Master Fidelity NADAC
DAC Revisited

Kevin Fiske

We ran a review of this remarkable combination in Issue 239. Why a reprise so soon? Because the DAC, only a handful of months into production, has been given an upgrade by its maker. Was the original design flawed? Was the launch overly rushed? Master Fidelity will have to take such questions on the chin.

In my original review, I judged the NADAC pair to be ground-breaking. From a technology viewpoint, the DAC (NADAC D) and clock (NADAC C) were, by turns, a return to the past and a leap forward. At their price point, the pair was considered disruptive to the market. Because of the sonic quality they revealed to be locked inside digital files of all bit-depths and frequencies, I suggested they posed a profound challenge to the supposed sonic superiority of vinyl replay.

Following the review, Master Fidelity's design head, Weishen Xu and his team continued to work on their proprietary digital clocking scheme. What they discovered turned out to be so profound that they decided to bite the bullet, apply the revisions immediately to NADACs on the production line, and issue the upgrade recall for units already with customers.

Unaware of this having gone on behind the scenes, I did not expect the upgrade to result in anything but inconvenience while the DAC was away. Xu, it turns out mischievously, had not promised any specific sonic improvements, only saying that 'we've made some changes.' When the DAC returned, I was staggered at the sonic uplift, and told Xu so. He replied, "Now you understand the reason for the upgrade. Your subjective listening impressions align very closely with our objective technical measurements."

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As highlighted in my original review, the NADAC is worthy of examination for its technology alone, let alone the sonic result it achieves. It is built around the first one-bit application-specific integrated circuit (ASIC) to be designed and manufactured since the Philips TDA1547 in 1988. Xu contends that the theoretical superiority of one-bit D to A conversion that Philips and others were reaching for back then is now within grasp – and that makes the price of revisiting the technology worthwhile.

Top trumps

Xu believes that one-bit conversion trumps all other techniques because it is the most linear and, thereby, the most natural. Other designers express alternative preferences, but we need to recognise that it's not simply a matter of pushing and shoving between competing technical ideologies. A significant factor in the conversion debate is the comparative cost of implementation. If we design a DAC around one or more of the ubiquitous delta-sigma chips, our key component costs can be very low indeed. If we choose the discrete resistor ladder route instead, the price will be higher because high-accuracy resistors are primarily expensive. We might opt for writing our decoding software and flashing it onto a programmable logic device or two, and if we do, we will be facing an even higher order of expense. Talented software engineers don't come cheap.

The one-bit ASIC route is the most expensive of all – and by a considerable margin. To justify the huge front-loaded cost, the designer needs a compelling sonic argument, deep pockets, and, please excuse me, large cojones. Xu won't say precisely how much the development has cost Master Fidelity. Still, he does note that payback will be a long time coming, given the relatively small production runs typical at this level in the market. To speed up return on investment, Master Fidelity may eventually allow other vendors to buy the ASIC to build into their DACs.

One bit at a time

A one-bit DAC is a clock whose duty cycle varies with the audio signal. The digital stream is a high-frequency series of pulses where the precise timing and ratio of high to low bits directly represent the analogue

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signal. That is why timing accuracy—particularly edge consistency and jitter performance—is critical. It was the foremost of the challenges that faced designers in the era of the Philips chip, and it remains a serious impediment even today. Xu says that one-bit conversion implemented on generic programmable logic devices, such as FPGAs, is inescapably compromised for this very reason. He speaks about the criticality of timing in the accompanying TechTalk.

The upgraded NADAC features an unchanged one-bit conversion stage. It upsamples PCM up to 96kHz into DSD 128 and PCM from 176.4kHz to 384kHz into DSD 256. The upgrade has seen minor tweaks to the user interface, but it's in the DAC's clock recovery module that things now look very different. It might be assumed that the NADAC C 10 MHz master clock (which is also a Word clock) provides an accurate time reference; however, it is more accurate to say that it allows for a precise time reference. Master Fidelity's new learnings have led to a refined cascaded clocking scheme in which the NADAC C is focused on minimising what are considered in this context long-term timing variations, such as wander and drift. The clock data recovery module locks onto this 10 MHz baseline and further refines it with a focus on removing residual jitter, aligning timing between clock domains, and generating the exact multi-channel clock signals required by the one-bit ASIC. The resulting level of precision wasn't possible in the 80s, and that is one reason why the pioneers of one-bit decoding never achieved the sonic results they knew were theoretically possible.

