CHAPTER 17

Audio Components

This chapter presents the PC 98 requirements and recommendations for audio devices.

Contents

Introduction to PC 98 Audio

The PC 98 audio basic requirements are designed to identify the baseline operating system and hardware audio support available for existing and emerging multimedia applications. They are also designed to ensure that a minimum audio capability exists across a majority of platforms.

The advanced recommendations describe additional software and hardware features beyond the minimum requirements. These recommendations support vertical applications and provide scalability above the baseline audio capabilities by offering higher compatibility, performance, concurrency, or quality.

WDM and PC Audio. One key to the successful advancement of audio in the PC is WDM Audio class support. The architecture performs all audio processing in kernel mode, which significantly improves latency. WDM provides a method for non-Microsoft code to run in kernel mode, facilitating the development of host algorithms from multiple vendors.

WDM also provides a more complete architecture than previous generations. Code common to all audio hardware on a given bus is now part of the operating system, making for faster development with more consistent results. WDM promises to streamline development through the integration of the Windows and Windows NT driver models. Now, the same driver will work under both operating systems.

Advanced Features Enabled by PCI. Once an audio device moves beyond the basic playback and recording functions of low bandwidth material, a more advanced bus interface is required. Simple audio sample transport over the ISA bus can consume a significant portion of system bandwidth. Features that require more than two streams of audio will overload the ISA bus. Because features such as 3-D positioning use as many as eight streams of audio, a shift to PCI is necessary.

PCI audio accelerators offer another powerful feature because of the high bus bandwidth available. In the digital-ready architecture, PCI devices can perform audio processing and output either to a built-in codec or back into memory for delivery to an external digital audio device. In the external case, the host can perform final mixing and sample rate conversion (SRC) if necessary, and then can send the audio to an external USB or IEEE 1394 device.

In addition, the PCI architecture with a separate audio codec targets high-quality audio, that is, with a dynamic range of greater than 85 dB.

External Digital Audio. USB and IEEE 1394 provide excellent mechanisms for delivering digital audio to external peripherals for high-quality conversion (greater than 85 dB dynamic range) to and from analog. In the near term, the popularity of USB makes it a natural choice. In the long term, the consumer-electronics industry envisions IEEE 1394 transporting audio and video among many devices in a simple, high-performance manner.

PC Audio Transitions

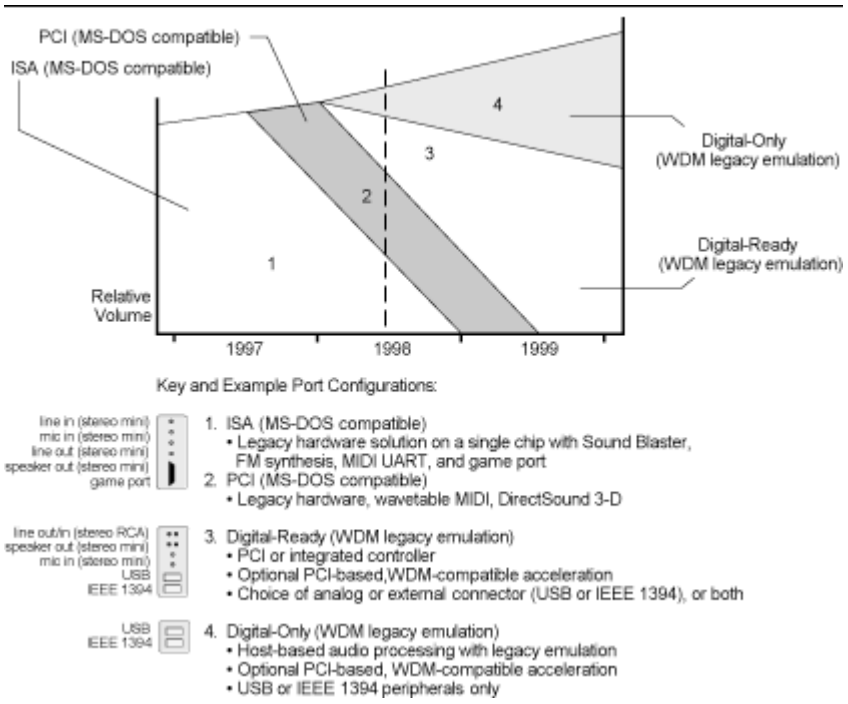
Throughout 1997 and 1998, audio in the PC will offer a wide array of possibilities as a number of transitions take place. Perhaps the most significant transition is the continuing shift from where hardware exclusively processes audio to where the host processor shares some if not all of the burden. To provide the flexibility and performance that is required, a new architecture is needed to connect audio hardware and software. WDM will serve as the support mechanism for the next generation of PC audio.

