Federal Agencies
Digitization Guidelines Initiative

Audio Analog-to-Digital Converter Performance Specification and Test Method

Guideline (High Level Performance)

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The FADGI Audio-Visual Working Group

http://www.digitizationguidelines.gov/audio-visual/

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Table of Contents

Normative References

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Scope

This document specifies a set of metrics and methods pertaining to the performance of the audio analog-to-digital converters (ADCs) used in preservation reformatting workflows. It is the central element within the larger topic of audio digitization system performance, which also includes the problem of interstitial errors, where samples are dropped or otherwise altered in the final digital audio file, and consideration of the impact of other devices, cables, or interfaces that may be placed in the signal chain. Interstitial errors and their identification is the subject of a separate investigation by the Working Group, while the impact of other system elements is out of scope at this time.

The metrics specified in the guideline pertain to the production of files using the highest quality ADC devices. Comments from within and without the Working Group, however, have called attention to the range of types of archival organizations, some with strong resources and others in modest circumstances. Commentators have also noted the variation in the categories of material to be reformatted, asking if there might be circumstances in which relaxed levels of device performance would be acceptable. The Working Group hopes to address this topic in the near future.[1]

This guideline is one of four related documents pertaining system performance. The companion documents are:

- *Audio Analog-to-Digital Converter Performance Specification and Test Method: Introduction* (August 2012)
  - http://www.digitizationguidelines.gov/audio-visual/documents/ADC_performIntro_20120820.pdf
- *Assess Audio System Evaluation Tools: Consultant's Initial Report* (March 2011)
  - http://www.digitizationguidelines.gov/audio-visual/documents/FADGI_Audio_EvalPerf_Report.pdf
- Previous draft of the introductory discussion and performance guideline (February 2012)
  - http://www.digitizationguidelines.gov/audio-visual/documents/ADC_Perf_Test_2012-02-24.pdf

The Working Group's expert consultant Chris Lacinak (Audiovisual Preservation Solutions) was the principal investigator and main author for all of these documents. During their development, Lacinak received valuable guidance from a number of members of the Working Group and from outside experts, notably Richard Cabot[2] and Ian Dennis.[3]

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[1] In a parallel effort by the Federal Agencies Still Image Working Group, four performance levels have been associated with the same set of target specifications. All levels have the same "aim points," but they allow for varying tolerances, i.e., the highest performance level allows very little variation from the target value while the lowest performance level allows for a much greater level of variation.

[2] Richard C. Cabot has a Ph.D. from Rensselaer Polytechnic Institute and his professional career has included work at Tektronix, Audio Precision (which he co-founded), XFRM, Inc., and Qualis Audio. Cabot also chairs the committee that developed the AES-17 digital audio measurement standard.

[3] Ian Dennis is the co-founder and Chief Technical Officer at Prism Sound, a well-known manufacturer of digital audio systems.

ADC Performance Guideline (High Quality)

Test Name	**Frequency Response**
Test Method	According to AES-17: Frequency response shall be measured at –20 dBFS with a sinewave whose frequency varies from 10 Hz to 50 kHz in steps no larger than 10 per octave.
Performance Specification	see table below

Sample Rate	Frequency	Limit
48kHz	20 – 20k Hz	+/- 0.1 dB
96kHz	20 – 20k Hz	+/- 0.1 dB
96kHz	20k - 40k Hz	+/- 0.5 dB

Test Name	**Total Harmonic Distortion + Noise (THD+N)**
Test Method	Based on AES-17: The EUT shall be stimulated with a low distortion sine wave. The test signal present in the output shall be removed with a notch filter and bandwidth limited from 20 Hz to 20 kHz. The RMS amplitude is reported as a ratio to the RMS amplitude of the unfiltered signal. The measurement should be performed at the following amplitude and frequency combinations: -1.0 dBFS at 41 Hz, 997 Hz and 6597 Hz, –10 dBFS at 997 Hz, and -20 dBFS at 997 Hz, and -60 dBFS at 997 Hz.
Performance Specification	see table below

Freq	Level	Limit (unweighted)
Hz	dBFS	
41	-1	-100
997	-1	-100
6597	-1	-100
997	-10	-100
997	-20	-90
997	-60	-50

Test Name	**Dynamic Range (Signal to Noise)**
Test Method	Based on AES-17: The measurement is the ratio of the full-scale amplitude to the weighted r.m.s. noise and distortion, expressed in dB, in the presence of signal. It includes all harmonic, inharmonic, and noise components. The test signal shall be a 997-Hz sine wave producing – 60 dBFS at the EUT output. Any 997-Hz test signal present in the output is removed by means of a standard notch filter. The remaining noise is filtered with an A weighting filter limited to 20 kHz. The results shall be reported as unweighted and A-weighted in dBFS.
Performance Specification	see table below

Weighting	Limit
Unweighted	-110 dB
A weighted	-112 dB

Test Name	**Cross-Talk**
Test Method	One channel of the EUT is driven with a -1 dBFS sinewave and the maximum amplitude of this frequency appearing in any other channel is noted. The measurement is repeated for each input channel and the maximum amplitude for all channels is determined. This amplitude, expressed in dBFS, is increased by 1 dB and reported. The measurement shall be performed at frequencies of 20 Hz, 1 kHz and 20 kHz.
Performance Specification	(see table below)

