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AES information document for digital audio - Personal computer audio quality measurements

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Abstract

This document focuses on the measurement of audio quality specifications in a PC environment. Each specification listed has a definition and an example measurement technique. Also included is a detailed description of example test setups to measure each specification.

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Foreword

[This foreword is not a part of AES information document for digital audio — Personal computer audio quality measurements, AES-6id-2000.]

This document was prepared by a writing group of the SC-02-01 Working Group on Digital Measurement Techniques of the SC-02 Subcommittee on Digital Audio. Steven Harris headed the writing group.

The text of the Crystal Audio Division of Cirrus Logic, Inc. version 1.0 paper on measurement of PC audio was used to create the first proposed working group draft of this document. The working group felt that the wide-spread use of the Cirrus paper in the computer industry warranted the preparation an AES document based on it.. AES documents are subject to due process based on AES procedures and receive a public review. Their format is based on the IEC-ISO Directives, Part 3, which may be downloaded from www.iec.ch.

Initial discussions revealed that a full consensus on all provisions of the first proposed draft would not be possible. The group chose, therefore, to prepare an information document rather than a standard. An AES information document, while formatted in the same style as a standard, does not require full consensus for publication. Instead, public comments that cannot be resolved may be published in an informative annex to the document. In this manner, the information becomes quickly available for use in the industry while questions regarding particular provisions are made available for consideration by users. The comments are compiled in annex D at the end of this document.

The document remains under continuous review under project AES-6-id-R assigned to the SC-02-01 working group. It may be amended by following AESSC due-process procedures which require the same public review before publication as a new standard. Participation in this process is open to all directly and materially affected individuals who join the working group in the manner described at www.aes.org/standards/.

The document does not suggest performance limits. Such limits for some of these measurements are suggested in, for example, Microsoft PC-2001, Intel’s AC ‘97, and in the MPC3 specification.

Richard Cabot, chair SC-02-01
Chris Travis, vice-chair SC-02-01
2000-02-20

Foreword to 2006 revision

There have been many improvements in PC audio since the original AES-6id document was published. This revision of AES-6id includes substantial updates that reflect the improvements in the PC sound sub-system, as well as some updates based on many real world measurements. I would like to thank Wayne Jones and Thomas Kite for their contributions to this revision, and all the SC-02-01 committee members who submitted valuable comments.

Steve Harris, Chair, SC-02-01
2006-08-13

AES information document for digital audio - Personal computer audio quality measurements

1 Scope

This document focuses on the measurement of audio quality specifications for devices used in or connected to a personal computer (PC). Each specification listed has a definition and an example measurement technique. Also included is a detailed description of example test setups to measure each specification. Information on signal paths and weighting filters is given in annexes.

2 Normative references

The following standard contains provisions which, through referenced in this text, constitute provisions of this document. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the indicated standards.

AES17-1997, *AES standard method for digital audio engineering — Measurement of digital audio equipment*. NY: Audio Engineering Society, Inc., (1997, reaffirmed 2003).

3 Definitions

3.0 Personal Computer (PC)
A computer designed for use by an individual in the form of a desktop or notebook. In this context, a "PC audio device" is what is commonly called a "sound card", which may be an externally-connected device, or a mother-board audio implementation.

3.1 Signal Paths
A PC audio device has several signal paths that should be characterized independently and in various combinations. The following definitions describe the common paths present in most PC audio devices. Also see annex B for a more detailed description of each path and block diagrams.

3.1.1 Playback (D-A) Path
The path from the internal PC bus routed through the digital-to-analog converter, the Playback Mixer, and out through the analog output amplifier. Digital signals may be present on the PC bus by playing or streaming a Wave file from hard disk or PC memory or by routing a signal from the digital input to the PC bus.

3.1.2 Analog Loop (A-A) Path
The path from the analog input amplifier, routed through the Playback Mixer, and back out through the analog output amplifier. Several analog inputs may exist such as: Line Input, Microphone Input, Auxiliary Input, CD Drive Input, Telephone Modem (TDA) Audio, and others.

3.1.3 Record (A-D) Path
The path from the analog input amplifier, routed through the Record Mixer, and through the analog-to-digital converter to the PC bus. The digital signal on the PC bus may reside in memory or be streamed to hard disk. Alternatively, the digital signal on the PC bus may be routed out to the digital output. Several analog inputs may exist such as: Line Input, Microphone Input, Auxiliary Input, CD Drive Input, Telephone Modem (TDA) Audio, and others.

