dCS Insights & Innovation

dCS | VARÈSE

New Technologies & Innovations

Varèse: Our Most Ambitious Undertaking...

Varèse is the most advanced dCS system to date. Here, we explain how our engineers set new standards in measured and sonic performance, developing new technologies, protocols and platforms to bring listeners an even more profound musical experience...

Varèse builds on a long tradition of innovation at dCS. It is the most advanced, best-performing system we've ever created, and sets new benchmarks in a range of key areas, from noise floor to jitter performance.

Our most ambitious undertaking yet, it reflects our dedication to preserving the integrity of musical signals at all stages of the signal path – and the extreme lengths we go to in order to achieve this. It is the culmination of several multi-year development projects, undertaken with a single aim: to further enhance the musical experience we provide, and bring listeners an even deeper connection with the music they love.

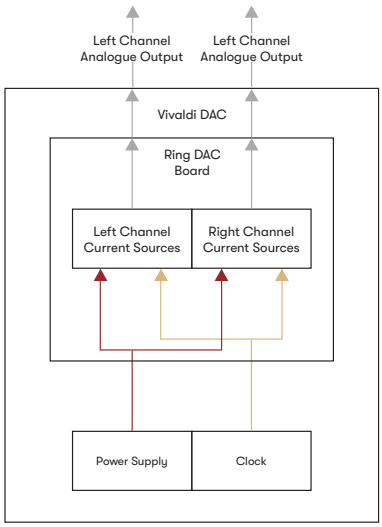
Here, we provide a more detailed look at the new innovations and technologies Varèse presents, explaining how our engineers were able to exceed the capabilities of existing products and platforms and once again advance the state-of-the-art in digital audio.

A New Architecture: The Varèse Mono DACs

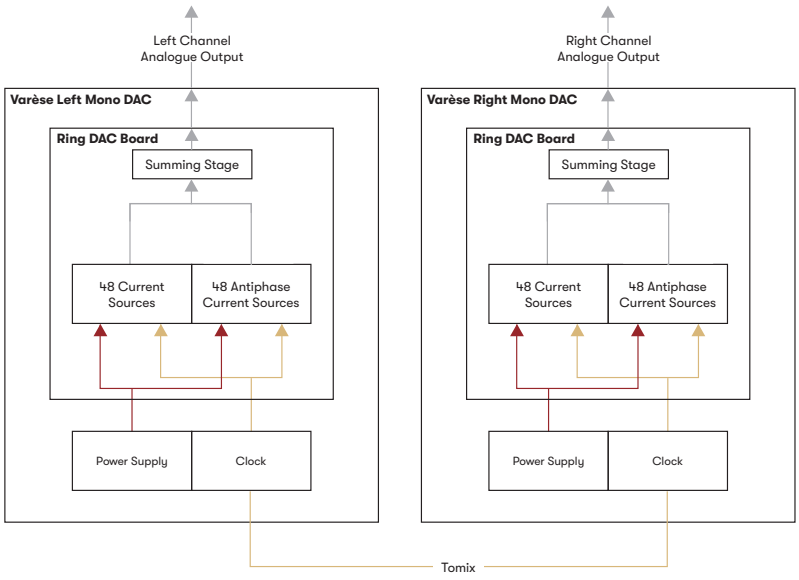
All current dCS DACs – including APEX models – feature 96 current sources: 48 for the left channel and another 48 for the right. Each current source generates an equal amount of voltage and is operated to distribute any component errors (tolerances in resistor values) in the current sources as random noise instead of harmonic distortion. The current sources are located on a single Ring DAC board within the DAC, with the left and right channels separated on the board.

With Varèse, the left and right channels have been separated into 'Mono DACs', with an entire DAC unit for each audio channel. This allows for several significant improvements to be made. Some are general engineering improvements. Others are advances made possible with the development of new proprietary technologies.

