Federal Agencies
Digital Guidelines Initiative

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

Guideline (Low Cost)

Approved by Working Group
September 30, 2017

The FADGI Audio-Visual Working Group
http://www.digitizationguidelines.gov/audio-visual/

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Scope

This document specifies a set of metrics and methods pertaining to the performance of low cost audio analog-to-digital converters (ADCs) used in preservation reformatting workflows. A complement to the Audio Analog-to-Digital Converter Performance Specification and Test Method Guideline (High Level Performance) published by FADGI in July 2016 which detailed guideline for the production of files using the highest quality ADC devices, this document is produced in response to the needs of institutions which have more modest means or workflow requirements as identified through field testing and by comments from within and without the Working Group. FADGI recognizes that detailed testing is the ideal but practical realities dictate that a modified but still rigorous testing protocol is preferred to not testing at all.

The testing of ADC performance 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.

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

- *Audio Analog-to-Digital Converter Performance Specification and Test Method Guideline (High Level Performance)* (July 2016)
  - http://www.digitizationguidelines.gov/audio-visual/documents/ADC_performGuide_v1-1_20160216.pdf
- *ADC Performance Testing: Low Cost Performance Test Setup Background Report* (September, 2016)
  - http://www.digitizationguidelines.gov/audio-visual/documents/ADC_Low_Cost_BackgroundSetup_Report_20160901.pdf
- *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 (AVPreserve) was the principal investigator and main author for all of these documents. In the effort that led to this guideline, Lacinak worked closely with the audio engineer Phillip Sztenderowicz.[1] 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]

Requirements for Equipment-Under-Test (EUT) Settings

General Equipment Settings

The equipment controls shall be set to their normal operating positions except where noted. The switches and controls of the equipment under test (EUT) shall be consistent for all measurements in this standard.

Emphasis Settings

If any emphasis is provided, it shall be set to the manufacturer's recommended position. This setting shall be clearly indicated in the specifications. If a recommended position is not stated by the manufacturer, emphasis shall not be used. If desired, some measurements may be repeated with other settings, but measurements so obtained shall be clearly indicated as supplementary and shall be reported in addition to the results of the same tests performed using the recommended position.

Dither Settings

If a dither is provided, it shall be turned on, and this fact shall be clearly indicated in the specifications. If desired, some measurements may be repeated without dither. Measurements so obtained shall be clearly indicated as supplementary and shall be reported in addition to the results of the same tests performed with dither.

Limiter and Compression Settings

If selectable limiter or compression circuits are included in the EUT, they shall be disabled. If their effect may be measured with additional tests, the results shall be reported separately.

Device Preconditioning

The device shall be connected under normal operating conditions for the manufacturer-specified preconditioning period prior to any measurements being performed. This condition is intended to allow the device to stabilize. If no preconditioning period is specified by the manufacturer, a 5-min period shall be assumed. Should operational requirement preclude preconditioning, the manufacturer shall so state.

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[1] Sztenderowicz participated in this project under the auspices of AVPreserve; he also works as a technical engineer at Sterling Sound in New York

[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.

Power Interruption
Should power to the device be interrupted during the measurements, sufficient time shall be allowed for restabilization to occur.

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Test Name	**Frequency Response**
Test Method	Frequency response shall be measured at –20 dBFS with a sine wave whose frequency varies from 20 Hz to 20 kHz in steps no larger than 10 per octave. Results should be reported as a graph and the greatest point of variation shall be documented in dB.
Performance Specification	**Limit** +/- 0.2 dB

Test Name	**Total Harmonic Distortion + Noise (THD+N)**
Test Method	The EUT shall be stimulated with a sine wave. Using a 32k point FFT based spectrum analyzer, with a Kaiser7 window, calculate the percentage of the square root of ratio of power sum of higher harmonics and the noise power to the total signal power that also include distortion and noise power. The measurement should be performed at the following amplitude and frequency combinations and reported in dB relative: -1.0 dBFS at 41 Hz, 997 Hz and 6597 Hz; –10 dBFS at 997 Hz; -20 dBFS at 997 Hz; -40 dBFS at 997 Hz.
Performance Specification	

Freq	Level	Limit (unweighted)
Hz	dBFS	
41	-1	-70 dB
997	-1	-70 dB
6597	-1	-70 dB
997	-10	-75 dB
997	-20	-70 dB
997	-40	-60 dB

Test Name	**Dynamic Range (Signal to Noise)**
Test Method	The test signal shall be a 997 Hz sine wave producing – 40 dBFS at the EUT output. Using a 32k point FFT based spectrum analyzer, with a Kaiser 7 window and exponential averaging set

	for 16 averages, measure the THD and THD+N as a percentage. Subtract the THD measurement from the THD+N measurement, convert to dB, subtract 40 dB and report as dBFS.
Performance Specification	<table><tr><th>Limit</th></tr><tr><td>-105 dBFS</td></tr></table>

Test Name	**Cross-Talk**
Test Method	One channel of the EUT is driven with a -1 dBFS sine wave. The output of the other channel is measured using an FFT. The value measured at the frequency of the stimulus is measured. The measurement is repeated for each input channel and the maximum amplitude across all channels is determined. This amplitude is increased by 1 dB and reported as dBFS. The measurement shall be performed at frequencies of 20 Hz, 997 Hz and 20 kHz.
Performance Specification	<table><tr><th>Frequency</th><th>Limit</th></tr><tr><td>20 Hz</td><td>-140 dBFS</td></tr><tr><td>997 Hz</td><td>-120 dBFS</td></tr><tr><td>20 k Hz</td><td>-110 dBFS</td></tr></table>

Test Name	**Low Frequency Intermodulation Distortion (LF IMD)**
Test Method	IM measurements shall be performed with a twin tone signal consisting of 41 Hz and 7993 Hz in a 4:1 amplitude ratio. When summed the signal shall equal -1 dBFS. The amplitudes of the sidebands around 7993 Hz are summed and expressed as dB relative to the amplitude of the 7993 signal.
Performance Specification	<table><tr><th>Frequency</th><th>Limit</th></tr><tr><td>LF</td><td>-65 dB</td></tr></table>

Test Name	**High Frequency Intermodulation Distortion (HF IMD)**
Test Method	IM measurements shall be performed with a twin tone signal consisting of 20 kHz and 18 kHz in a 1:1 amplitude ratio. When summed the signal shall equal -1 dBFS. The second and third order difference frequency components in the output are measured and calculated using the following formula: *20*LOG10((2nd order % + 3rd order %)/100)*. The result is

	reported in dB relative to the amplitude of the stimulus.
Performance Specification	<table><tr><th>Frequency</th><th>Limit</th></tr><tr><td>HF</td><td>-65 dB</td></tr></table>

Test Name	**Spurious Inharmonic Signals**
Test Method	A 997 Hz sine wave shall be applied at -1 dBFS. The output spectrum shall be measured with an 32k point FFT using a Kaiser 7 window and linear averaging with 32 maximum averages. Results are reported as a graph and the largest inharmonic component up to 20 kHz should is reported in dBFS.
Performance Specification	<table><tr><th>Frequency</th><th>Limit</th></tr><tr><td>> 50Hz</td><td>-120 dBFS</td></tr></table>