

# Audio Codec '97 Controller / Codec / System Design Considerations

revision 1.0

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# 1. Introduction

This paper is addressed to IHVs and OEMs who have detailed working knowledge of 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-supply/platform/ac97/>.

The purpose of this paper is to describe system level considerations and recommendations for AC '97 based high volume PC systems in 1997.

## 1.1. Audio System Level Recommendations

The AC '97 architecture defines an audio subsystem which offers the OEM who partners with one or more audio vendors a high degree of flexibility in meeting the requirements of a wide range of PC systems:

- The vendor specific AC '97 Controller can implement scalable features by offering a baseline Controller and an upgrade Controller (same footprint) and/or companion accelerator.
- The AC '97 Codec can provide scalable quality and analog features via multiple sources with a standard footprint.

The following subsections offer general system level recommendations for Home, and Corporate Desktop PCs. Detail on the implementation of specific Controller or Codec features are provided in subsequent sections of this white paper.

## 1.2. Home PC Market Segment

Three classes of PCs define the Home market segment:

1. Baseline Desktop PC
2. Multimedia Desktop PC
3. Family Room PC

### 1.2.1 BaselineDesktop PC

It is desirable that the audio subsystem for the BaselineHome Desktop PC provide support for audio playback and capture, DOS\* and Windows\* 95 games, Red Book CD, headset and speakerphone for DSVD modems and video conferencing, and accommodate upgrade cards such as TV tuner and/or video capture, hardware MIDI synthesis, and hardware Dolby\* Digital AC-3 decode (for Pentium Processor based platforms with soft MPEG2 video decode).

A baseline AC '97 Controller + baseline AC '97 Codec solution can deliver these capabilities for nearly the same cost as a 1-chip ISA Codec solution, while offering PCI performance, higher quality audio and excellent interconnect support for OEM configuration or aftermarket upgradeability.

The baseline AC '97 Controller for a Baseline Desktop PC might implement the following:

- PCI 2.1 bus master interface and AC-link Controller
- 100% Sound Blaster\* compatible legacy audio via PC/PCI:
  - SB Pro\* register set, FM synth, MPU 401, analog joystick
- High quality digital sample rate conversion to/from {8.0, 11.025, 16.0, 22.050, 32.0, 44.1} and 48Kss
- "Digital loopback" returns 48Kss stereo composite PCM out (digital + analog) to system memory in order to enable external digital audio output via USB or 1394

The baseline AC '97 Codec is described in the AC '97 Component Specification.

### 1.2.2. Multimedia Desktop PC

In addition to the Baseline Desktop PC capabilities, the audio subsystem for the Multimedia Desktop PC might also be expected to incorporate a DVD-ROM drive and TV tuner/video capture card, provide CD quality audio playback and capture via RCA jacks for multimedia presentation and authoring, support stereo echo cancellation for speakerphone and voice recognition, and have built in high quality MIDI synthesis, 3D positional audio, and AC-3 decode (for Pentium Processor based platforms with soft MPEG2 video decode).

A feature enhanced AC '97 Controller + feature enhanced AC '97 Codec solution can deliver these capabilities in a highly cost effective 2-chip implementation.

The feature enhanced AC '97 Controller for a Multimedia Desktop PC might implement the following:

- PCI 2.1 bus master interface and AC-link Controller
- 100% Sound Blaster compatible legacy audio via PC/PCI (SB Pro register set, FM synth, MPU 401, analog joystick)
- High quality digital sample rate conversion to/from {8.0, 11.025, 16.0, 22.050, 32.0, 44.1} and 48Kss
- "Digital loopback" returns 48Kss stereo composite PCM out (digital + analog) to system memory in order to enable external digital audio output via USB or 1394
- Hardware MIDI synthesis with downloadable samples in main memory
- Hardware 3D positional audio in support of Microsoft's DirectX\* APIs
- Hardware Dolby AC-3 decode (for Pentium Processor based platforms)

The feature enhanced AC '97 Codec for a Multimedia Desktop PC might implement the following options:

- 18-bit DACs for higher audio quality
- Analog tone control and 3D stereo enhancement
- 3rd ADC channel for dedicated mic input and stereo echo cancellation

### 1.2.3. Family Room or "Socializing" PC

The PC has become a new audio source in the family room. PC output can be a mix of one or more of the traditional PC audio sources, such as CD audio, games, MIDI music, speakerphone, etc. PCs with built in DVD-ROM drives also function as outboard AC-3\* decoders and can source 2 or more channels of decoded AC-3 audio.