Frequency	Limit
20 Hz	-110 dB
1k Hz	-110 dB
20 k Hz	-105 dB

Test Name	**Common-Mode Rejection Ratio (CMRR)**
Test Method	The input shall be driven from a sinewave generator whose output impedance is less than 100 Ohms. The amplitude is adjusted to achieve -20 dBFS at the EUT output. The signal is removed, and the generator reconnected between the chassis ground and one side of the input. A 600 Ohm resistor is connected between this point and the other side of the input. If the input is asymmetrical, the generator should be connected to the low side and the resistor to the high side. The output should be measured through a bandpass filter at the sinewave frequency. The resulting RMS value, measured in dBFS, is increased by 20 dB and reported as a dB (not dBFS) value. The measurement should be performed at 60 Hz, 1 kHz and 20 kHz.
Performance Specification	(see table below)

Frequency	Limit
60 Hz	70 dB
1k Hz	70 dB
20 k Hz	50 dB

Test Name	**Low Frequency Intermodulation Distortion (LF IMD)**
Test Method	Based on AES-17: IM measurements shall be performed with a twin tone signal with a peak amplitude of -1.0 dBFS. The lrms sum of second- and third-order difference frequency components in the output are measured and reported in dBFS. The test frequencies shall be 41 Hz and 7993 Hz in a 4:1 amplitude ratio.
Performance Specification	(see table below)

Frequency	Limit
LF sum	-100 dB

Test Name	**High Frequency Intermodulation Distortion (HF IMD)**
Test Method	Based on AES-17: IM measurements shall be performed with a twin tone signal with a peak amplitude of -1.0 dBFS. The lrms sum of second- and third-order difference frequency components in the output are measured and reported in dBFS. The test frequencies shall be 20 kHz and 18 kHz in a 1:1 amplitude ratio.
Performance Specification	**Frequency** / **Limit**: HF sum / -105 dB

Frequency	Limit
HF sum	-105 dB

Test Name	**Amplitude Linearity**
Test Method	Based on AES-17: Level-dependent logarithmic gain is measured at 997 Hz from -5 dBFS to -105 dBFS and reported as standard deviation value in dB.
Performance Specification	(see table below)

	Limit
Standard Deviation	0.05 dB

Test Name	**Spurious Aharmonic Signals**
Test Method	A 997 Hz sinewave shall be applied at -1 dBFS. The output spectrum shall be measued with an 32,768 point FFT. The largest inharmonic component is reported in dBFS.
Performance Specification	(see table below)

Frequency	Limit
> 50Hz	-100

Test Name	**Alias Rejection**
Test Method	Based on AES-17 and IEC 61606-3: The device is stimulated with a variable frequency sine wave at -10 dBFS. Beginning at half the sample rate, the frequency is continuously increased until it reaches 200 kHz. For a 48 kHz sample rate, the frequency is swept from 24 kHz to 200 kHz. For a 96 kHz sample rate, the frequency is swept from 48 kHz to 200 kHz. The rms amplitude at the converter output, increased by 10 dB, is graphed. Results are reported as the lowest frequency at which the alias component was equal to or greater in amplitude than all other alias components across the frequency range tested. Amplitude is expressed relative to the stimulus amplitude in dB.
Performance Specification	(see table below)

SR	Limit
48 kHz	-80
96 kHz	-80

<table>
<tr><td>Test Name</td><td>Sync Input Jitter Susceptibility</td></tr>
<tr><td>Test Method</td><td>Based on AES-17: The converter input is driven with a -3 dBFS low distortion sinewave at 12 kHz. The reference input is driven with a signal whose phase is jittered with a 40 ns p-p sine-wave whose frequency varies from 62.5 Hz to 8 kHz in octave steps. The output spectrum is measured at each step and the results overlaid. The measurements are repeated with a 997 Hz input to the converter. Results are expressed as dBFS for each octave step.</td></tr>
<tr><td>Performance Specification</td><td>12 kHz
<table>
<tr><th>Frequency</th><th>Limit</th></tr>
<tr><td>8 kHz</td><td>-130 dB</td></tr>
<tr><td>4 kHz</td><td>-120 dB</td></tr>
<tr><td>2 kHz</td><td>-120 dB</td></tr>
<tr><td>1 kHz</td><td>-120 dB</td></tr>
<tr><td>500 Hz</td><td>-100 dB</td></tr>
<tr><td>250 Hz</td><td>-90 dB</td></tr>
<tr><td>125 Hz</td><td>-70 dB</td></tr>
<tr><td>63 Hz</td><td>-60 dB</td></tr>
</table>
997 Hz
<table>
<tr><th>Frequency</th><th>Limit</th></tr>
<tr><td>500 Hz</td><td>-110 dB</td></tr>
<tr><td>250 Hz</td><td>-100 dB</td></tr>
<tr><td>125 Hz</td><td>-90 dB</td></tr>
<tr><td>63 Hz</td><td>-80 dB</td></tr>
</table></td></tr>
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<table>
<tr><td>Test Name</td><td>Jitter Transfer Gain</td></tr>
<tr><td>Test Method</td><td>Based on AES-17: The reference input shall be driven with a signal whose phase is jittered with a 40 ns p-p sine-wave jitter signal whose frequency varies from 62.5 Hz to 8 kHz in octave steps. The p-p jitter at the output shall be measured at each step and the results shall be graphed. Results shall also report the maximum p-p jitter value in ns.</td></tr>
<tr><td>Performance Specification</td><td><table>
<tr><th>Limit</th></tr>
<tr><td>< 20ns p-p</td></tr>
</table></td></tr>
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