Subjectivist trigger alert

Master Fidelity won't be the first DAC developer to claim that listening tests played a key part in the development of a product. Still, Xu's previous life as a recording engineer lends the assertion more credibility than usual. In an admission that will likely trigger objectivists into scornful fingers-on-keyboard action, he notes: "In early prototype designs we achieved THD+N as low as -122 dB, virtually eliminating distortion, yet the sound felt somewhat bland and lacking musical tension and emotional engagement. We therefore placed equal, if not greater, emphasis on real-world musicality, listening in particular for accurate imaging, a rich and well-layered musical texture, along with controlled harmonic content that enhances musicality without stepping over the line into artificial coloration."

There's a rarefied stratum in digital audio currently populated by a mere handful of DACs. While 'spendy', the NADAC is very far from being the costliest of the bunch, yet even before the upgrade, it set a challenging sonic benchmark. The upgrade has taken the delivery of all four musical pillars to an even higher level. There's more tonal density and texture, more micro-dynamic detail, more dynamic expression, and more solid and convincing musical timing, all delivered from a blacker background and an arrestingly precise sound stage. So far, so hi-fi.

What sets the NADAC further apart still is the way it dissolves the plaques between the music and our brain wiring. If we are expecting digital hardness, a mechanistic gloss that telegraphs 'this is digital', then the NADAC comes as a revelation because it sounds so uncannily natural. Xu wants us to understand that the hardness is not on the recording (well, mostly) but is created in the conversion chain, where wander and jitter cause frequency drift and near-end phase noise. These effects distort the entire audio spectrum—especially its phase integrity—resulting in degraded sound quality and listening fatigue.

Xu points out that analogue tape machines exhibit a form of low-frequency wander in the form of mechanical wow and flutter. Still, due to the physical nature of tape playback and the continuity of the medium, this mechanical modulation does not compromise the full audio bandwidth in the same way digital timing errors can. Optimising the NADAC's revised clocking architecture meant designing yet another dedicated ASIC. Still, by now the Master Fidelity team had had enough practice to rattle off the new chip relatively quickly.

Underlined

I don't think I've ever used the word 'substance' in a review before. Still, listening via the NADAC to Max Bab's album Wild Pitch, I was captivated by how Max von Mosch's saxophone now sounded more vividly present, more extant than I'd heard it before. It wasn't a matter of simple clarity, but such a level of tonality and controlled energy that a 3D-ness, a seemingly physically present completeness, was created in the listening room. In capital letters, I wrote the word 'SUBSTANCE' in my listening notes and then, just for good measure, repeated it and underlined it. Readers who have heard a tenor saxophone played up close in an intimate space may recognise the qualities I was trying to give a name to with that word. I'd not heard digital do that before, but there it was, and the intriguing part was that in

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so much of what else I played – simple vocals, orchestral symphonic, folk – I heard the same effect. The NADAC changed it from being a once-in-a-blue-moon exception into an 'oh, there is again' common event.

I'll offer two hostages to ridicule here and suggest that taken in the round, the improvements make the NADAC some 25% better still. It also enables the NADAC to emphatically overturn the analogue/digital hierarchy by lifting the replay of even well-recorded 16/44.1 files to a level beyond what the best of vinyl can regularly achieve—files with more bit depth and higher frequency tip the balance even further.

Evolutionary revolutionary

As I noted in my first NADAC review, if we are recording digitally (most studios are), then playing back digitally should be better than if we add three lossy electro-mechanical stages (lacquer cutting, pressing, replay) between the performance and our ears. The NADAC is the first DAC I have heard of that makes that theory a reality. Suppose we are building a system from scratch and have the money for a NADAC. In that case, we can make a perfectly rational decision on the grounds of sonic quality alone to simply side-step analogue completely. That's not to suggest that the NADAC drives a stake through the heart of vinyl. If we already have a treasured record collection, then there remain plenty of reasons to keep it and the means to play it. However, what digital does at the level of the NADAC is render vinyl an evolutionary dead-end. Sorry to be so blunt, but that's just the way it is.

