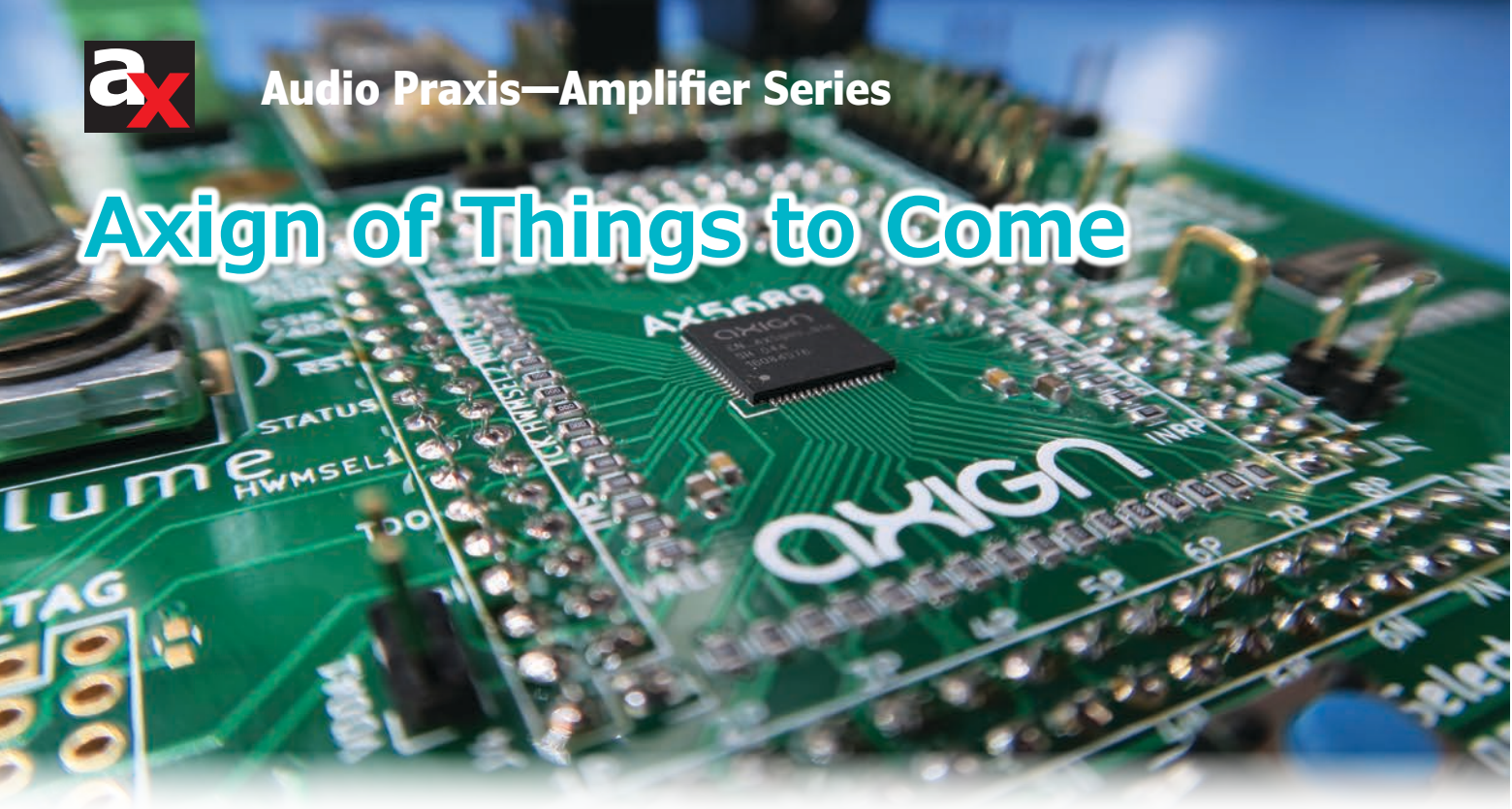
Axign of Things to Come



Axign is a new company from The Netherlands, founded by former Philips and NXP employees who worked on the pioneering Class-D efforts. Established in 2014, their efforts have resulted in the development of the AX5689, a Class-D audio amplifier controller chip in a QFN package. The solution uses a digital control loop with feedback behind the output filter, across the loudspeaker terminals. It requires a digital input signal and suppresses all artifacts with a fifth-order digital feedback loop. *audioXpress* visited the company to find out more information.