3.1.4 Record-Play Loop (A-D-PC-D-A) Path

This is a combination of the Record and Play paths through the PC bus. The signal path is from the analog input amplifier, through the Record Mixer, through the analog-to-digital converter to the PC bus, through the digital-to-analog converter, the Playback Mixer, and back out through the analog output amplifier.

3.1.5 Digital Loop (D-D) Path

The path from a digital input, through the PC bus, and returning out via the digital output. These inputs and outputs are as specified in IEC 60958-3 and also sometimes called S/PDIF. Note that AES-3id specifies an unbalanced digital interface, also with a 75 Ω impedance, but with professional status bits and 1.0 Vpp signal level. Most consumer sound cards use the 0,5 Vpp signal level specified by IEC 60958-3.

3.2.1 Record Mixer

The input or record user interface part of the driver associated with a PC audio device. It is mostly associated with the analog paths although it occasionally includes some controls for digital paths. This mixer will typically have several faders, one for each analog, and sometimes digital, input. These faders are used to set level for the particular input. Faders are not generally calibrated and it is not usually possible to set specific gain conditions, including unity gain. Typically, associated with each input is an enable or mute check box that will turn the input on or off. In most consumer PC audio devices, these check boxes are mutually exclusive thereby making this “mixer” actually a one-of-several multiplexer.

3.2.2 Playback Mixer

The output or playback user interface part of the driver associated with a PC audio device. Like the record mixer, it is mostly associated with the analog paths although occasionally it includes some controls for digital paths. This mixer will typically have several faders, one for each analog, and sometimes digital, output. These faders are used to set level for the particular source. Faders are not generally calibrated and it is not usually possible to set specific gain conditions including unity gain. Typically, associated with each input is an enable or mute check box that will turn the input on or off. It is generally possible to have more than one signal source active at a time with relative levels of the active sources set by the respective faders.

3.3 Wave file (.wav)

A Wave file is a file format for transferring digital audio data between systems of different type and manufacture. It may reside in PC memory or on hard disk. The audio signal may be stereo or mono program material or test signals. The header of this file identifies the characteristics of the file including sample rate, stereo or mono, bit depth, etc. This type of file has the extension “.wav”.

3.4 Full-scale amplitude (digital)

Root-mean-squared (rms) amplitude of a 997 Hz sine wave in the digital domain whose positive peak value reaches the positive digital full scale, leaving the negative maximum code unused.

3.4.1 Decibels, full-scale (dB FS)

Digital signal rms amplitude expressed as a level in decibels relative to full-scale amplitude (20 times the common logarithm of the amplitude over the full-scale amplitude). Note that dB FS expresses a signal level of a digital signal and should not be used to express the signal level of an analog signal.

3.4.2 Percent, full-scale (% FS)

Digital signal rms amplitude expressed as a percentage of full-scale amplitude (100 times the amplitude over the full-scale amplitude)

3.4.3 Maximum signal level (analog)

0,5 dB lower than the analog signal rms amplitude of the highest undistorted signal level that is possible in an analog signal path. Undistorted in this context shall mean not to exceed -40 dB THD+N (1 % THD+N). See also annex B for additional discussion.

3.4.4 Full-scale input voltage (FSIV)

RMS voltage level of the *maximum analog signal level* at the input of an analog-to-digital converter such that the THD+N ratio measured at the output of the converter does not exceed -40 dB.

3.4.5 Full-scale output voltage (FSOV)

RMS voltage level of the analog output signal from a digital-to-analog converter with a digital input consisting of a 997 Hz sine wave input whose positive peak value reaches the positive digital full scale.

> Note: some devices may not able to handle a signal with an amplitude this high. In this case, 0,5 dB below the maximum signal level that just reaches -40 dB THD+N will be used. See the explanation in annex C.

3.4.6 Reference signal level

Signal amplitude used for ratio-metric computations such as dynamic range and signal-to-noise ratio. A Reference Signal Level of 0 dBr will be the Maximum signal level or, if it can be achieved, Full-scale amplitude.

3.4.7 dBr

A signal level referred to a reference signal level. Used for measurements involving ratio such as dynamic range. 0 dBr for dynamic range measurements is determined as specified in the maximum signal level definition.

3.5 Frequency response

Variation in output rms signal level, relative to the level at 997 Hz, as the frequency is varied.

> Note: Amplitude limits or amplitude corners are required to define frequency response and are usually set at either ± 1 dB or ± 3 dB.

3.6 Total Harmonic Distortion plus Noise (THD+N)

THD+N is expressed as 20 times the $\log_{10}$ of the ratio of the rms amplitude of all signal harmonics plus noise within the measurement bandwidth, to the rms amplitude of the test signal, expressed in dB.

