells for more than $1000, depending on the samples it includes. The technology is less appropriate for interactive applications, such as games, but competes instead with hardware-based music-authoring tools. Anyone that buys an audio card based on a Rockwell chip set gets the Endless Wave engine, although the sample set measures only in the megabytes. Unlike Staccato's physical-modeling technology, the impact on the host to run the Endless Wave engine is constant, regardless of the sounds produced. Only memory, hard-disk space, and PCI bandwidth limit the number of audio streams that you can play.

FIGURE A




**Staccato's physical-modeling technology delivers incredibly realistic sounds, including everything from car engines to string and wind instruments.**

vendors face the problem of obtaining approval for modem DAA designs from regulatory agencies worldwide. Different countries require different designs. AC'97, however, raises the possibility of moving the codec and DAA to a small, low-cost riser card (**Figure 4** ). The system vendor can ship different riser cards to different regions of the world, but the motherboard can host the modem processing whether the implementation relies on the host µP or on a dedicated data pump.




**Most current audio ICs integrate an ISA interface, an audio controller, a codec, and legacy audio devices, although the market will soon move to a PCI-bus interface.**

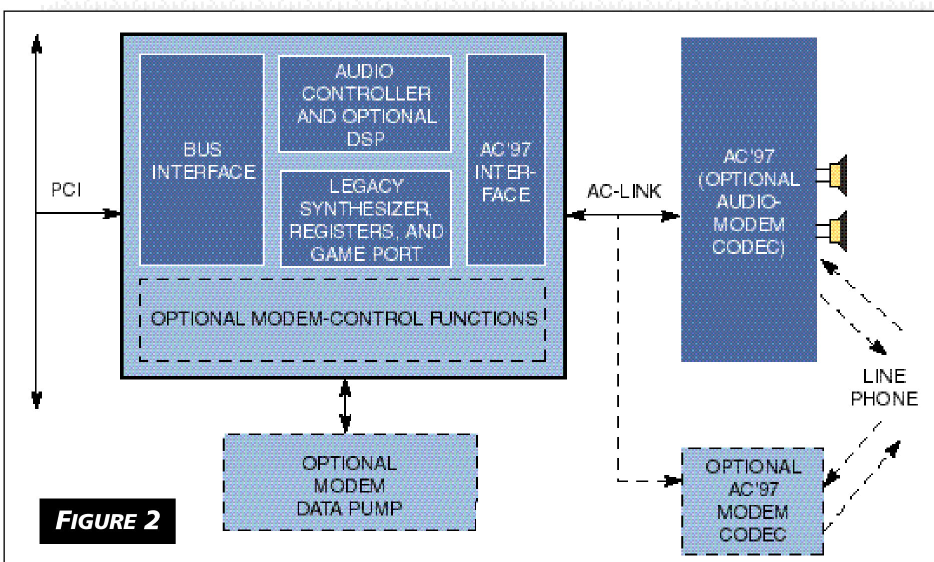
At press time, Intel appeared poised to formalize the riser-card concept with a name and a standard connector. Essentially, the cards will use AC-link as a bus, and motherboards will support two to four cards. Typical designs will probably support two cards with back-panel connectors that are indistinguishable from those on ISA or PCI cards.

Fortunately or unfortunately, depending on your perspective, the audio subsystem won't immediately migrate to a core AC-link with a host-based processing model. Legacy-software support demands a more gradual change. Moreover, system vendors sell a variety of configurations to different market segments. For example, corporations typically buy systems without modems. Remove the modem from the mix, and the AC'97 approach may not be cost-justified. Even in the consumer-market segment, the system vendors must offer options, such as premium audio support—for example, 5.1-channel Dolby SurroundSound. Whether you design PCs or embedded systems, you need to evaluate the ways to migrate away from ISA and choose an approach that matches your application. Moreover, you must chronologically match an approach with an evolving set of choices and with a migration from legacy- or DOS-based applications.