By
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(The Netherlands)

A traditional application area for Class-D amplifiers is high-power amplification for professional use. Efficiency, weight, and reliability are determinant factors for such uses. They might be workhorses, but audio-quality-wise, they have not been good enough to run in the Kentucky Derby. In the past few years, however, the industry has seen the rise of high-quality Class-D amplifiers. Not only did they keep (and reinforce) their traditional strengths, but claims have been made (and confirmed) that they could also play a role in high-end audio applications. From that moment on, the entire game started to change.

The combination of high-quality and low cost is, as could be expected, irresistible to audio manufacturers. Most people listening to Class-D amplifiers, do recognize the qualities in the bass area, but doubt the merits in the mid and high regions. Checking a datasheet often reveals some Class-D artifacts in the distortion curves and some load dependent behavior. As we have said in previous articles dedicated to this topology, we saw a dramatic change in performance as more Class-D manufacturers are able to minimize these effects.

So, the use of Class-D in the high-end market is now a reality. The new Marantz PM 10 flagship, powered by Hypex Ncore Class-D amplifiers, is one of the obvious examples. And for those who still have doubts, that's where the efforts of Dutch chip developer Axign can persuade even the most reluctant "traditional" analog diehard. To put it simply, Axign's new AX5689 chip lays a very high-speed feedback loop around a Class-D amplifier, transforming its performance to almost theoretical levels. Too good to be true? Let's see.

Challenges with Class-D Amps

Back in the days when Bruno Putzeys at Philips developed the first self-oscillating Class-D amps, these efforts were also used in their semiconductor branch (now known as NXP Semiconductors), specifically by the group that developed amplifiers for automotive applications. One of the key concerns in developing high-quality Class-D amplifiers is the

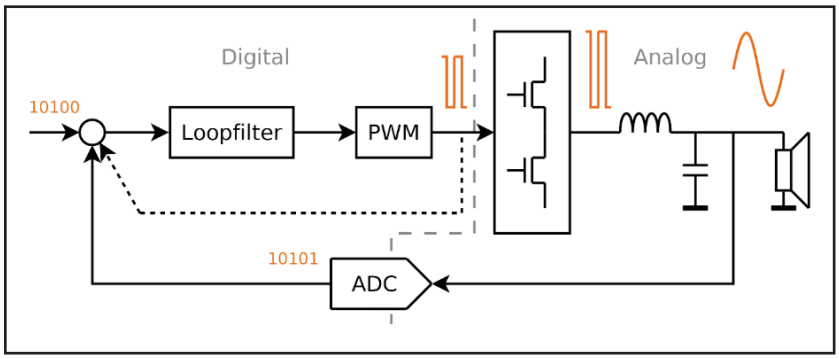

Figure 1: The AX5689 is a Class-D amplifier controller chip in a QFN package. It has a high speed digital control loop with feedback behind the output filter.

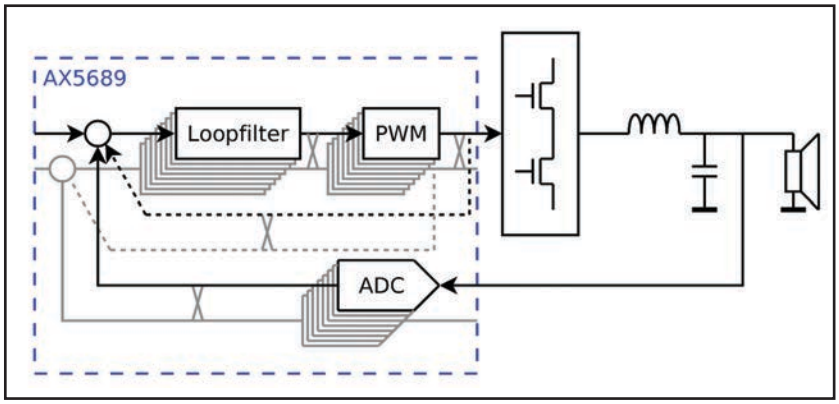

Figure 2: The AX5689 has eight identical programmable high-order digital loop filters, PWMs, and ultra-fast LLADCs. It is suitable to control eight loops in real time.

amount of obtainable loop gain without getting into stability problems. Often the obtainable gain is rather low. To avoid a load-dependent performance, a feedback after the output filter is also desired.

But, there are a few ways to tackle these problems. The use of nested feedback loops is not an easy path, but as more and more experience is gained with this kind of solution, the quality of Class-D amps has improved step-by-step over the last few years.