Vivaldi DAC



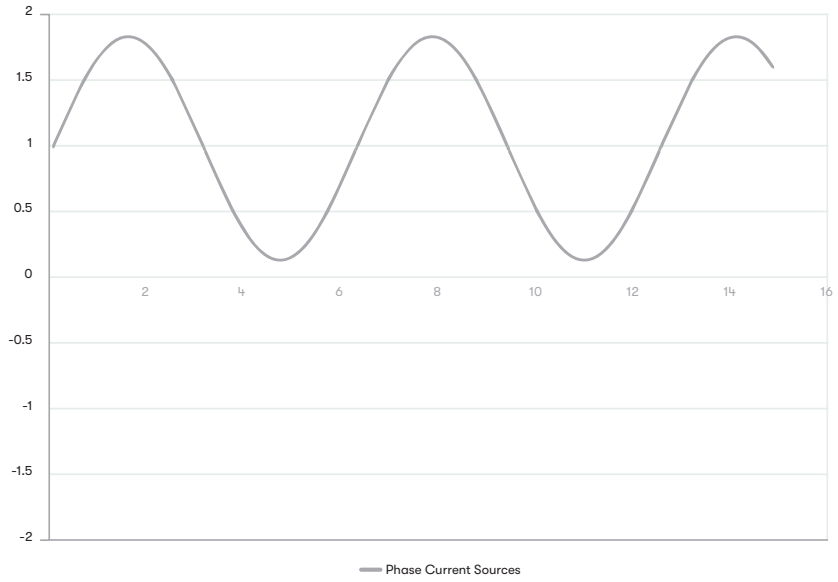
Varèse Mono DACs



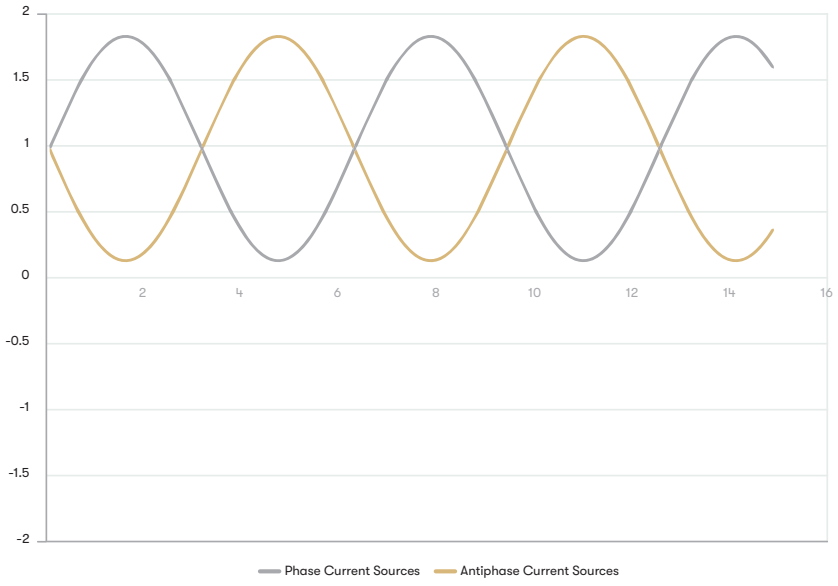
Each Varèse Mono DAC features 96 current sources. This means there are now twice as many current sources for each audio channel. These current sources are fed a 5-bit PCM signal synchronously modulated to either 5.644MHz or 6.144MHz, depending on the source content's sample rate.

