Zoom UAC-232 Test Report using Multi-Instrument

Rev: 02
Oct. 6, 2023

This report is valid only for the particular ZOOM UAC-232 unit we tested. The testing focused on its performance under 32-bit float mode.

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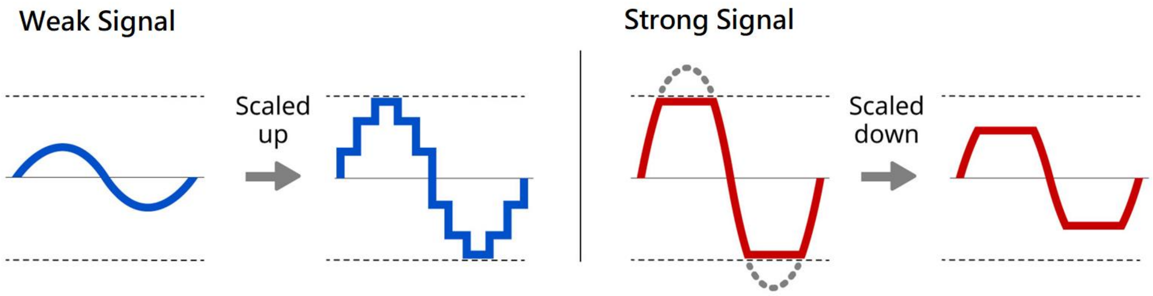
1. Introduction

Zoom UAC-232 is one of the first audio interfaces that support 32-bit float format. This format provides much higher dynamic range than the 16-bit, 24-bit and 32-bit integer formats both theoretically and practically. Ideally, the noise level would only cause the least significant bit to toggle while the maximum level would fully utilize all bits. The theoretical dynamic ranges offered by these formats are shown in the table below.

	Range	Noise Level (minimum value above 0)	Noise Level (dB)	Max. Level (dB)	Dynamic Range (dB)
16-bit Integer	Unsigned: 0~65535 Signed: -32768~32767	1	-96.3	0	96.3
24-bit Integer	Unsigned: 0~16777215 Signed:-8388608~8388607	1	-144.5	0	144.5
32-bit Integer	Unsigned: 0~4294967295 Signed: -2147483648~2147483647	1	-192.7	0	192.7
32-bit Float	$-3.40282347\times10^{38}\sim3.40282347\times10^{38}$	1.17549435×10^{-38}	-1535	0	1535

In practice, achieving a dynamic range of 125 dB with a single ADC, even if it is claimed to be 24-bit or 32-bit, is challenging due to the fact that it is difficult to keep the noise level below 1 bit in such a big dynamic range. The dynamic range of a microphone nowadays can extend as high as 140 dB, which coincides with the dynamic range of human hearing. It is thus a skill-required task to adjust the input analog gain such that the major part of the audio is within the dynamic range of the single ADC. Audio that is too loud will be clipped at the top of their waveforms while audio that is too quiet will lack fidelity or even be buried in the noise floor (see figure below).



Issues due to the limited dynamic range of a single ADC with 16/24/32-bit integer format

A larger dynamic range is required to solve this problem. Instead of pushing the performance limits of a single ADC, audio devices that support 32-bit float format usually have two ADCs working in tandem to create a single output data stream (see figure below). One "low gain" ADC is optimized for high-level audio, and the other "high gain" ADC is optimized for low-level audio. If the high gain ADC clips due to loud sounds, the low gain ADC does not. And if sounds are too quiet for the low gain ADC to capture clearly above its noise floor, the high gain ADC still has plenty of headroom above its noise floor. As a consequence, the overall dynamic range is prominently expanded, allowing for clip-free, low-noise recordings without even the need to adjust analog gain. This is the reason why Zoom UAC-232 comes with no analog gain switches and knobs. One of the primary objectives here was to find the actual dynamic ranges this device can attain. Another point of

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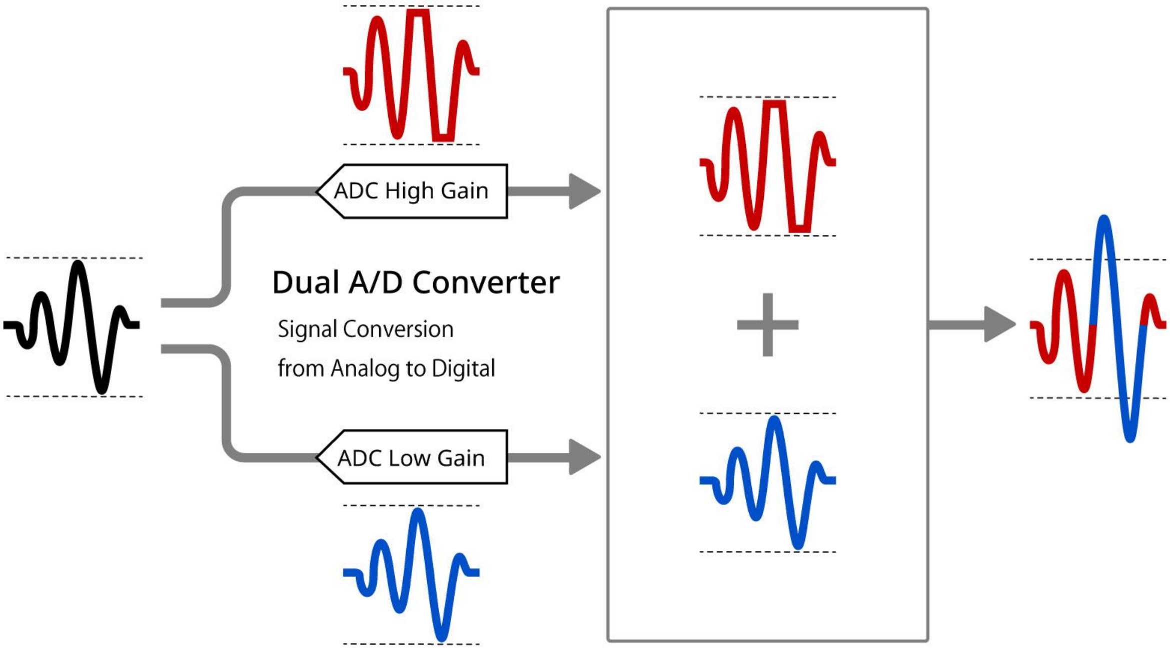
interest here was to investigate the ADC switching algorithm and its impacts through experiments.



Two ADCs used in devices that support 32-bit float format

Multi-Instrument is one of the first test and measurement software applications that support 32-bit float format. **The software interprets a dimensionless sample value of 1 as representing 0 dBFS under this mode.** It can be calibrated to the actual voltage it represents via [Setting]>[Calibration]> “Other/ASIO”> “Range”. **Keep in mind that 0 dBFS under this mode is not necessarily the maximum level.** The maximum level at which the signal eventually clips was also measured here. “Range” was set to 1Vp by default without calibration during testing, unless stated otherwise. In this way, the raw sample values were revealed directly. For example, an instant voltage value of 1V meant a raw value of 1 in the 32-bit float format.

The following tests were carried out with ZOOM UAC-232 ASIO driver V1.1.0 released on May 30, 2023 and ZOOM UAC-232 Mix Control V1.0.0.13 released on Feb. 9, 2023. ZOOM UAC-232 Mix Control is an application designed to control the internal mixer settings of the UAC-232. Of particular interest here is its default digital gain setting for different input sources, as shown below. These default settings can be changed and persisted in the hardware device through ZOOM UAC-232 Mix Control. The aforementioned “Range” calibration will be invalid if the digital gain setting changes. Under the 32-bit float mode, the recording quality will not be degraded by digital gain settings. For this reason, the following tests were carried out with the digital gain setting at 0 dB.

Input Source	Digital Gain (factory defaults)
Dynamic Mic (phantom power off)	+45 dB
Condenser Mic (phantom power on)	+27 dB
Line Input (Guitar/Bass off)	+24 dB
HiZ Input (Guitar/Bass on)	+18 dB

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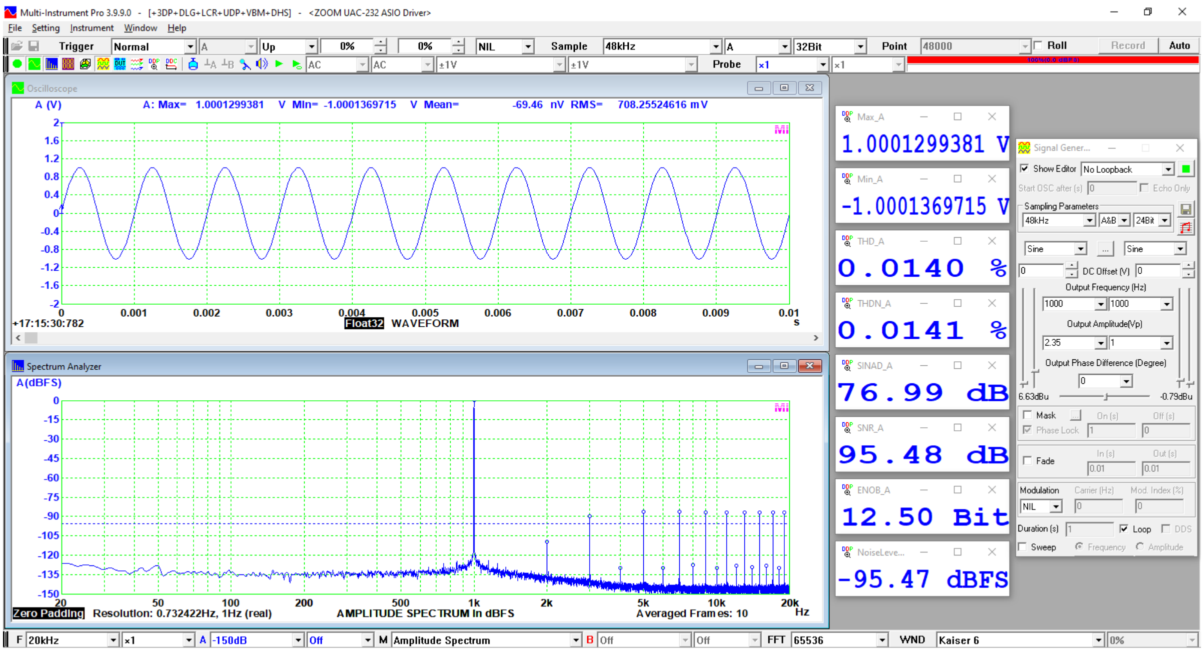
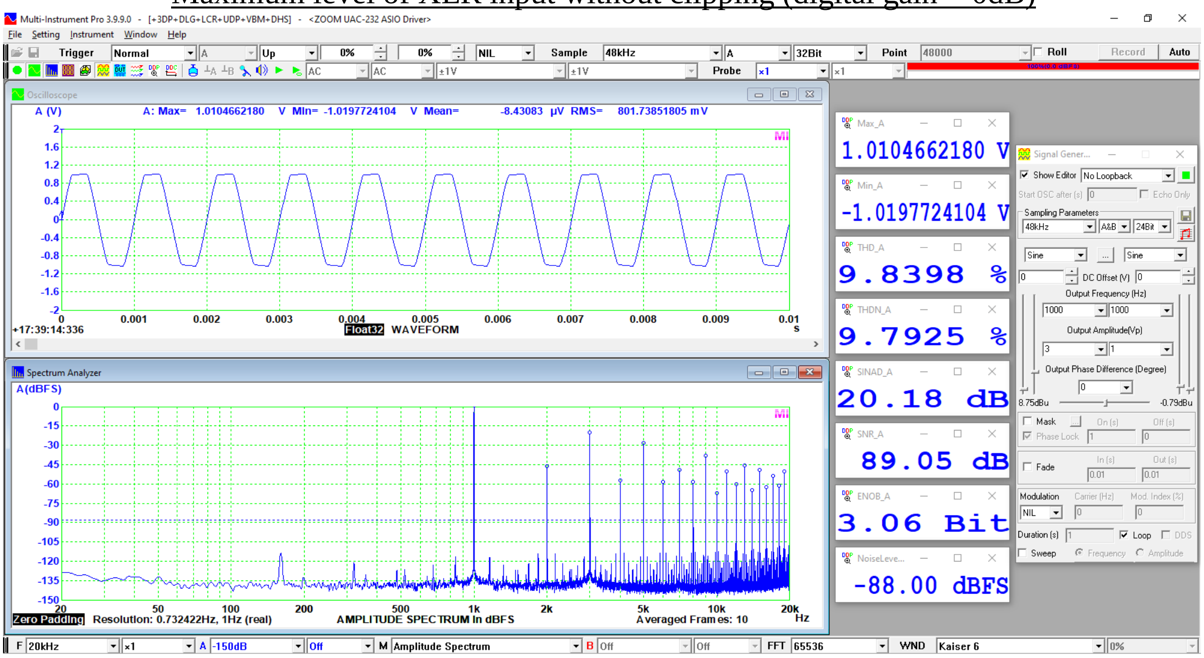
2. XLR Input

2.1 Maximum Level

The maximum level was measured by injecting a balanced 1kHz sinewave into the XLR input. No discernible difference in maximum level was found with 48V phantom power on and off. The measured maximum level happened to be about 1Vp (uncalibrated) or 0 dBFS, which corresponds to a calibrated value of 2.35Vp (6.63 dBu). This slightly exceeds the ZOOM specified maximum level of 2.19Vp (6 dBu). The second picture below confirms that the waveform clips at 1Vp (uncalibrated) or 0 dBFS.



