AS401 & AS402 comparative review in Hi-End Audio-DAC application

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At the end of September, I completed a significant part of the AS401 and AS402 hybrid OpAmps evaluation process being started in late July. The research was implemented by means of a test DAC model based on the AK4497, which I am very familiar with.

In order to obtain sufficiently reliable signal spectrum information at the output of the breadboard, the A/D conversion was implemented with an external professional sound card RME ADI-2 Pro FS R (based on a 32-bit AK5574 ADC) and additional scaling amplifier/antialiasing filter AD842 OpAmp. To reduce the internal distortions of the ADC, I used the additional software plugins specially developed to work in conjunction with the main spectrum analyzer math program. They subtract the internal distortions of the ADC for a specific level and type of test signal.

The studied OpAmp was installed in the DAC circuit as a subtractor, forming a single-phase signal from a pair of differential signals taken from the outputs of the DAC. The test circuit utilizes the ultra precision Vishay resistors (0.005%) and precision Mial capacitors (0.25%), matched in pairs.

The block diagram is shown in the figure:

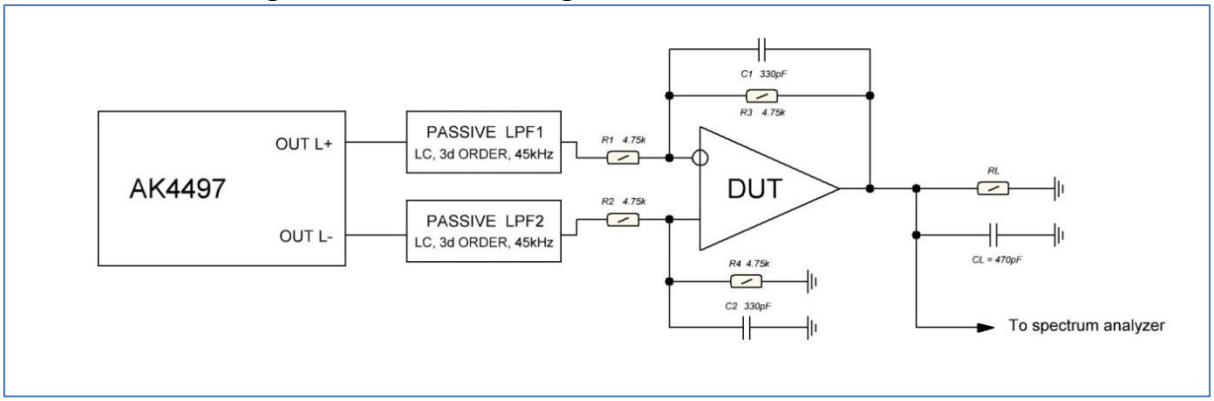

Fig.1 DAC structure

PCM digital signals synthesized with 64-bit resolution and dithered to the native AK4497 32-bit resolution were fed to the DAC input. The DAC output signals were pre-filtered by a third-order Chebyshev LC filter and then processed in the subtractor, in which three types of devices were used as an OpAmp: ADA4627 (Analog Devices), OPA1611 (Texas instruments), and AS401 (Alfa).

The load impedance for the comparative test was selected as 4.7kOhm//470pF.
The test results in the form of spectrograms are shown in the following figures (for ease of comparison, they will be placed three per page in the sequence: ADA4627 - AS401 - OPA1611).

The first three spectrograms are a 1kHz DAC full scale test signal (voltage amplitude - 2.95V).

Among the three investigated OpAmps, the highest level of distortion is obtained by the ADA4627 (both the integrated total power of harmonics and low-order harmonic level). OPA1611 has the smallest integrated level of the total distortion products power, but at the same time provides the hardest spectrum of harmonics - practically all harmonics are clearly visible on the spectrogram up to 20th, and the level of any of them does not fall below -138dB.

AS401 has the softest distortion spectrum, limited to the 9th harmonics. The slightly higher level of the 2nd, 3rd and 5th harmonics compared to the OPA1611 is quite reliably explained by the lower loop gain of the AS401, and the lower level of higher harmonics is due to the better linearity of the output stage of this op amp compared to the OPA1611.

The ADA4627 has lower loop gain than the AS401 and OPA1611, which explains the higher low-order harmonics, but also has an emitter follower based output stage that is more linear than the OPA1611 rail-to-rail output stage.