The PC can also be employed as a powerful outboard effects processor, providing many audio enhancements, including:

- reverb and ambiance
- multi-band equalization for tone control and room EQ
- cross-talk cancellation
- speaker virtualization and placement

The consumer A/V receiver is the established audio hub in millions of family rooms today. It is home of the power amplifier and attach point for high quality speakers (2, 4, or 6 channels). PC to A/V receiver connections can be made via analog line in / line out, or ideally, bi-directional digital control and data connections enabled by USB and/or IEEE 1394. But until end to end digital connectivity is ubiquitous, one cannot ignore the legacy market that will depend on analog RCA interconnect.

For existing A/V receivers, the upper bound to audio quality will be gated by the audio solution in the PC. It is therefore desirable to have cost effective high quality analog connections via RCA jacks built into the PC, or via digital-to-analog adaptor dongles (internal or external). An AC '97 based audio solution

similar to the one described for the Multimedia Desktop PC can meet these cost and quality requirements, and offers baseline 2 channel output with the following potential configurations:

- Stereo
- 3D enhanced stereo
- Pro Logic\* encoded stereo
- Virtualized Multi-channel output

In the near future, USB and IEEE 1394 can significantly expand the range of output options for those who purchase digital peripherals or upgrade to digital ready A/V equipment. But analog support for backwards compatibility may continue to be attractive for years to come. Without basic analog support the family room PC can only target digital ready A/V equipment.

### **1.3. Corporate PC Market Segment**

#### **1.3.1 Corporate Desktop PC**

It is desirable that the audio subsystem for the Corporate Desktop PC support audio playback and capture for multimedia presentation and authoring, headset and speakerphone for DSVD modems and video conferencing, and accommodate Red Book CD audio and upgrade cards such as video capture.

A baseline AC '97 Controller + baseline AC '97 solution can deliver these capabilities for equivalent or less than the cost of a 1-chip ISA Codec solution which supports full Sound Blaster compatibility, while offering PCI performance, higher quality audio and excellent interconnect support for OEM configuration or aftermarket upgradeability.

The baseline AC '97 Controller for a Corporate Desktop PC might implement the following:

- PCI 2.1 bus master interface and AC-link Controller
- High quality digital sample rate conversion to/from {8.0, 11.025, 16.0, 22.050, 32.0, 44.1} and 48Kss
- "Digital loopback" returns 48Kss stereo composite PCM out (digital + analog) to system memory in order to enable external digital audio output via USB or 1394

The baseline AC '97 Codec is described in the AC '97 Component Specification.