As the PC is increasingly called upon to play the part of a consumer-electronics device (for example, video-disc playback), sound quality becomes more important. A number of initiatives are underway to achieve optimal sound quality. Another implication of this trend is the need for simpler operation and hardware configuration.

The state of audio functionality is far from stagnant, presenting a challenge for the industry to maximize performance and simplicity, and to add more advanced features. This chapter will focus on how and when this can be done.

The shift to higher quality and support for external digital connectivity will not happen overnight. One objective of PC 98 Audio is to facilitate the transition over the next few years. The remainder of this section is a summary of the projected evolution of PC audio.

The following figure demonstrates that by mid-1998, four viable audio solutions will exist in the PC marketplace. The figure also projects the estimated market share for each solution over the next three years.



Digital Audio Migration

The following explains the marketplace options illustrated in the previous figure:

- **ISA (legacy MS-DOS–compatible).** These are mature, low-cost, single-chip implementations that deliver support for Sound Blaster registers and mixing, Yamaha OPL-compatible frequency modulation (FM) synthesis, MPU 401 MIDI UART, and game port. Each is fully Plug and Play-compatible.
- **PCI (legacy MS-DOS–compatible).** The majority of current PCI implementations are two-chip split digital/analog system-board or add-on designs based on Audio Codec ’97 architecture. Many of these designs incorporate hardware support for legacy ISA devices using PC/PCI DMA, distributed DMA (DDMA), or other similar techniques, and are fully Plug and Play-compatible. Many also support high-quality wave table MIDI synthesis and DirectX acceleration.

- **PCI (digital ready).** The next generation of PCI-based designs have the potential to deliver WDM-compatible audio acceleration that can be part of a filter graph targeting either a built-in audio codec or an external USB codec for output. These designs have the option of leveraging the WDM legacy emulation capabilities or incorporating hardware legacy compatibility. A digital-ready PC can support mixed configuration of analog and/or digital peripherals.
- **USB (digital only).** These systems eliminate all built-in audio rendering resources and use external USB speakers and microphones for audio I/O. Hardware acceleration can be provided by WDM-compatible PCI devices.

The following factors will determine which of the previously listed audio solutions are suitable in 1998:

- Cost. The total bill of materials for ISA, PCI, and USB solutions, including microphone and speakers.
- Compatibility. The desired level of legacy MS-DOS–based game compatibility.
- Quality. The system output dynamic range and total harmonic distortion plus noise (THD+N) performance necessary to meet specific market requirements.
- Features. Support for 48-kHz sample rate operation, which is necessary for DVD.
- Performance. Dependent on the choice of host processor, audio bus (ISA, PCI, or USB), and system audio hardware acceleration features, such as Downloadable Samples (DLS) wave-table MIDI synthesis and multistream Head Related Transfer Function (HRTF) 3-D.
- Connectivity. Internal analog mixer connectivity for legacy CD audio, analog television tuner, line input, or video capture audio input.

Three audio applications merit more detailed discussion and are described in the following sections:

- Scalable audio for 3-D games
- CD and DVD media playback
- Full-duplex H.323/H.324 video and audio conferencing

Scalable Audio for 3-D Games

WDM audio supports the following features specifically for 3-D games under Windows 98 and Windows NT 5.0:

- Software emulation of legacy hardware to support MS-DOS–based games. WDM drivers, which run in kernel mode, provide virtual Sound Blaster Pro, MPU 401, and legacy joystick interfaces.
- A standard interface for the application to provide multiple streams of 3-D–positioned audio. DirectSound 3-D supports software-simulated 3-D (pan and volume) and true HRTF 3-D processing at 22.05 kHz, or hardware acceleration. The architecture supports optimal configuration based on CPU performance and installed hardware.
- A wave-table General MIDI synthesizer entirely in kernel-mode software. This provides 24 voices of music synthesis with 22.05-kHz output. DirectShow, DirectMusic, MMSYS, and virtual MPU 401 can use the synthesizer functions. The architecture supports optimal configuration based on CPU performance and installed hardware.
- A high-quality kernel-mode software SRC capability, which converts data streams (including composite mixes of all 11.025-kHz or 22.05-kHz sources) to the final output mix format, typically 16-bit 44.1 kHz (general SRC support includes other rates).
- A kernel-mode system-wide software mixer, which supports DirectSound, DirectShow, and MMSYS clients, plus kernel-mode WDM filters, including Red Book CD-ROM and MIDI drivers. The mixer implements highly optimized, same sample rate PCM mixing at 8-bit or 16-bit 11.025, 22.05, 44.1, and 48 kHz (general mixing support includes other formats).
- Flexible control of the output destination. The WDM drivers can send the master 16-bit 44.1-kHz or 48-kHz or other format output to an ISA, PCI, USB, or IEEE 1394 audio device. Additionally, support is provided for redirection of PCI-device final-mix output to USB speakers.