Maximum level of XLR input without clipping (digital gain = 0dB)



Maximum level of XLR input with clipping (digital gain = 0dB)

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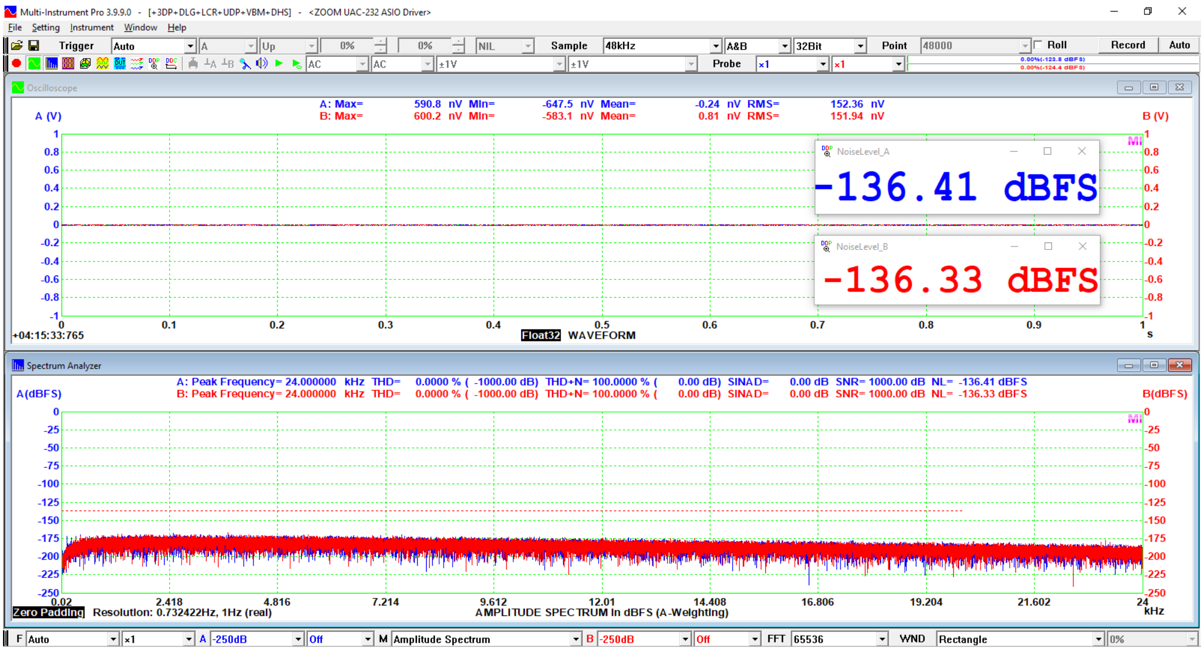
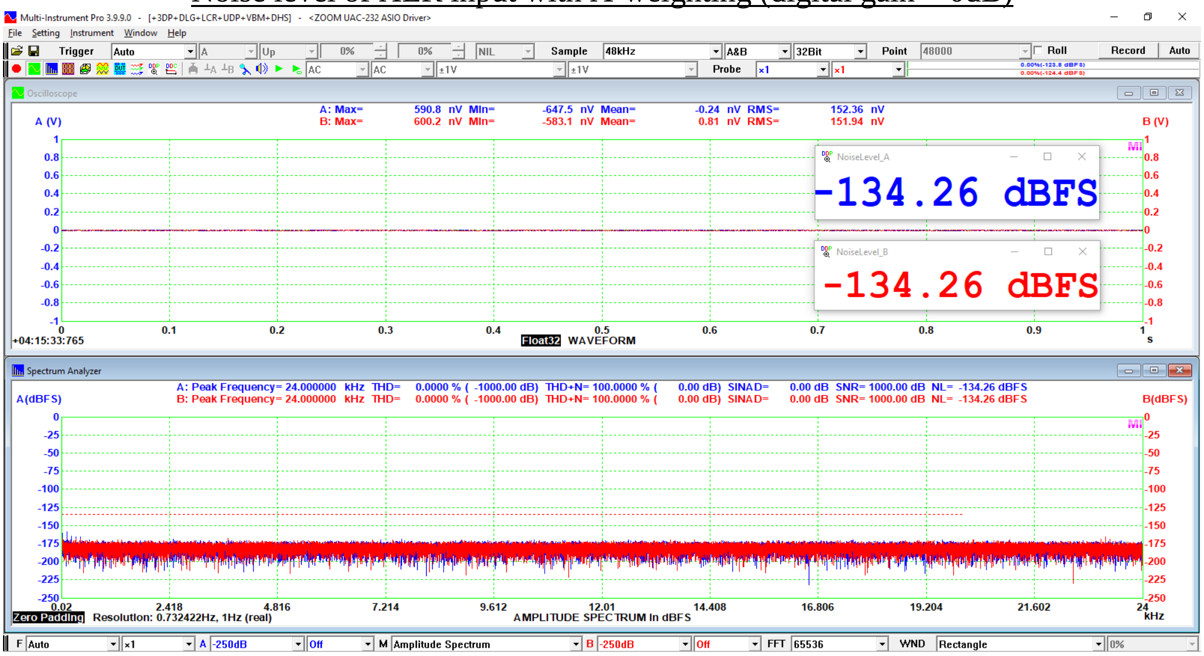
2.2 Noise Level

The noise level was measured with the XLR input "+" and "-" shorted to ground, otherwise, the measured noise level would have been increased by about 12 dB. This is because the noise level of the ZOOM UAC-232 is extremely low and any external interference could affect the results. In the software, the fundamental frequency for THD measurement was manually set to 24 kHz to ensure continuous calculation of noise levels from 20Hz to 20kHz, without the fundamental and any distortion components in between. The following two screenshots show the noise level measurement at 0dB digital gain with and without A-weighting. The noise level measured was about -136.4 dBFS with A-weighting or -134.3 dBFS without it. No discernible difference in noise level was found with 48V phantom power on and off.



Noise level of XLR input with A-weighting (digital gain = 0dB)



Noise level of XLR input with no frequency weighting (digital gain = 0dB)

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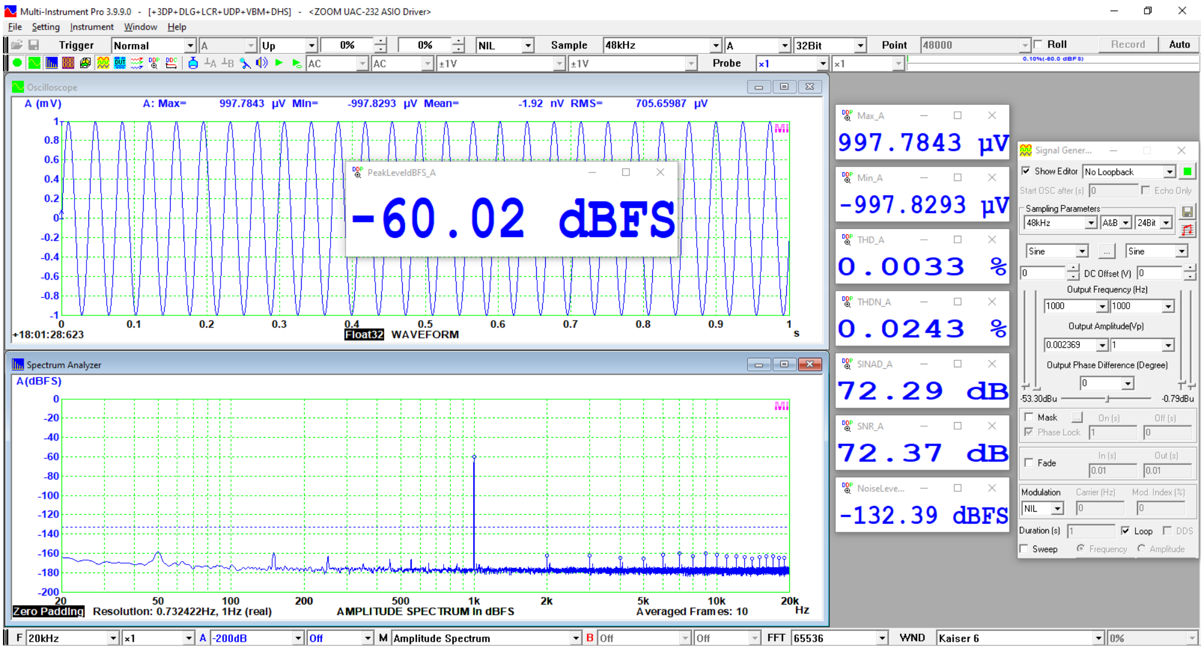
The equivalent input noise level can be calculated as: $2.35 \times 0.7071 \times 10^{-134.3/20} = 3.2 \times 10^{-7}$ (Vrms) or -127.7 dBu, which agrees well with the ZOOM specified value of -127dBu.

2.3 Dynamic Range

Dynamic range is equal to the difference of the previously measured maximum level (0 dBFS) and noise level (-134.3dBFS, or -136.4dBFS with A weighting), that is, 134.3dB or 136.4dBA.

By convention, the dynamic range is measured by measuring SNR at the signal level of -60dBFS. Then it can be calculated as SNR+60 (dB). The following picture shows the results of such a measurement. The measured SNR is 72.4 dB and thus the dynamic range is calculated to be 132.4dB. However, the signal generator used in this testing has a slightly higher noise level than the equivalent XLR input noise level of ZOOM UAC-232. Hence the previously measured dynamic range of 134.3dB is more accurate.



SNR of XLR input measured at -60dBFS (digital gain = 0 dB)

2.4 THD, THD+N, SNR, SINAD, ENOB, Noise Level

The THD, THD+N, SNR, SNAD and Noise level at the signal level -1dBFS were measured to be 0.0026%, 0.0032%, 90.03dB, 94.85dB and -95.84 dBFS, respectively. The noise level here is much higher than those measured previously, indicating that it was from the low-gain ADC rather than the high-gain one due to the high signal level here.

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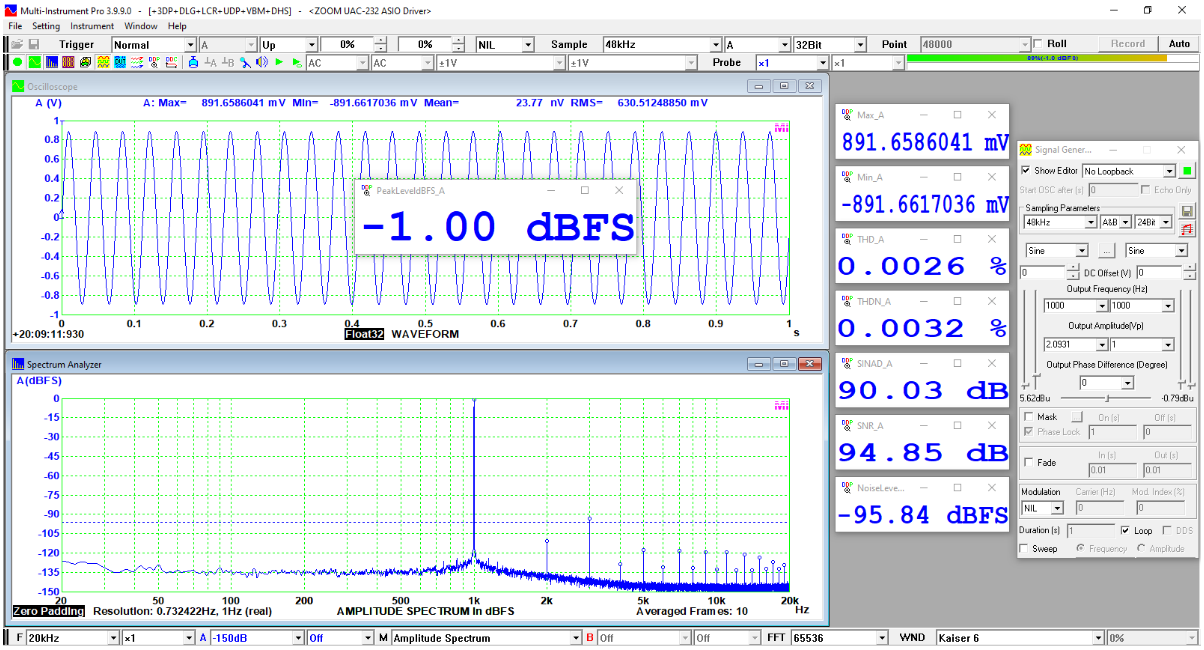
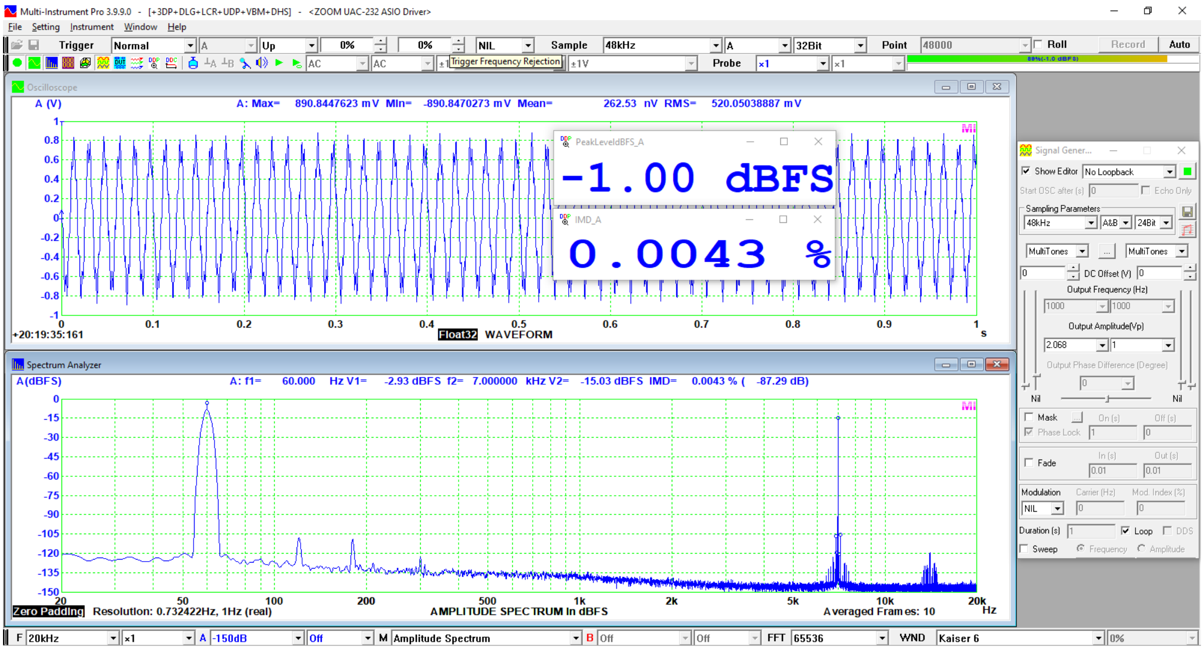


THD, THD+N, SINAD, SNR and Noise Level of XLR input measured at -1 dBFS (digital gain = 0 dB)

2.5 IMD



SMPTE IMD of XLR input measured at -1 dBFS (digital gain = 0 dB)