As a related and highly relevant aside here, some readers may be as shocked as I was to learn that many of today's digital recordings are made by studios using analogue-to-digital converters (ADCs) costing just a few thousand pounds and with poor linearity and phase performance. Imagine then what a one-bit ADC, in simplistic terms, a NADAC in reverse, would do for the recording industry. Xu confirms that such a product is already in the works, a project that Master Fidelity's considers as a logical step for bringing an ultimate analogue-feeling digital sound along the whole production chain. Is your mouth watering at the prospect? Mine too.

Some of the competition to the NADAC costs twice as much or more. I haven't heard all of it, so I am not equipped to suggest even a tentative hierarchy. I am also not suggesting that the alternatives don't have technical merit. They deploy some seriously complex supporting electronics to make the best of their alternative decoding schemes. As a trophy purchase, the NADAC, with its understated two-box form-factor, hardly competes with a six-figure multi-box behemoth DAC. However, there's no doubt in my mind that the elegance of one-bit conversion so painstakingly implemented enables the NADAC, at the very least, to live sonically in the very top tier. Weishen Xu and his colleagues deserve respect for a truly formidable display of quality audio engineering and for exhibiting no small measure of commercial bravery, too. +

Technical specifications

NADAC D

Type: Digital to Analogue converter

Inputs: USB Type C, AES3 (XLR), S/PDIF RCAx1, TosLink optical x1 (RAVENNA RJ45 to follow), Clock BNCx1

Outputs: Analogue balanced line 2x XLR, single-ended, 2x RCA, 4.4mm balanced mini headphone jack, 6.35mm single-ended headphone jack

Formats supported 44.1-384kHz, 16bit-true 32-bit. Native DSD64-DSD512 true 1bit (USB) 44.1-192kHz, 16-96bit, DoP64 (AES and S/PDIF), 44.1-384kHz, 16-32-bit. Native DSD64-DSD256, true 1bit (RAVENNA to follow).

Analogue volume control: 3dB/step attenuation, total 20 steps

Dimensions (WxHxD): 43.5x9.5x39cm

Weight: 9.2kg

Price: £25,000, €25,000, $27,500

NADAC C

Type: Master Clock

Crystal type: Selected high-stability pre-aged, SC-cut crystal

Clock output options: 10MHz, 625Hz, Word Clock

Word Clock output frequencies (in kHz): 44.1, 48, 88.2, 96, 176.4, 192, 352.8, 384, 705.6, 768,1141.2, 1536.

Frequency accuracy: <10ppb

Nominal Impedance: 50Ω (10MHz clock, 75Ω supported), 75Ω (Word Clock, 625Hz)

Dimensions (WxHxD): 43.5x9.5x39cm

Weight: 9.2kg

Price: £25,000, €25,000, $27,500

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TECH TALK

Crystal Radios to 1-bit DSD: Master Fidelity's Weishen Xu

Master Fidelity's design lead, Shanghai-born Weishen Xu, has had something of an obsession with digital audio since he first encountered it in 1985.

Then chief sound engineer and recording director at China's premier performance venue in Beijing, he collaborated with Philips/Polygram engineers Roddy de Hilster and Dick van Schuppen to record the very first CDs of Chinese music. It was his first experience with digital recording, and it left him conflicted. He was impressed by the 96dB dynamic range and the efficiency of nonlinear editing, but less so by the sonic comparison with analogue. Thus began a personal quest as an engineer to create a new digital environment which combined the upsides of the old and the new.

In 1988, Xu emigrated to Canada, joining the Canadian Broadcasting Corporation just as its radio system was undergoing a complete digital transformation. He relished the flexibility that digital brought to the production and mastering process, but still missed 'the beauty of analogue sound.'