The minimum PC 98 audio hardware support necessary for 3-D games is built-in or external audio codec support for playback of 16-bit stereo PCM data at a 44.1-kHz sample rate. For a list of the PC 98 requirements, see the “Basic Audio Requirements” section later in this chapter.

The system designer might choose to include the following optional software or hardware in order to provide additional capabilities:

- Hardware that provides legacy MS-DOS–based interfaces for compatibility with games (Sound Blaster Pro, FM synthesizer, MPU 401, game port)
- Hardware for higher quality or concurrency DLS wave-table MIDI synthesis, with associated mixing and SRC support
- Hardware for higher concurrency HRTF 3-D positional audio, with associated mixing and SRC support
- Digital-ready, WDM-compatible MIDI and HRTF 3-D hardware acceleration

The following table presents actual measurements collected by Intel Architecture Labs (IAL) for scalable audio for 3-D games on Intel Pentium II processors with Intel MMX technology.

Performance Measurements for Scalable Audio for 3-D Games

Function	233-MHz Pentium II processor[1]
Wave-table MIDI synthesis, 24 voices at 22.05 kHz	5%
Mixing with pan and volume for simulated 3-D, eight stereo streams at 22.05 kHz	3%
SRC, upsampling of the stereo composite mix of all 22.05-kHz sources to 44.1 kHz	2%
Audio effects (reverb, tone, or pseudo 3-D), stereo at 44.1 kHz	2%
Audio sample transport to PCI or USB codec	2–4%
Total with simulated 3-D	**14–16%**
HRTF 3-D with cross-talk cancellation for speakers, eight streams at 22.05 kHz	12%[2]
Total with true HRTF 3-D	**23–25%**

[1] Actual performance is dependent on specific processor, chip-set, memory, and I/O subsystem implementations, as well as the software implementation (integer, floating point [FP], or MMX technology). To estimate the performance on other processor speeds with MMX technology, use a ratio based on the processor's MHz rating.

[2] HRTF 3-D performance is based on the 3Q1997 release of Intel 3D Realistic Sound eXperience (RSX); performance of the 1Q1997 3D RSX is 20 percent.

CD and DVD Media Playback

WDM audio supports the following features for CD and DVD media playback under the Windows 98 and Windows NT 5.0 operating systems:

- A kernel-mode CD-ROM driver that emulates MSCDEX commands and implements reading, parsing, and streaming of Red Book CD digital audio to the kernel-mode WDM system-wide mixer at 16-bit 44.1 kHz.
- A Universal Disk Format (UDF) DVD file reader, splitter, and navigator that provides access for DirectShow clients to separate video and audio streams.
- A kernel-mode, system-wide software mixer, which supports DirectSound, DirectShow, and MMSYS clients, plus kernel-mode WDM filters, including Red Book CD-ROM and MIDI drivers. The architecture provides the ability for algorithms from any vendor to decode the DVD audio, and it supports mixing at 16-bit 48 kHz.
- Flexible control of the output destination. The WDM drivers can send the master 16-bit 44.1-kHz or 48-kHz or other format output to an ISA, PCI, USB, or IEEE 1394 audio device. Additionally, support is provided for redirection of the PCI-device final-mix output to USB speakers.

Baseline PC 98 audio hardware support for CD-ROM and DVD media playback requires that the built-in or external audio codec support playback of 16-bit stereo PCM data at either a 44.1-kHz or 48-kHz sample rate. For a list of the PC 98 requirements, see the “Basic Audio Requirements” section later in this chapter.

For MPEG content, the system designer might choose to include optional DirectShow or WDM kernel-mode streaming filter components or hardware that can provide the following capabilities:

- Greater than 85-dB dynamic range codec audio quality to the performance requirements of the consumer-electronics market
- Software or hardware Dolby AC-3 or MPEG-2 multichannel decode and downmix to stereo at 16-bit 48 kHz
- Software or hardware MPEG-1 layer-2 stereo at 16-bit 32, 44.1, or 48 kHz
- Software or hardware support for up to 24-bit 96-kHz linear PCM (LPCM) data, down-converted to 16-bit 48 kHz.

The following table presents actual measurements collected by IAL for software Dolby AC-3 decode on Intel Pentium II processors with MMX technology.

Performance Measurements for Dolby AC-3 Decode

Function	233-MHz Pentium II processor[1]
Dolby-certified 5.1-channel AC-3 decode and downmix to ProLogic-encoded stereo at 48 kHz	8%
Optional Dolby-certified virtual surround for rear channels, two channels at 48 kHz	12%[2]
Total for AC-3 decode with HRTF 3-D virtual surround	**20%**

[1] Actual performance is dependent on specific processor, chip-set, memory, and I/O subsystem implementations, as well as the software implementation (integer, FP, or MMX technology). To estimate the performance on other processor speeds with Intel MMX technology, use a ratio based on the processor's MHz rating.

