Overview of Audio Codec '97

revision 1.0

Written by
Dan Cox - IAL Media & Interconnect Technology Lab
dan_cox@ccm.jf.intel.com

Intel Corporation

1. Introduction

This paper is addressed to 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 (AC '97) Component Specification, which is available on the Intel Web site at: http://www.intel.com/pc-supp/platform/ac97/.

The purpose of this paper is to provide an overview of AC '97 and an introduction to the AC '97 architecture. Related white papers provide detailed background and recommendations for the development and implementation of high performance / high quality audio subsystems for high volume PC platforms in the 1997 time frame. The Design Guide targets IHVs who are developing to the Audio Codec '97 (AC '97) architecture definition, as well as OEMs who are adopting AC '97 based designs.

1.1. Background on audio

Audio has arrived on the PC motherboard but the motherboard can be an electrically noisy place. Windows* 95 APIs are beginning to replace the Sound Blaster* (DOS) programming model for games but many OEMs are requiring 100% hardware legacy compatibility in 1997. Full-duplex audio for communications has become commonplace, but software support for low latency (ring 0) audio is not yet fully in place under Windows 95. PCI and USB are replacing ISA but OEMs don't want to lose backwards compatibility or have a fragmented audio architecture. Multi-channel audio is becoming widely available to consumers, but the baseline PC cannot bear the cost of 6 DACs and 6 speakers, and there are few digital audio standards for inter-operability.

For the PC audio to "go 100% digital", it will take time to migrate analog sources and interconnect to digital. These sources include Red Book CD audio, analog mic and line in, analog TV tuner or video capture cards, and analog speakerphone modem connections. Even after digital audio is introduced, cost effective backward compatability with analog may remain an OEM requirement for business reasons, not technical ones. Issues with cost, interconnect, software driver architecture, system resources (processor, BUS, memory), and digital reproduction capabilities have yet to be resolved. Adding additional complexity is the fact that many audio sources, even the digital ones, are tied to a specific bus (ISA or PCI), and may be difficult to re-route to USB or IEEE 1394.

It is within this context that AC '97 defines a high quality audio architecture for the 1997 volume platform segment which should advance the migration to digital audio, but also maintain support for analog audio sources and analog interconnect for backwards compatibility. The presence of analog support does require using it, each OEM is given the freedom to configure a solution that fits their business model. The architecture put in place by AC '97 supports a wide range of high quality audio solutions, from a 2-channel mix of digital and analog audio inside the PC, to multi-channel digital audio outside of the PC.

1.2. Audio Applications for 1997

The following is a list of audio applications categories which were examined and used to define the baseline feature set and optional capabilities defined by the AC '97 architecture:

1. Arcade Quality 3D Games
    - DOS based Sound Blaster* compatible
    - Windows* 95 DirectX* APIs
2. MIDI Wavetable Synthesis
    - High quality music synthesis and playback
3. Consumer Video and Audio Conferencing (via POTS, ISDN, LAN, and Internet)
    - Full-duplex, low latency audio, headset or speakerphone using system audio mic & speakers
4. DVD-ROM Movie Playback
    - Dolby* AC-3* audio decode with consumer quality 2 speaker output
5. PC TV or Video Capture card
    - Audio mixer supports a "CD style" connection for video/audio playback, capture, and edit
6. Multimedia and Internet Presentation and Authoring
    - Audio mixer supports playback as well as content creation (capture, mix, and edit)
7. Voice Recognition for Command & Control and Dictation
    - High quality, continuously available mic input
8. Interactive Internet and 3D virtual worlds - Java*/VRML*/ActiveX*
    - Interactive full-duplex, low latency, 3D rendered audio for the Internet

1.3. Audio Hardware Capabilities for 1997

The following is a list of audio hardware capabilities extracted from the audio applications list. Not all of these capabilities will be requirements for every 1997 audio subsystem, but generally they each merit consideration:

1. Sound Blaster compatibility
    - DOS games: SB register set, FM synthesis, MPU 401* MIDI interface, analog joystick
2. Low CPU utilization
    - Meets MPC3* requirements via conditioned DMA (type F or equiv.) on ISA, or PCI
3. Full-duplex audio w/ mixed sample rates
    - Simultaneous audio output (stereo 11, 22, or 44Kss) with voice input (mono 8 or 16Kss)
4. High quality audio output
    - ~90 dB SNR output at speaker jack
5. 3D stereo enhancement
    - Audio Codec supports analog stereo enhancement (post analog mix)
6. Multimedia audio mixer
    - Play and record support: PCM, CD, line, video, synth, mic, speakerphone, or mix of sources
7. High quality mic input
    - ~70-80dB SNR at the ADC, programmable gain, dynamic or electret mic
8. Headset support
    - Switchable input (desktop mic or headset mic), switchable output (speakers or headset)
9. Line out (or digital connection) to consumer audio equipment
    - Line level stereo analog output (or digital connection via USB or IEEE 1394)
10. Speakerphone echo cancellation reference
    - Audio Codec analog mixer implements hardware support for software echo cancellation (mic input with speaker output reference signals)
11. AC-3 decode for PC based DVD-ROM movie playback
    - AC-3 decode (5.1 ch to stereo)
12. Hardware support for MIDI synthesis & DirectSound 3D position and mix