Another solution is to use a high-speed ADC, comparing the analog output signal with the digital input signal and then do a correction in the digital domain. However, such a solution requires a major development effort—an effort that could not be made by NXP Semiconductor at that time due to capacity limitations. The high-speed ADC was seen as the most critical development item and it was outsourced to Axiom-IC (now Teledyne-DALSA). Then, after an extensive market research and many discussions with potential customers, Jeroen Langevoort (formerly of NXP Semiconductors) took the project and development ideas and established Axign. Supported by Teledyne and Daniel Schinkel, who was strongly involved in the ADC development, the design of the AX5689 was realized.

The AX5689

The AX5689 is a digital amplifier controller that compares the analog signal at the loudspeaker terminals with the input signal (see **Figure 1**). All the disturbances in the loop (e.g., the power supply ripple and nonlinearity from the power stage and

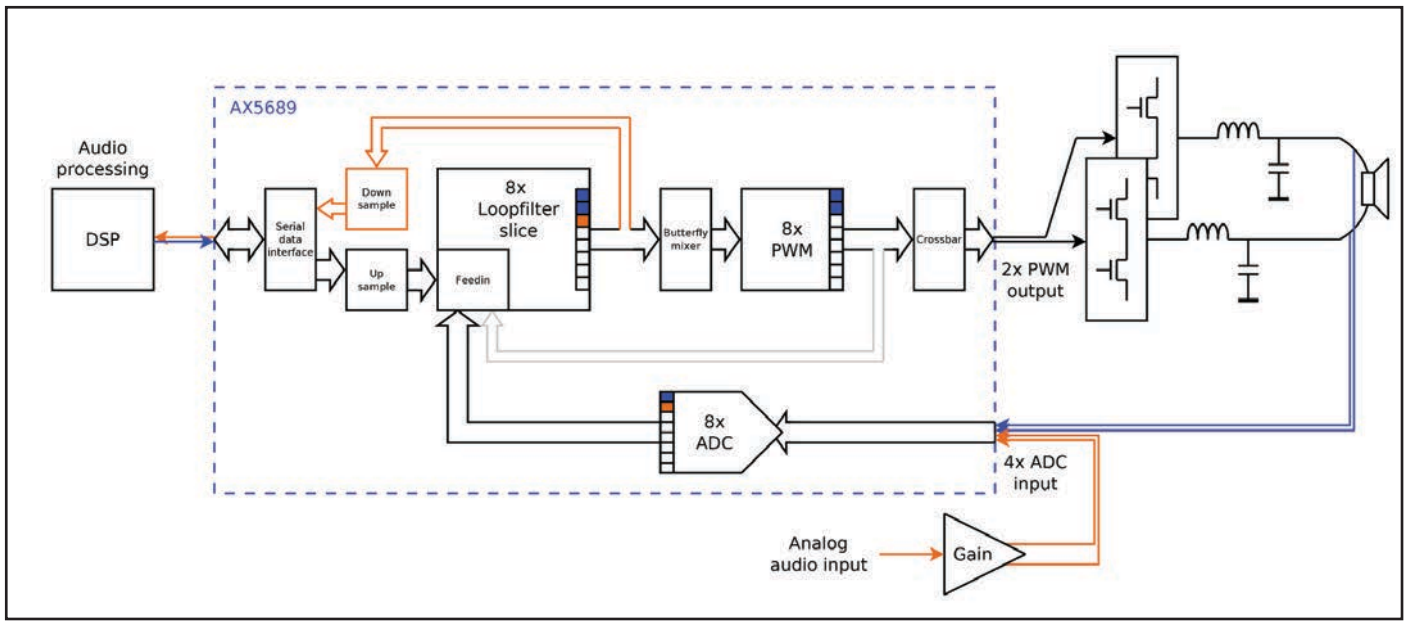

Figure 3: An application example shows that a complete audio system can be built with an AX5689. Adaptation to an active loudspeaker system is easily done.

reconstruction filter) are compensated in real time and suppressed thanks to the extraordinarily high digital loop gain. The analog signal at the load is converted by a high-performance low-latency ADC. The latency is in the order of 20 nanoseconds, giving a total of 200 nanoseconds to act for a bandwidth of 5 MHz.

The AX5689 has eight identical processing slices and eight ADCs, making it suitable to control eight loops in real time (see **Figure 2**). This enables a wealth of configuration possibilities (see **Figure 3**). This means the chip can be used for the Class-D controller function and for other periphery audio functions. One of the interesting possibilities is the option to parallel the sections and increase the already impressive 115 dB signal-to-noise ratio (SNR) to 124 dB, on set level. With the AX5689, silence becomes silence again.