[2] HRTF 3-D virtual surround performance is based on 3Q1997 release of Intel 3D RSX; performance of the 1Q1997 3D RSX is 24 percent.

Full-Duplex H.323/H.324 Video and Audio Conferencing

WDM audio supports the following features for full-duplex video and audio conferencing under Windows 98 and Windows NT 5.0:

- Native 32-bit DirectSound support for simultaneous audio input and output, not dependent on 16-bit MMSYS components
- Input and output position reporting mechanisms for synchronization of speaker and microphone streams, accurate to 1 ms or better
- WDM Stream class driver that provides access to acoustic echo cancellation (AEC) reference interfaces supported by hardware codecs
- WDM system audio filter graph that supports insertion of a non-Microsoft kernel-mode AEC filter module adjacent to the WDM Stream class driver in both the input and output streams

Baseline PC 98 audio hardware support for H.323/H.324 video and audio conferencing requires full-duplex audio capability. For a list of the PC 98 requirements, see the "Basic Audio Requirements" section later in this chapter.

The system designer might choose to include optional hardware to provide the following capabilities:

- Full-duplex operation at independent sample rates for simultaneous 8-kHz microphone input and 44.1-kHz speaker output
- Hardware AEC references for echo cancellation filtering

The following table presents actual measurements collected by IAL for H.323/H.324 audio on Intel Pentium II processors with MMX technology.

Performance Measurements for H.323/H.324 Audio

Function	233-MHz Pentium II processor[1]
Full-duplex G.723.1 encode and decode, mono at 8 kHz	10%
Full-duplex AEC, mono at 8 kHz	6%
Total H.323/H.324 audio	**16%**

[1] Actual performance is dependent on specific processor, chip-set, memory, and I/O subsystem implementations, as well as the software implementation (integer, FP, or MMX technology). To estimate the performance on other processor speeds with Intel MMX technology, use a ratio based on the processor's MHz rating.

Basic Audio Requirements

This section defines basic PC 98 hardware feature requirements for audio components. These are system-based requirements, targeted for the entire PC solution as it ships, regardless of whether the audio components are separate add-on devices or are built into the system (for example, on the system board or the video monitor).

System Requirements for Audio

This section summarizes the PC 98 system requirements for audio.

1. PC system includes PC 98 audio capabilities

Consumer PC 98	*Office PC 98*	*Entertainment PC 98*
Recommended	*Recommended*	*Required*

Although audio is a standard feature in most PC market segments, it is understood that certain SOHO and Office PC designs that focus heavily on cost will not require audio. For PCs that include audio, the requirements defined in this chapter must be met.

2. Audio device does not connect to ISA bus

Consumer PC 98	*Office PC 98*	*Entertainment PC 98*
Required	*Required*	*Required*

In 1998, the transition away from ISA will be underway. Some of the reasons that ISA is not acceptable include the high overhead of transferring audio samples, the excessive requirements of resources such as IRQs, DMA, and I/O, plus limited power management capabilities.

There will be a delayed phase-in period for this requirement, during which only system-board ISA devices will be allowed. Please notice that the ISA requirements that apply during the transition phase are the same as those defined in *PC 97 Hardware Design Guide*, and are also summarized in the "Legacy Support" appendix in the References part of this guide.

Audio Performance and Feature Requirements

This section summarizes the required performance and features for audio on PC 98 systems.

Several companies have joined together to develop a standardized testing procedure for measuring audio performance titled "Personal Computer Audio Quality Measurement Definitions," available on the web site at http://www.crystal.com/new/papers/meas.htm. Contributors to this specification include Audio Precision, Compaq Computer Corporation, Crystal Semiconductor, Intel Corporation, and Microsoft Corporation. Microsoft test procedures are based on this methodology and are available at http://www.microsoft/com/hwtest/.

3. Audio performance meets PC 98 requirements

Required

The following table summarizes audio performance requirements for all audio-enabled PC 98 systems, with the exceptions noted for mobile audio.

The tests isolate half-duplex play or record performance. Additional attention should be paid to full-duplex systems with an embedded microphone and speakers, such as mobile PCs and multimedia monitors, where acoustic coupling can significantly degrade microphone performance.

For precise definitions of the terminology used in the following charts, please refer to the test methodology paper at http://www.microsoft/com/hwdev/devdes/, as described earlier in this section.