## 1.2. AC '97 layout considerations for Legacy HW and Audio/Telephony

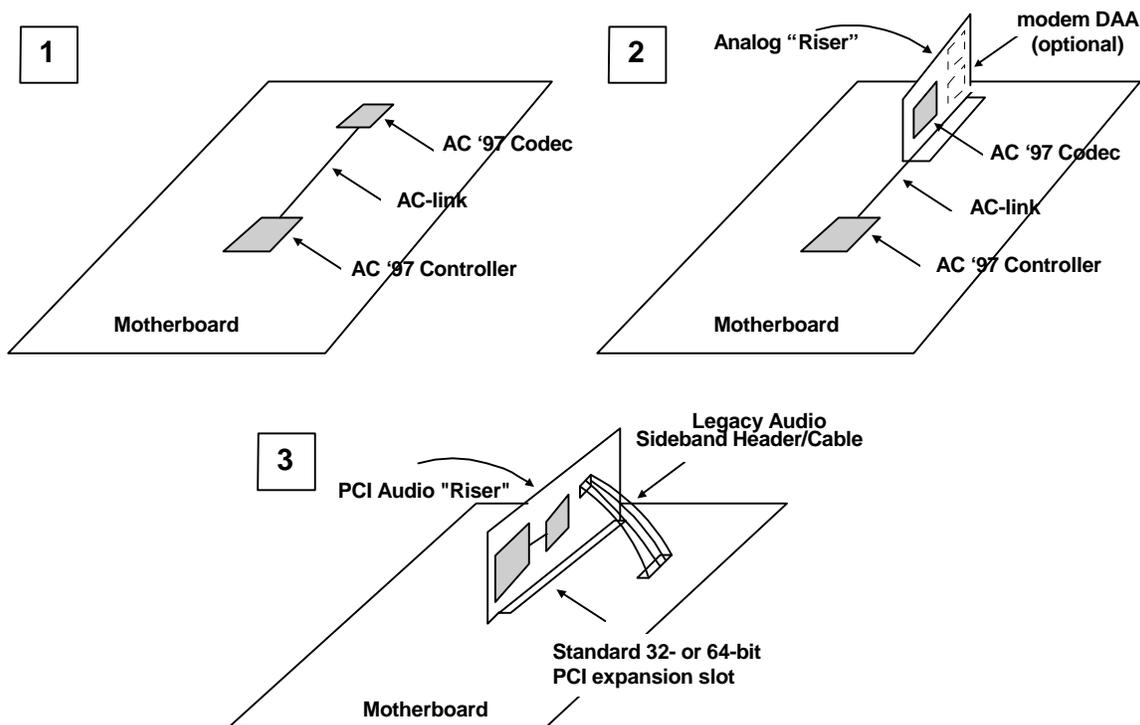
The integration of system audio with telephony enables a more cost effective system solution, while also creating a tight coupling between the two subsystems. However, when also considering the need for legacy audio hardware compatibility several issues arise. Hardware compatible legacy audio, for reasons discussed in other related Intel whitepapers, dictates that the audio subsystem logically reside on the motherboard, being enumerated by the BIOS. At the same time the OEM motherboard attach rate for modem is not equivalent to that of audio. Additionally, modem down on the motherboard may result in time consuming internationalization and certification processes which could significantly delay new OEM product introductions.

For the above reasons an IHV planning the development of a product that integrates audio/telephony may lean towards a PCI bus add-in solution that would allow a scalable solution space for his customers while also offloading the certification process from his customers. An IHV could now go through the certification processes in parallel with, for example, an OEMs motherboard development. This is where the problem with respect to maintaining legacy audio compatibility arises.

Hardware compatible legacy audio needs to be a BIOS enumerated motherboard device, yet the audio/telephony integration appears to be a better business model fit as a scalable PCI bus add-in solution. To help facilitate the integration of audio/telephony the Intel audio team would like to suggest a range of possible solutions that address the integration and legacy compatibility issues.

Three specific for AC '97 Controller and Codec placement are discussed in the following sections:

1. Controller down + Codec down (down = on the motherboard)
2. Controller down + "analog riser" with Codec, audio connectors, and optional modem DAA and RJ11
3. OEM PCI Motherboard Audio "riser" card with Controller, Codec, optional audio/telephony, and/or legacy sideband connector



### **1.2.1. Option 1: Fully Motherboard Integrated Solution**

The AC '97 Controller and Codec are physically, and logically down on the motherboard.

#### **PROs**

- Lowest audio/telephony system cost
- Legacy compatibility

#### **CONs**

- Motherboard attach rate in some cases does not warrant modem down
- FCC certification delays to motherboard intro

IHV's are encouraged to develop scalable, pin compatible AC '97 Controllers as well as AC '97 Codecs. With an IHV's scalable product family, the OEM can address the modem down or not business issue by designing one motherboard and scaling up or down based upon the IHV's scalable product offerings.

While this configuration may solve both the legacy and audio and audio/telephony scalability issues, the serial delays to OEM product introduction associated with FCC certification remain unresolved.

### **1.2.2. Option 2: AC '97 Codec Riser Solution**

The AC '97 Controller is soldered down on the motherboard, and its AC-link<sup>1</sup> feeds a riser connector for the AC '97 Codec/DAA etc...