To be clear, this is a Class-D controller not an output stage. It will control whatever Class-D output stage is used. It is even fast enough to include an already available controller in the loop. So how do you demonstrate the qualities of such a product? Well, it's rather easy. First, you take a reference design from the most well-known Class-D amplifier manufacturer and see how much you can improve that design. Second, you listen to the results and check how it sounds.

After a long time in development, the guys at Axign ended up with the results shown in **Table 1**. The proof is in. But those results did not come automatically. At the moment, a fifth-order loop filter is used. Theoretically, a 56th order could be implemented. Not very practical, but it gives an idea of the chip's capabilities. So yes, it took some time before the expected results were realized.

SNR	115 dB to 124 dB
THD vs. frequency	>0.001% (10 W, 20 Hz to 20 kHz)
Output noise	25 µV (for a 2× 100 W/4 Ω solution)
Channel separation	>100 dB (20 Hz to 20 kHz)
Output impedance	<2 mΩ (20 Hz to 20 kHz)
Frequency response -3 dB	DC – 35 kHz (20 Hz to 20 kHz flat, load independent)
IMD (19 kHz and 20 kHz)	below -100 dB

Table 1: These are the results for the AX5689 Class-D audio amplifier controller chip.

Putting the Chip to the Test

For a real-world test, the AX5689 was used in combination with a few Texas Instruments (TI) and STMicroelectronics chips (the TAS5558, the TAS5624A, the TAS5342A, and the STA516B, respectively). Looking at **Figure 4**, we see the THD+N vs. Pout graph for 100 Hz, 1 kHz, and 6 kHz at 4 Ω for both the STA516B and the TAS5342A. The first part of the graph is determined by the noise floor. Then when the amplifier starts to clip, the distortion starts to rise. No traditional Class-D artifacts can be seen.

Figure 5 shows a direct comparison

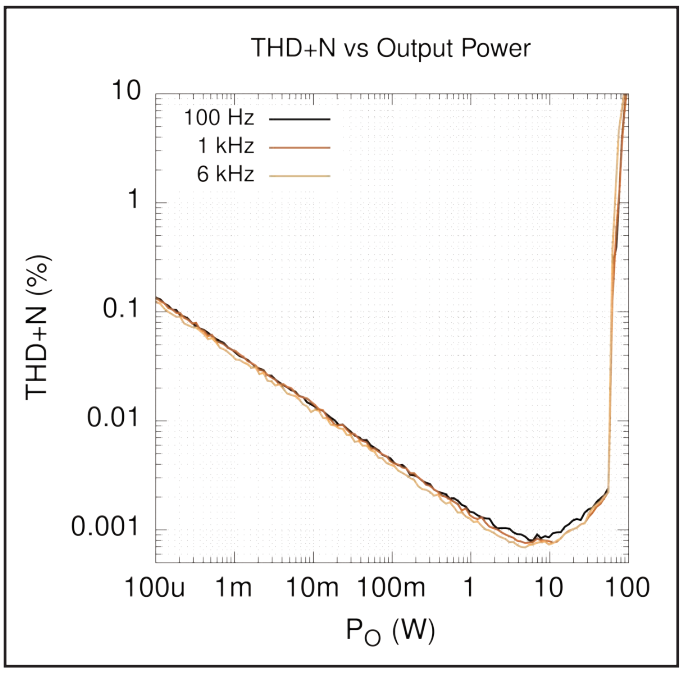

Figure 4: The AX5689 + STA516B or AX5689 + TAS5342A Pout in 4 Ω PVDD = 28 V, 2× LLADC per BTL, BD mod. A difference between the STA516B and the TAS5342A could not be observed.

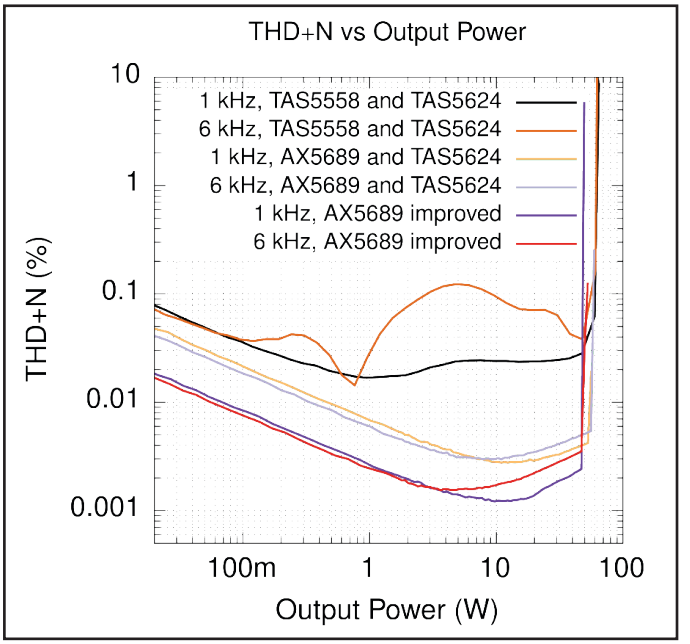

Figure 5: The improvements are clear. The AX5689 is a significant improvement over the TAS5558. Not satisfied with the initial results, the Axign team obtained even better performance after optimizing the chip's parameter settings.

