

DAC TWO DEVELOPMENT

Cees Ruijtenberg :

"It's easy to see how the Adagio is part of the same family as our Pavane, yet under the hood we optimized it to excel as a Preamplifier. Compared to the Pavane, we made several changes to ensure that performance of the volume control remained constant across its range. Since we alter the reference voltage of the converters to change volume, we needed the very best performance from them.

Therefore we drive them almost to their limits for the lowest distortion and best S/N ratio.

We also changed the DAC ONE module of the Pavane to the newer DAC TWO. As you'll remember, we used an FPGA to split up the 24-bit domain into two streams, each fed to a single DAC ONE module. Afterwards we summed these streams to get back the full analog signal with improved low-level linearity.

I'd always wanted to get this process under the hood of just one module. In other words, take two of the DAC ONE modules plus their external FPGA, then put them in the small housing we already used. First steps were taken under a microscope and successful. We aced this during the spring of 2016 but a lot of effort then went into optimizing our test facilities. We must load each DAC with the algorithm and test it at the same time. Because we like to watch for consistent performance, production capacity was limited.

For instance, we see the effect of pollution on very low levels due to solder residue. It's one more reason why one should never build ladder DACs in free air. Another disadvantage are temperature changes. Those can be avoided in our housing which keeps the temperature constant for each resistor of the ladder.

Look at the table below. It shows you the accuracy needed for 24 bits of resolution which can only be achieved with laser trimming. The very best resistors today have an accuracy of ~0.01%. That means about 14 bits. What can also be seen is that due to so-called 'Johnson noise', you can *never* exceed 24-bit accuracy in the analog domain. Johnson noise is the thermal self-noise of a resistor itself. This can only be lowered by suppressing the ambient temperature. For a normal environment at 25°C (even higher inside many electronics), 32-bit resolution is *commercial hooley*. It's impossible. Johnson noise will dominate. Perhaps in the Arctic's sub-zero temps of -40°C, resistors will perform better but to be more precise, higher resolution is currently only possible in the digital domain. That's in fact our FPGA which runs at 400MHz using 64-bit words.

RESOLUTION N	2^N	VOLTAGE (10V FS)	ppm FS	% FS	dB FS
2-bit	4	2.5 V	250,000	25	- 12
4-bit	16	625 mV	62,500	6.25	- 24
6-bit	64	156 mV	15,625	1.56	- 36
8-bit	256	39.1 mV	3,906	0.39	- 48
10-bit	1,024	9.77 mV (10 mV)	977	0.098	- 60
12-bit	4,096	2.44 mV	244	0.024	- 72
14-bit	16,384	610 μ V	61	0.0061	- 84
16-bit	65,536	153 μ V	15	0.0015	- 96
18-bit	262,144	38 μ V	4	0.0004	- 108
20-bit	1,048,576	9.54 μ V (10 μ V)	1	0.0001	- 120
22-bit	4,194,304	2.38 μ V	0.24	0.000024	- 132
24-bit	16,777,216	596 nV*	0.06	0.000006	- 144

*600nV is the Johnson Noise in a 10kHz BW of a 2.2k Ω Resistor @ 25°C

Another advantage for our DAC TWO module is that it contains paired converters. Using the same number of modules as before, we now double the effective number of ladders.

The Pavane ran four modules per side, hence four ladders. The Adagio gets eight per channel even though you only see four. This doubling has a positive effect on noise, distortion and linearity. A final advantage of the DAC TWO module is that it frees up the slot for the external FPGA on the digital input board for future options.

Sonically, the Adagio (or Pavane Level 2 or 3) goes a step further and is even more refined than what you've heard from us so far. It's also compliant with 384kHz sample rates. Running the Adagio as a normal converter is realized by setting its volume to 12:15. This is equivalent to an upgraded Pavane run with a standard Preamplifier. However, when the Adagio connects directly to a power amp, it relies on a new mind set. Now any kind of 'secret sauce' or 'signature' disappears. It certainly brings you closer to minute musical details but can also be a reason to change out cables or other types of tweaks. I don't have to tell you that the sum of all parts in the chain will have a clear effect on the final result.

As to max output setting that was a careful match between noise figures and voltage so we set it above 4/2V RMS for XLR/RCA. You probably have to increase the encoder's setting a bit more for very low-level recordings but in all the cases we tried (including Pass Amps), adjustments were very convenient. With a 2Vrms output, the noise floor in Amp-direct mode is now -155Db ! That's because our converters run on twice the voltage and thrice the reference voltage as before. This boosted the Pavane's already very good noise figures by another 10dB.

It takes about three weeks of use before the sound fully matures, so leave it on for the duration."