According to most prognosticators, audio will remain an ISA technology through the end of this year. According to Dean McCarron, principal at market-analyst company Mercury Research (www.mercuryresearch.com), less than 10% of the PCs shipped this year will use PCI-based audio subsystems. You can take that 10% in two ways because it implies PCI audio is unpopular. The 10% is certainly a lower number than Microsoft and Intel had hoped for. But Daryl Sartain, director of systems architectures at ESS Technology, points out that it represents a significant sales volume given the size of the market and especially given that virtually no PCI audio existed in 1997. Come Jan 1, 1999, the move to PCI will begin in earnest. After that date, Microsoft and Intel will attempt to effectively ban ISA from systems. In fact, Microsoft won't certify systems that use ISA peripherals under the company's PC9x-compliance program.

You might wonder what's blocked the move to PCI because ATA, LAN, SCSI, and many other functions easily moved to the more modern interface. One factor is the attractive $5 price of ISA audio, given that the less-than-$1000, "segment-zero" PC (low-end consumer PC) represents the fastest growing part of the market. Most PCI-audio ICs include high-end features, such as embedded DSPs that handle 3-D sound. These features necessarily drive the price well past $10, and the extra $5 to $10 is a huge premium in segment-zero PCs.

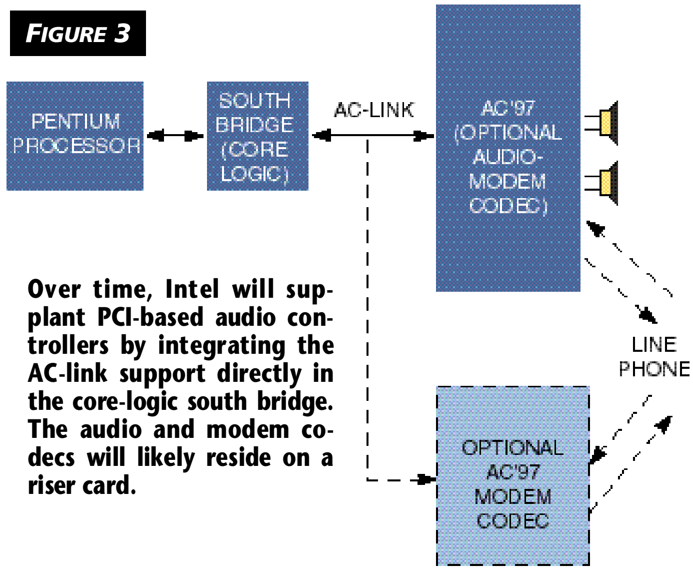
However, legacy-software support has proved to be a bigger problem in the move to PCI. All ISA single-chip audio products include a game port and the registers and interfaces from the original Sound-




**The AC'97 audio approach connects separate audio and digital ICs via the AC-link TDM serial bus. You can place the ICs together on a motherboard or PCI add-in card, or you can separate them with the codec on a riser card.**

Blaster cards. Many of the best-selling PC games still rely on DOS and write directly to the game port and these legacy I/O locations and registers. Windows applications don't have the problem because the programs write to an intermediate application-programming interface that lies between the software and the hardware. Unfortunately, there's no simple and sure-fire way to support DOS games over PCI, although many approaches exist. Moreover, system vendors consider legacy support important because customers are notorious for becoming unhappy when their favorite software doesn't run on their shiny new systems.

**FIGURE 3**




**Over time, Intel will supplant PCI-based audio controllers by integrating the AC-link support directly in the core-logic south bridge. The audio and modem codecs will likely reside on a riser card.**

When you consider a move to PCI audio, you obviously must decide whether legacy support is important to your application. PCI-audio ICs can include hardware, such as a game port, but the PCI bus doesn't directly support ISA addressing, DMA, and interrupt-request schemes. If legacy support is important, you can look to four places for help. The first approach uses DOS-based terminate-and-stay-resident (TSR) programs that most of us hope we never encounter again. The TSRs trap accesses to key memory and I/O locations and translate or redirect the commands and data to PCI devices. TSRs have proved unsuitable as single-point solutions for widespread legacy support, and you should rely on these techniques only if you can verify that they work for your application.