#### **PROs**

- Legacy compatibility
- Scalability

#### **CONs**

- Higher cost than Option #1

As for option #1 IHV's are encouraged to develop scalable, pin compatible AC '97 Controllers as well as AC '97 Codecs. With an IHV's scalable product family, the OEM can layout his motherboard for a pin compatible series of scalable Controllers, and with a single motherboard can ship a range of products with or without the telephony integration based upon the appropriate Controller being matched up with its corresponding Codec riser card.

The OEM can either design their own riser cards, or subcontract the IHV to deliver them to the OEM customer's specifications. In either case the FCC certification process is decoupled from the motherboard design.

### **1.2.3. Option 3: OEM PCI Motherboard Audio "Riser" Solution**

The OEM provides a "Legacy Header" on the motherboard a that standard form factor PCI add-in card can cable onto with their complementary header. This option brings legacy DMA/IRQ sideband signals over to the standard formfactor PCI bus add-in.

With this option the OEM is presented with a maximally scaleble platform partitioning, and the IHV can sell their add-in into the retail market segment (without legacy support) as well as the OEM market segment.

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<sup>1</sup> In addition to other telephony related digital signals, such as ring det, hook switch control, etc.

In order to enable legacy hardware compatibility the OEM PCI audio riser, when utilizing the legacy header, is treated as an OEM motherboard subsystem. This OEM targeted product is configured as a riser card conveniently plugged into a standard PCI expansion slot with additional signals provided via the header/cable. The audio subsystem must be enumerated via the motherboard BIOS to enable the legacy compatible hardware.

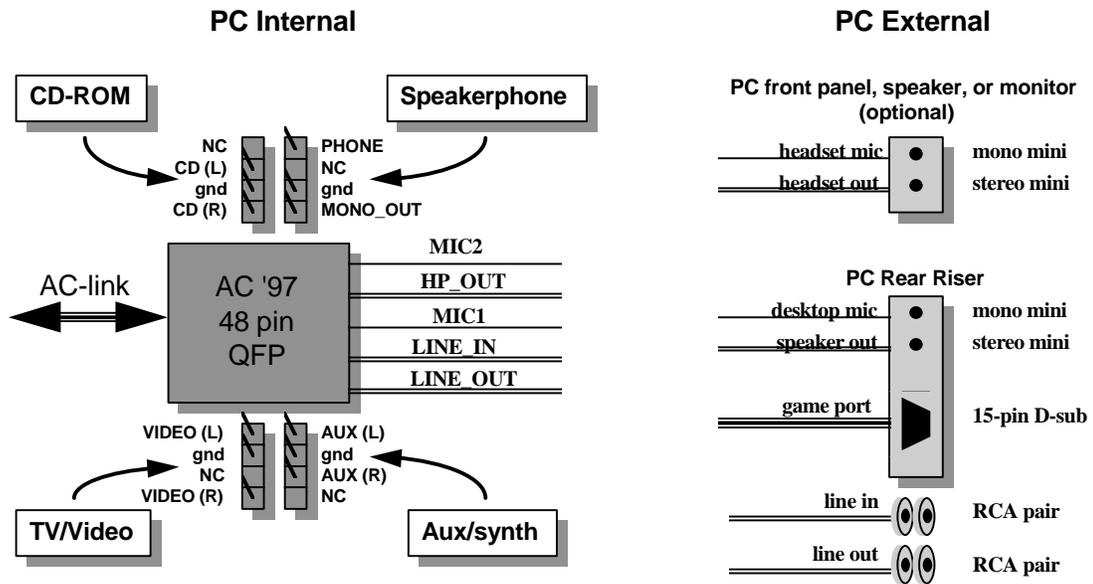
**PROs**

- Can be sold into retail and OEM market segments
- Legacy compatibility (OEM only)
- Max. Scalability

**CONs**

- Legacy compatibility lost in retail versions
- Higher cost than Option #2
- Consumes a PCI expansion slot

**1.3. Internal and External Audio Interconnect**



**Figure 1. Example of audio interconnect**

AC '97 accommodates the internal interconnect necessary to support audio for analog CD-ROM connections, modem speakerphone, video, and an additional internal source. It supports the external analog audio interconnect standards that provide universal compatibility with existing audio equipment: stereo mini and RCA jacks.