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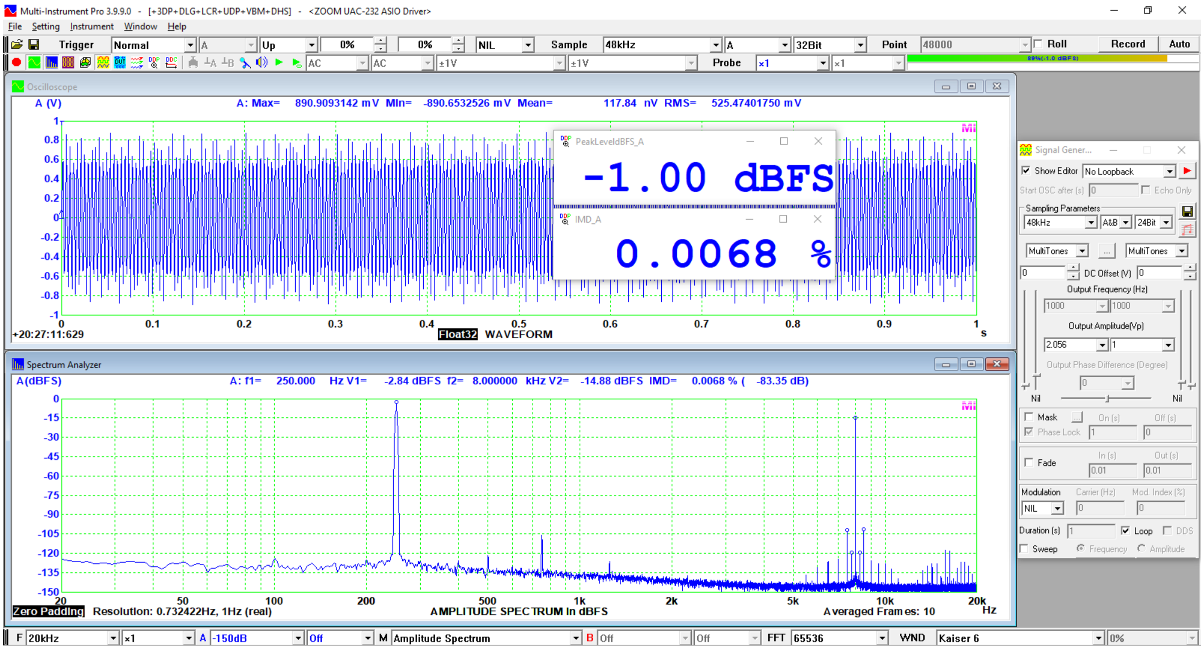
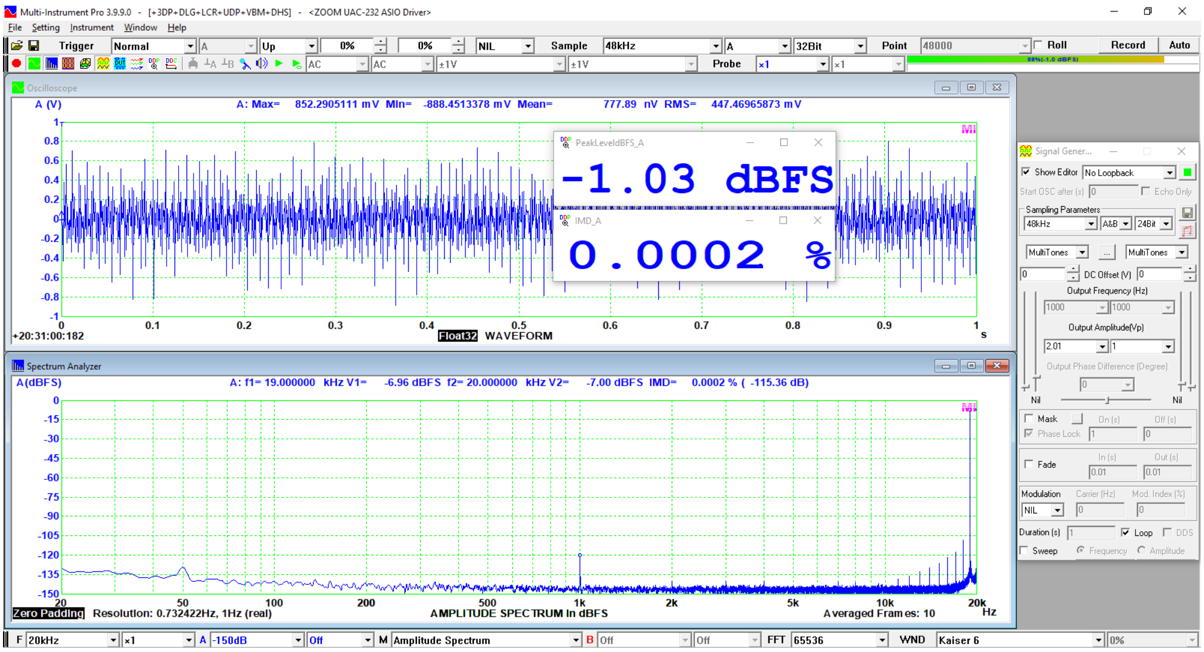


DIN IMD of XLR input measured at -1 dBFS (digital gain = 0 dB)



CCIF2 IMD of XLR input measured at -1 dBFS (digital gain = 0 dB)

2.6 Bandwidth

The bandwidth of ZOOM UAC-232 was measured using a 20-second logarithmic frequency sweep together with 1/96 octave analysis.

-3dB bandwidth @48kHz: 9.5Hz ~ 23.8kHz; 20Hz~20kHz, ±0.21dB which matches with ZOOM specified +0.1 ~ -0.2dB.

-3dB bandwidth @96kHz: 9.5Hz ~ 47.6kHz; 20Hz~40kHz, ±0.22dB.

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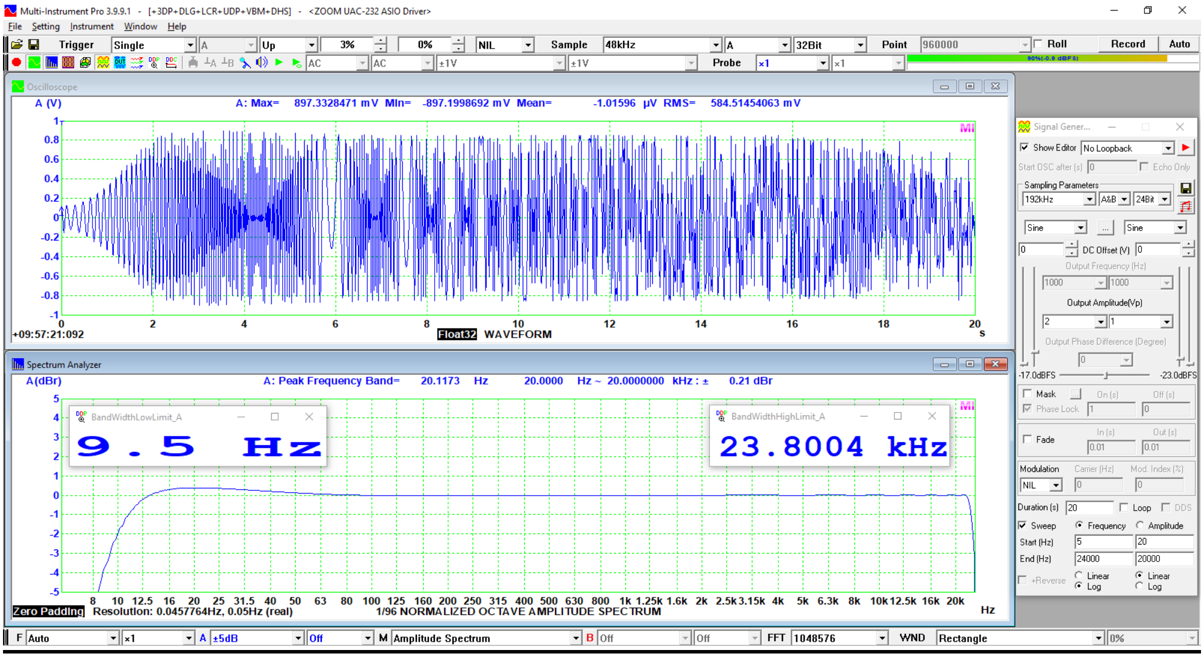
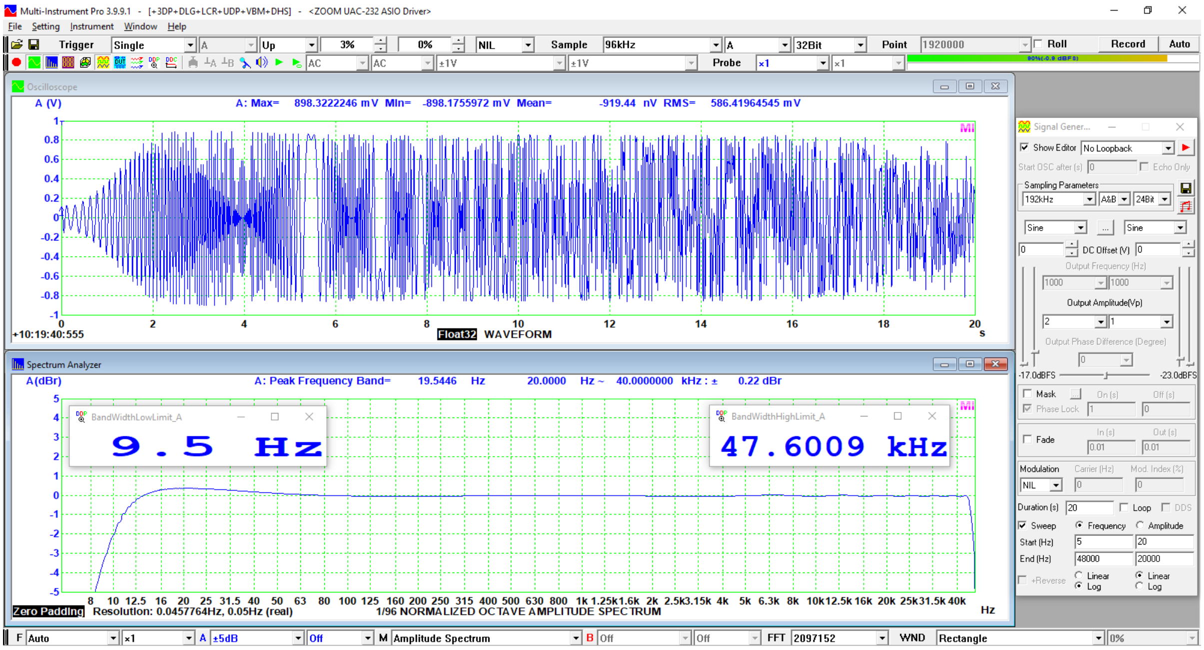
-3dB bandwidth @192kHz: 9.6Hz ~ 91.8kHz; 20Hz~80kHz, ±0.21dB which matches with ZOOM specified +0.1 ~ -0.2dB.



Bandwidth of XLR input measured at sampling rate 48kHz (digital gain = 0 dB)



Bandwidth of XLR input measured at sampling rate 96kHz (digital gain = 0 dB)

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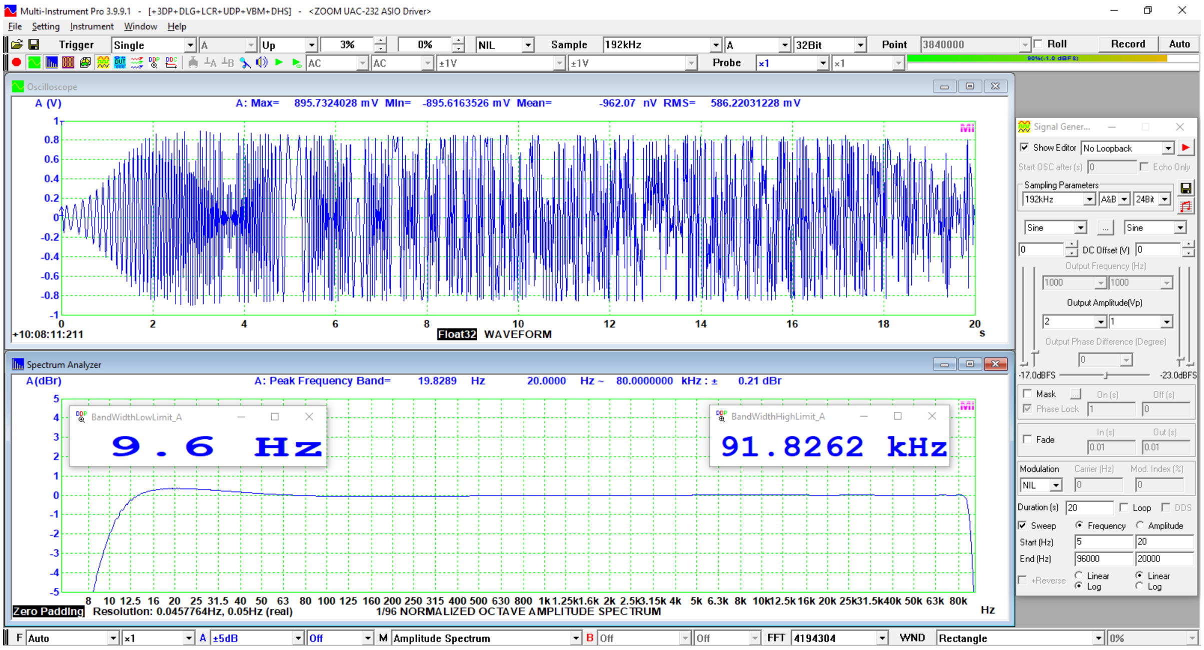
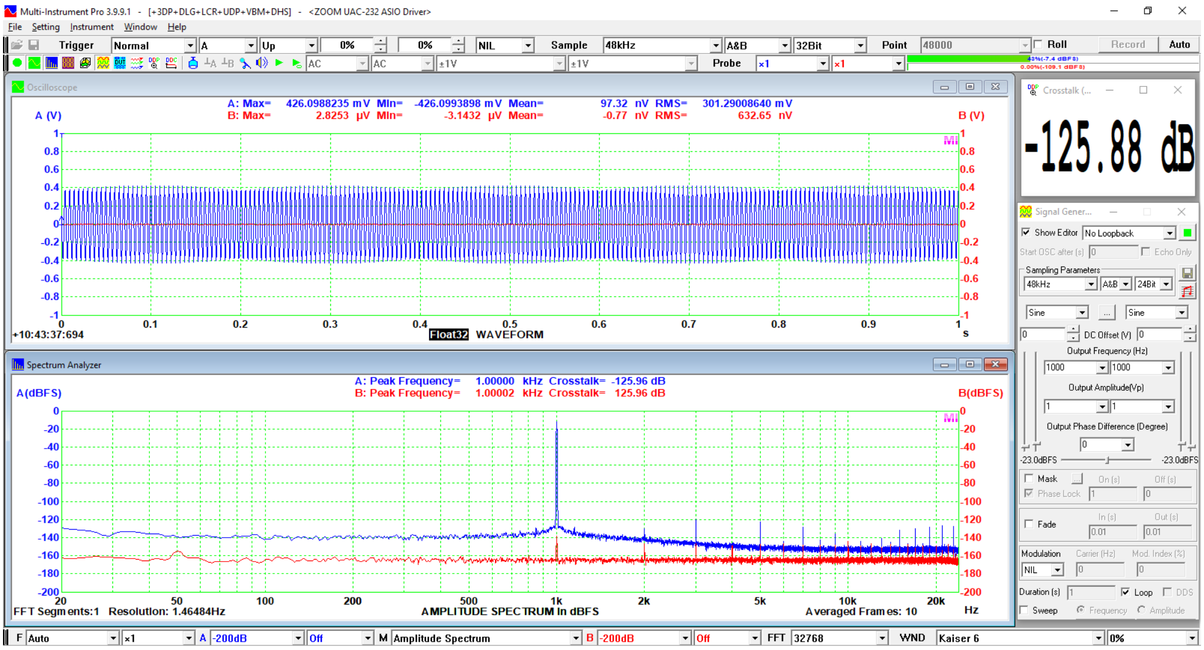


