Analogue-to-Digital Conversion with the Lightest Touch Ever

Introduction

Our work is centered on the faithful reproduction of an analogue performance using modern digital techniques. It is informed by substantial evidence that a more precise capture of micro-temporal elements in sound is significant for the human listener. [1, 3] Core to our approach is a concentration on the actual spectrum of natural sounds and music – signals humans have evolved listening to.

While there appears to be universal agreement that audio represented in the digital domain establishes the basis for repeatable, lossless distribution, the industry had seemingly long accepted the status quo for capture (analogue-to-digital) and playback (digital-to-analogue). In fact, there had been little fundamental improvement since the 80's.

Therefore, the most critical steps remain at the analogue-to-digital and digital-to-analogue gateways, and in the compromises and permanent limitations made at these points. [1]

The FOQUS by MQA Labs analogue-to-digital converter (ADC) design is a breakthrough, delivering a new level of clarity and micro-dynamics in the sound.

As previously published in [6], QRONO by MQA Labs, and its design of digital-to-analogue converter filters, represents a step change in performance by avoiding unnatural pre-ringing and post-ringing that can blur events discernible by our hearing.

Background

Typical ADC

For roughly 40 years, audio ADCs have used Delta-Sigma architecture to keep distortion low. The high-oversampled, low-bit modulator typical of common audio ADCs requires a downsampler to provide audio at sampling rates ranging from 44.1 kHz to 768 kHz. Traditionally, a multistage downsampler requantises at each stage, introducing challenges with achieving audio transparency.

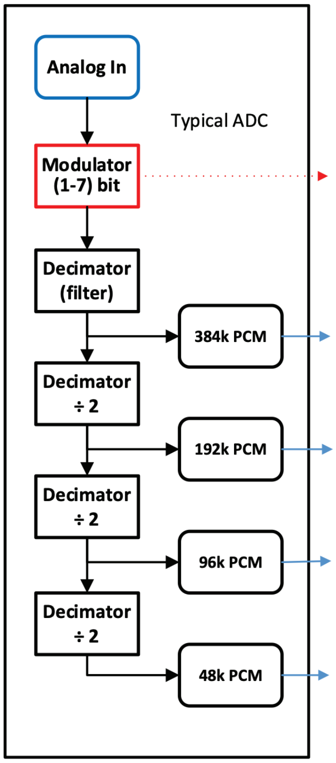

Figure 1: Typical ADC design

Figure 1 shows the generic design – popular because it requires minimal analogue pre-filtering and readily integrates into a single chip.

Noise-shaping in the Modulator gives wide dynamic range in the audio band but filtering is necessary. The decimation chain typically quantises to restrain the word size at each step. Error-shaping or poorly dithered quantisation at these steps commonly leads to modulation noise.

FOQUS ADC
We employ a decimation method in which the word-width grows more slowly at each step, so there is only one, fully dithered quantisation if necessary to produce a final audio output. The noise, modulation and distortion errors are therefore restricted to the modulator (where A/D conversion actually takes place) giving the possibility of 'integer conversion'. Our 'integer decimation chain' is perfectly linear and adds no noise.

When compared to the 3–4 quantisations in most common designs, FOQUS offers a huge uplift in transparency by avoidance of quantisation time blur.

All processing is minimum-phase and based on B-spline kernels. B-spline kernels match the natural 'triangular' space of music natural sounds and align with the principles introduced in [1] which optimise for a specific compact impulse response, no pre-responses and minimal (zero) modulation noise. [2]

The design is more fully described in [3].

Figure 2 shows the measured impulse response of a FOQUS enabled ADC chip with 48kHz output. There is zero pre-ring. Typically, the 48kHz output of an ADC has the most ringing of any output option as it requires the most decimation from the modulator output. The FOQUS output delivers substantially less ringing than a traditional design outputting a higher sample rate.

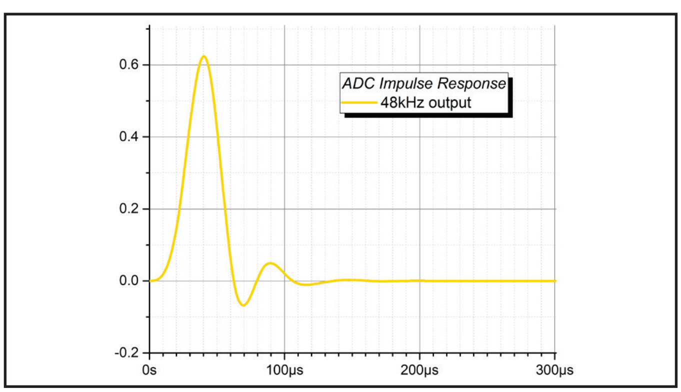

Figure 2: Measured response of FOQUS-enabled ADC chip with 48kHz output

Figure 3 shows the measured impulse response of a FOQUS enabled ADC chip with 192kHz output. There is zero pre-ring or post-ring with no undershoot. This is comparable to the transparency of an analogue signal traveling through a couple of meters of air.

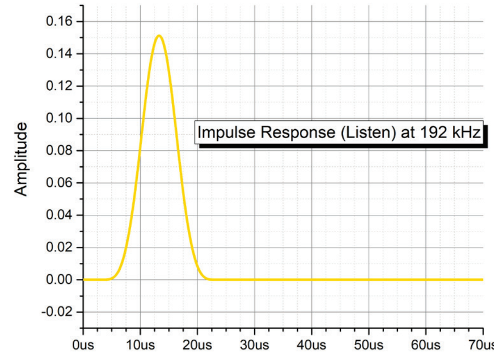

Figure 3: Measured response of the FOQUS-enabled ADC chip with 192kHz output

FOQUS provides a measure and listen option at each output rate. These measurements were made in listen mode which optimises the impulse response.

Where to Find FOQUS by MQA Labs

FOQUS comes to market in partnership with semiconductor companies who specialise in audio chips.

A FOQUS ADC chip can be employed in any device where an analogue source is supported. Expect to see FOQUS in leading professional studio gear, prosumer devices, and high-end playback equipment. FOQUS currently offers output sample rates from 768kHz to 44.1kHz.

References

[1] J. R. Stuart and P. G. Craven, “A Hierarchical Approach for Audio Capture, Archive and Distribution,” J. Audio Eng. Soc., Vol. 67, (May 2019). Open access: https://aes2.org/publications/elibrary-page/?id=20456

[2] J.R. Stuart, and P. G. Craven, “The Gentle Art of Dithering,” J. Audio Eng. Soc., vol. 67, no. 5, pp. 278-299, (May 2019.). Open access: https://aes2.org/publications/elibrary-page/?id=20457

[3] P.G. Craven, and J. R. Stuart, “Improved Analogue-to-Digital converter for High-Quality Audio”, Paper #267, AES 157 Convention, (New York Oct 2024), Open Access: https://aes2.org/publications/elibrary-page/?id=22725

[4] P. L. Dragotti, M. Vetterli, and T. Blu, “Sampling Signals with Finite Rate of Innovation,” IEEE Trans.Sig. Proc., vol. 50, no. 6, pp. 1417–1428 (May 2007).

[5] Stuart, J.R. ‘Coding for High-resolution Audio Systems’, J. Audio Eng. Soc., Vol. 52, No. 3 (March 2004) https://aes2.org/publications/elibrary-page/?id=12986

[6] Lenbrook Media Group ‘MQA Labs/QRONO Digital Whitepaper’, (Dec 2024) https://mqalabs.com/wp-content/uploads/2024/12/MQA-Labs-QRONO-White-Paper_updated.pdf

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