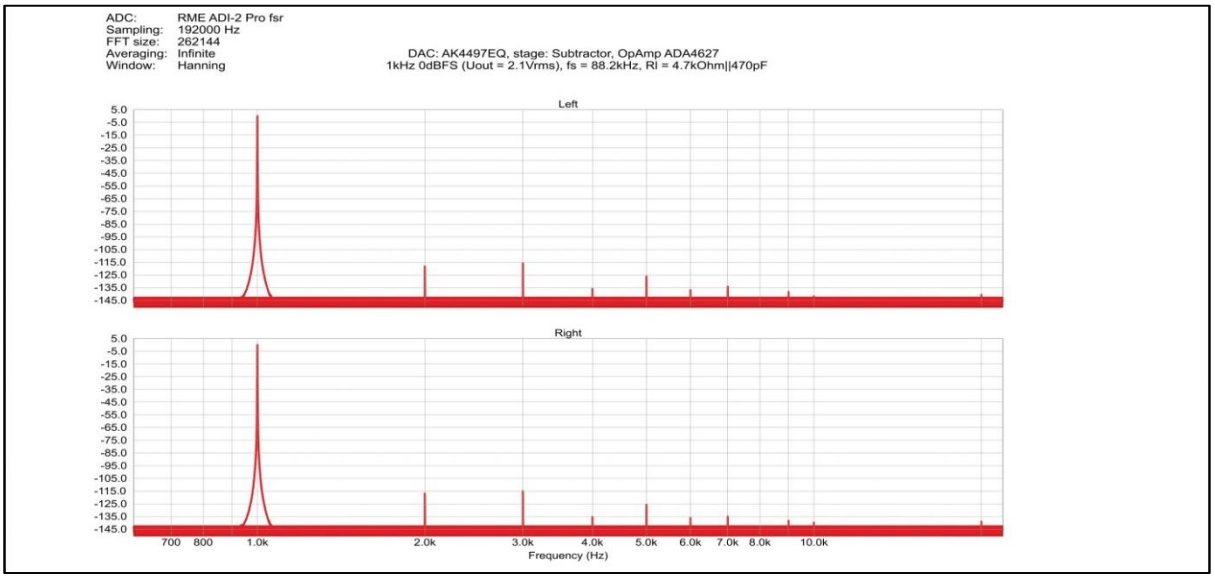

Fig.1 DAC. 1kHz . Subtractor ADA4627

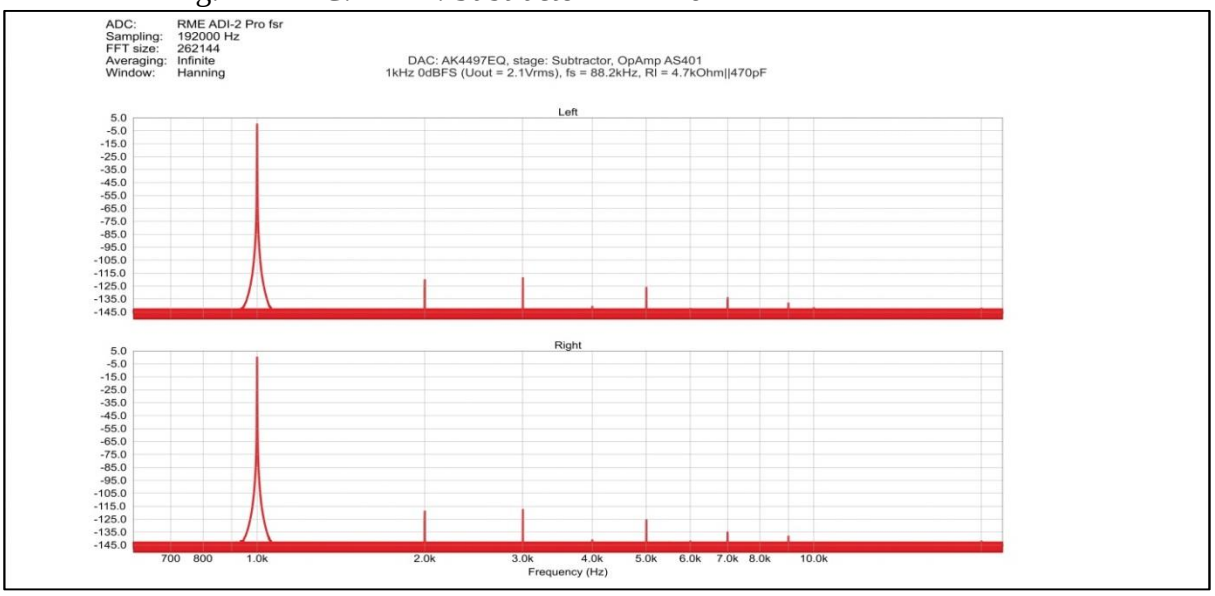

Fig.2 DAC. 1kHz . Subtractor AS401

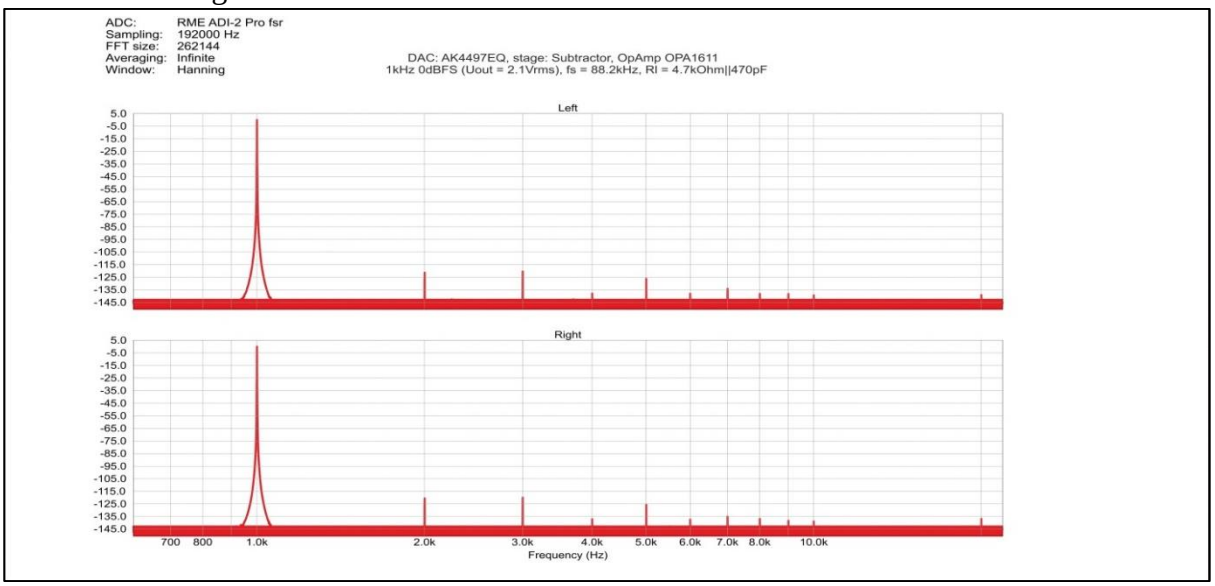

Fig.3 DAC. 1kHz . Subtractor OPA1611

Preliminary data based on the analysis of the distribution of harmonics for a single-frequency test signal is also confirmed by the nature of the distribution of the combinational components of the two-frequency test signal 19 kHz + 20 kHz (see the following three spectrograms).

