Chapter 11 Audio

IMPORTANT: The requirements in this guide provide instructions for designing PC systems that will result in an optimal user experience with typical Windows-based applications running under either the Microsoft Windows Millennium Edition or Windows 2000 Professional or later operating systems. These design requirements are not the basic system requirements for running any version of Windows operating systems.

This chapter provides the hardware and software requirements for PC 2001 audio.

Unless this chapter defines a specific requirement or exception, all requirements apply for audio devices as presented in Chapter 3, “PC System,” and Chapter 6, “Buses and Interfaces.”

Basic Audio Requirements

This section defines the basic hardware requirements for audio on PC 2001 systems. These are system-based requirements, targeted for the entire PC solution, regardless of whether the audio components are separate add-on devices or are built into the system, for example, on the system board, on the audio card or riser, or on the display monitor. These requirements, with the exception of AUD–0323, apply to the design of system audio devices, and not accessory audio peripherals, such as a TV tuner, camera with audio, voice modem, telephone handset, and so on.

AUD–0322. Audio device does not use legacy hardware interfaces for MS-DOS–based applications

If the audio device supports MS-DOS–based applications, it must use operating system–provided or operating system–compatible software emulation of legacy interfaces. Legacy hardware does not meet PC 2001 requirements if the legacy technique allows MS-DOS–based applications to communicate directly with ISA IRQ, DMA, or I/O hardware resources, such as PC/PCI or distributed direct memory access (DDMA).

Appendix A, “Resource Mapping,” provides a comprehensive list of legacy and legacy-free assignments.

This requirement also applies to PCI-based audio devices. Whether Windows-based or MS-DOS–based applications are running, the PCI device must not allocate or use ISA IRQs, DMAs, or hard-coded I/O locations. The BIOS and Windows driver must not contain any options to select the use of ISA resources for the audio device.

If a device supports real-mode operation, the only acceptable manner for acquiring ISA resources is to use a real-mode configuration utility.

When running MS-DOS–based applications in a virtual MS-DOS box, the level of legacy compatibility provided by Windows 98 software emulation is comparable to hardware. A comprehensive report on "Windows 98 MS-DOS Box Game Compatibility" is available on the Web site listed in "Audio References."

AUD–0323. PC 2001 audio subsystem is digital ready

PC 2001 audio sources must be available as digital audio streams accessible to the system-wide kernel, that is, they must not rely exclusively on any analog mixing stage between the digital-to-analog converter and the speaker jack as the only means for output. Sources that continue to offer an analog mixing output configuration must also provide the user a configurable digital option.

One model for providing the user such an option is Windows support for CD Music.

The audio sources covered by this requirement, which must be available digitally to USB speakers if attached, are:

- CD-ROM or DVD
- TV tuner
- FM radio
- Voice modem

Analog Mic and Line In with available analog-to-digital converters (ADCs) are digital ready by definition. Devices for which the operating system supports emulation equivalents, such as hardware accelerated 3-D and MIDI synthesis (Microsoft DirectSound® 3D emulation and the Windows GS Wavetable SW Synth) are excepted.

This requirement assures that all audio content can be made available at both the analog jack and USB port. Elimination of the dependency on analog mixing for output is key to making PC audio easier to configure and use, and it removes a major obstacle for USB audio rendering devices.

AUD–0324. Audio subsystem supports basic data formats

Windows provides software mixing and sample rate conversion, which eliminates the need for hardware to support all possible rates. Therefore, either the audio

controller or the audio codec hardware, or both, are only required to support two key rates: 44.1 kilohertz (kHz) and 48 kHz (and, at these two rates, must not depend on sample rate conversion in the driver or operating system).

- 44.1 kHz is required for efficiency reasons. Most game content uses a sampling rate that is an integer divisor of 44.1 kHz, and CD audio is 44.1 kHz. When the highest input stream is 44.1 kHz and below, the optimal way to operate the audio output is to convert everything to 44.1 kHz and run the audio device at this rate. This conversion provides the best quality and least CPU overhead.
- 48 kHz is required because it is the prevalent sampling rate for entertainment content, such as DVD movies. When 48 kHz content is present, the operating system switches the audio output to 48 kHz.
- Support for other rates (8 kHz, 11.025 kHz, 16 kHz, 22.05 kHz, or 32 kHz) in hardware is optional.