Bandwidth of XLR input measured at sampling rate 192kHz (digital gain = 0 dB)

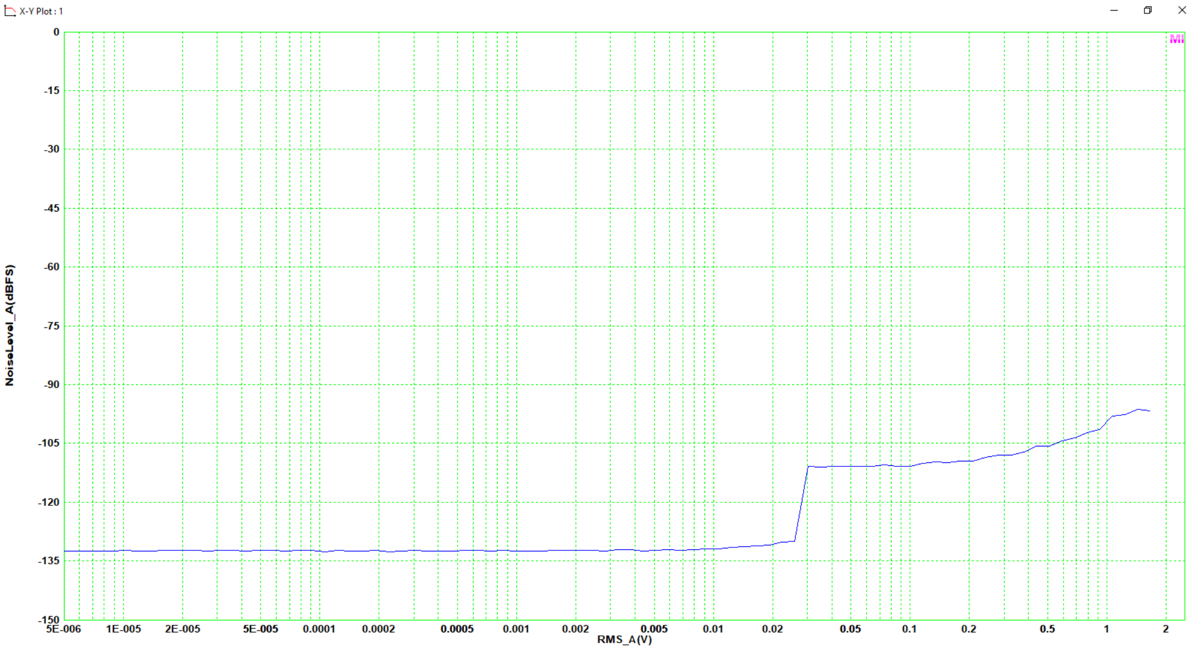
2.7 Crosstalk



Crosstalk of XLR input measured at 1kHz (digital gain = 0 dB)

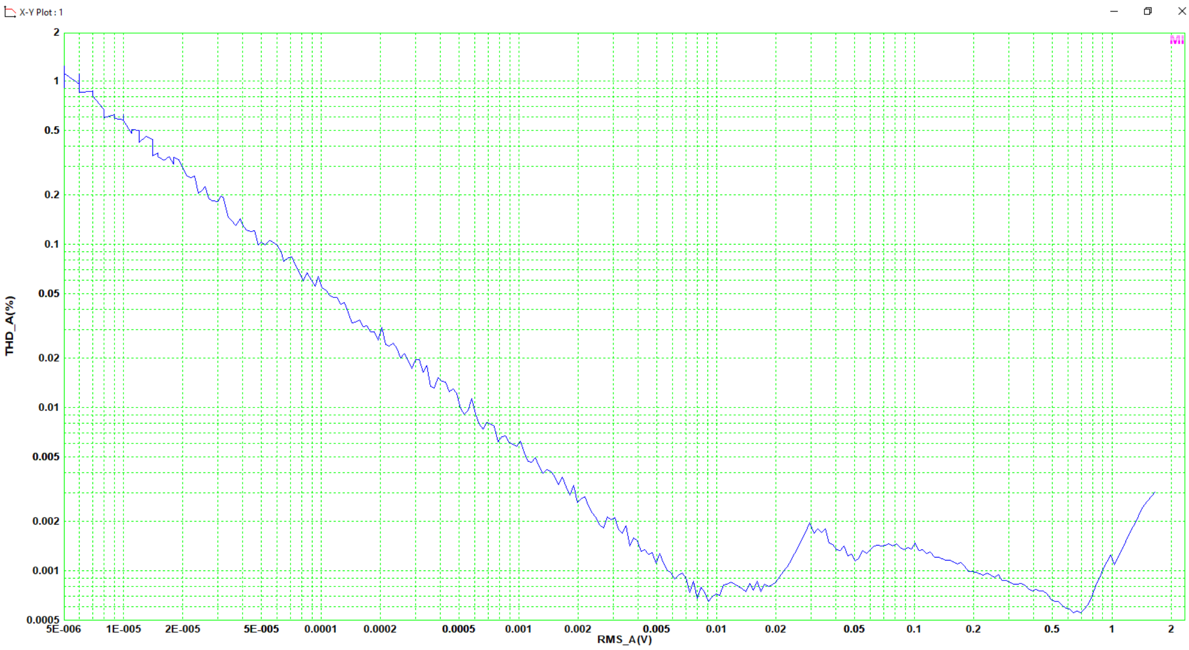
2.8 THD, THD+N, Noise Level vs Calibrated Input RMS Amplitude

This test was performed using the Device Test Plan of Multi-Instrument. The test signal was a 1kHz sinewave. Its amplitude was stepped up from 5μVrms to 1.66Vrms (2.35Vp, i.e. 0 dBFS as calibrated previously) in 300 increments. The signal generator of the Audio Analyzer RTX6001 was employed to do the job. It has three output voltage ranges: 0.1Vrms, 1Vrms, and 10Vrms. The software was configured to automatically switch to a higher range if the output level reached 0 dBFS. The following are the results.



Noise Level vs Calibrated Input RMS Amplitude of XLR input (digital gain = 0 dB)

Again, at low signal level, the noise level measured here is slightly higher than the previously measured 134.3dBFS due to the relatively high noise level of the signal generator. Despite this, the figure above illustrates an abrupt increase in noise levels at the signal level of approximately 0.03 Vrms (equivalent to -34.9 dBFS). As this change occurs within the lowest output range of the signal generator, with no DAC range switching involved, it clearly indicates the transition from the high-gain ADC to the low-gain one.



THD vs Calibrated Input RMS Amplitude of XLR input (digital gain = 0 dB)

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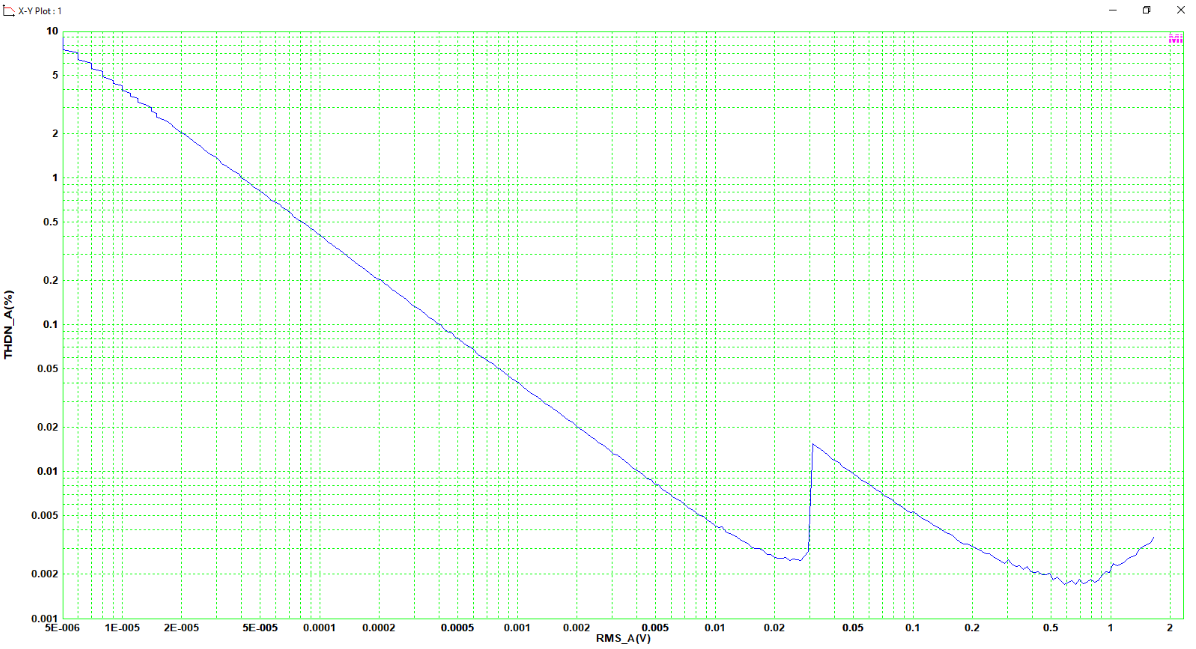
The figure above indicates that the THD of the high-gain ADC decreases as the amplitude increases until the amplitude reaches approximately 0.01 Vrms. Afterward, it begins to rise until the amplitude reaches about 0.03 Vrms, where the low-gain ADC takes over. Subsequently, the THD of the low-gain ADC decreases again with the amplitude until the amplitude reaches a turning point at approximately 0.7 Vrms where it rises again. The lowest THD that both ADCs can attain is about 0.0006%.



THD+N vs Calibrated Input RMS Amplitude of XLR input (digital gain = 0 dB)

The figure above reflects the combined effects of the previous two charts. The switching between the two ADCs at the signal level of about 0.03Vrms looks more prominent.

2.9 Input-Output Linearity Graphs

This test was performed using the Device Test Plan of Multi-Instrument. The test signal was a 1kHz sinewave and its amplitude was stepped from a specified low limit to a specified high limit in 300 increments. The horizontal axis represents the specified output RMS value from the signal generator, while the vertical axis represents the measured RMS value of the peak frequency detected. Both are calibrated values. Using the RMS value of the peak frequency obtained from the frequency domain, instead of the total RMS value acquired from the time domain, effectively excluded the contribution of noises. This is particularly crucial when the signal level is very low. The figure below shows the input-output linearity graph of the XLR input of ZOOM UAC-232 from 3.535 μVrms to 1.661 Vrms. It looks like a perfect straight line in log-log scale.