Microsoft, meanwhile, promises to solve the problem with Windows 98. The new OS will feature an improved DOS box that encapsulates legacy applications and traps references to legacy I/O and audio devices. Microsoft claims that Windows 98 will run more than 95% of all legacy applications. It is unclear, however, whether system vendors will accept this level of support as suitable. Windows 98 will still allow users to boot to a real-mode DOS prompt. Once in DOS, that Windows 98 legacy support becomes inactive. It's likely that vendors of consumer PCs will also want some hardware support for legacy applications.

Both Intel and Compaq (www.compaq.com) have developed PCI-audio schemes that add sideband signals to the PCI bus. Intel developed its approach, PC/PCI, to allow notebook computers access to ISA slots in a docking station. Compaq targeted its approach, distributed-DMA (DDMA), at PCI support for legacy devices. It appears that both techniques work relatively well in a software-transparent manner. Unfortunately, they both require sideband signals that the PCI

## MANUFACTURERS OF AUDIO ICs

For more information on audio ICs such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card or use *EDN*'s Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

**AKM Semiconductor Inc**
San Jose, CA
1-408-436-8580
www.akm.com
**Circle No. 301**

**Analog Devices**
Norwood, MA
1-617-329-4700
www.analog.com
**Circle No. 302**

**Aureal Semiconductor**
Fremont, CA
1-510-252-4245
www.aureal.com
**Circle No. 303**

**Cirrus Logic Inc**
Fremont, CA
1-510-623-8300
www.cirrus.com
**Circle No. 304**

**Creative Labs**
Milpitas, CA
1-408-428-6600
www.soundblaster.com
**Circle No. 305**

**ESS Technology Inc**
Fremont, CA
1-510-492-1088
www.esstech.com
**Circle No. 306**

**National Semiconductor**
Santa Clara, CA
1-408-721-5000
www.national.com
**Circle No. 307**

**NemeSys Music Technology**
Austin, TX
1-512-219-9181
www.nemesystech.com
**Circle No. 308**

**Rockwell Semiconductor Systems**
Newport Beach, CA
1-714-221-4600
www.rss.rockwell.com
**Circle No. 309**

**Staccato Systems Inc**
Palo Alto, CA
1-650-853-7035
www.staccatosys.com
**Circle No. 310**

**Tritech Microelectronics**
Milpitas, CA
1-408-941-1300
www.tritechmicro.com
**Circle No. 311**

**VLSI Technology Inc**
San Jose, CA
1-408-434-3000
www.vlsi.com
**Circle No. 312**

**Yamaha Systems Technology**
San Jose, CA
1-408-467-2300
www.yamahayst.com
**Circle No. 313**

**Super Circle Number**

For more information on the products available from all of the vendors listed in this box, circle one number on the reader service card.

**Circle No. 314**

connector doesn't support. Therefore, you can use motherboard core logic that supports PC/PCI or DDMA with PCI-audio devices that support the techniques as long as the audio devices are also on the motherboard. You can't use the techniques with PCI add-in cards.

Virtually every PCI-audio IC does support PC/PCI and DDMA, but you may need a technique that you can apply to an add-in card. For a last line of defense, you can turn to proprietary legacy-support mechanisms developed by each audio-IC vendor. For example, ESS Technology was among the first with PCI devices, and the company's products use a legacy-support scheme called Transparent DMA. More recently, Cirrus announced its CrystalClear legacy support. Aureal doesn't use a fancy name but just promises legacy support without the need for sideband signals.