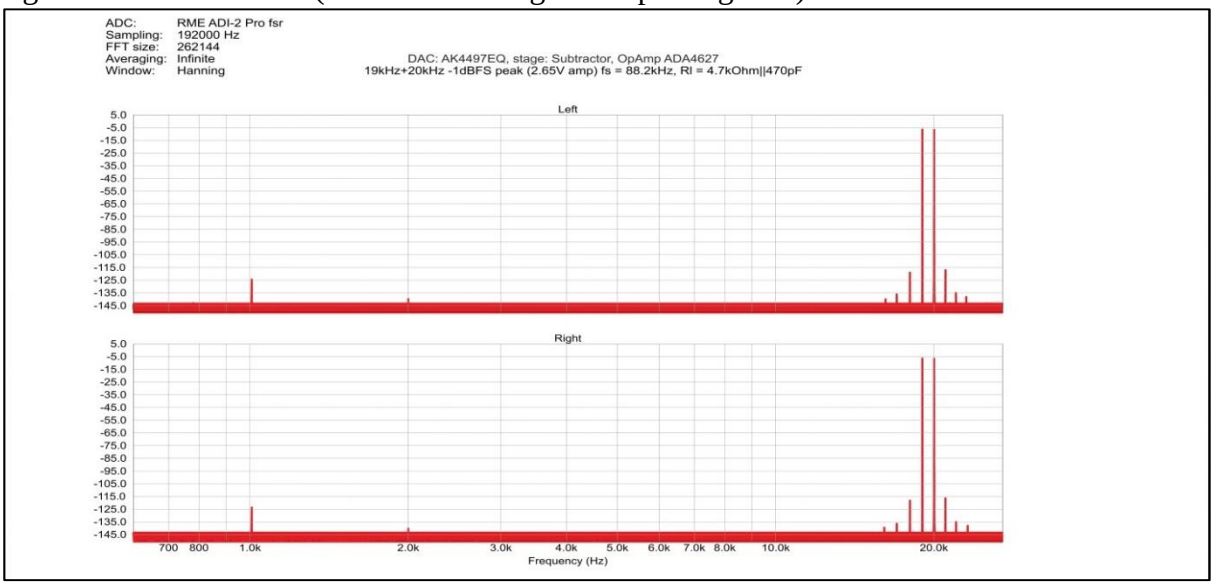

Fig.4 DAC. 19kHz+20kHz. Subtractor ADA4627.

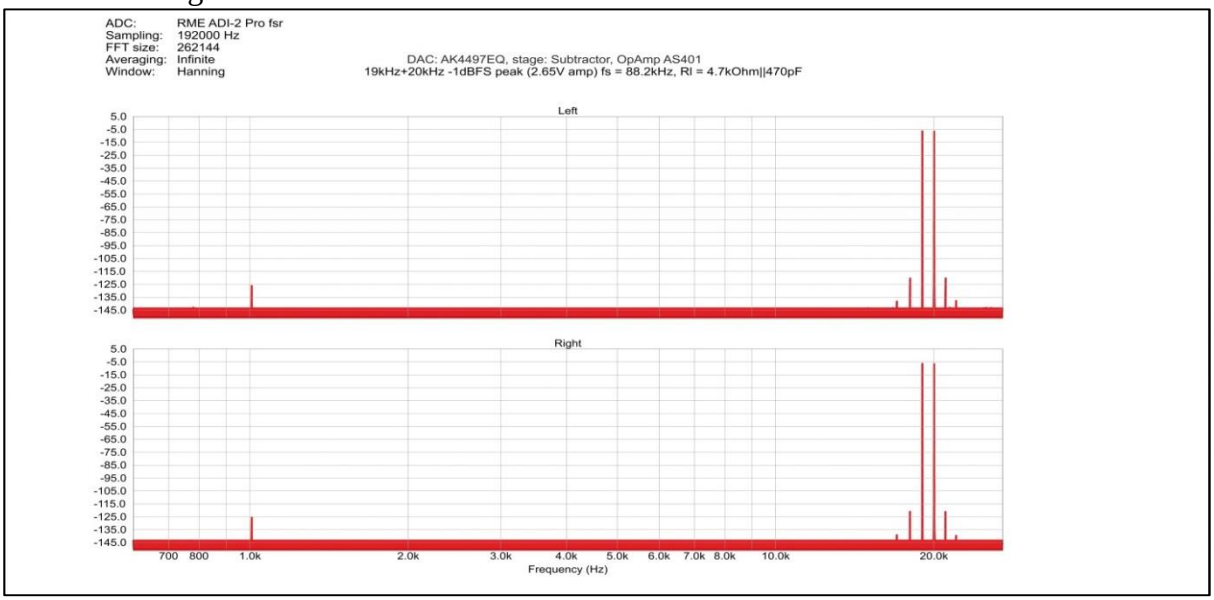

Fig.5 DAC. 19kHz+20kHz. Subtractor AS401.