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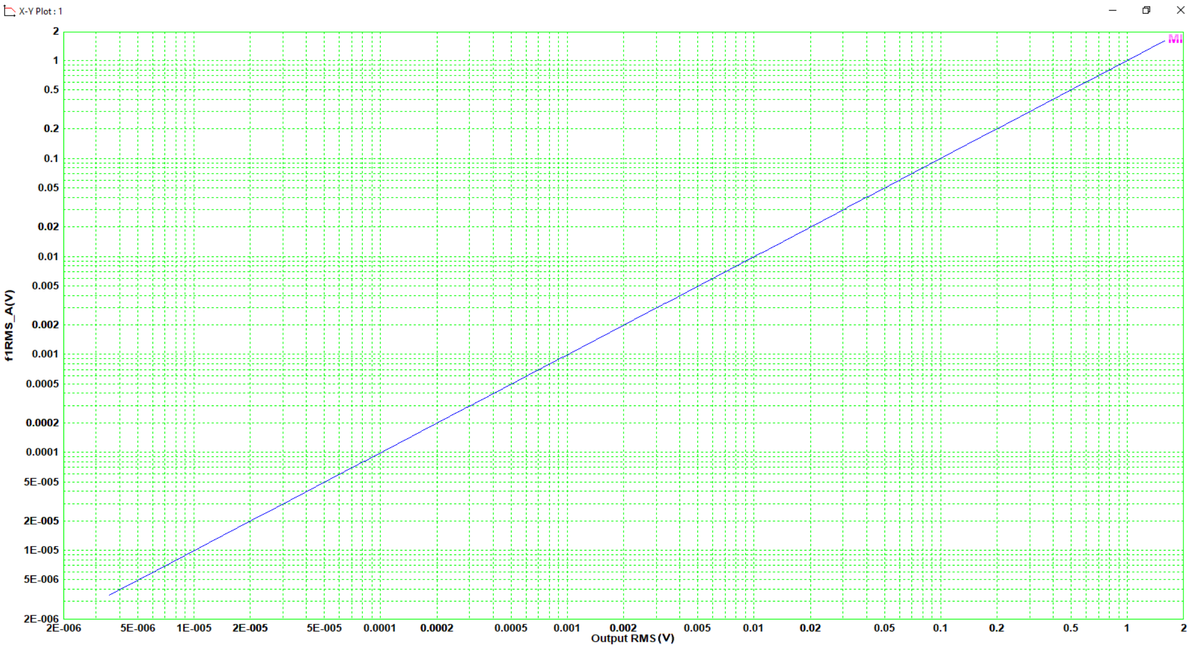
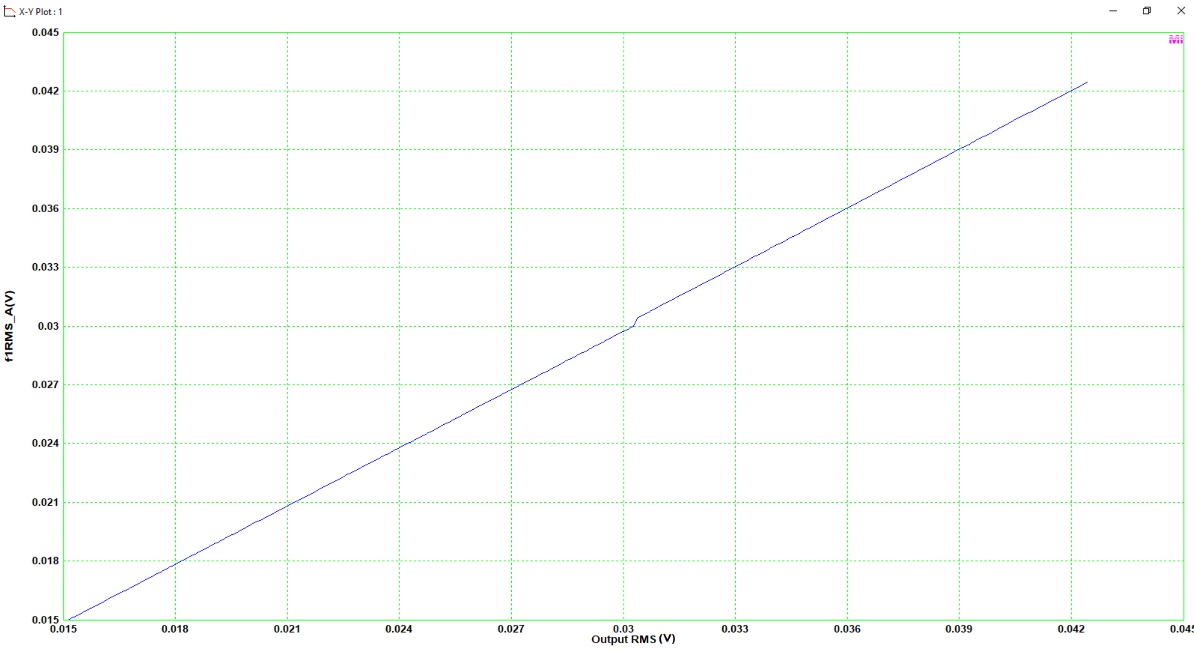


Overall Input-Output Linearity Graph of XLR input (digital gain = 0dB)

In order to check if there is any discernible effect during the ADC switching on this type of graph, the same test was performed again but with the amplitude stepped from 0.0141Vrms to 0.0424 Vrms in 300 increments. The results are shown below. It can be seen that there is a small jump at about 0.03Vrms. This is where the ADC switching occurs, as captured previously.



Input-Output Linearity Graph of XLR input zoomed in on ADC switching (digital gain = 0dB)

To further investigate the tiny "nonlinearity" introduced by the ADC switching, this test was repeated for the third time. This time, the amplitude was stepped from 0.028Vrms to 0.032Vrms in 300 increments. The results are shown as follows. It can be seen that the height of the jump is about 0.0003V.

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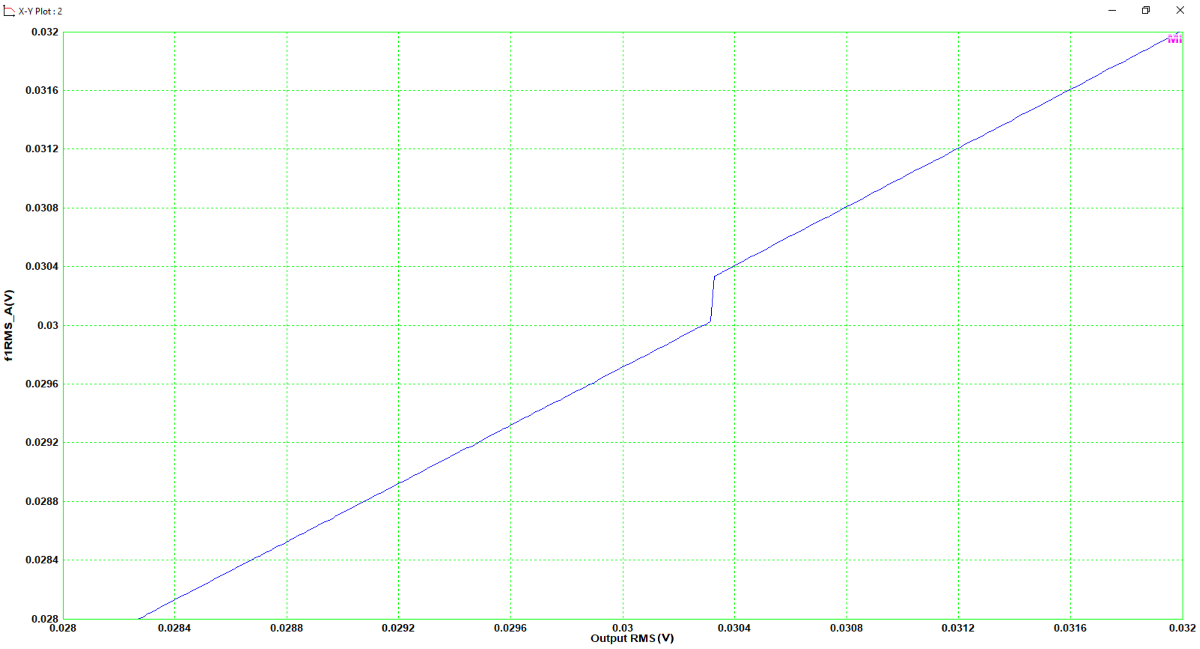
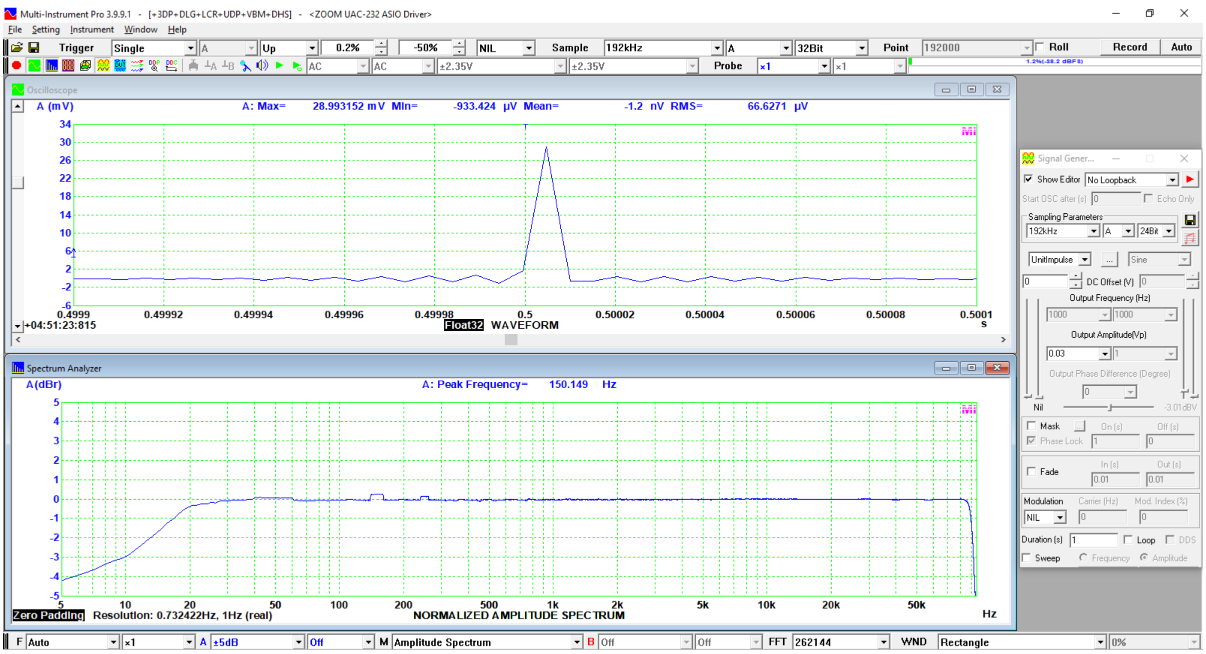


Input-Output Linearity Graph of XLR input with focus on ADC switching (digital gain = 0dB)

2.10 Experimental Investigation of ADC Switching Algorithm

2.10.1 Impulse response with and without the involvement of the low-gain ADC

Two impulse responses (see picture below) were measured. The first one had an amplitude of 0.03Vp (0.021Vrms) and thus it should only involve the high-gain ADC. The second one had an amplitude of a 0.18Vp (0.127Vrms) which should be enough to trigger the switching from the high-gain ADC to the low-gain one.



Impulse response with only the high-gain ADC involved (digital gain = 0dB)

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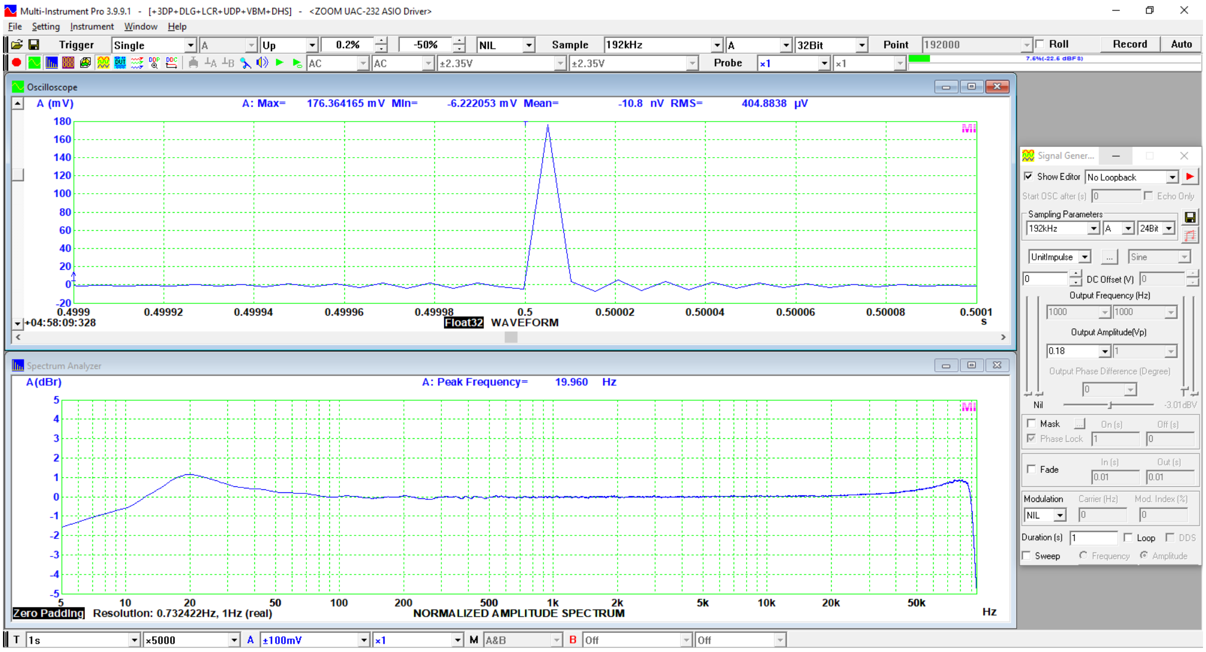
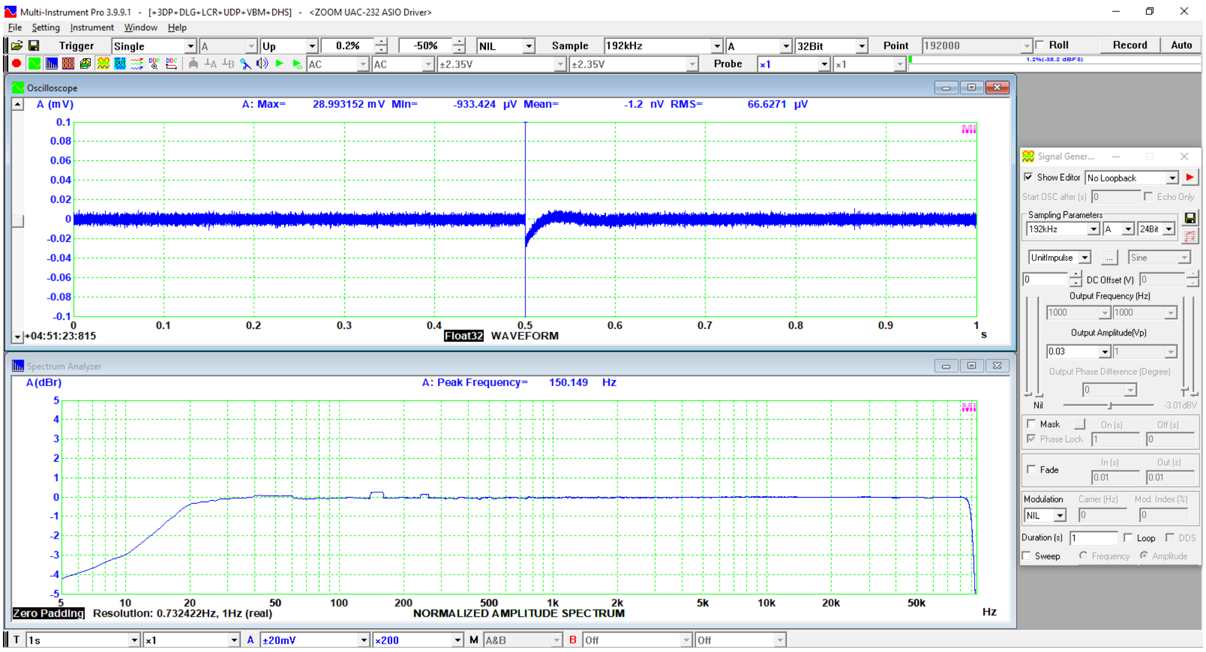


Impulse response with the low-gain ADC involved (digital gain = 0dB)

It was not expected to see any noticeable ADC switching effect on the impulse waveform because the impulse is too short, and the change from sample to sample is so steep that it could hide any gain and offset discrepancies in the two ADCs. There are some minor differences in the frequency responses measured with this impulse response method, though.