between the TI output stage TAS5624A with a TI controller TAS5558 and the same TAS5624A with the Axign controller AX5689. Clearly, the AX5689 has better control over the output stage. After the first test, the settings of the AX5689 were adapted, providing an even better performance. **Figure 6** reveals an interesting phenomenon. The less sophisticated TAS5342A performs slightly

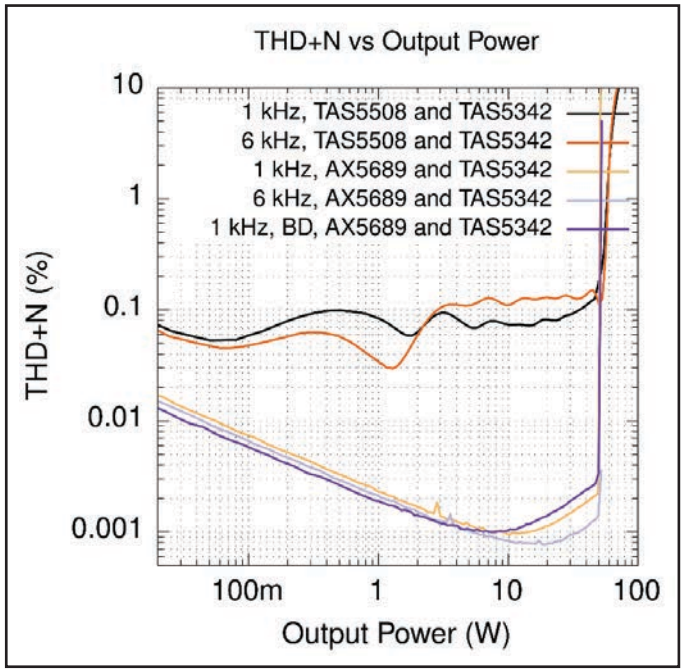

Figure 6: The team also made large improvements in the distortion performance as well. It is interesting to note that the TAS5342A performs better distortion-wise than the TAS5624A. Not having to "wrestle" with an internal feedback loop, the AX5689 performs better.

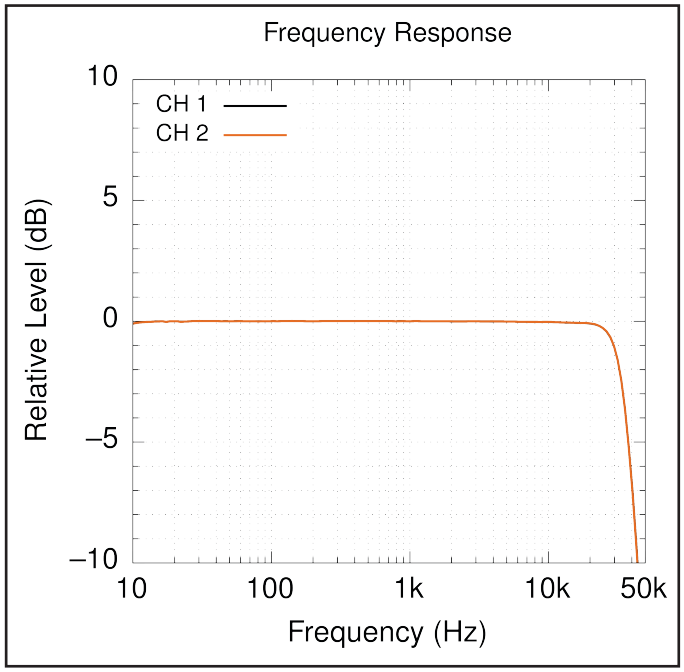

Figure 7: A straight line can be seen in this frequency response. Since the feedback occurs behind the output filter, no load dependent under- or over-damping can be observed.