PC 98 Audio Performance Requirements

Feature	Requirement	
Playback performance (PC-D-A) for line output	Frequency response (-3 dB)	
	44.1-kHz source material	20 Hz to 17.6 kHz[4]
	48.0-kHz source material	20 Hz to 19.2 kHz[4]
	Dynamic range (SNR)	≥80 dB FS A[1,2]
	THD+N	≤–60 dB FS A[3]
Recording performance (A-D-PC) for line input	Frequency response	
	44.1-kHz destination material	20 Hz to 17.6 kHz[4]
	48.0-kHz destination material	20 Hz to 19.2 kHz[4]
	Dynamic range (SNR)	≥75 dB FS A[2]
	THD+N	≤–55 dB FS A[3]
Analog pass-through performance (A-A)	Line input to line output	
	Frequency response (-3 dB)	20 Hz to 20.0 kHz[4]
	Dynamic range (SNR)	≥80 dB FS A[2]
	THD+N	≤–60 dB FS A[3]
	Line input to speaker output with 8-ohm load	
	Frequency response (-3 dB)	20 Hz to 20.0 kHz[4]
	Dynamic range (SNR)	≥70 dB FS A[2]
	THD+N	≤–50 dB FS A[3]
	Microphone input to line output	
	Frequency response (-3 dB)	100 Hz to 12.0 kHz
	Dynamic range (SNR)	≥70 dB FS A[2]
	THD+N	≤–50 dB FS A[3]
Full-scale input voltage	FSIP (A-D-PC) line input	1.0 to 2.0 Vrms
	FSIP (A-D-PC) microphone input	50 to 200 mVrms
Full-scale output voltage	FSOP (PC-D-A)	1.0 to 2.0 Vrms
Line output cross-talk	Channel separation between output channels (for example, left to right, center to right)	≥55 dB
Sampling frequency accuracy	Playback	0.1%
	Record	0.1%

[1] Decibels relative to full scale (FS), measured using “A weighting” filters.

[2] For mobile PCs, the dynamic range requirements are relaxed by10 dB FS A.

[3] For mobile PCs, the THD+N requirements are relaxed by 10 dB FS A.

[4] For mobile PCs, the required frequency response is 20Hz to 15kHz, measured using 6 dB corners.

4. Audio system provides support for basic data formats
Required
The audio system must provide full-duplex support of the following audio formats:

- Mono/stereo
- 8-bit unsigned
- 16-bit signed

The audio system must provide support for both recording and playing back of sample rates that include 8, 11.025, 16, 22.05, 44.1, and 48 kHz.

5. Audio system reports sample position for stream synchronization
Required
The driver must be capable of returning an accurate indication of the current position of the buffer being rendered. Sample accuracy is in relation to the samples given to the codec. Accurate reporting of the current position in the buffer being rendered means reporting the position within 1 ms. This requirement applies for both compressed and uncompressed data.

For information about WDM device driver support for streaming capabilities, see the Windows NT 5.0 DDK. See also the related articles available on the web at http://www.microsoft.com/hwdev/pcfuture/.

6. Audio system provides sufficient externally accessible inputs and outputs
Required
At a minimum, the audio system must have the following features:

- A monaural microphone, stereo line input, or both
- Stereo line-level output

These inputs and outputs can be located anywhere on the system, including on the speakers and video monitor.

7. Audio system connectors are labeled with icons as defined for PC 98
Required
To reduce user confusion, the external connections must use a consistent set of symbols based on the standard artwork defined in the “Icons” appendix in the References part of this guide.

Advanced Audio Recommendations

This section outlines the future direction of PC audio. It offers a view of the market requirements to come for PC audio, describing a number of directions that the industry is taking.

8. Audio performance meets PC 98 advanced recommendations

Recommended

The expectations for audio quality in the consumer-electronics industry are quite high. For those applications where audio quality is important, such as for Entertainment PC, it is strongly recommended that audio performance meet the capabilities recommended in the following table.

PC 98 Audio Performance Recommendations

Feature	Recommendation	
Playback performance (PC-D-A) for line output	Frequency response (-3 dB)	
	44.1-kHz source material	20 Hz to 20 kHz
	48.0-kHz source material	20 Hz to 20 kHz
	Dynamic range (SNR)	≥85 dB FS A
	THD+N	≤–65 dB FS A
Recording performance (A-D-PC) for line input	Frequency response (-3 dB)	
	44.1-kHz destination material	20 Hz to 20 kHz
	48.0-kHz destination material	20 Hz to 20 kHz
	Dynamic range (SNR)	≥80 dB FS A
	THD+N	≤–60 dB FS A
Analog pass-through performance (A-A)	Line input to line output	
	Frequency response (-3 dB)	20 Hz to 20.0 kHz
	Dynamic range (SNR)	≥85 dB FS A
	THD+N	≤–65 dB FS A
	Line input to speaker output with 8-ohm load	
	Frequency response (-3 dB)	20 Hz to 20.0 kHz
	Dynamic range (SNR)	≥75 dB FS A
	THD+N	≤–55 dB FS A
	Microphone input to line output with 8-ohm load	
	Frequency response (-3 dB)	20 Hz to 20.0 kHz
	Dynamic range (SNR)	≥75 dB FS
	THD+N	≤–55 dB FS