## 1.4. PC Beep

PC\_BEEP supports motherboard AC '97 Controller /Codec implementations. The intention of routing PC\_BEEP through the Codec analog mixer is to eliminate the requirement for an onboard speaker or piezoelectric device by guaranteeing a connection to speakers connected via the output jack. In order for this to be viable the PC\_BEEP signal needs to reach the output jack at all times, with or without the audio driver's support.

The primary sources of PC\_BEEP are:

- Power On Self Test (POST) error reporting (at system boot time before the audio driver has loaded)
- Windows OS system alerts (when no audio driver is installed)
- DOS applications which make BIOS calls or write directly to IO port 61 (independent of audio driver)

The AC '97 Component Specification recommends a passive connection between PC\_BEEP and LINE\_OUT\_L/R whenever the AC-link RESET# is held active low. PC\_BEEP for POST error reporting can be guaranteed if the AC '97 Controller holds AC-link RESET# low until after the AC '97 Controller is first accessed (by BIOS) following a cold reset. It may also be possible to enable the passive PC\_BEEP connection whenever the AC '97 mixer is in powerdown state (this is an option left up to the IHV).

The following is one possible power on sequence which supports the PC\_BEEP passive connection:

1. Cold reset.	1. AC '97 Controller powers up.
2. BIOS performs POST	2. During this stage the AC '97 Controller holds AC-link RESET# active low, and the PC_BEEP passive connection is enabled.
3. BIOS begins PnP	3. BIOS PnP configures AC '97 Controller legacy & native PCI audio device(s). AC '97 Controller de-asserts RESET# and begins Codec initiation sequence. PC_BEEP switchover from passive to active begins. BIOS completes AC '97 Controller PnP config and moves on w/o waiting for AC '97 Codec to be fully powered on.
4. BIOS completes PnP	4. AC '97 Codec completes power up (0-500ms later), AC '97 Controller completes legacy device initialization, including unmuting the AC '97 mixer master volume. Sound Blaster is now ready.
5. DOS prompt	5. PC_BEEP through AC '97 Codec mixer enabled.
6. Win 95 loads	6. Win 95 AC '97 driver loads and initializes native PCI device(s).

Care should be taken to avoid the introduction of a pop when powering the mixer up or down, and that the above described functionality for the passive PC\_BEEP connection does not jeopardize the audio quality of LINE\_OUT (i.e. introduce unwanted noise). Support for this feature should not come at the expense of the AC '97 quality goals, the OEM has the option to route PC\_BEEP external to the AC '97 Codec.

## **2. PCI based AC '97 Controller Recommendations**

Although the 2-chip AC '97 architecture supports any bus, this section specifically targets PCI implementations. The reason for this is that, for most segments, the high volume platform in 1997 will see audio transition from ISA to PCI. In 1997 the low end may stick with ISA, which needs little new development, and external 100% digital audio solutions based on USB or IEEE 1394 are just emerging.

### **2.1. Scalable audio Controller model: Baseline/upgrade**

The scalable audio Controller model allows the OEM and IHV to work together to support a range of audio capabilities across a product line. The IHV supplies the OEM a baseline audio Controller for the motherboard, and offers an upgrade Controller or companion accelerator which balances system CPU performance with the need for HW audio acceleration. Ideally the OEM and IHV work together to ensure that these upgrade Controllers implement the "right" set of capabilities and carefully target the "window of opportunity" for HW acceleration functions, thereby delivering cost effective solutions with high value.

### **2.2. Baseline features**

#### **2.2.1. Legacy compatibility**

Full legacy games compatibility requires a minimum set of functional requirements for the AC '97 Controller, including, but not limited to:

- Sound Blaster\* register set
- OPL3\* compatible FM synthesizer
- MPU 401 MIDI UART
- Analog joystick (via game port)

#### **2.2.2. Sample Rate Conversion (SRC) to/from 48Kss**

AC '97 encourages the migration of multi-stream functionality into the digital realm. The adoption of a fixed sample rate Codec and requirement for SRC and mixing in the digital Controller (or on the host) were major architectural considerations, and carefully evaluated. Several of the 1-chip multimedia audio Codec vendors are already shipping fixed rate Sigma-Delta DACs and ADCs and utilizing digital SRC and mixing, and many others are developing this capability.