> Note 1: It is important to include all non test-signal frequencies, not just multiples of the test signal frequency, since converters may generate aliased components anywhere in the measurement frequency band. The THD+N measurement is easier to perform than THD, since the only requirement is to filter out the test tone and then perform a broadband measurement of the residual, rather than perform a spectral analysis (see D.4).
> Note 2: THD+N measurements are dependent on test signal amplitude; therefore, the test signal amplitude relative to the Reference Level should be listed with THD+N measurement results.

3.7 Intermodulation Distortion (IMD)

A measurement of the distortion produced by the interaction of two or more test signals. The most common technique is to use a test signal composed of two sine waves and measure the sum and difference products produced. The two sine waves are typically near the upper band edge, commonly 18 kHz and 20 kHz (for analog circuits) or 17,987 Hz and 19,997 Hz (for digital circuits). The difference product at 2 kHz (2,02 kHz digital) is measured and its amplitude as a ratio of the averaged rms levels of the two high frequencies expressed as the magnitude of IMD. This technique, unlike THD+N, permits valid distortion measurements near the upper band edge of a device.

3.8 Dynamic range (DR)

20 times the logarithm of the ratio of the Reference Signal Level to the rms noise floor within the measurement bandwidth, expressed in dB. The measurement must be made in the presence of signal.

> NOTE: This specification is sometimes referred to as signal-to-noise ratio (SNR) in the presence of a signal. The label SNR should not be used because of industry confusion over the exact definition. SNR is often used to indicate signal-to-noise ratio, with the noise level being measured with no signal. This can often give an optimistic result because of muting circuits, which mute the noise when no signal is present.

3.8.1 A-weighted dynamic range (DRA)

20 times the logarithm of the ratio of the signal Reference Level to the A-weighted rms noise floor in the presence of signal, expressed in dB. See D.2

3.8.2 ITU-R BS.468-4-weighted dynamic range (DR-ITU)
20 times the logarithm of the ratio of the signal Reference Level to the ITU-R BS.468-4-weighted rms noise floor in the presence of signal, expressed in dB (see D.3)

3.9 Continuous power
Average power into a specified load using a 997-Hz sine wave played at the full-scale output voltage

> NOTE: This specification is only required when the line output jack is used to drive headphones or loudspeakers directly.

3.10 Cross-talk between signal channels
Leakage of information from one channel to another, expressed as 20 times the $\log_{10}$ of the ratio of the amplitude of the test signal measured at the output of one channel versus the amplitude of the leakage of the test signal into an undriven channel with its input terminated.

3.11 Interchannel Phase Difference
Interchannel phase response is the phase difference between a designated reference channel and all other channels. The phase differences between every other channel and the reference channel shall be reported in degrees as a function of frequency.

3.12 Passband Ripple
A measurement of the amplitude variation caused by anti-aliasing and reconstruction filters associated with analog-to-digital and digital-to-analog converters. See annex E for additional details.

3.13 Sampling Frequency Accuracy
Comparison of the actual sampling frequency to the theoretical sampling frequency expressed in Hz or percent. For example, if the theoretical sampling frequency is 48 000 Hz but the measured sampling frequency is 48 001,45 Hz, the error is 1,45 Hz or 0,003 02 %.

3.14.1 Interface jitter
Deviation in timing of interface data transitions (zero crossings) expressed in Unit Intervals (UI) when measured with respect to an ideal clock. See AES3 and IEC 60958-1 for a definition of Unit Interval.

3.14.2 Intrinsic jitter
Output interface jitter of a device that is either free running or is synchronized to a jitter-free reference. Expressed in Unit Intervals (UI). See AES3 and IEC 60958-1 for a definition of Unit Interval.

4 Measurement techniques

4.0 General

This section is a general description of measurement techniques for all of the measurements defined in this document. Included are recommendations for obtaining most accurate results, discussions of possible sources of errors, and suggestions for how to avoid these errors.

All digital test signals should be properly dithered. The dither signal should be a random or pseudorandom sequence having triangular probability density and a peak-to-peak amplitude of 2 least significant bits (which is ± 1 LSB) of the digital audio word length. The power spectral density of the noise should be flat, that is constant per unit bandwidth (white) to the upper band-edge frequency of the measured bandwidth.

For specific information on how to perform tests on PC audio devices including a step-by-step procedure, see 6.

> NOTE: These measurement techniques are based on the normative reference AES17-1998 (r2004) and the informative references *Audio Precision Audio Measurement Handbook* and the EIAJ CP-307 CD measurement standard (see annex A).