The Differential Ring DAC: Overview

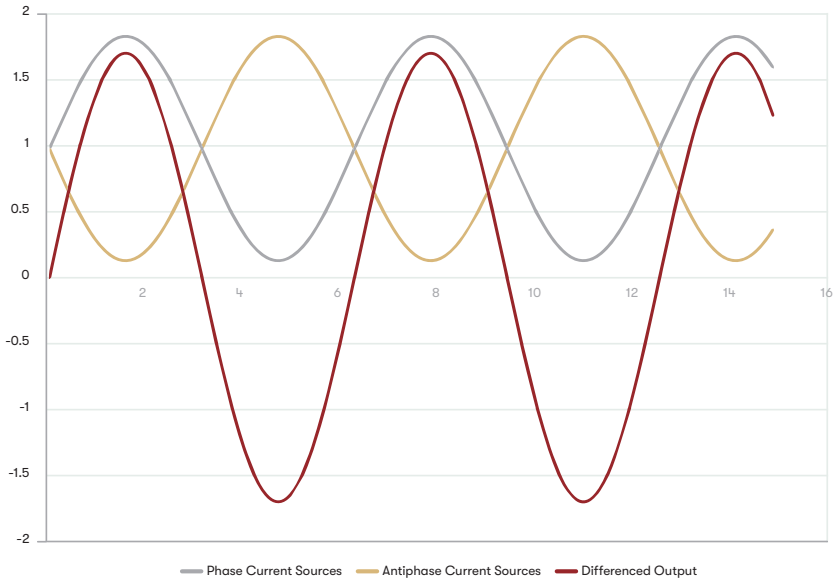
The Ring DACs in Varèse are run in a differential architecture. The 96 current sources on the Ring DAC board are split into two groups of 48, with one group reproducing the musical signal in the correct phase and the other reproducing the signal in antiphase. The outputs of these two sets of current sources is differenced, meaning the phase of the antiphase current sources is reversed and summed together with the correct phase current sources.



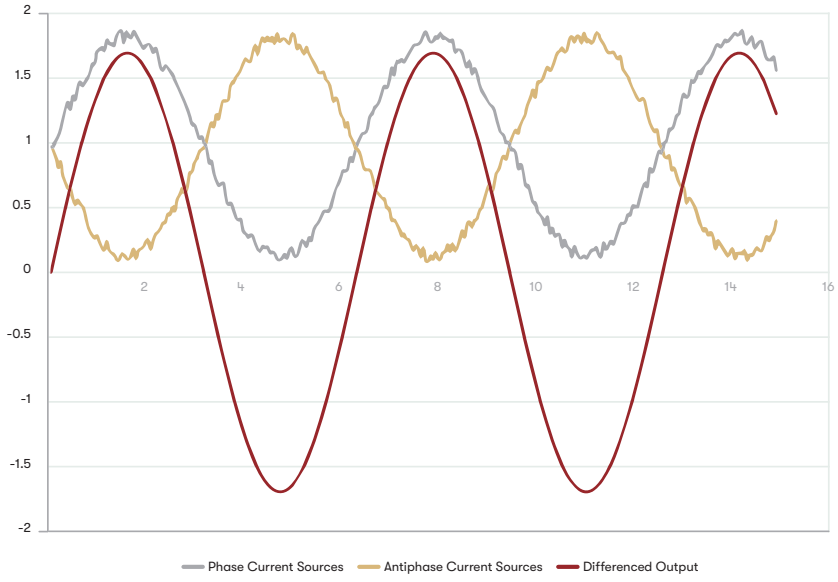
One set of 48 current sources generates the analogue signal in the correct phase.



The second set of 48 current sources generates the same analogue signal, but in antiphase.



The output of these two sets of current sources is differenced, resulting in the correct phase signal at twice the amplitude with no DC offset.



The differential operation means any noise or nonlinearities created in the Ring DAC are effectively removed from the output.

Differential Ring DAC Advantages & Benefits

Running the Ring DAC in this differential manner brings several benefits:

- **Balances draw on reference supply***

  *The reference supply is the voltage which is fed to the current sources. This gets multiplied up by however many current sources are switched on. Anything other than clean DC being fed to the current sources is also multiplied up – where the correct phase side of the Ring is at a higher voltage, the antiphase side is at a lower voltage. This means that the draw on the reference supply is not signal dependent, as both sets of current sources are working in a complementary manner. This removes a mechanism for second harmonic generation within the Ring DAC, improving distortion performance.