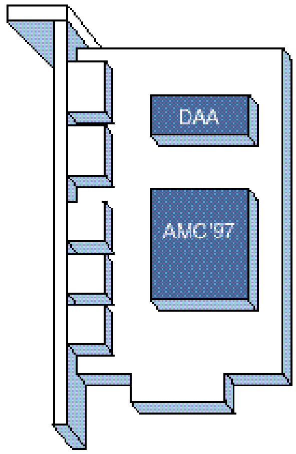



**FIGURE 4**

**Although Intel hasn't yet named or defined a riser-card bus based on AC-link, this conceptual diagram from Inquest (www.inqst.com) demonstrates that the cards will likely use a simple low-cost connector and host little other than codecs.**

Creative Labs claims that its legacy support is superior because the company invented the SoundBlaster. Moreover, the company won a legal battle that prevents competitors from claiming 100% SoundBlaster compatibility even on ISA implementations. In the move to PCI, however, it's unclear whether the company has an advantage because the problem centers on handling ISA interrupts, addresses, and DMA channels rather than on compatibility with the SoundBlaster audio engine.

If legacy support is important, you must carefully investigate the techniques. Rarely does a group of companies shroud techniques in such secrecy, but none of the audio-IC vendors have revealed how their legacy support works. You can draw some general conclusions, however. ESS Technology has been shipping PCI audio for more than a year and perhaps has done more brute-force lab testing to verify support of legacy applications than others. Aureal has shipped PCI-audio devices for nine months and has data from independent labs to verify the effectiveness of its legacy support.

At some point, however, system vendors must wean their customers away from a reliance on hardware-legacy support or fall short of the ultimate AC'97 goals. Once the vendors integrate the AC-link into core logic, it's unlikely, if not impossible, for them to add a legacy-hardware device. Intel believes the day will come when joysticks and, possibly, all audio devices will connect via the Universal Serial Bus (USB) rather than legacy-hardware interfaces. Windows 98, including the DOS-box support, will still be able to redirect legacy calls in software—for example, routing game control to a USB joystick.

Assuming that you're convinced that a move away from ISA is imminent, you might wonder about the audio-implementation options. You must choose from a mixture of strategic technologies that companies offer for reproducing audio and logistic technologies for packaging and shipping a product.

PCI-audio-pioneer ESS Technology, for example, has taken a dual-pronged approach. The company offers the Maestro family that follows AC'97 in separating the digital and audio subsystems. The company also offers the Solo product that integrates a codec on chip, much like the company's ISA products. In both families, ESS offers on-chip game ports and full legacy support.

Most other vendors are eschewing the single-chip approach for now, concentrating instead on a flexible AC'97 product line. For example, Cirrus' first AC'97 audio IC, the CS4614, leverages the company's SoundFusion DSP core to handle functions such as 3-D audio and wavetable sound. As this article hit the streets, however, the company was planning a lower cost, pin-compatible IC that relies on host cycles for most audio processing.

Creative Labs offers perhaps the largest selection of PCI-audio devices, and all use digital controllers that are split from the codec. The company uses the split approach on its high-end ISA products to improve audio quality. The company acts as an OEM for the ICs it developed for the SoundBlaster card family. It also offers PCI ICs that it acquired by purchasing Ensoniq. The Ensoniq ICs targeted motherboard applications more than do Creative's products, which have been more successful on add-in cards. Finally, Creative Labs recently bought Opti's audio group, which has PCI-audio ICs optimized for notebook applications.

You may also want to consider the audio features a chip includes. For example, Aureal's A3D 3-D positional audio appears to have gained a following among game developers. Although almost every audio IC supports some 3-D audio, the popularity of A3D may dictate your choices. Aureal offers support in its Vortex IC, and others, including Cirrus, Yamaha, and VLSI Technology, have licensed the technology for use in their ICs.