AUD–0325. Audio subsystem supports full duplex operation

Full duplex audio is essential to support emerging communications applications such as Internet Protocol (IP) telephony, conferencing, and network gaming. These applications require the audio system to play back and record simultaneously. The following requirements ensure that full duplex operation is available and performance is consistent across implementations.

- **AUD–0325.1. Full duplex operation is supported for all sampling rates supported by the hardware.** If the built-in or external audio device includes both input and output capabilities, full duplex operation must be supported for basic formats (16-bit, and 44.1 kHz and 48 kHz), and for all other formats supported by the hardware, for example, at 8 kHz, 11.025 kHz, 16 kHz, 22.05 kHz, or 32 kHz.
- **AUD–0325.2. Independent selection of input and output sample rates.** If the built-in or external audio device includes both input and output capabilities, the audio device must support independent selection of input and output sample rates.
- **AUD–0325.3. Sample rates are time-synchronized.** If the built-in or external audio device includes both input and output capabilities, the timing relationship between input and output sample rates must remain constant (i.e., no drift). For example, if 8 kHz is selected for both input and output sampling rate, audio hardware must ensure that the sampling rate for input and output is precisely matched.

Further, when input and output sample rates are set to integer ratios, the actual sample rate ratios must match (i.e., no drift). For example, if 8 kHz input sampling rate and 32 kHz output sampling rate are selected, the ratio of actual sampling rates must be precisely 8:32. This requirement can be accomplished by ensuring that both input and output sampling rates are derived from the same clock, and that sample rate divisors are set correctly.

This requirement helps ensure that Acoustic Echo Cancellation (AEC) and Noise Reduction algorithms maintain performance and convergence.

AUD–0326. Audio driver reports sample position for stream synchronization

The driver must be capable of reporting within 1 ms the current position of the buffer being rendered, in relation to the samples given to the codec. This requirement applies for both compressed and uncompressed data.

AUD–0337. Audio meets PC 2001 requirements for WDM driver support

All audio devices must have drivers that use the WDM architecture exclusively. Audio devices must not use VxDs. The manufacturer can either supply a WDM driver with the audio device or rely on a WDM driver provided with Windows Me and Windows 2000.

For information about WDM device driver support for streaming capabilities, see "WDM Kernel Streaming Architecture" and "Kernel Streaming Overview," available on the Web pages indicated in "Audio References."

AUD–0327. If implemented, audio system provides 2-D and 3-D hardware acceleration according to PC 2001 requirements

If the audio hardware provides acceleration for Microsoft DirectSound or DirectSound3D, it must declare its capabilities as follows:

- The device must accurately report the maximum number of 2-D and 3-D buffers it can play simultaneously on the minimum PC 2001 system. For example, if the device declares that it can support 20 2-D buffers and 30 3-D buffers, it must be able to play 20 2-D buffers or 30 3-D buffers simultaneously.
- The device must accurately report the number of available 2-D and 3-D buffers. The device must be able to open and play another 2-D or 3-D buffer when the reported number of available voices is greater than 0.

AUD–0328. If implemented, audio system provides DLS acceleration according to PC 2001 requirements

If the audio system provides hardware acceleration of DLS using Microsoft DirectMusic®, the audio system must be able to fulfill all of the capabilities it declares. For example, if the DirectMusic device indicates that it can play 64

voices and provide reverb, then it is required to support both capabilities, simultaneously on the minimum PC 2001 system.

Audio Performance Requirements

This section summarizes the performance requirements for audio on PC 2001 systems.

Several companies joined together to develop *Personal Computer Audio Quality Measurements* (PCAQM), a standard testing procedure for defining and measuring audio performance. Contributors to PCAQM include Audio Precision, Compaq Computer Corporation, Crystal Semiconductor, Intel Corporation, and Microsoft Corporation. PCAQM definitions and test methods are available from the *Personal Computer Audio Quality Measurements* Web site listed in "Audio References."

AUD–0329. Audio meets PC 2001 minimum performance requirements

The following table summarizes audio performance requirements for all audio-enabled PC 2001 systems, with the exceptions noted in "Requirements for Mobile PC Audio." These requirements establish a minimum performance level for PCs.

For precise definitions of the terminology used in the following table, please refer to the PCAQM test methodology paper cited earlier in this section.