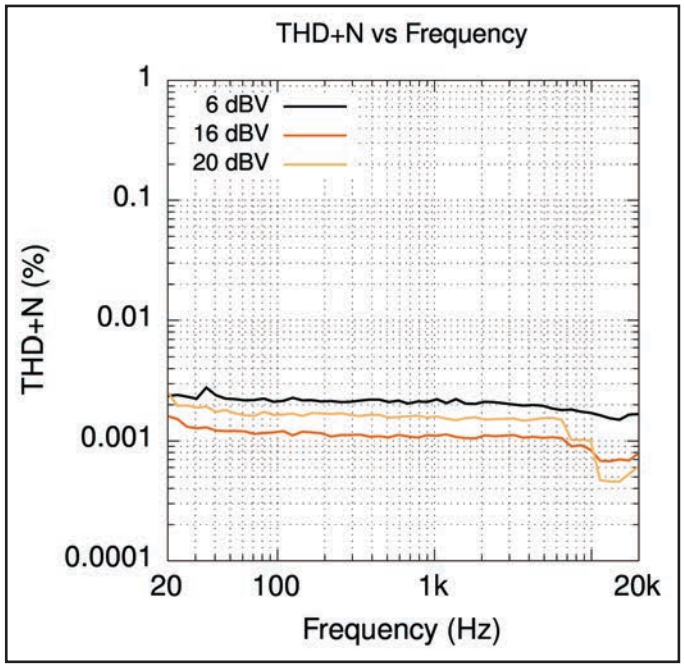

Figure 8: The AX5689 + STA516B THD+N vs. Frequency at 4 Ω PVDD = 28 V. Most Class-D amplifiers do suffer from an increasing distortion with the frequency. Distortion itself is very low with only a small output power dependency.

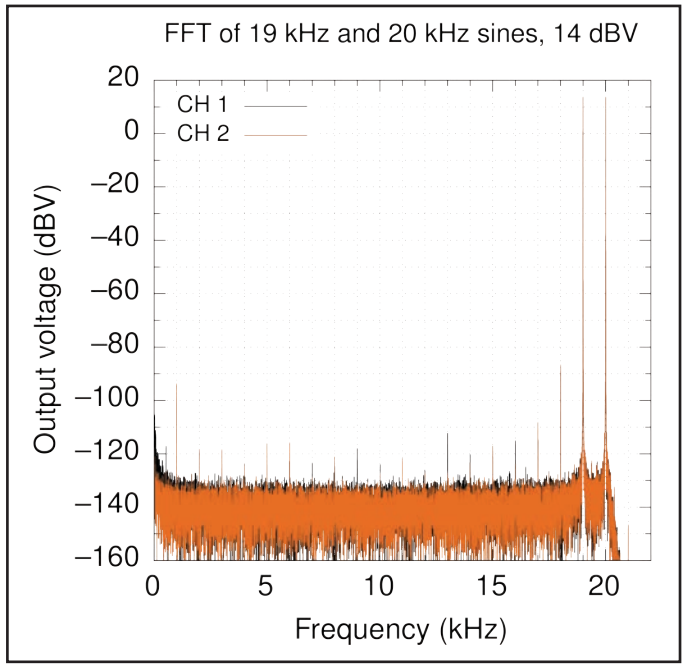

Figure 9: The intermodulation distortion (IMD) with 19 kHz and 20 kHz is below -100 dB. A value that can be shown! Nonlinear behavior is under control.

Photo 1: Prior to Axign, its CEO Jeroen Langevoort was with Royal Philips Electronics and NXP Semiconductors holding various R&D positions. In his work, he was in charge of all developments within the audio amplifiers group and introduced about 30 new products including dedicated automotive Class AB amplifiers and switching Class-D amplifiers. After starting his own consultancy firm to help companies develop their own "mean and lean" product development machines, Langevoort took over as CEO of Axiom-IC and the development of the low-latency ADC that is now at the heart of the Axign controller IC.

better. Having to cope with the TAS5624A's internal control loop is apparently challenging the AX5689 to bring out the maximum possible performance of the output stage.

Another important feature of the AX5689 is that it measures the output signal after the output filter. **Figure 7** shows a frequency response curve, which is a very straight line until 20 kHz (±0.05 dB). The same frequency curve can be observed at 4 Ω or 8 Ω, which is a very uncommon result. Looking at traditional Class-D amplifiers, the frequency response is very dependent on the load. **Figure 8** shows very low values in the TDH+N vs. Frequency graph. Again, it is an almost straight line (almost power independent), not typically seen with the Class-D amplifiers on the market today. And the icing on the cake is revealed in **Figure 9**, which shows the intermodulation distortion (IMD) with 19 kHz and 20 kHz—where a -100 dB is achieved.

The results are simply stunning. These results are not only extremely good for Class-D amplifiers, but there are not many other amplifiers that can match these results.