Also, a long list of AC'97-codec vendors offer products that you can pair with PCI-audio accelerators. According to McCarron from Mercury Research, first-generation AC'97 codecs have dropped in price to $1 to $2, with Tritech, Analog Devices, and AKM leading in shipments. Ironically, the codecs are selling well into DVD and CD-ROM markets because of their high level of integration and 90-dB SNR despite the fact that AC'97 has been slow to take off in PCs. Other vendors include Cirrus, ESS, and National Semiconductor.

With AC'97-codec prices so low, you might think that a PCI-based AC'97 design can approach ISA prices. Most PCI-audio-IC vendors, however, are quoting prices of approximately $15 (10,000). ESS is probably the only company with a less-than-$10 PCI-audio IC with its Solo that integrates the codec but revives the problem of locating a mixed-signal PCI device on a motherboard.

Should you decide on an AC'97 product, you must also decide how to partition the implementation. The AC'97 PCI ICs can all work when you mount them on a motherboard with a codec, together with a codec on a PCI add-in card, or in Intel's new riser configuration. The choice may be simple when you consider only audio, but a modem can complicate the picture. Moreover, AC'97 may not compete from a cost perspective until you merge the audio and modem subsystems. By combining the two and employing a riser-card approach, you regain the integration you lose with AC'97. An AMC'97 codec on the riser card and a combo modem/audio controller on the motherboard provide a two-chip implementation of the merged subsystem.

Thus far, only Rockwell has announced an AMC'97 2.0 combo codec and companion audio/modem controller, called Riptide. The product includes software wavetable synthesis and legacy support in the PCI IC. As the modem-market leader, Rockwell obviously has modem experience. Moreover, with an internal audio program and its acquisition of Brooktree (San Diego), Rockwell has vast audio experience as well.

The two-chip Riptide product comes with a host-based modem or a DSP data pump. OEMs can also design a single PCI card or motherboard and leave the DSP-versus-host-modem choice as a stuffing option. The Riptide chip set sells for $36 (10,000) or for $49 with the DSP data pump.

ESS Technology is the only other company ready to deliver an internally developed combo audio and modem subsystem. The Maestro-2M works with the company's host-based modem software, which ESS announced last year, and includes an interface to an optional ESS data-pump IC. So far, however, ESS hasn't announced an AC'97 Revision 2.0 or 2.1 combo codec, instead relying on separate audio and modem codecs. In the long run, however, the lowest cost systems will use a merged codec. Expect ESS to deliver such a product this summer.

Other audio companies also offer their ICs with third-party software modems. Both Rockwell and ESS sell their internally developed host-based modems. But PC-Tel (www.pctel.com), SmartLink (www.slink.co.il), and other independent software vendors offer host modem software. For example, Yamaha has announced a partnership with PC-Tel, although the combination would initially require separate audio and modem codecs. SmartLink has even devised a way to use a standard audio codec concurrently for the modem and audio functions (**Reference 1**). Analog Devices and Cirrus have announced that their codecs will support SmartLink's software.

You might also wonder how long audio-IC companies can remain viable, even if they offer modem technology. Certainly, the AC'97-codec vendors will persevere, but an integrated AC-link could eliminate the traditional digital-audio IC. The transition to an integrated AC-link will probably not happen until 2000. Vendors will ship the technology late next year, but legacy-audio concerns and the need to ship enabling technologies by August for the year-end holiday-season sales will delay widespread acceptance.

The PCI market will also remain valid, even after the AC-link moves to core logic. PCI will be the only way designers can add audio technologies that require hardware acceleration—technologies not even on the drawing board yet. Moreover, system vendors need a way to offer value-added features, including upgraded audio, thereby differentiating their products and increasing profit margin.

Still, audio- and modem-IC vendors had best plan for a day when the market for their ICs diminishes. They still may have opportunities to sell their technologies as cores or software intellectual property. And they may still sell some PCI ICs if they innovate and add features. It's hard to imagine, however, that in 2000 or 2001 a company can stay in business strictly as a purveyor of audio ICs. EDN

## Reference

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