PC 2001 Audio Minimum Performance Requirements

Feature	Requirement	Value
Full-scale input voltage	FSIV (A-D-PC) line input	≥1.0 Vrms
	FSIV (A-D-PC) microphone input	≥100 mVrms
Full-scale output voltage	FSOV (PC-D-A) line output	≥1.0 Vrms[1]
Digital playback (PC-D-A) for line output	Frequency response (–3 dB)	
	44.1 kHz source material	20 Hz to 17.6 kHz[3]
	48.0 kHz source material	20 Hz to 19.2 kHz[3]
	Passband ripple[5]	<+/–0.5 dB
	Dynamic range	≥80 dB FS A[2, 3]
	THD+N (–3 dB FS)	≤–65 dB FS[3]
Digital playback (PC-D-A) for speaker output	Speaker output with 8-ohm load[4]	
	Frequency response (–3 dB)	
	44.1 kHz source material	100 Hz to 17.6 kHz[4]
	48.0 kHz source material	100 Hz to 19.2 kHz[4]
	Dynamic range	≥80 dB FS A[2, 3]
	THD+N (–3 dB FS)	≤–65 dB FS[3]

Feature	Requirement	Value
Digital recording (A-D-PC) for line input	Frequency response 44.1 kHz destination 48.0 kHz destination	 20 Hz to 17.6 kHz[3] 20 Hz to 19.2 kHz[3]
	Passband ripple	<+/–0.5 dB
	Dynamic range	≥70 dB FS A[2, 3]
	THD+N (–3 dB FS)	≤–60 dB FS[3] (input-referenced)
Digital recording (A-D-PC) for microphone input	Frequency response (–3 dB) 22.05 kHz destination	 100 Hz to 8.8 kHz
	Passband ripple	<+/–0.5 dB
	Dynamic range	≥70 dB FS A[2, 3]
	THD+N (–3 dB FS)	≤–60 dB FS[3] (input-referenced)
Line output cross-talk	Channel separation between left and right line out channels (measured at 10 kHz)	≥60 dB[3]
Sampling frequency accuracy	Playback	0.1%
	Record	0.1%

[1] For 3.3V audio codec the required full-scale output voltage (FSOV) for line output is ≥0.7 Vrms.

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

[3] For mobile PC, the dynamic range requirements are relaxed by 10 decibel (dB) FS. The total harmonic distortion plus noise (THD+N) requirements are relaxed by 10 dB FS. The required frequency response is 30 Hz to 15 kHz, measured using 3 dB corners. The cross-talk requirements are relaxed by 10 dB FS.

[4] Where separate line and speaker outputs are provided.

[5] Bandpass for ripple measurements is from 40 Hz to (0.4xFs)/2 Hz.

Requirements for Voice Input

This section discusses incremental requirements for audio subsystem and peripheral devices to support applications requiring voice input on the PC.

These requirements address issues related to microphone input compatibility for voice-input enabled applications such as acoustic echo cancellation, speech recognition, speakerphone telephony, and conferencing.

AUD–0330. Audio subsystem supports AEC reference inputs

Built-in or external audio devices that support full-duplex, stereo playback and record for speakers and microphone must support simultaneous capture of microphone and one or more AEC reference inputs.

At minimum, the audio device must support capture of microphone input in the left channel and a monaural output mix in the right channel, where the monaural output mix is the left and right channels of the main output merged into a single

channel. This 1+1 channel interleaved format (similar to stereo) will be referred to as “mic+ref”, and can be easily achieved using existing stereo ADCs.

For more information, see Section 6.2 of *Audio Codec ’97, Revision 2.1,* from Intel Corporation, which describes one possible implementation. This specification is listed in “Audio References.”

AUD–0331. If implemented, analog microphone input meets PC 2001 jack and circuit requirements

This requirement enables users with electret or dynamic microphones to connect the device to their PC and achieve consistent results. This requirement also maintains compatibility with the installed base of microphones. For information about headset microphones, see AUD–0332, “If implemented, close-speaking headset microphone meets PC 2001 performance requirements.”

If the PC has an analog microphone input, it must meet the following specifications:

- Three-conductor 1/8-inch (3.5 millimeters) tip/ring/sleeve microphone jack where the microphone signal is on the tip, bias is on the ring, and the sleeve is grounded.

  This design is optimized for electret microphones with three-conductor plugs, but will also support dynamic microphones with two-conductor plugs, where the ring and sleeve are shorted together.
- Minimum AC input impedance between tip and ground: minimum, 4 kilohms.
- Input voltages of 10–100 millivolts (mV) must deliver full-scale digital input, using software-programmable gain.
- Maximum 5.5 V with no load, minimum 2.0 V with 0.8 milliampere (mA) load, direct current bias for electret microphones.
- Minimum bias impedance between bias voltage source and ring: 2 kilohms.
- AC coupled tip.