For any manufacturer that wants to check these results, there are demo kits, and with the available samples, they can check the AX5689 with their own output stages. Several manufacturers already did this and they confirm the results. As the feedback inputs of the AX5689 are current controlled, output stages from a few watts up to several kilowatts can easily be configured.

Music to the Ears

Now, the million-dollar question is, of course, how does it sound? A demonstration setup was assembled on the premises of Axign, in Enschede, The Netherlands. The demo amp with one of the first samples of the AX5689 was built into a small suitcase for easy demonstrations. A set of small and medium

Photo 2: Richard Langezaal is Director of Marketing at Axign with a bachelor's degree in Electronic Engineering. He has 25 years of experience in the semiconductor business where he held several technical and management positions in the audio amplifier group, and marketing positions for lighting solutions. He has a broad knowledge of audio amplifier systems from a customer and chip producer perspective. Richard has a passion for audio, business development, and sales. Richard has built his own 600 W UcD Class-D audio amplifier solution based on ICs from his own product portfolio.

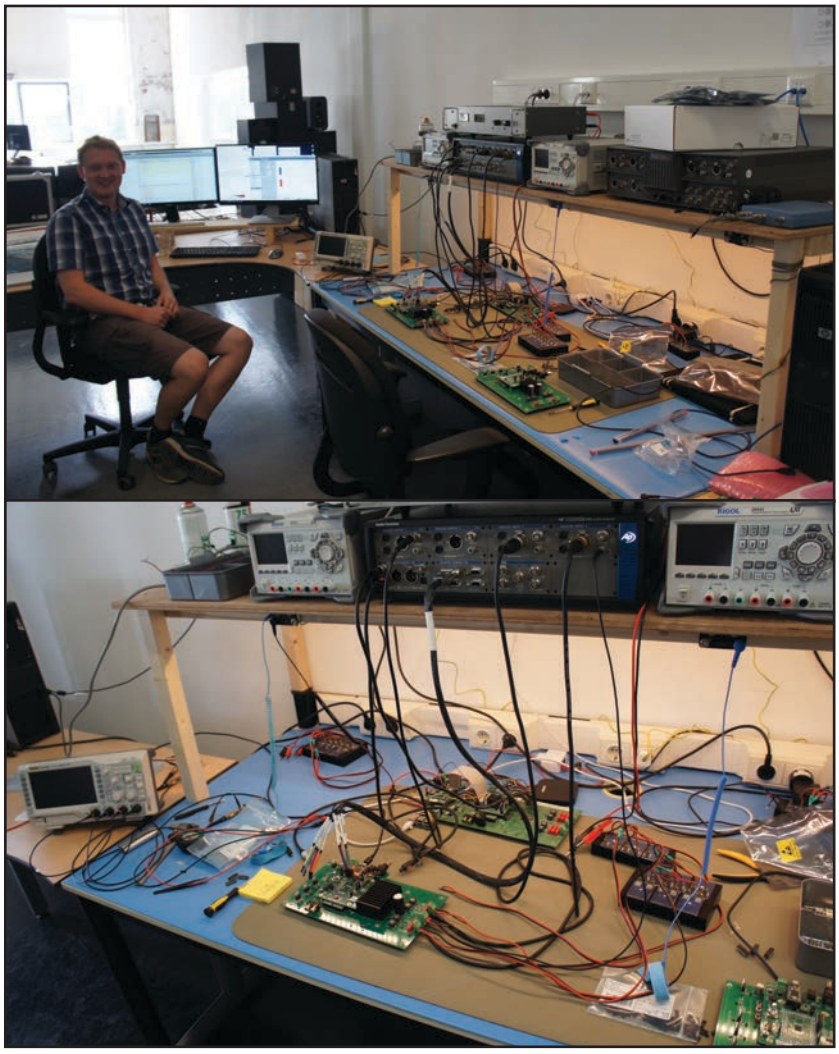

Photo 3: System application engineering is in progress by Tim van Doesum (a). Interesting results were obtained when output filter stages proved to be much simpler and less expensive. More rewarding was the testing with the reference designs of well-known Class-D amplifier manufacturers. The improvements neared theoretical values proving that, not only they were on the right track, they were onto something big here. This is the measurement set up on the bench (b).

sized Bowers & Wilkins (B&W) loudspeakers were used. Actually, these were the private loudspeakers of the management team. The creation of a full-scale demo room is in the planning stages.

The first thing that stands out is the absolute absence of noise. With no music, there is no sound. Then, when the music starts, there is this tremendous detailed soundstage where each instrument and voice has its own place. Combined with the tight bass control, it presents a wonderful, transparent picture. It is also very pleasant during long listening sessions. Wow!