The two screenshots above were zoomed in vertically to check for any variation in the noise level before and after the impulse (see pictures below). As expected, the noise level does not change in the first case. However, in the second case, the change of the noise level clearly indicates the switching between the two ADCs: from the high-gain ADC before the impulse to the low-gain ADC (within and) after the impulse, and after about 60ms, back to the high-gain ADC again due to the very low signal level.



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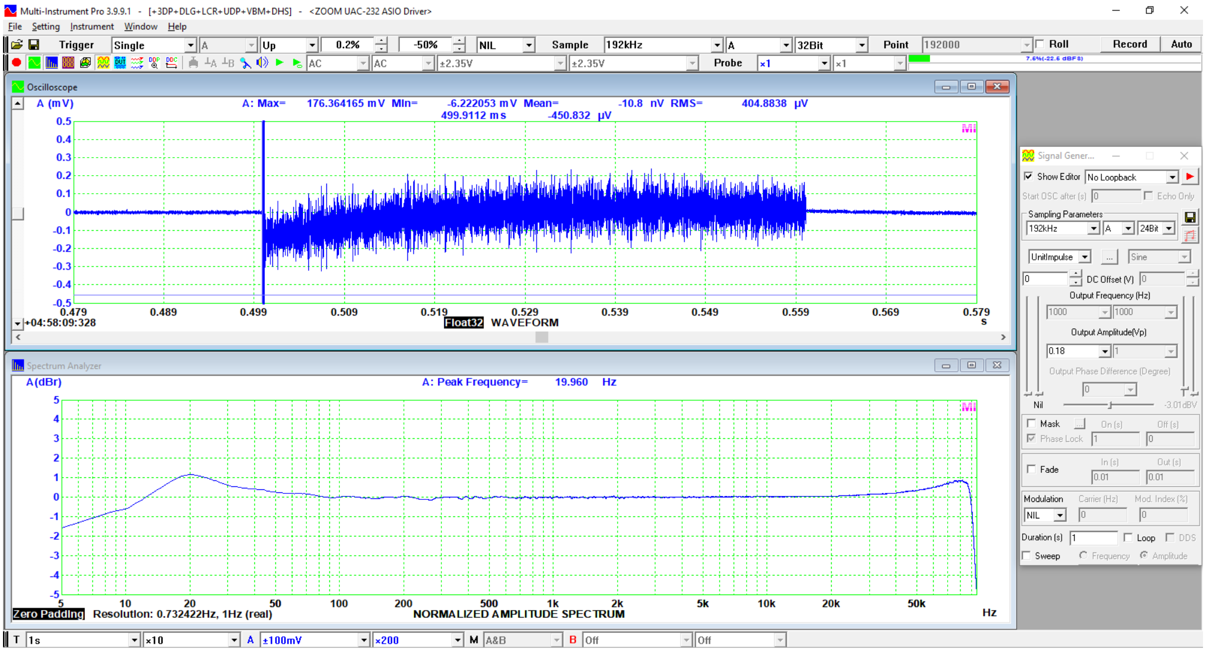
Impulse response with only the high-gain ADC involved (digital gain = 0dB)



Impulse response with the low-gain ADC involved (digital gain = 0dB)

2.10.2 Amplitude sweep across the ADC switching point

In order to see if there is a step change in the waveform during the ADC switching, a continuous linear amplitude sweep was performed, from 0.03Vp to 0.05Vp in 0.5s, then from 0.05Vp to 0.03Vp in the subsequent 0.5s, and the same process was repeated. The results are shown below. The red line represents the amplitude envelope of the waveform, which was obtained by amplitude demodulation of the original waveform through Hilbert Transform. A bolder red line is indicative of higher noise level in the original waveform. The upper and lower thresholds for ADC switching was measured to be 44.2mV and 31.8mV respectively. These two thresholds were found to remain constant within the carrier frequency range of 300Hz ~ 20kHz. For carrier frequencies below 300Hz, the upper threshold increases while the lower threshold decreases for unknown reasons.

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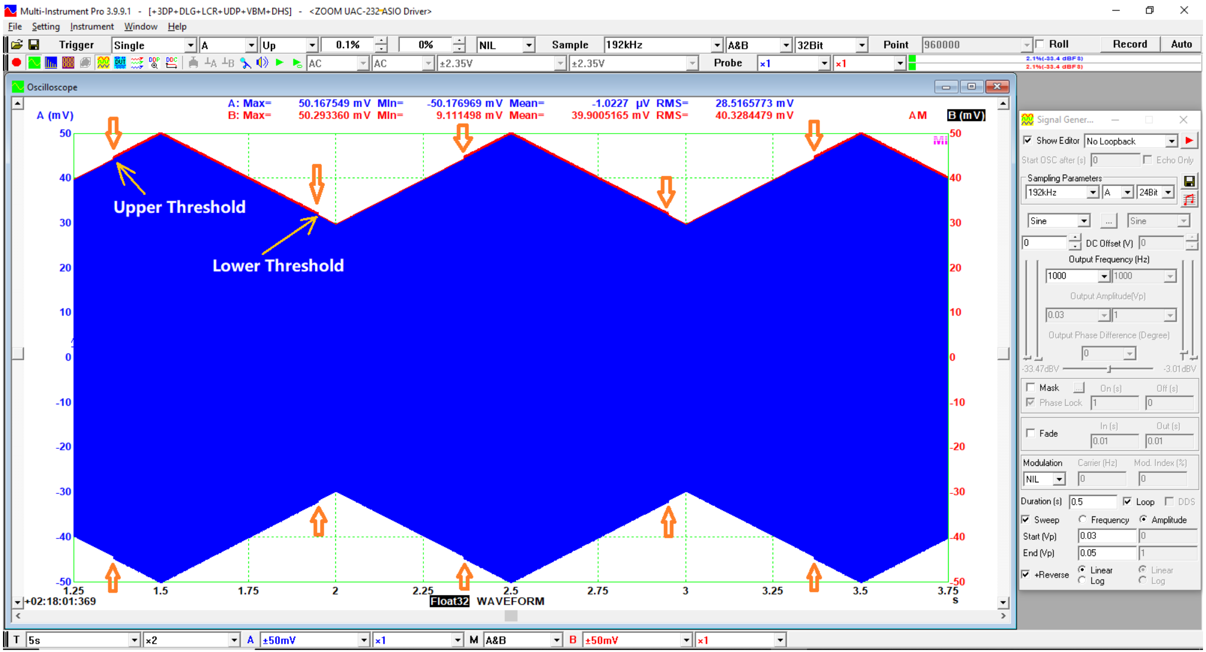
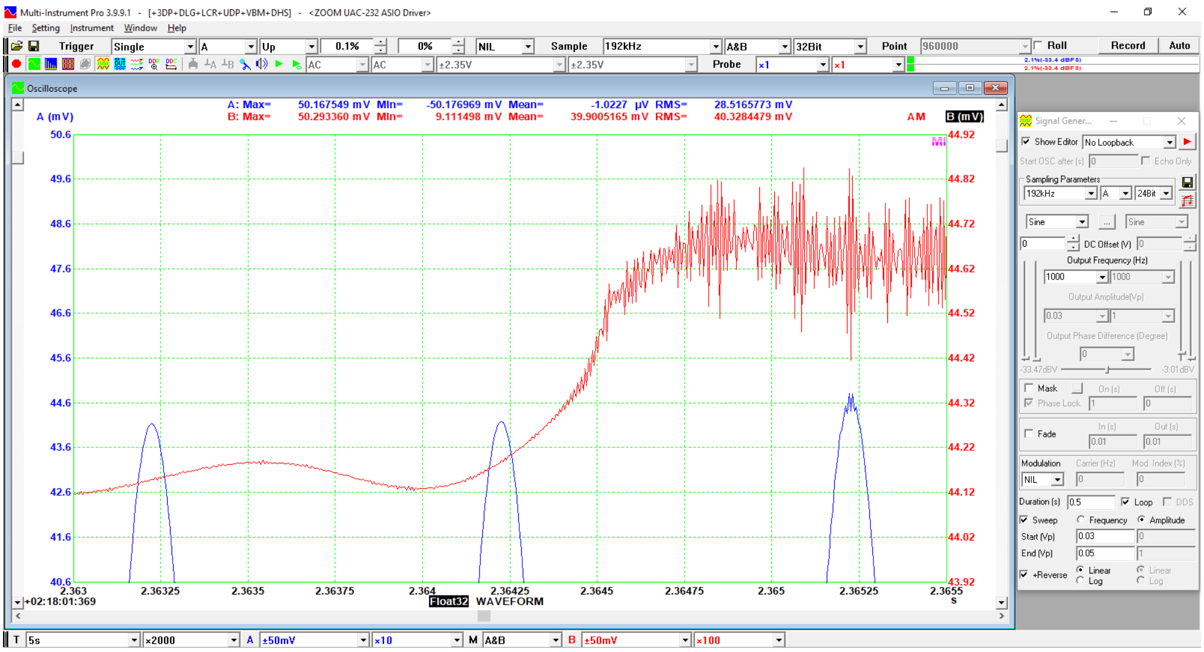


Linear amplitude sweep which triggers ADC switching (digital gain = 0dB)

No discernible step change could be found upon zooming in the screenshot above to inspect the waveform at the point of ADC switching. The waveform appeared smooth, as if there was no ADC switching. The picture below shows a close-up of the transitional area from the high-gain ADC to the low-gain one. The top (or bottom) of a sinewave is an ideal location to illustrate the noise level due to its flatness. The third peak of the sinewave exhibits a noticeably higher noise level than the previous two, further confirming the ADC switching location indicated by the red amplitude envelope. It can also be observed from the red amplitude envelope below that the noise level increases gradually rather than instantly, implying a stitching DSP algorithm in place during the transition, to fade in the new data stream from the low-gain ADC and fade out the old one from the high-gain ADC. The transition seems to be about 0.5ms in length.



Transition at the point of ADC switching (digital gain = 0 dB)

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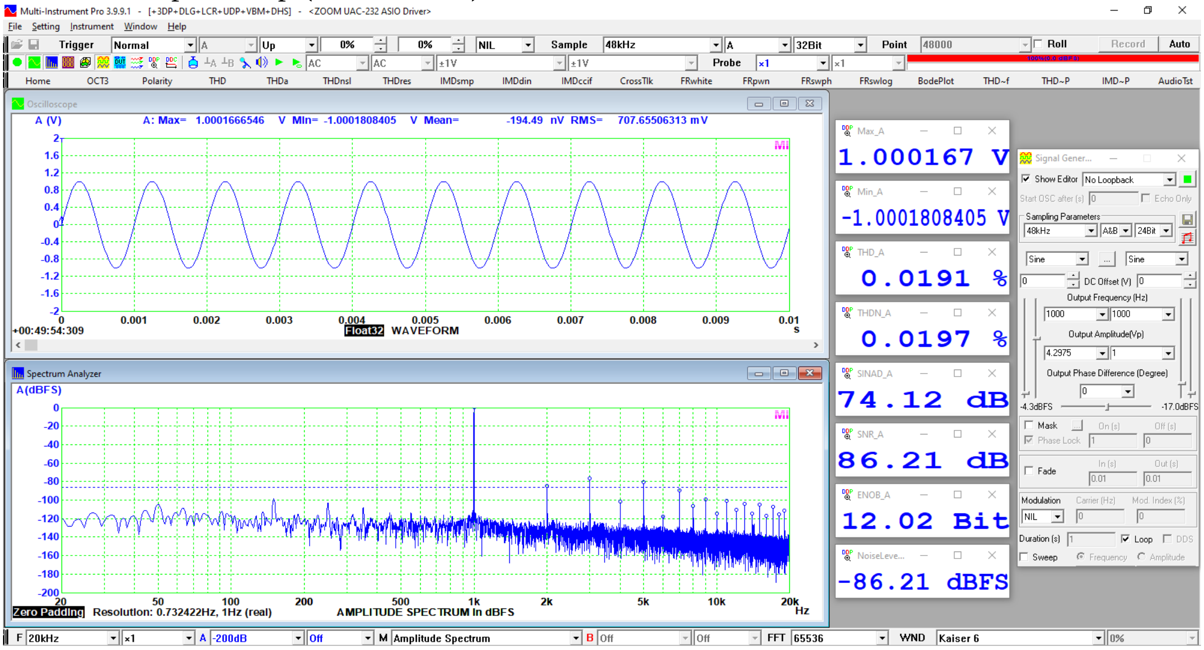
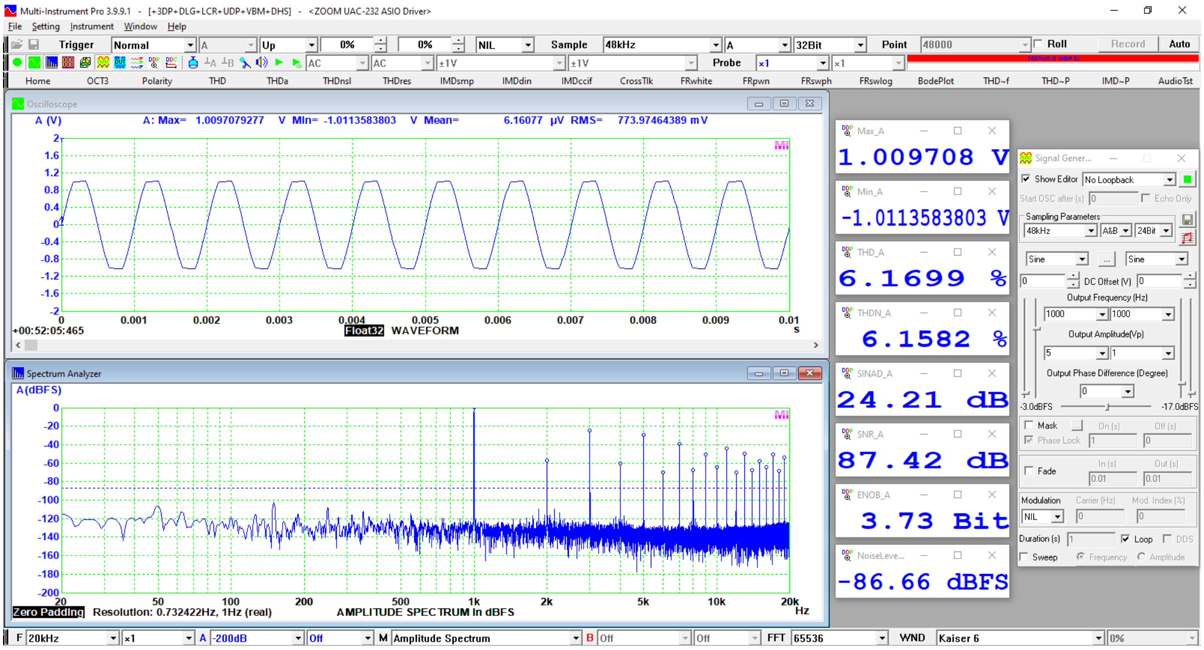
3. Line / HiZ Input

3.1 Maximum Level

The tests with the balanced line input and unbalanced HiZ input confirm that the maximum level always corresponds to a dimensionless sample value of 1 (0 dBFS) under the 32-bit float mode when the digital gain is at 0 dB. The corresponding calibrated maximum level is 23.0Vp (26.4 dBu) for the line input and 4.30Vp (11.9 dBu) for the HiZ Input. These values are slightly higher than the ZOOM specified maximum levels of 24dBu and 11.5dBu respectively. The first picture below shows that the uncalibrated 1Vp (0 dBFS) was reached when the input amplitude is 4.30Vp at HiZ. The second picture below confirms that the waveform clips at 1Vp (uncalibrated) or 0 dBFS.