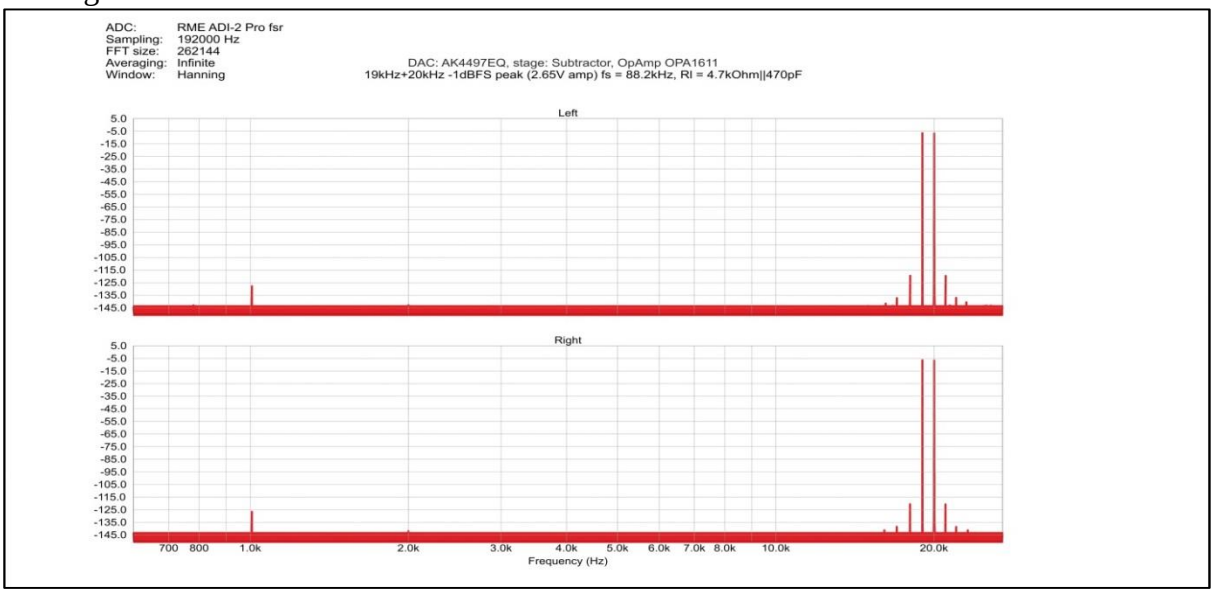

Fig.6 DAC. 19kHz+20kHz. Subtractor OPA16111kHz .

The highest level of difference (type f2 - f1) tone provides the ADA4627 op amp, the lowest - OPA1611, AS401 - between them and this distribution corresponds to the ratio of the loop gain values of the tested op amps.

Combination components of high orders (n * f1 ± m * f2 type) are less dependent on the loop gain and more on the internal parameters of the op amp stages. In this case, AS401 is unrivalled - it gives the narrowest and fastest-falling spectrum of "near" intermodes, which indicates a excellent internal linearity of all stages of this op-amp and a fairly good stability of the input differential stage to the influence of a high-amplitude common-mode wideband signal. ADA4627 and OPA1611 are significantly inferior to AS401 in this part - the spectrum of their "near" intermodes is more saturated - above the noise and interference level are not only 2nd and 3rd order intermodes, but also 4th order, and for ADA4627 the "upper" and "lower" intermodes of 2-th order also have different amplitudes.

Control listening to the DAC with each of the tested types of OpAmps (speakers: 1) Dynaudio Confidence C2 and 2) mancrafted based on high sensitive Isophon / Telefunken driver units, amplifier - push-pull tube total triode no feedback, 6P5G (RCA) + 2 * type71 (Cunningham) + 2 * 300W (Cetron)) showed the following (based on the results of processing the opinions of 4 listeners):

1. The sound of the DAC with AS401 in the subtractor is more "vivid", "pure" and "spatial" in comparison with both OPA1611 and ADA4627. It has a "velvet", "unobtrusive", "very analogous" sound with a good elaboration of the rhythmic component of musical works and timbre correct reproduction of the sound of "natural" instruments, especially violins and cellos. Quiet sounds are well reproduced over the background of loud ones, moreover there is a good effect of "silence" between individual sounds.
2. OPA1611 was recognized as the worst option according to subjective reviews. Apparently, this is due to its "hard" spectrum of distortions, despite the fact that the integral level of their total power was the lowest. The only thing that three out of four listeners also noted was the "firmer" bass when operating the OPA1611 compared to both the AS401 and ADA4627.
3. ADA4627 - in sound it was closer to AS401, but in all the test episodes it was inferior to the latter in the naturalness of the reproduction of the sound of a "live" instrument and voice, and did not have the ability to convey the effect of "silence after sound".