AUD–0332. If implemented, close-speaking headset microphone meets PC 2001 performance requirements

The following requirements are for close-speaking headset microphones intended for use in speech-recognition applications.

These requirements are compatible with most of the installed base of sound cards and audio-enabled system boards.

The requirements for a PC 2001 speech-recognition microphone are:

- Close-speaking headset design positions microphone within 1.5 inches of the corner of the speaker’s mouth.

- FSOV: 100 mV (0 dB FS).
- Microphone connector meets requirements stated in the requirement AUD–0331, “If implemented, analog microphone input meets PC 2001 jack and circuit requirements.”
- Operating bias voltage from 2.0–5.0 volts direct current (VDC) with a maximum current drain of 0.8 mA.
- Capable of sustaining a maximum voltage of 10 VDC on tip or ring without damage.
- Frequency response:
  - ±3 dB from 100 Hz to 10kHz
  - 0 dB at 1 kHz
- Minimum sensitivity of –44 dB relative to 1 volt per pascal.
- Maximum 2 percent THD+N 100 Hz to 10 kHz at 94 decibel sound pressure level (dBSPL).
- Noise cancellation null sensitivity at 90 degrees and 270 degrees, ±10 degrees, with the following minimums:

  20 dB at 100 Hz
  20 dB at 400 Hz
  20 dB at 1000 Hz
  20 dB at 4000 Hz
  10 dB at 10 kHz
- Maximum wind noise sensitivity of –65 dB with 0 dB = 1 V (measured with wind speed of 1 meter per second at the 0 degree axis of microphone).
- Maximum output impedance of 1 kilohm (using a 1-kHz full-scale test tone with 2.0 VDC bias).

Requirements for PCI, USB, and IEEE 1394 Audio

This section discusses additional requirements and exceptions for audio devices implemented for PCI, USB, and IEEE 1394.

Audio devices must meet the applicable requirements in Chapter 6, “Buses and Interfaces,” unless specified in this chapter.

AUD–0333. PCI device supports initiator, target, and block transfer

For complete implementation details, see PCI 2.2. Full-duplex audio sample transport must be supported using separate PCI bus mastering hardware for playback and capture sample streams.

AUD–0334. PCI device supports efficient audio buffer management

The audio device must be able to fully function when the system can only provide single pages of contiguous memory. In other words, the audio device can require

many pages of memory, but must not require the largest block of contiguous memory to exceed one page.

This requirement ensures audio support in docking and dynamic loading scenarios where memory may be fragmented with respect to pages.

The audio device and associated device-specific driver must not introduce unnecessary latency. If the audio driver adds more than 2 milliseconds of computational latency between buffer transfer and queuing for rendering, the driver must provide a programmatic method for a latency sensitive application to temporarily disable the computation.

This requirement helps to ensure that telephony applications closely resemble the performance of a conventional phone and minimizes the possibility that audio and video streams will appear out of synch.

AUD–0335. USB audio meets USB specifications

If USB audio is implemented, the device must comply with *Universal Serial Bus Specification, Revision 1.1* and with *Universal Serial Bus Device Class Definition for Audio Devices, Release 1.0*. This requirement ensures that all Plug and Play requirements are met and that drivers provided with the operating system support this device.

USB audio devices must use an HID to control basic functions. If a USB audio device plans to implement volume adjustment controls, it must employ the HID usages provided on the consumer controls page in the *USB HID Usage Tables, Version 1.1* specification and in "Windows Support for HID-based Audio Controls," listed in "Audio References."

Power Management for Audio

This section summarizes the power management requirements for audio components.

AUD–0336. Audio device complies with device class power management reference specification

Audio devices must comply with *Audio Device Class Power Management Reference Specification, Version 1.0*, which provides definitions of the OnNow device power states (D0–D3) for these devices. The specification also covers the device functionality expected in each power state and the possible wakeup event definitions for the class. The device and driver are required to implement support for power states D0, D2, and D3. Other power states are optional.

Audio devices implemented on the system board must comply fully with ACPI 1.0b.

Requirements for Mobile PC Audio

Mobile audio must meet the requirements for PC 2001 audio as defined earlier in this chapter, with exceptions as defined in this section. These exceptions acknowledge mobile-specific design challenges, such as dual power supplies (battery and AC), low power operation, and smaller form factors.