- Microsoft's proposed PC 97* Entertainment platform requirements

1.4. Motivation for a 2-chip split digital/analog audio architecture

The following is a list of features which have led many industry audio vendors to adopt a 2-chip solution:

1. Consumer grade audio
    - Consumer electronics OEMs are requiring high quality audio (~90dB SNR) output
2. Scaleability & flexibility
    - OEM's want audio components to be hardware scaleable like the graphics component model (i.e. one footprint, several different stuffing options)
3. More connectivity, ability to cost efficiently support the audio needs of other subsystems
    - Telephony & full-duplex speakerphone, using headset and system mic and speakers
    - Video (TV tuner, video capture) audio input
4. PCI transition is driven by new features enabled (or made more efficient) by PCI
    - Low cost downloadable wavetable (waveform samples in system memory)
    - Multi-stream 3D positioning for DirectX
    - AC-3 decode
5. Cost reduction for OEMs and end users through integration
    - Telephony, Graphics, SuperIO or chipset

1.5. Potential benefits of a 2-chip architecture: quality, cost, flexibility

The following is a summary of the potential benefits of a high quality 2-chip digital/analog split architecture (as defined by AC '97):

1. Delivers ~90dB SNR in the analog component
    - removes a substantial amount of the digital circuitry which generates on-chip mixed signal noise
    - fixes the DAC and ADC sample rates and all filtering at 48Kss, hence easier to optimize (high quality sample rate conversions to/from 48Kss are performed by the digital controller)
    - enables OEMs to isolate the small analog component (7x7mm body, 48-pins) from off-chip noise sources in a quiet place on the motherboard (or circuit board) near the audio connectors
2. Decreases overall system cost
    - increases integration in the digital controller
    - consolidates baseline audio, wavetable, DirectX, AC-3, telephony, etc., in one package
    - improves manufacturability
        digital controller moves to generic process (vs. mixed signal)
        analog component becomes a relatively small mixed signal die
    - decreases re-design, OEMs can design/tune the analog portion of an entire product line once
3. Improves implementation flexibility
    - enables digital controllers on any bus (PCI, USB, 1394, ISA)
    - supports audio inside or outside of the box
    - offers ample headroom for future expansion
        including 4 or 6 channels of output with up to 20-bit DAC resolution

1.6. AC '97 Working Group objective and operating methodology

The objective of the Audio Codec '97 initiative is to develop an ***industry standard architecture*** for high quality 2-chip audio:

- Make ***high quality audio*** broadly available at volume PC price points
- Promote ***interoperability*** between AC '97 controller / AC '97 sourced by different vendors
- Define ***architectural headroom*** for additional features and flexibility
- Work ***closely with industry IHVs and OEMs*** to target and deliver the right set of system features

A royalty-free, limited license is available to those who wish to make use of the AC '97 Component Specification.

For followup and future AC '97 development, it is the intention of the Intel AC '97 team to interactively solicit *industry wide* input and feedback via the AC '97 Web page. Everyone who wishes to participate will have equal opportunity to comment on material as it is posted on the Web[1]. Vendors are encouraged to monitor the AC '97 Web page, which will also include AC '97 Component Specification errata information and a list of technical Frequently Asked Questions (FAQ). Below is the web address:

http://www.intel.com/pc-supp/platform/ac97/

The Intel Audio 97 team appreciates the high level of industry interest already generated by the AC '97 Component Specification, and the many suggestions that have already been submitted for advancing the AC '97 architecture in the future.

1.7. AC '97 Timeline

AC '97 Component Specification 1.0 published	May 17, 1996
White papers: Digital audio, hardware acceleration, Legacy on PCI	May 1996
Development and industry review of AC '97 Design Guide via web page	June-Aug 1996[2]
Audio Quality Measurement Specification and Methodology	July-Dec 1996[2]
First AC '97 controller / AC '97 samples demonstrated	Oct 1996[2]
OEMs shipment of AC '97 equipped PCs to the retail channel	2H97[2]

1.8. Related documents and specifications

- Intel/Partners Audio Codec '97 Component Specification (Codec '97)
- Intel Audio Hardware Interface '96 Design Guide (Codec '96)
- Intel NSP Reference Platform Design Guide (Codec '95)
- Intel Audio Quality Specification and Measurement Methodology (TBD)
- MPC Working Group's MPC2 & MPC3 specifications (http://www.spa.org/mpc/default.htm)
- Microsoft's "PC 97" suppliment to "Hardware Design Guide for Windows 95"
- Microsoft's "PC 96" suppliment to "Hardware Design Guide for Windows 95"
- Microsoft's "Hardware Design Guide for Windows 95"

[1] Intel will not consider or treat any such feedback as the confidential information of the party providing it. Intel shall be free to use any such feedback at its discretion.

[2] Estimates