Getting back to earth, I guess the audio quality I heard can be contributed to the improvements in the mid and high regions resulting in this performance. My impression is that the loudspeaker is very controlled and that the amplifier dictates what the loudspeaker has to do, and not the other way around. Feedback after the output filter clearly has its advantages.

Walking the Miles

During the last six months Langevoort (see **Photo 1**) and Director of Marketing Richard Langezaal (see **Photo 2**) have appeared at audio and consumer electronics shows with their small business suitcase and a pair of small, portable B&W loudspeakers. The two men have met with several audio companies to demonstrate that their designs can perform to a new unheard level (see **Photo 3**). Now, companies are asking the question, "Should we rethink our amplifier strategy?"

"Once we can demo, we are in," says Langezaal. "It starts with the silence, then the music does the rest."

It must be said that the AX5689 is not a chip that you just put in your design and the performance is there. The design team went through a lot of trial and error before the AX5689 started to perform as expected. For an audio manufacturer that wants to use the chip to its full potential, the datasheets and certainly the development package are absolutely essential. Further support from Axign will prove beneficial and speed up the development process.

And, there is one item that has not yet been discussed. Costs. Being impressed with the performance is nice, of course, but the cost of the chip and the implementation are important for its commercial success. At the moment, the first samples and demo boards are available for manufacturers (see **Photo 4**).

Production samples are scheduled to be available in the fourth quarter of 2017 (at the time of writing). Qualification and release to the market will be in 2018 and beyond. Prices are quantity dependent but

are in line with other controller chips. The truth is that the price/performance ratio for a high-quality Class-D amplifier goes from unbeatable to ...well, more unbeatable?

Final Thoughts

The AX5689 is a game changer. Class-D amplification no longer aspires to be at par with other forms of high-quality amplification, it can now claim the throne. Due to its highly versatile structure, we can expect to see this chip not only in amplifiers but also in more complex surroundings (e.g., soundbars, soundplates, active loudspeakers, and certainly the new ascending category of voice controlled home systems). The AX5689 is also a proof of concept that the days when a cheap product sounds cheap will come to an end. Clever algorithms will take over audio amplification.

For a young company such as Axign, these are exciting times. For many startups, the first funding is based on the belief of having a good idea. Proving that the idea not only works but can be seen as a solution that will have a profound influence on the audio industry, is expected to provide funding on a larger scale. Growth will not be difficult.

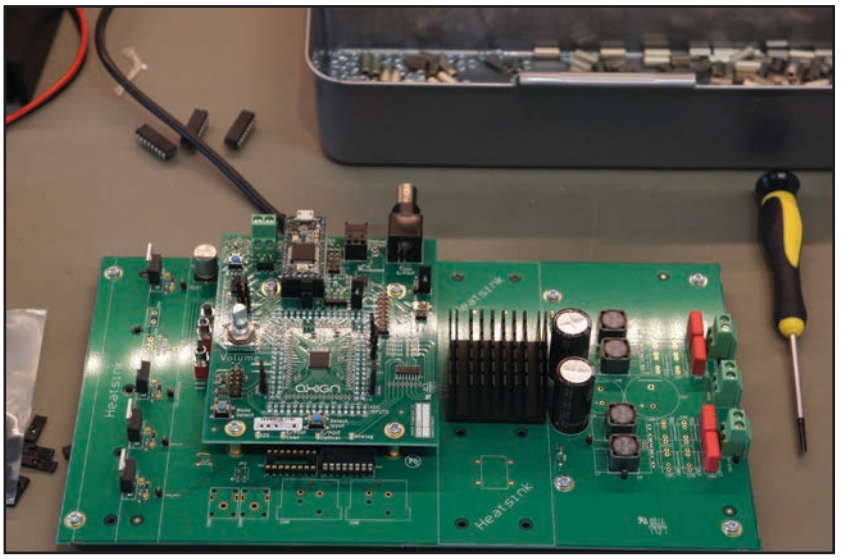

Photo 4: The AX5689 demo board served as the playground for many tests. It is built in a universal way to make it adaptable to all the tests you could imagine.

About the Author

Ward Maas is the owner of Pilgham Audio. He studied electronics, marketing, and amplifier design. During his career in consumer electronics, Ward worked in areas ranging from CD standardization to radio and television to personal GPS navigation. Ward has worked on an extreme low-noise magnetic cartridge preamplifier and several special amplifier products. As the CTO of "Witchworld," a theme park near Amsterdam, he also works with animatronics. He lives in Almere, Netherlands, with his wife and son.