Pivotal Moment

Then came a pivotal invitation. Swiss company Merging Technologies, the co-pioneer with Philips of DXD, asked Xu to collaborate with Merging's Dominique Brulhart on the development of new digital studio platforms, including the first-generation NADAC (it's an acronym for Network Attached DAC) in 2015. Multiple delta-sigma DAC chips were the decoding technology choice at the time. Still, the work, at Merging's Vancouver development site, subsequently spun off as a new »

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company, Master Fidelity, enabled Xu to learn a lot about the strengths and weaknesses of all the contending decoding schemes.

He notes: "Dom and I got close to the essence of analogue master tape with the gen 1 NADAC, but I later learned enough to know that if there was ever a gen 2, only true 1-bit decoding on an ASIC would do."

Not bespoke code on a programmable logic device such as an FPGA? "No. The fixed layout of logic blocks and tracks on a PLD means that there can be no control over block-to-block propagation delay. In addition, delays *within* the logic blocks themselves vary with voltage and temperature. All that combines to produce an environment in which jitter cannot be eliminated. Many applications don't care, but 1-bit decoding does. It is ultra-sensitive to even minuscule variations in timing.

"Designing our own ASIC gives complete control over the layout. Logic blocks and tracks can be arranged for precise control of clock edge timing and pulse widths. Jitter and phase distortion can be mitigated through the use of optimised internal clock trees, and timing uniformity can be made predictable and thermally stable. We've also implemented some functions conventionally hosted on co-located PLDs on the ASIC. Here again, having complete control over routing and logic delays meant inter-chip clock domain transition delays could be eliminated."

The revisions to the NADAC's clocking scheme are responsible for the sonic uplift noted in the accompanying review, and Xu is relatively forthcoming about what he and his team have done. It surprises him that there appears to be a sizeable cohort in the audio engineering community that still believes anything going on out of the nominally 20Hz to 20kHz audio band is irrelevant to sonic quality. The NADAC's overall design pays close attention to minimising EMI emissions in the high kHz to low GHz range. Still, Xu regards that as unexceptional, simply tidy housekeeping and just one hallmark of quality engineering. It's in the clocking scheme that the attention to detail becomes, shall we say, somewhat obsessive?

Controlling time

Xu and his colleagues found that, in conjunction with 1-bit decoding, it is in the accurate control of time that lies the key to making digital sound just as natural as analogue. The NADAC therefore employs several advanced ideas, including edge entanglement technology (look it up, it isn't very easy). Xu and his colleagues have also paid particular attention to digital wander, especially phase noise below 5 Hz. "Our measurements even extend down to 0.1 Hz, says Xu. "While these frequencies are well below the threshold of human hearing, their higher-order harmonics can intrude into the audible band, influencing the sense of realism and physicality in reproduced music.

"No single clock can be flawless across all performance dimensions. We are interested in frequency accuracy, although the influence on audio quality is relatively minor. What matters is short-term stability, which directly impacts sonic qualities such as how solid and controlled the low end is, and phase noise, which has a significant influence on SNR and THD+N. Lower phase noise translates into greater clarity, darker backgrounds and more natural retrieval of musical detail. That's why we use multi-stage processing to harness the strengths of different clock circuits and components, ultimately producing a clock signal as close to perfect as possible.

"The rise time of the NADAC clock system has improved from 1.2 nanoseconds (1200ps) to 600 picoseconds, and it achieves a stability floor of approximately 7×10^{-13}, with optimisation applied to any deviations above roughly 0.7 Hz. What we do is similar to practices in crystal oscillator phase noise analysis systems, where multiple specialised circuits are cascaded to achieve the best performance. The NADAC C has multiple outputs that allow sources with 10MHz clock inputs to be included in this clock cascade, and if that's taken advantage of then the sonic results can be even better, but even without clocking the source the results we have achieved surpass what we hear from an analogue master tape, so I'm happy that we can say we got there in the end."

What are Xu's listening preferences away from the development laboratory? "I play the harmonica, but as a listener and a recording engineer, I 've always been drawn to the piano and the cello—two instruments that, in very different ways, challenge both musicians and audio engineers alike. But the human voice is the most intimate and expressive instrument we have. As moving as visual art can be, it's the human voice that has the power to bring me to tears." +