Since AC '97 specifies fixed 48K sample rate DACs and ADCs, an SRC resource is required in the AC '97 Controller. SRC can be viewed as a key hardware acceleration capability provided to the PC audio subsystem by the AC '97 Controller. However, an in-line model which targets existing Codec requirements may be preferable to the cost and complexity associated with implementing and supporting a generalized N input stream, M output stream model.

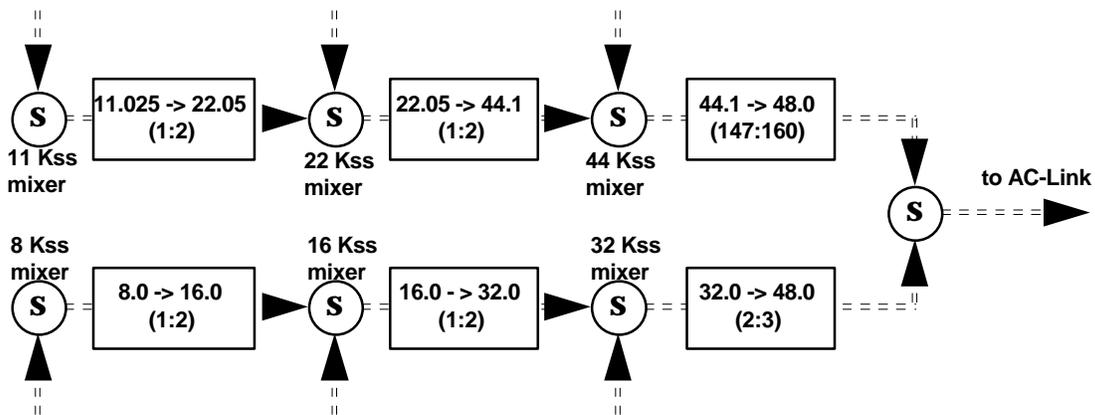
Although the 44.1 KHz sample rate has been the standard high quality PC format, 48 KHz can no longer be ignored. With the introduction of the DVD-ROM drive the PC audio subsystem needs to support MPEG movie audio with encoded AC-3 and/or MPEG audio soundtracks at 48 KHz sample rate. It is more attractive to upsample all audio material to the 48 KHz rate than to compromise the bandwidth or quality of these audio soundtracks.

A PCI based audio Codec needs to support multiple concurrent input and output sources at diverse sample rates, such as PCM, MIDI, CD digital audio streamed from memory, or decoded AC-3 streamed from memory. The choice is either implement multiple DACs and ADCs running at various sample rates followed by analog mixing, or perform digital sample rate conversion and mixing at one common rate. The digital solution is preferred based on quality, cost and flexibility of implementation.

Sample Rate
8.000 Kss
11.025 Kss
16.000 Kss
22.050 Kss
32.000 Kss
44.100 Kss
48.000 Kss

**Figure 2. Recommended set of sample rates for AC '97 Controller**

The following is one possible implementation of digital SRC and mixing which can support an arbitrary number of digital PCM output sources at any of the standard PC sample rates with a minimum of dedicated SRC hardware resource:



**Figure 3. Possible implementation of SRC support**

### 2.2.3. MIDI wavetable synthesizer

Software MIDI wavetable synthesizer will establish itself as a baseline platform capability in 1997. Several audio vendors have begun bundling with their Codec drivers a software MIDI wavetable synthesizer which is capable of supporting Windows 9x and DOS games (in a DOS box) via mixing and sample rate conversion.

Hardware MIDI wavetable can be added to a PCI Controller with very little cost if the sample set is stored using the system main memory. Because the PCI Controller has access to memory with low latency only a small local cache is required. This enables very low cost wavetable (no local ROM/RAM) that can operate with much higher quality than SW (44.1K or 48K s/r) and have little or no load on the CPU. Being RAM based it also enables “downloadable” sample sets through the DirectMusic API of Microsoft.

Hardware based wave table need only work in Native Win9X and DOS Box modes. Because of the driver/software overhead real mode DOS support is not a requirement.

