

“Digital Audio” and the 1997 Desktop PC

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1. Introduction

This paper is targeted at IHVs and OEMs who have detailed working knowledge of the current PC audio architecture. It is also recommended that the reader be familiar with the Audio Codec '97 Component Specification available on the Intel Web server at <http://www.intel.com/pc-supply/platform/ac97/>.

The goal of this paper is to clarify several terms and capabilities relating to digital audio and propose a practical digital audio output solution for the 1997 high volume PC.

Issues involved with the migration to digital audio, and in particular the configuration of digital speakers, will be explored in detail in this white paper. An OEM solution based on a "digital loopback" capability supported by the newly introduced Audio Codec '97 architecture is examined as a possible means of supporting digital speakers on USB (or 1394). A digital audio migration roadmap is also sketched.

Companion white papers address two related subjects:

- Hardware acceleration models and re-direction of audio streams
- Implementing legacy audio on the PCI bus

2. The "100% Digital Audio" PC

Although many support a long term goal that PC audio "go digital", there are various interpretations of what "digital audio" for the PC really means. For some "digital audio" means nothing less than "100% digital audio" and a sealed PC without DACs and ADCs or analog mini jack connectors; for others it means digital "bus independent audio" which can be output to any device; for still others it only means support for digital speakers.

100% digital audio: ALL audio, whether inside or outside the box, is *digitally sourced or captured*, uses *digital interconnect* (bus or point-to-point), and is *digitally rendered*. A/D and D/A conversions take place as close to the transducers as is possible (typically built in).

Based on this definition, "100% digital audio" is NOT a realizable goal for the *high volume* PC in the 1997 time frame. Some of the issues that must be resolved before "100% digital audio" can become a high volume PC audio solution are:

- digital peripheral cost and availability
- replacing analog sources and interconnect
- preserving backwards compatibility
- characterization of system resource utilization: bus, CPU, memory, latency
- ring 0 software infrastructure services: mixing, sample rate conversion, real time threads
- legal issues with the capability to make perfect digital reproductions

No one has yet presented a clear, market acceptable roadmap describing how to arrive at a "100% digital audio" PC. However, this ideal definition can guide the vision of those working on long term PC audio roadmaps for high performance digital audio. In any case, whenever the "100% digital audio" PC appears, it will, by definition, support bus independent audio, and digital speakers.

3. Bus Independent Audio Output

Adding additional complexity to the digital audio picture is the fact that many audio sources, even the digital ones, are tied to a specific bus (ISA or PCI), and difficult to re-route to USB (or 1394). A primary example is the ISA specific HW required to support legacy audio compatibility (support for DOS games). There is growing uncertainty about whether the "pull" for Windows* 95 games in 1997 will be sufficient to render support for DOS games non-essential. Many PC OEMs are unwilling to risk the exposure to a best selling

real mode only DOS game. Legacy HW compatibility is almost certain to be a requirement in 1997, even for a high end "Living Room PC".

Bus independent output: Audio output is "bus independent", if ALL audio sources can play out PCI *or* USB (or 1394). This can be accomplished by requiring that each audio source be bus independent, or by providing some mechanism whereby the entire audio output mix (digital *and* analog sources) is accessible via memory for re-direction to USB (or 1394).

From a platform architecture standpoint, bus independence is what will enable the PC platform to deliver a choice of audio output solutions, inside or outside of the box:

- **analog speakers:** DACs inside the PC, audio out via standard stereo mini jack
- **digital speakers:** DACs outside the PC, audio out via USB connector (or 1394)

4. The "Digital Audio Ready" PC

The definition of bus independent output can be applied to distinguish between two types of PCs:

A "**digital audio ready**" PC has bus independent audio output (via bus independent sources *or* re-direction).

"Digital audio ready" PCs, by definition, have no issues with attaching digital speakers, or routing digital audio to consumer equipment via a high speed digital bus such as USB (or 1394).

A "**conventional**" PC has one or more analog or bus dependent audio sources, and no re-direction capability.

An inventory of standard PC audio peripherals and interconnect shows why, in the 1997 time frame, without re-direction capability, most PCs will be "conventional" PCs, not "digital audio ready" PCs:

- legacy audio (bus dependent)
- Redbook* CD audio (analog interconnect)
- analog mic & line in (analog sources)
- analog speakerphone connections (analog interconnect)
- analog TV/Video Capture (analog interconnect)
- hardware Dolby* AC-3 decode (bus dependent)

5. Support for Digital Speakers

The majority of PCs shipping in 1997 will physically support the attachment of digital speakers via USB (or 1394).

CAUTION: The end user needs to hear ALL audio sources through the configured speakers. Digital speakers do NOT provide a "total audio solution" on "conventional" PCs with analog and/or bus dependent audio sources and no re-direction capability.

OEMs designing "conventional" PCs have no choice but to configure them with analog speakers.

The following two scenarios are discussed in the next sections:

- OEMs who wish to ship "digital audio ready" PCs can work with audio IHVs to develop an AC '97 based re-direction capability
- End users with conventional PCs who wish to upgrade to digital speakers actually need "hybrid" speakers

5.1. The AC '97 based "digital audio ready" PC

OEMs with what might otherwise be "conventional" PC architectures may wish to ship "digital audio ready" PCs in 1997. This might represent a high end "Living Room PC", but could also be a "modular" high volume PC with a USB hub and digital speakers built into the monitor.