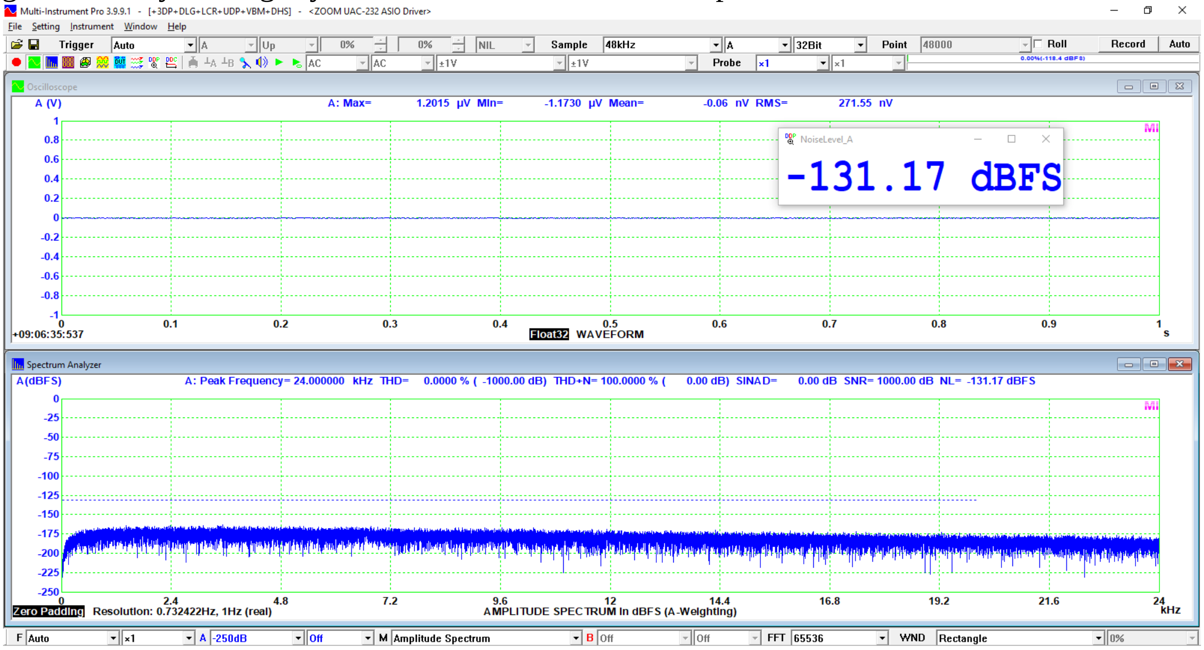
Maximum level of HiZ input without clipping (digital gain = 0dB)



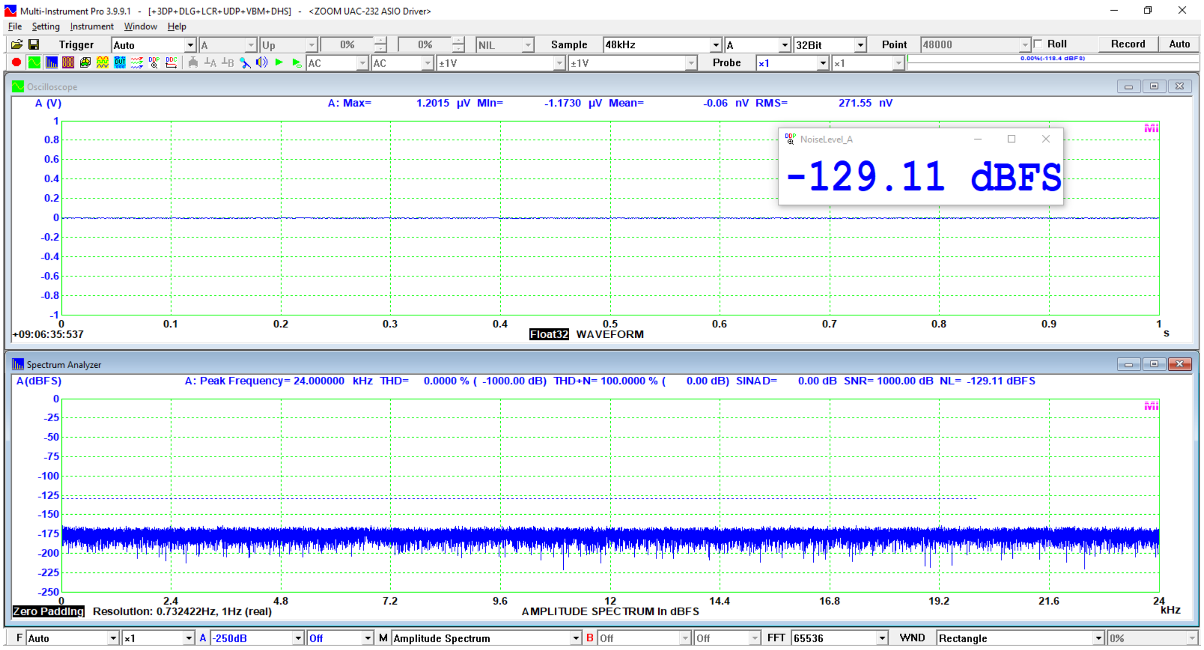
Maximum level of HiZ input with clipping (digital gain = 0dB)

3.2 Noise Level

The noise levels for the line input and HiZ input were measured with the inputs shorted to ground. They are slightly worse than that of the XLR input.



Noise level of line input with A-weighting (digital gain = 0dB)



Noise level of line input with no frequency weighting (digital gain = 0dB)

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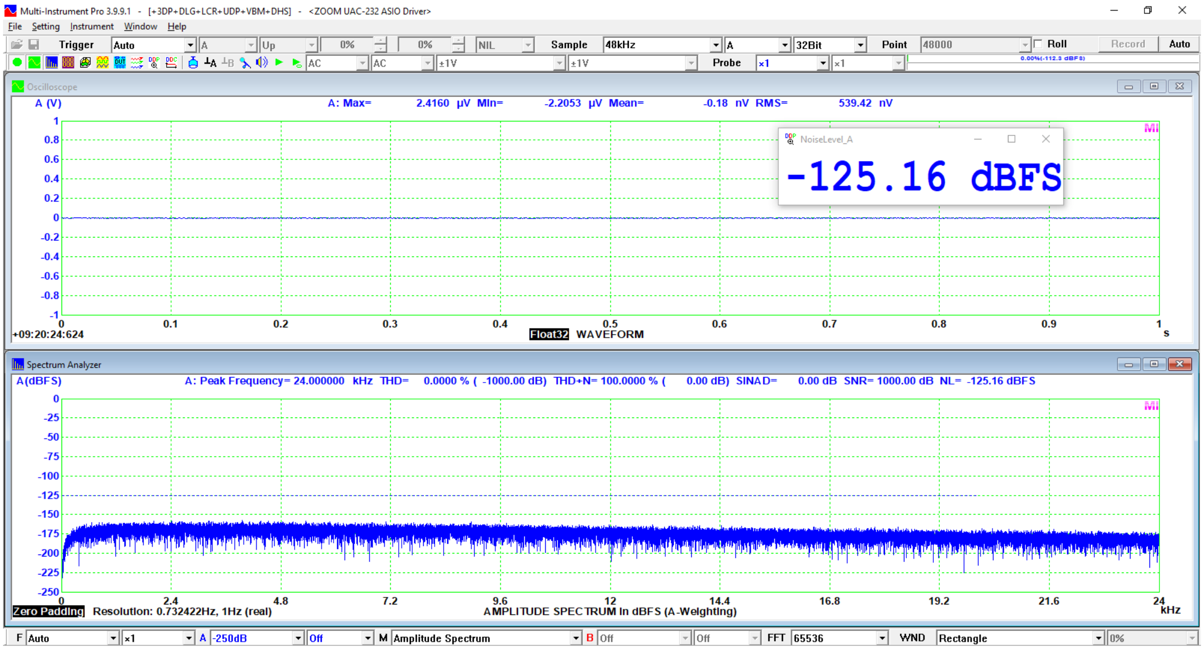
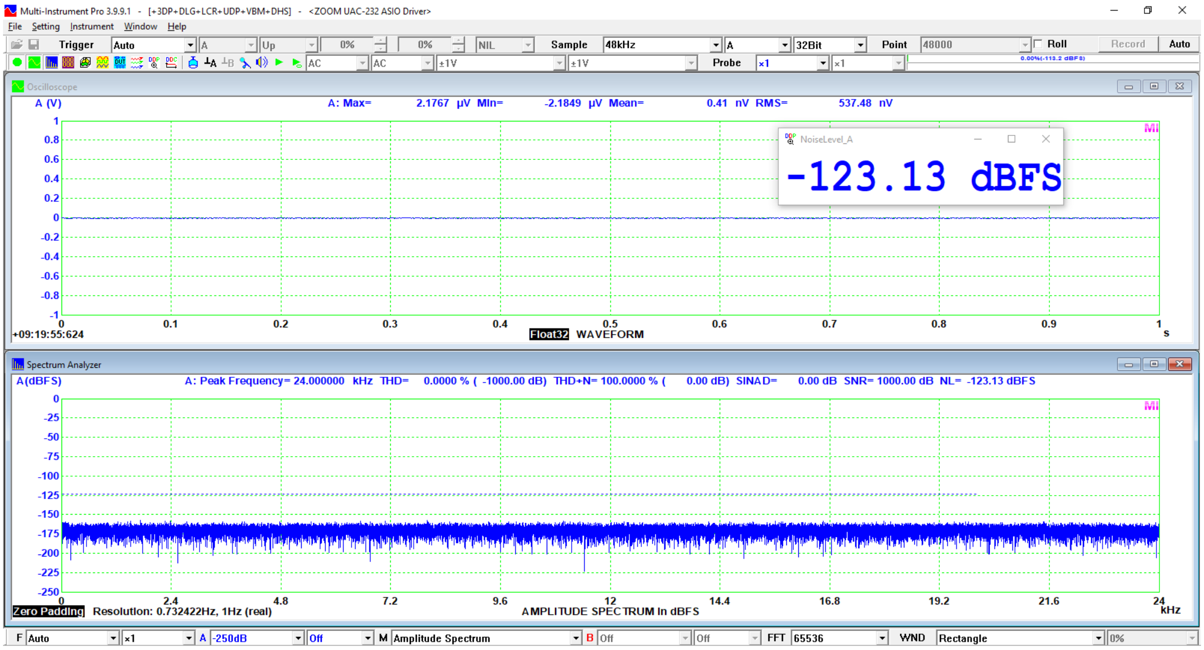


Noise level of HiZ input with A-weighting (digital gain = 0dB)



Noise level of HiZ input with no frequency weighting (digital gain = 0dB)

3.3 Dynamic Range

The differences of the maximum levels and noise levels measured previously yield the dynamic ranges, which are 129.1dB or 131.2dBA for the line input, and 123.1dB or 125.2dBA for the HiZ input.

The following two pictures show the SNR measured at the signal level of -60 dBFS for the line input and HiZ input respectively. The dynamic ranges for them can then be calculated as SNR+60 (dB), which is 128.9 dB for the line input and 122.9 dB for the HiZ input. These values are very close to the dynamic ranges measured using the previous method.