#### **2.2.4. “Digital loopback” capability**

In support of “digital audio ready” PCs, as defined in the white paper ([http://www.intel.com/pc-supply/platform/ac97/wp/dig\\_aud.htm](http://www.intel.com/pc-supply/platform/ac97/wp/dig_aud.htm)), PCI based AC ‘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 WDM audio 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)

#### **2.2.5. Front panel “Master” volume control (up/down/mute)**

A “master” volume control allows the user to control the overall volume of the audio produced by the computer from all sources. This theoretically provides a single point of control that can be used to adapt to the changing environment and to changes in individual user preferences. In practice, there can be as many as three independent “master” controls in a PC audio system:

1. Software applications with audio content typically allow control of the software master volume supported by the audio Codec mixer. This is achieved through the use of a setup program, or some other screen based software representation of the Codec’s mixer interface.
2. Applications also exist that control the master volume based on such things as the arrival of a phone call, time of day, feedback from the room, etc. These volume changes are also accomplished via software control of the Codec’s post-mixer master volume.

3. Almost all PC speakers have their own built-in amplifiers and also provide a hardware volume control. This gives the user immediate access to volume adjustments, which can be made even when a software mixer interface is unavailable (such as before boot time, or after a crash).

A front panel volume control provides the user with easy access to the master volume for the audio subsystem. While software applets exist for this purpose, this control in hardware provides a convenient and familiar “knob” for the user to tweak. Additionally, where the PC speaker master volume control will alter the volume in a unilateral fashion that may actually cause certain concurrent applications to falter, volume changes affected by a correctly implemented front panel control would be visible to all concurrent applications.

When implementing a front panel volume control, one must be careful to do so in a manner that will allow other applications to comprehend any changes made by this control to the master volume. The simplest way to meet this objective is to provide “volume up”, and “volume down” momentary switch inputs on the AC '97 Controller. When one of these switches is pulsed an interrupt is generated, and based upon which switch was pushed, the AC '97 interrupt service routine would adjust the master volume accordingly via the standard AC '97 control register protocol utilizing the AC-link.

### **2.2.6. Game port**

In order to round out legacy audio games compatibility an IHV may wish to implement the gameport in the AC '97 Controller. Legacy games titles talk directly to the joystick port (gameport) which is located at I/O base address of 0x201. As the industry transitions away from dependence on legacy compatibility the time will come when this subsystem can be dropped in favor of a digital joystick perhaps located on the USB.

For the 1997 timeframe however, so long as legacy audio hardware compatibility is an OEM requirement this subsystem should be considered to be an integral part of the legacy audio solution.

## **2.3. Optional features**

### **2.3.1. Hardware acceleration**

In-line acceleration has been the traditional PC media acceleration model. Individual function by function acceleration and re-direction enable bus independent audio but potentially impact overall acceleration efficiency and may add significant latency. In today's multiple expansion bus PC architecture the OEM may have to choose between maximally effective hardware acceleration targeted toward one particular output bus and the desirability to source audio output via multiple busses.

### **2.3.3. Digital input and output ports**

#### **2.3.3.1 Asynchronous I<sup>2</sup>S digital input port(s)**

I<sup>2</sup>S ports enable internal digital point-to-point connections between the digital AC '97 Controller and other digital sources or companion accelerators (such as CD-ROM audio electronics or AC-3 decoders). In the case of asynchronous digital sources a SRC capability may be required to adapt the I<sup>2</sup>S sourced audio sample rate to the AC '97 Controller's 48 Kss.

#### **2.3.3.2 S/P-DIF output**

S/P-DIF output may be an attractive consumer audio compatible output to support in the digital AC '97 Controller until external digital connections via USB and IEEE 1394 busses become more prevalent in consumer audio equipment (CE). S/P-DIF output can support a variety of audio formats:

- stereo
- Pro Logic encoded stereo

- virtualized multi-channel stereo
- encoded AC-3

In the future, the requirements for external digital connections may be better met with USB and IEEE 1394 busses, which will provide the capability for exchange of bi-directional data *and* control between the PC and CE.

### 3. AC '97 Codec Features

The following sections outline the baseline and optional features specified for the AC '97 Codec.