In support of “digital audio ready” PCs, PCI based Audio Codec ‘97 controllers have the flexibility to implement a “digital loopback” capability, in which the AC ‘97 controller can be configured to return to system memory a composite 48Kss stereo stream of ALL audio sources, both digital and analog. Providing there is Microsoft* OS / Win32* Driver Model (WDM) driver support for this “digital loopback” capability, the audio driver can re-target this stream towards any destination, including a pair of digital speakers on USB (or 1394).

In “digital loopback” mode the AC ‘97 controller digitally generates the composite PCM out stream as usual, including upsampling to 48Kss stereo. But instead of transmitting it over the AC-link for output via the system DACs, it digitally mixes this composite PCM out with a 48Kss stereo recording of all analog sources passing through the AC ‘97 mixer, and returns this to system memory. With PCM out muted, and the AC ‘97 input mux set to record the stereo output mix, all unmuted analog sources passing through the analog mixer are captured, including Redbook CD audio.

CAUTION: Use of AC ‘97’s input ADCs to re-direct analog audio passing through the AC ‘97 mixer has impact on the audio subsystem’s full-duplex capabilities (use of mic, headset, and speakerphone). The OEM should carefully evaluate this impact based on the desired configuration. Two general solutions exist:

1. use AC ‘97 components which support the optional 3rd ADC dedicated to the mic
2. omit the analog mic and line in jacks and bundle a digital mic or speakerphone with the platform

Digital loopback PROs:

- All digital audio (PCM out) generated in the AC ‘97 controller can be fed back to memory (PCM out may include: SB out, FM, wavetable, decoded AC-3, DirectX* 3D rendered, etc.)
- AC ‘97’s ADCs may be used to capture analog audio and add it to the “digital loopback” stream (a way to re-direct analog Redbook CD, TV tuner/Video capture, speakerphone out, etc...)
- AC ‘97’s 3rd ADC minimizes impact on Codec’s full-duplex capabilities

Digital loopback CONs:

- Requires additional development effort (IHVs, OEMs, Intel, and/or Microsoft)
- Has impact on latency, CPU, bus, memory
- Replaces in-line accelerator model with a multi-trip model (out PCI, back in PCI, out USB) (adds additional dependencies on WDM audio for re-direction, and would benefit from audio class driver <--> USB audio driver pointer exchanges to save on mem to mem copies)

5.2. “Hybrid” speakers support end user upgrades for “conventional” PCs

Since the majority of PCs shipped in 1997 will probably be “conventional” PCs, and most end users are unaware of the capabilities of the audio subsystem inside their PC, digital speaker vendors need to address the *end user upgrade* market for “conventional” platforms by developing “hybrid” speakers, which accept USB (or 1394) *and* analog line out. This appears to be the *ONLY end user* upgrade solution for “conventional” PCs. The analog speaker input is necessary to guarantee that analog and bus dependent sources can be heard (legacy audio, Redbook CD, analog mic & line in, speakerphone, TV tuner/Video capture, HW AC-3 decode). “Hybrid” speakers should have minimal cost and performance differences as compared to “digital only” speakers.

Hybrid speaker PROs:

- Addresses all unmigrated analog and bus dependent audio sources
- Covers all USB (or 1394) enabled PCs
- No cost or performance burden to base PC
- Only impacts the users who upgrade
- Attractive as an end user upgrade solution

Hybrid speaker CONs:

- Requires both digital AND analog connections between PC and speakers
- Not attractive as an OEM configured solution (adds little value)

6. Digital Audio Migration Roadmap Sketch

SHORT TERM: Help OEMs distinguish “Conventional” PCs from “Digital audio ready” PCs

- Encourage digital migration, but continue to support analog sources
- “Digital audio ready” PCs offer OEMs and end users a choice of output speakers:
 - analog speakers:** DACs inside the PC, audio out via standard stereo mini jack
 - digital speakers:** DACs outside the PC, audio out via USB connector (or 1394)

LONG TERM: PC audio architecture offers a full range of solutions, from low end to high end

- Migrate from “Conventional audio” to “Digital audio ready” to “100% digital audio”
- “Digital audio ready” PCs offer OEMs and end users a scaleable choice of output speakers:
 - analog speakers:** DACs inside the PC, audio out via standard stereo mini jack
 - digital speakers:** DACs outside the PC, audio out via USB connector (or 1394)
- “100% digital audio” appears on PCs which migrate ALL audio *sources* and *interconnect* to *digital*, whether inside or outside the box. ALL audio plays out USB (or 1394). There are plausible replacements for most of the existing analog sources, timing is the real question. The 100% digital audio PC might look something like this:

Legacy (SB) audio	-->	software legacy emulation (or dropped entirely)
Redbook CD audio	-->	replace with soft CD or DVD (all data accessed via bus)
Wavetable synthesis	-->	software wavetable
Mic & line in	-->	replace with USB mic & line in
Speakerphone	-->	replace analog audio/modem interconnect with WDM services
TV/VidCap	-->	replace analog interconnect with digital capture & WDM services
AC-3 decode	-->	software AC-3 decode (or built into the speakers)

7. Conclusions

The 1997 crop of analog, inside the box, PCI audio solutions promises to deliver very high quality audio at an attractive cost. “Digital audio” can be viewed as a way of introducing new capabilities (such as quality, Plug and Play peripheral connectivity, and modularity) into the PC platform, rather than as a discontinuous, “flip of the switch”, complete replacement for existing audio solutions.

We expect a variety of platforms to be shipped in the 1997/1998 time frame; their audio capabilities will determine which output solutions will and will not work:

- “Conventional” PCs with analog audio output only
- USB (or 1394) enabled “Conventional” PCs which do not fully support digital audio output
- “Digital audio ready” PCs with analog and/or digital audio output capability
- “100 digital audio” PCs with digital audio output only