As a result, the version of the DAC with the AS401 was unambiguously marked as the best with a significant gap from the other two op amps by all four listeners.

4. Installation of "half" AS402 instead of AS401 during the "blind" comparison was not noticed by any of the listeners.
5. Instrumental measurement did not show any fixed differences between AS401 and AS402 “halves”, as well as visible differences between AS402 “halves”. The degree of identity of the OpAmp of different specimens is also quite high. Out of 4 AS402s (8 amplifiers), only one amplifier had a higher level of the 9th and 10th harmonics (by 2 and 2 dB, respectively), and all 4 AS401s under the same conditions had almost identical distortion spectra - the difference in the levels of visible above the harmonic noise does not exceed 1 dB. Excellent result!!!
6. At the end of the tests, the operation of the op-amp was tested for a load of 4.7 kOhm and 390 Ohm. Distortion spectra are shown in the figure below - the spectrograms are combined on one graph, and for clarity, the spectrogram is shifted "to the right" when operating at 390 Ohm. With a decrease in load impedance more than 10 times to a value that is already unacceptable for the vast majority of monolithic op amps due to the rapid growth of distortions, especially higher orders, the AS401/402 OpAmps show excellent linearity! The levels of harmonics have grown extremely insignificantly - by about 1 dB, and, which is very important (!!!), the envelope of the spectrum has practically not changed, i.e. it can be assumed (and listening has confirmed this) that the subjective character of the sound of these op amps is practically unchanged in a very wide range of load impedances - an extremely rare and VERY important feature !!!

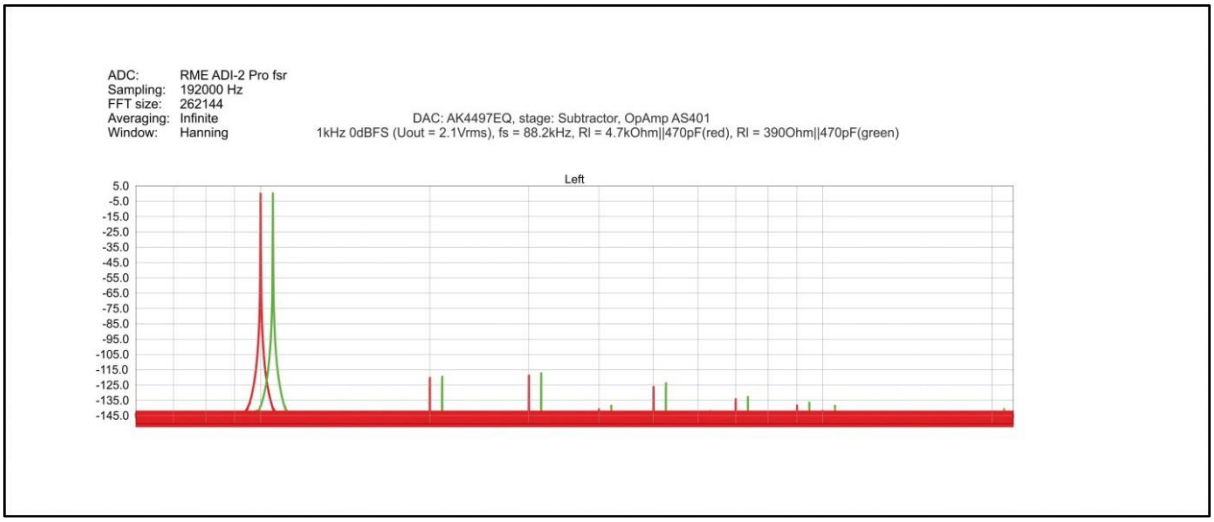

Fig.7 DAC. 1kHz . Subtractor AS401

RED: $R_L||C_L$ = 4.7 kOhm||470 pF

GREEN: $R_L||C_L$ = 390 Ohm||470 pF