#### 3.1. *Baseline features*

- Analog I/O component of 2-chip PC audio solution
- Standard 48 and 64 pin packages
- Split digital/analog architecture for improved S/N ratio (> 90dB achievable)
- 16-bit stereo full-duplex Codec with fixed 48K sampling rate
- Four analog line-level stereo inputs for connection from LINE IN, CD, VIDEO and AUX
- Two analog line-level mono inputs for speakerphone (or DLP<sup>1</sup>) and PC BEEP
- Mono mic input switchable from two external sources
- High quality pseudo-differential CD input
- Stereo line level output
- Mono output for speakerphone (or DLP<sup>2</sup>)
- Power management support

#### 3.2. *Expanded/optional features*

The AC '97 architecture was defined to comprehend 5 classes of optional features:

1. Analog Audio effects
2. I/O enhancement options
3. Digital Sound quality scalability
4. Communications (modem) options
5. Vendor specific options

##### 3.2.1. *Analog Audio effects*

The optional audio effects specified in the AC '97 Codec specification have been defined in a fashion that would enable a common hardware "API". While the programming interface for these optional features is common, the underlying implementations, and resultant audio experience from vendor to vendor is expected to vary.

The audio driver, after having determined the Codec's capabilities via the AC '97 Codec Reset register, could provide a generic user interface for each of the optional features given the common software interface that has been defined.

Options defined with a common programming interface in the AC '97 specification include:

- tone control
- loudness boost
- simulated stereo
- 3D stereo enhancement

Tone Control (i.e., bass and treble), if supported, provides two 4-bit fields that encode a 16 step graduated scale for bass and treble

Loudness boost, simulated stereo and 3D stereo enhancement if supported, provide on/off bits in the General Purpose Register. As for the tone controls, each vendor's implementation and the perceived experience for each of these features may be different but the software interface is common for all.

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<sup>2</sup> Down Line Phone

In the case of 3D stereo enhancement, numerous vendor-specific 3D enhancement techniques are accommodated which could yield even more differentiated results, while still being interoperable via a common programming interface.

### **3.2.2. I/O Enhancement Options**

#### **3.2.2.1. *Third ADC***

The third, optional ADC can be implemented to provide dedicated microphone input in support of voice applications and advanced echo cancellation. This optional ADC can also enable “digital + analog loopback” capabilities (record CD or TV tuner audio for re-direction out USB) on the Codec without sacrificing full-duplex applications requiring the use of the microphone.

#### **3.2.2.2. *Headphone output***

Especially attractive for mobile if it eliminates the need for an external amplifier.

### **3.2.3. Digital Sound quality scalability**

The PCM playback and record paths are scalable up to 20 bits of resolution. The standard DAC and ADC are defined as having 16 bits of resolution. However the AC-link has been defined such that 16, 18 or 20 bit samples can be implemented on the Codec in a seamless way with respect to the AC '97 Controller.

If the AC '97 Codec supports wider sample streams and the AC '97 Controller supports it, better resolution is achieved. If the AC '97 Controller does not support wider streams the enhanced Codec, while not well matched to the Controller will playback and record samples at the resolution supported by the AC '97 Controller.

### **3.2.4. Modem line DAC and ADC**

The combined audio/telephony solution typically requires processing of input and output data at various multiples of the modem baud rate, these rates could include:

- 7200, 8000, 8229, 9000, 9600, 10287

Either a fixed or variable DAC and ADC rate approach may be taken in the AC '97 Codec.

From a quality standpoint, where audio is running concurrently with modem operation, it may be desirable to avoid introducing interference within the AC '97 Codec by running the modem DAC and ADC at 48 KHz and resampling on the digital side to the desired modem rate. If the fixed 48 KHz rate approach is taken, it may be advantageous to band limit the modem ADC input to ~3300 Hz within the analog section in order to simplify the digital resampling task. Similar optimizations may apply to the DAC output.

However, the fixed rate acquisition with digital resampling may introduce undesirable delays or complexity. Through use of the modem rate register, AC-link slot tag bits, and implementation of re-timing FIFOs on one or both sides of the AC-link, it should be possible to acquire and transfer data at any desired rate.

### **3.2.5. Vendor specific optional features**

A bank of 64 registers are defined for use by the vendor, or partnering team of vendors who provide the complete AC '97 Controller/Codec solution. Using these registers the vendor is free to add differentiating features bounded only by the pin/die/cost budgets.