Continued

PC 98 Audio Performance Recommendations *(continued)*

Feature	Recommendation	
Full-scale input voltage	FSIP (A-D-PC) line input	2.0 to 3.0 Vrms
	FSIP (A-D-PC) microphone input	50 to 200 mVrms
Full-scale output voltage	FSOP (PC-D-A)	1.0 to 2.0 Vrms
Cross talk between signal channels	Stereo separation	≥65 dB A
Sampling frequency accuracy	Playback	0.1%
	Record	0.1%

9. Audio system supports full-duplex operation at independent sampling rates

Recommended

Voice recognition and audio/video conferencing require the audio system to simultaneously play back and record. Incoming and outgoing audio should be capable of operating at independent sampling rates. This recommendation considers the entire system, including the possibility of USB speakers or microphones.

10. Audio system provides hardware or software support for the Downloadable Samples specification

Recommended

Support for DLS as defined by the MIDI Manufacturers Association is recommended. For more information, see *DLS Specification, Version 1.0* or higher, at http://www.midi.org.

11. Audio system supports AEC reference inputs

Recommended

Full-duplex internal or external audio codecs that introduce additional digital or analog audio sources into the final mix are recommended to support simultaneous capture of microphone and AEC reference inputs. One analog-to-digital converter (ADC) is used to capture the microphone input, and another ADC is used to capture a monophonic representation of final output mix, which includes all digital and analog sources.

It is possible to use a single stereo ADC to capture the two monaural streams. The AEC reference should be time-synchronized and available at the same sample rate as the microphone input.

For more information, see Section 6.2 of the Audio Codec ’97 specification from Intel Corporation, which describes one possible implementation.

12. Audio system provides hardware filtering of HRTF 3-D filters

Optional

For those solutions that provide hardware acceleration of 3-D filters, support for eight separate audio sources is suggested, especially for Entertainment PCs.

13. CD, DVD, and broadcast audio playback meet PC 98 requirements

Required with DVD Video

These recommendations are specified to ensure quality playback of MPEG-2 audio from any source, including DVD, digital broadcast or satellite systems, hard drives, and so on. The goal for DVD and other A/V playback is to ensure that the end-user experience is the same or better than from a stand-alone DVD player.

For those PCs that support software or hardware decoding and playback of DVD-Video or MPEG-2 video, the audio decoder must be capable of supporting the following formats:

- Support for one or both of the following formats is required, depending upon the local requirements for DVD audio:
  - AC-3 (Dolby Digital) less than or equal to 5.1 channels, at 48 kHz less than or equal to 384 Kbps.
  - MPEG-2 multichannel less than or equal to 7.1 channels, at 48 kHz less than or equal to 912 Kbps.
- MPEG-1 Layer 2 stereo, at 44.1 and 48 kHz less than or equal to 384 Kbps.
- LPCM less than or equal to 8 channels, 16-bit, 20-bit, and 24-bit at 48 or 96 kHz less than or equal to 6.144 Mb/s.

Note: Conversion to 48-kHz 16-bit stereo is acceptable when the content exceeds the available resolution, sampling rates, or number of output channels.

14. Audio system provides consistent volume levels for different devices

Optional

In cases where each audio channel is set to the same position on the Windows mixer panel, it is suggested that each channel provide a comparable volume level. Users should not need to have radically different settings on the control panel to balance the relative volume of each audio channel.

PC 98 Design for Audio

This section summarizes requirements related to the PC 98 design initiatives as defined in Part 1 of this guide.

Plug and Play for Audio

The items in this section are requirements for all audio components.

15. Each device has a unique Plug and Play device ID
Required

Each bus-specific device must have a Plug and Play device ID for the bus it uses, as defined in Part 3 of this guide. For example, a PCI device must comply with PCI 2.1 requirements and also provide a Subsystem ID and Subsystem Vendor ID as defined in the "PCI" chapter in Part 3 of this guide. As another example, a USB device must provide a unique ID as defined in the *Universal Serial Bus Specification, Version 1.0* or higher.

Note: Each separate device or function enumerated by the BIOS on an audio adapter must have a separate Plug and Play device ID and separate resource configuration. If a game port or CD-ROM interface is supplied, resources must be allocated in addition to those required for the audio device. Such devices must also have independent dynamic disable capabilities. For complete information about requirements for multifunction cards, see the "Basic PC 98" chapter in Part 2 of this guide.