For mobile PCs, USB plays an especially important role in providing access to higher quality audio output. For more information, see AUD–0323, "PC 2001 audio subsystem is digital ready."

AUD–0338. Audio-enabled mobile PC meets mobile PC 2001 audio performance requirements

For Mobile PCs, the following exceptions and differences are allowed:

- All dynamic range requirements are relaxed by 10 dB FS A.
- All THD+N requirements are relaxed by 10 dB FS.
- The required frequency response (measured at line out) is 30 Hz to 15 kHz, measured using 3 dB corners.
- All cross-talk requirements are relaxed by 10 dB FS.

AUD–0339. Docked mobile meets PC 2001 speaker selection requirements

The PC 2001 design requirements allow for the audio controller to be implemented on the mobile PC with output capabilities implemented on a docking station. The docking station is not required to implement full desktop audio capabilities, but it can supplement the audio capabilities of the mobile PC. If audio is implemented, the docked mobile PC must meet the requirements for PC 2001 audio as defined in this chapter, with additional requirements as follows:

- Whether the mobile PC system is docked or not, users must be able to access the highest quality audio output in any given configuration. System vendors can choose to automate the process either in the docking station or the mobile PC to meet this requirement. If speakers are not automatically selected, then the user must be able to select speakers in the mobile PC or docked mobile PC upon docking. However, this requirement must not necessitate users changing the speaker configuration each time they dock and undock.
- Speakers must be switched off if the headphone jack is used.

Audio References

Following are the references, services, and tools cited in this chapter that are available to help build hardware that works optimally with Windows operating systems.

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

Audio Codec '97, Revision 2.1
http://developer.intel.com/ial/scalableplatforms/audio/index.htm

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

"Kernel Streaming Overview"
http://www.microsoft.com/ddk/

PCI Local Bus Specification, Revision 2.2 (PCI 2.2)
http://www.pcisig.com/developers/specification

Personal Computer Audio Quality Measurements
By Dr. Steven Harris and Cliff Sanchez, Crystal Semiconductor
http://www.cirrus.com/products/papers/meas/meas.html

Universal Serial Bus Device Class Definition for Audio Devices, Release 1.0
http://www.usb.org/developers/devclass_docs.html

Universal Serial Bus Specification, Revision 1.1
http://www.usb.org/developers/docs.html

USB HID Usage Tables, Version 1.1
http://www.usb.org/developers/hidpage.html

"WDM Kernel Streaming Architecture"
http://www.microsoft.com/hwdev/desinit/csa1.htm

Windows Driver Model (WDM) Technology Web page
http://www.microsoft.com/hwdev/wdm/

"Windows 98 MS-DOS Box Game Compatibility"
ftp://download.intel.com/ial/sm/compatibility.pdf

Windows 98 DDK and Windows 2000 DDK (with DirectX DDK)
http://www.microsoft.com/ddk/

"Windows Support for HID-based Audio Controls"
http://www.microsoft.com/hwdev/hid/audctrl.htm

Checklist for Audio

AUD–0322. Audio device does not use legacy hardware interfaces for MS-DOS–based applications

AUD–0323. PC 2001 audio subsystem is digital ready

AUD–0324. Audio subsystem supports basic data formats

AUD–0325. Audio subsystem supports full duplex operation

AUD–0326. Audio driver reports sample position for stream synchronization

AUD–0337. Audio meets PC 2001 requirements for WDM driver support

AUD–0327. If implemented, audio system provides 2-D and 3-D hardware acceleration according to PC 2001 requirements

AUD–0328. If implemented, audio system provides DLS acceleration according to PC 2001 requirements

AUD–0329. Audio meets PC 2001 minimum performance requirements

AUD–0330. Audio subsystem supports AEC reference inputs

AUD–0331. If implemented, analog microphone input meets PC 2001 jack and circuit requirements

AUD–0332. If implemented, close-speaking headset microphone meets PC 2001 performance requirements

AUD–0333. PCI device supports initiator, target, and block transfer

AUD–0334. PCI device supports efficient audio buffer management

AUD–0335. USB audio meets USB specifications

AUD–0336. Audio device complies with device class power management reference specification

AUD–0338. Audio-enabled mobile PC meets mobile PC 2001 audio performance requirements

AUD–0339. Docked mobile meets PC 2001 speaker selection requirements