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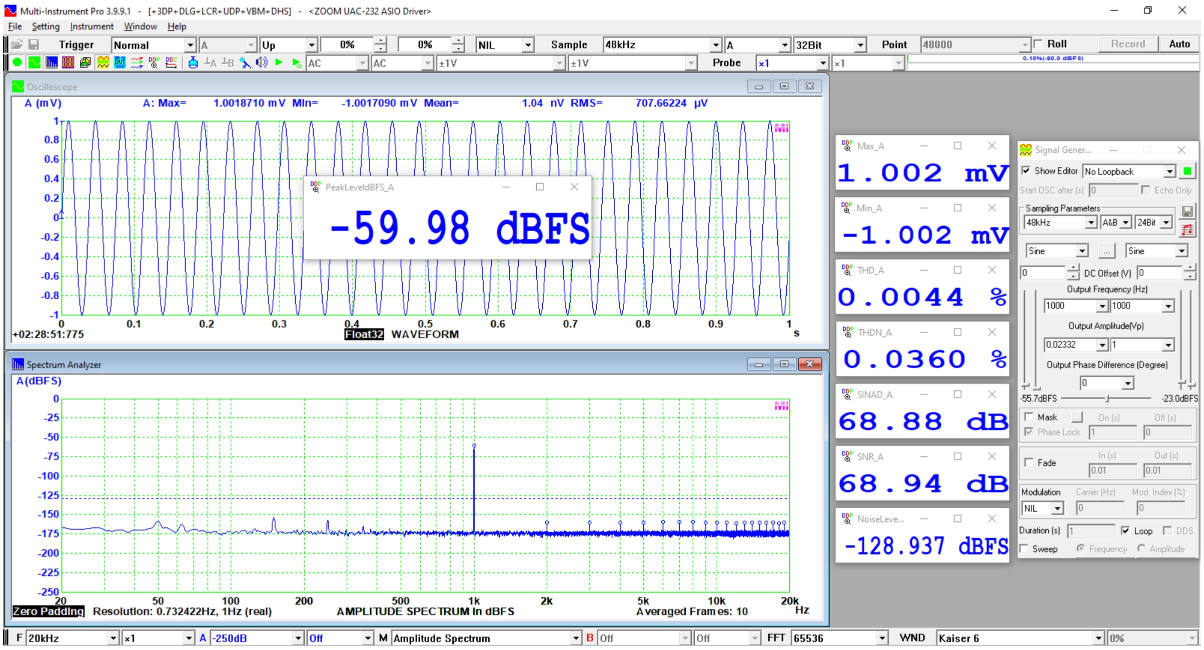
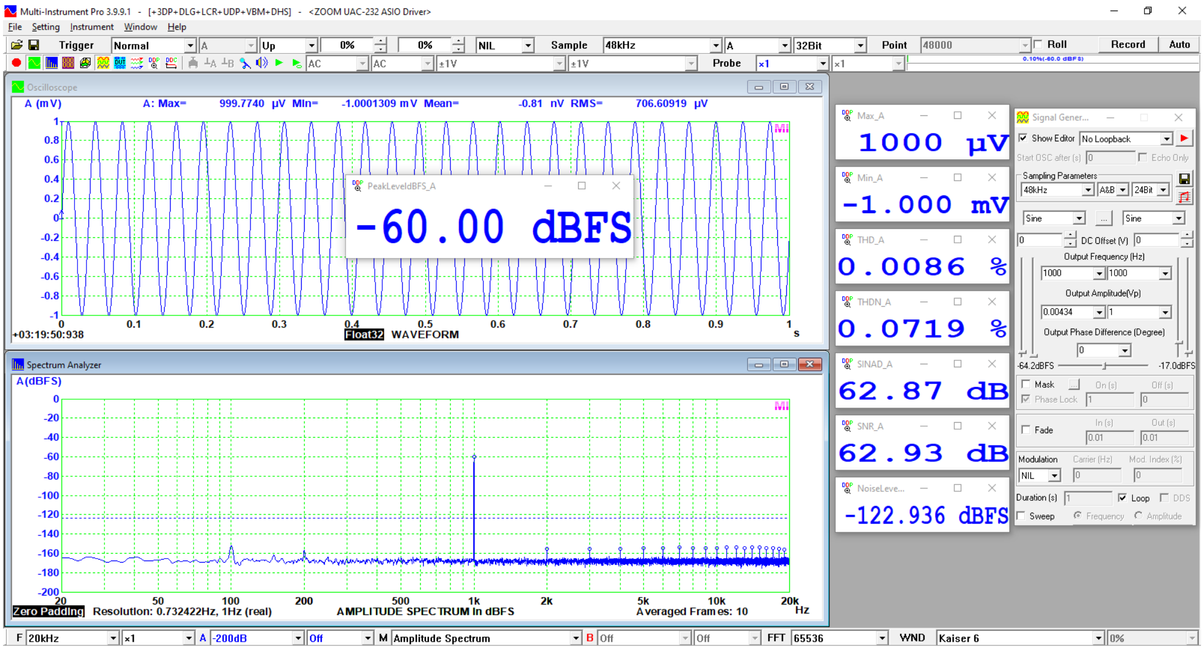


SNR of line input measured at -60dBFS (digital gain = 0 dB)



SNR of HiZ input measured at -60dBFS (digital gain = 0 dB)

3.4 Bandwidth

The bandwidth of ZOOM UAC-232 was measured using a 20-second logarithmic frequency sweep together with 1/96 octave analysis. Almost no difference was found in bandwidth between the line input and HiZ input.

-3dB bandwidth @48kHz: 9.9Hz ~ 23.8kHz; 20Hz~20kHz, ±0.23dB which matches with ZOOM specified +0.1 ~ -0.2dB.

-3dB bandwidth @96kHz: 9.9Hz ~ 47.3kHz; 20Hz~40kHz, ±0.25dB.

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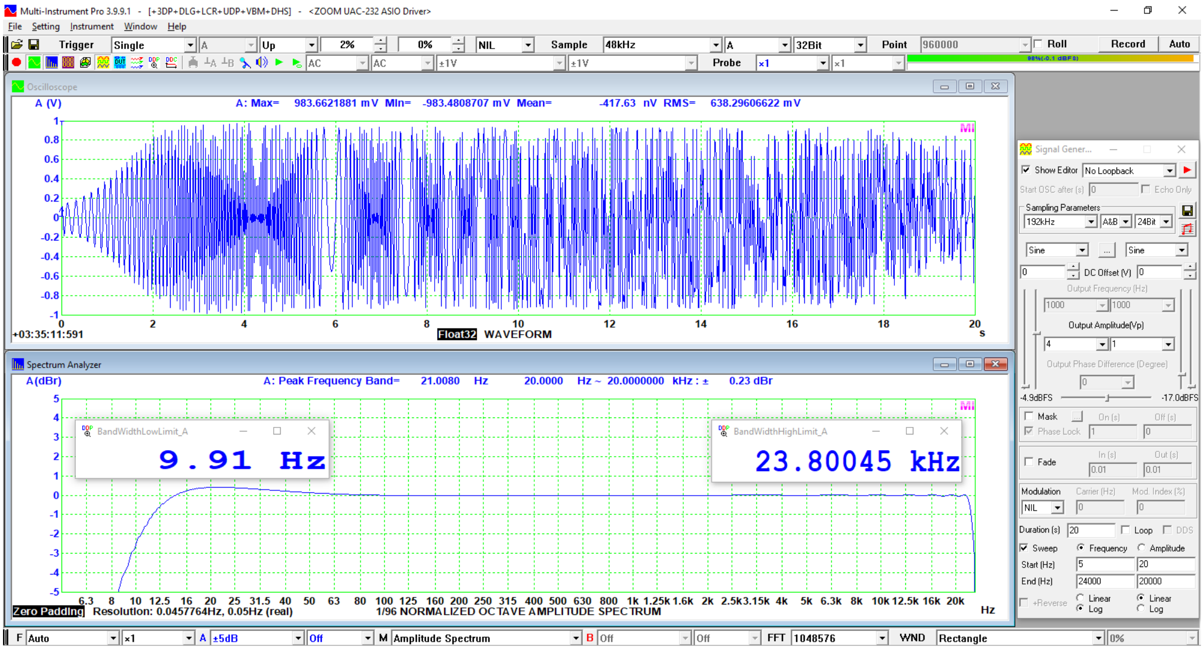
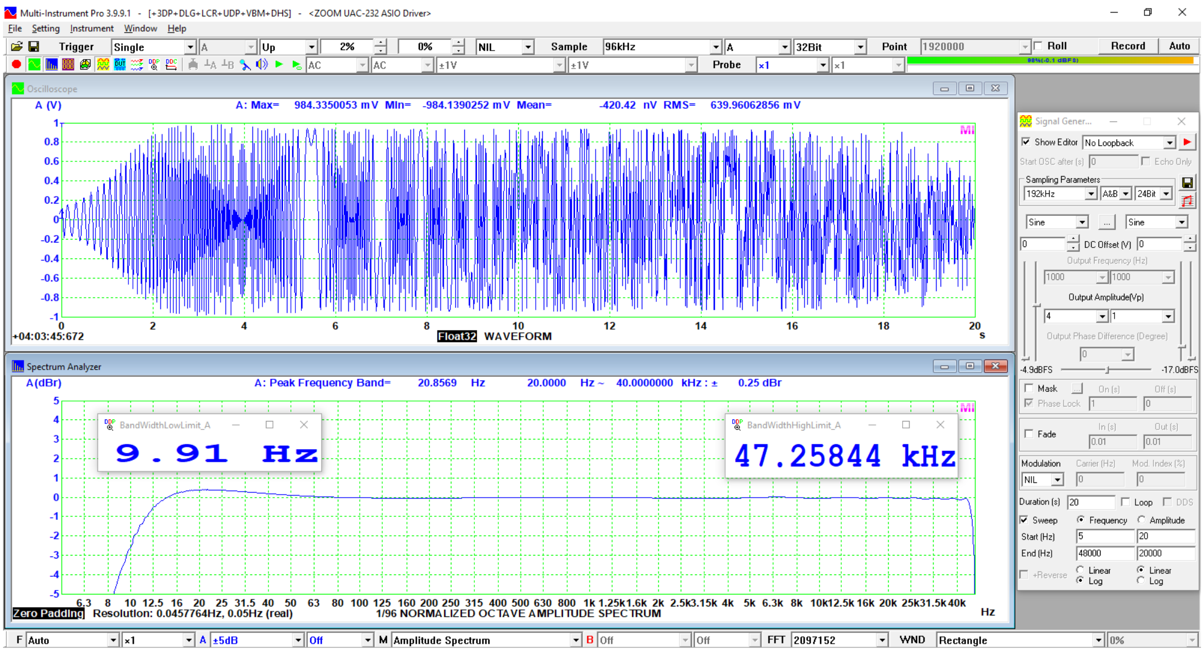
-3dB bandwidth @192kHz: 9.8Hz ~ 91.8kHz; 20Hz~80kHz, ±0.27dB which matches with ZOOM specified +0.1 ~ -0.2dB.



Bandwidth of HiZ input measured at sampling rate 48kHz (digital gain = 0 dB)



Bandwidth of HiZ input measured at sampling rate 96kHz (digital gain = 0 dB)

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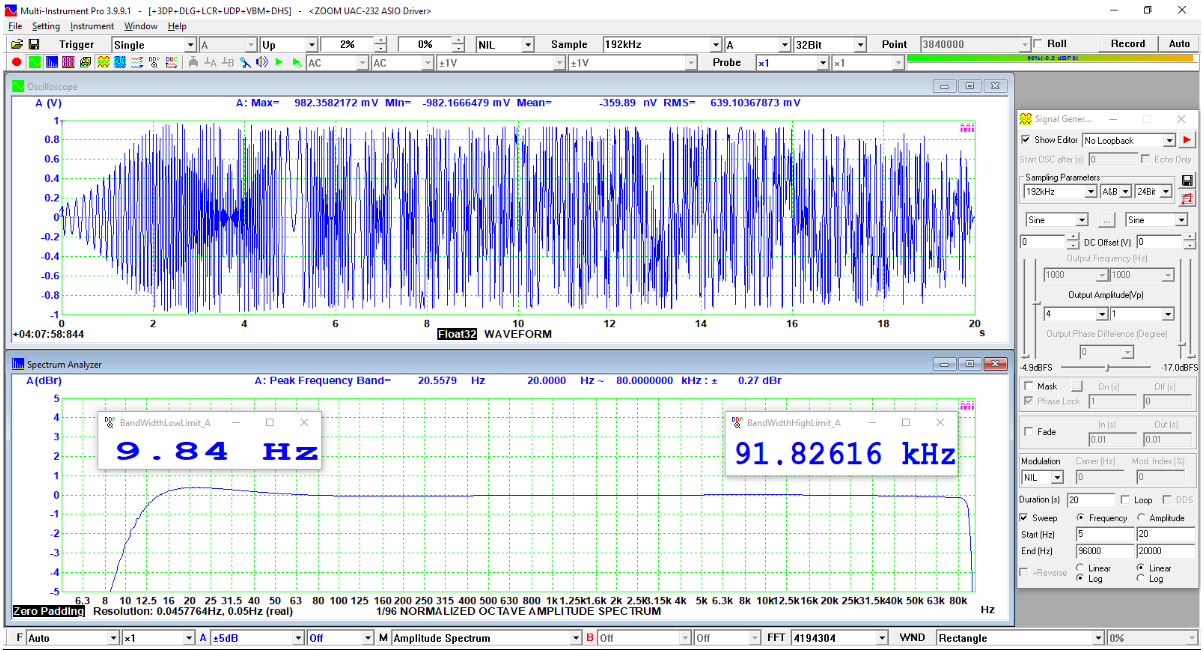


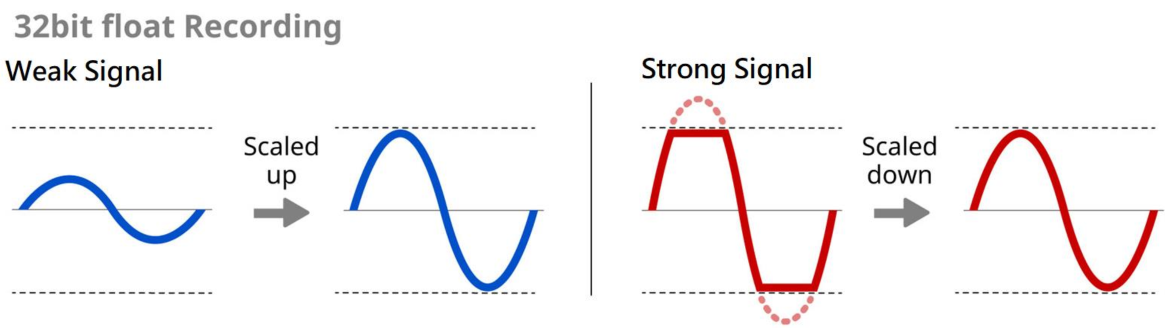
Bandwidth of HiZ input measured at sampling rate 192kHz (digital gain = 0 dB)

4. Output

ZOOM UAC-232 does not seem to be able to output signal under the 32-bit float mode. But fortunately, it is possible to use Sound Card MME under the 24-bit integer mode for signal output while using Sound Card ASIO under the 32-bit float mode for signal input in Multi-Instrument.

5. Conclusion

Under the 32-bit float mode and with the digital gain set to 0 dB, the sample value of 1 always corresponds to the maximum level beyond which clipping will occur. In Multi-Instrument, the sample value 1 is defined as 0 dBFS. The sample value changes with the digital gain setting and thus the signal may not clip beyond 0 dBFS if the digital gain is higher than 0 dB.



Advantages of 32-bit float ADC

Although there inevitably exists a very small misalignment between the high-gain ADC and the low-gain one, the switching between them is very smooth, and no step change was found in the waveform, thanks to the DSP stitching algorithm during the transition. In addition, the

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transition is confined to a very short time, hardly causing any audible artefact or noticeable sound measurement error. The dynamic range of ZOOM UAC-232 XLR mic input is about 134.3dB or 136.4dBA, which outperforms those single ADC solutions by more than 10 dB. With a proper microphone, it is possible to capture sound across the entire human hearing range without sacrificing fidelity at low signal levels or encountering clipping at high signal levels, and this can be achieved without the hassle of manual analog gain adjustment. This is a highly desirable feature in sound recording and measurement industries.

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