16. Automatic resource assignment and dynamic disable capabilities are supported
Required

The system must be capable of automatically assigning, disabling, and relocating the resources used by this device when necessary, using the method required for the related bus class. All configuration settings must be capable of being made through software, with no system reboot required.

When the end user changes this device or adds it to the system, setting resource assignments must not require changing jumpers or switches on either the adapter or the system board. In the event of an irreconcilable conflict with other devices on the system, the system must be able to disable the device in order to prevent the system from stalling. The device must not claim any resources while disabled.

Bus Design for Audio

This section defines the requirements for bus-specific design for PC 98 audio.

Requirements for PCI Audio Devices

For audio devices that connect to the PCI bus, the following requirements apply.

17. PCI device conforms to PCI 2.1 and additional PC 98 requirements
Required

If the device uses PCI, it must meet the requirements defined in the "PCI" chapter in Part 3 of this guide, including requirements for providing a Subsystem ID and Subsystem Vendor ID and for complying with PCI 2.1.

18. PCI device supports initiator, target, and block transfer
Required

For complete implementation details, see PCI 2.1.

Full-duplex audio sample transport must be supported using separate PCI bus mastering hardware for playback and capture sample streams.

It is desirable for sample transport mastering hardware to support burst capabilities in order to read or write multiple samples within the same PCI bus transaction. This will lessen the impact of sample transport on other agents in the system, which will have a positive effect on the system's responsiveness.

19. PCI audio components use a suitable configuration scheme if using ISA resources
Required

If a PCI audio device requires the use of ISA resources such as IRQs or DMA, it must configure these resources in a way that meets the following objectives:

- Any resource enabled while Windows or an MS-DOS window is active must be reported to the Windows Device Manager. Conversely, if a PCI device uses ISA resources in MS-DOS mode that do not appear in the Configuration Manager, then the device must disable these resources before Windows restarts.
- The ISA resources allocated by a PCI device must be used only for MS-DOS mode or for applications running in an MS-DOS window. Windows-based applications must not require the use of ISA resources.

Two acceptable means for achieving these objectives are as follows:

- For a PCI audio device on the system board, the BIOS can configure the ISA resources and present a device node to the operating system. The operating system can then understand and reconfigure the ISA resources.
- For a PCI audio device present in an add-on card, the device does not use any ISA resources while running Windows or an MS-DOS window. Only when the user enters MS-DOS mode does the ISA resource become enabled.

PCI devices on the system board do not have to provide relocatable I/O addresses for the following legacy I/O registers:

- Sound Blaster (220h to 22Fh)
- FM synthesis (388h to 38Bh)
- MPU 401 (330h to 331h)
- Windows Sound System (WSS) compatible (534h to 537h)
- Game port (200 to 207h)

20. PCI device is digital ready

Required

In order to transfer digital audio to USB or IEEE 1394 devices, all digital audio data created in the PC must be available to the operating system for mixing and streaming. All PCI audio devices must be able to route the final mix of all digital audio data created or processed on-chip to the host using bus master transfers.

Support for capture and inclusion of internal analog resources in the final mix is desirable but not required. CD-ROM drives that support direct reading of Red Book data through the primary interface are strongly recommended.

For example, a PCI audio device provides HRTF 3-D filtering and wave-table synthesis. After mixing all of the separate 3-D sources and wave-table channels down to a single stereo stream, the device transfers the data to host memory.

Requirements for USB Audio Devices

For audio devices that connect to a USB port, the following requirement applies.

21. Audio meets USB specification and USB audio device class specification
Required

The device must comply with *Universal Serial Bus Specification, Version. 1.0* or higher, and the USB device class specification for audio. This ensures that all Plug and Play requirements are met and that drivers provided with the operating system support this device.

Requirements for IEEE 1394 Audio Devices

For audio devices that connect to the IEEE 1394 bus, the following requirement applies.

22. Audio meets PC 98 requirements for IEEE 1394
Required

For requirements related to IEEE 1394 peripherals, see the “IEEE 1394” chapter in Part 3 of this guide.

Power Management for Audio

This section summarizes the power management requirements for audio components.

23. System and device comply with PCI bus power management specification
Required

PCI-based audio controllers must comply with the *PCI Bus Power Management Specification, Revision 1.0* or higher (PCI PM). Any PCI add-on audio device must comply with PCI PM. Audio devices implemented on the system board must comply fully with the ACPI 1.0 specification.

24. Audio device complies with device class power management reference specification
Required

The *Audio Device Class Power Management Reference Specification, Version 1.0* or higher, provides definitions of the OnNow device power states (D0–D3) for these devices. The specification also covers device functionality expected in each power state and the possible wake-up event definitions for the class. Implementation of power states D0 and D3 is required. Other power states are optional.

25. Device supports wake-up events
Optional

For PC 98, the ability to cause a wake-up event as defined in the *Audio Device Class Power Management Reference Specification, Version 1.0* or higher, is an optional feature.

Device Drivers and Installation for Audio

This section summarizes requirements for audio device drivers.

26. Device drivers and installation meet PC 98 requirements
Required

The manufacturer does not need to supply a driver for a device if the device passes PC 98 compliance testing using a driver provided with the operating system. If the manufacturer supplies the drivers, the requirements for the device drivers and installation are defined in the "Basic PC 98" chapter in Part 2 of this guide. The basic requirements include driver support for unattended installation and Help file support if special driver parameters are used.

27. Audio meets PC 98 requirements for WDM driver support
Required

All audio devices must have drivers that use the 32-bit WDM architecture exclusively. The manufacturer can either supply a WDM driver with the audio device or rely on a WDM driver provided with Windows and Windows NT. For information, see the Windows NT 5.0 DDK.

28. Applications provided with device meet Win32 requirements
Required

Any Windows-based applications provided with the device must meet software compatibility requirements as defined in the Win32 SDK.

Audio References

The following represents some of the references, services, and tools available to help build hardware that is optimized to work with Windows operating systems.

Advanced Configuration and Power Interface Specification, Revision 1.0
http://www.teleport.com/~acpi/

Audio '98 Roadmap, Audio Codec '97 Component Specification, and *Audio Codec '97 Design Guide* papers
Intel Corporation
http://developer.intel.com/pc-supp/platform/aud98/

Audio design for Windows operating systems white papers
http://www.microsoft.com/hwdev/devdes/

Audio Device Class Power Management Reference Specification, Version 1.0
http://www.microsoft.com/hwdev/onnow.htm

Downloadable Samples (DLS) specification
MIDI Manufacturers Association
Fax: (714) 736-9775
E-mail: mma@midi.org
http://www.midi.org

Personal Computer Audio Quality Measurement Definitions
by Dr. Steven Harris and Cliff Sanchez, Crystal Semiconductor
http://www.crystal.com/new/papers/meas.htm

PCI Local Bus Specification, Revision 2.1 (PCI 2.1)
PCI Bus Power Management Specification, Revision 1.0 (PCI PM)
http://www.pcisig.com

Plug and Play specifications
http://www.microsoft.com/hwdev/specs/

Universal Bus Specification, Version 1.0
USB device class specifications
http://www.usb.org

WDM device driver support white papers
http://www.microsoft.com/hwdev/pcfuture/

Windows DDK, Windows NT DDK, DirectX DDK, and Win32 SDK
MSDN Professional membership

Checklist for Audio Components

If a recommended feature is implemented, it must meet the PC 98 requirements for that feature as defined in this document.

Consumer PC 98	Office PC 98	Entertainment PC 98
1. PC system includes PC 98 audio capabilities		
Recommended	*Recommended*	*Required*
2. Audio device does not connect to ISA bus		
Required	*Required*	*Required*
3. Audio performance meets PC 98 requirements		
Required		
4. Audio system provides support for basic data formats		
Required		
5. Audio system reports sample position for stream synchronization		
Required		
6. Audio system provides sufficient externally accessible inputs and outputs		
Required		
7. Audio system connectors are labeled with icons as defined for PC 98		
Required		
8. Audio performance meets PC 98 advanced recommendations		
Recommended		
9. Audio system supports full-duplex operation at independent sampling rates		
Recommended		
10. Audio system provides hardware or software support for the Downloadable Samples specification		
Recommended		
11. Audio system supports AEC reference inputs		
Recommended		
12. Audio system provides hardware filtering of HRTF 3-D filters		
Optional		
13. CD, DVD, and broadcast audio playback meet PC 98 requirements		
Required with DVD Video		
14. Audio system provides consistent volume levels for different devices		
Optional		
15. Each device has a unique Plug and Play device ID		
Required		
16. Automatic resource assignment and dynamic disable capabilities are supported		
Required		
17. PCI device conforms to PCI 2.1 and additional PC 98 requirements		
Required		

18. PCI device supports initiator, target, and block transfer
Required

19. PCI audio components use a suitable configuration scheme if using ISA resources
Required

20. PCI device is digital ready
Required

21. Audio meets USB specification and USB audio device class specification
Required

22. Audio meets PC 98 requirements for IEEE 1394
Required

23. System and device comply with PCI bus power management specification
Required

24. Audio device complies with device class power management reference specification
Required

25. Device supports wake-up events
Optional

26. Device drivers and installation meet PC 98 requirements
Required

27. Audio meets PC 98 requirements for WDM driver support
Required

28. Applications provided with device meet Win32 requirements
Required