- **Equalises the offsets on each summing node, eliminating the need for explicit DC offset correction and improves the symmetry of the summing / filter circuit**

All processing and analogue functions within each Varèse Mono DAC are carried out on a single board rather than multiple boards connected together.

This enables us to improve on several design aspects and ensure an even more consistent performance. This approach builds on the single-circuit design first seen in the dCS Lina Network DAC – a design that came out of early Varèse research and development work.

Running dual Mono DACs, each with a dedicated Differential Ring DAC architecture, has enabled us to **further reduce distortion while simultaneously lowering noise floor by 5dB**, setting a new reference in measured performance and building on the exceptional capabilities of the Ring DAC APEX – another innovation that stemmed from development work on Varèse.

Hardware Innovations

In addition to developing a new DAC architecture, dCS engineers have made a range of improvements to our DAC hardware to further improve performance and ensure ultimate audio quality.

These include:
- Enhanced Power Supplies
- Optimised Transformers
- Improved Secondary Circuits
- New Regulator Topology
- Additional Regulation for Analogue Supplies

Enhanced Power Supplies

The Ring DAC is, by definition, a multiplying DAC. It takes a reference voltage fed to all current sources and multiplies it by a code – the digital audio sample, fed through the Mapper, which dictates which current sources need to be turned on at any given time to generate the correct voltage at the DAC's output.

If the reference voltage fed to the current sources varies from a perfectly clean DC voltage – for example if there is interference on the reference voltage – this interference or variance is multiplied up at the output by however many current sources are turned on at that time. This means the reference voltage inside of the DAC is critical to system performance.

It's impossible to isolate power supplies from the effects of the circuitry they are driving, and this means there will always be some risk of minor variances or fluctuations. This might not be noticeable in lesser-quality products, but with an architecture as revealing and transparent as the Ring DAC, every detail matters. Each aspect of a product must be of the highest quality if we are to ensure the best overall system performance, and this includes power supplies.

In a stereo Ring DAC configuration such as those found in other dCS DACs, the current sources for the left and right channels will mostly be reproducing different signals. The exception to this is mono recordings, where the left and right channels are identical.

This means that, when comparing the left and right channel current sources, different numbers of current sources will be being turned on and off and at different times. When current sources turn on and off, their impedance with respect to the reference supply changes, which can cause a rippling effect on the reference supply. This gets multiplied up through all active current sources, impacting the sound quality of the system.

The Ring DAC APEX improved upon this by making the system more resistant to these interactions between current source switching and the reference supply. This was achieved through lowering the impedance of the signal path that feeds the reference supply to the Ring DAC current sources.

> "Varèse is the most challenging undertaking of our careers in audio. We set out to redefine state-of-the-art whilst at the same time creating an entirely new and immersive user experience. We knew we had to embrace a singular vision, and be brave and relentless in our pursuit of this, to bring listeners a system that is measurably and demonstrably special."
>
> **David Steven,** Managing Director at dCS

With the Varèse Differential Ring DAC design, the correct phase and antiphase current sources operate identically (in signal terms). Both sets of current sources reproduce the same musical signal, with one set phase inverted. As noted, the draw on the reference voltage is equalised across the two. This means the reference voltage remains much more stable in operation, which for a multiplying DAC like the Ring DAC, has huge implications for musical performance.

Additional Improvements

Optimised transformers: The Rossini and Vivaldi DACs feature twin mains transformers, with the analogue and digital elements of the DAC each being fed from a separate transformer, improving performance. The Varèse Mono DACs also feature twin transformers, but each transformer in the Varèse Mono DACs has been specifically optimised for its use in either an analogue or a digital power supply. This improves both analogue and digital performance.

Improved secondary circuits: The power supply secondary circuits have been redesigned to reduce magnetostriction in the transformer core and thereby reduce the mechanical hum the transformers create. Whilst transformer hum is not generally speaking an issue in dCS products, anything that can be done to further reduce the risk of noise or mechanical vibration within a system is beneficial from a performance standpoint.

New regulator topology: The power supply regulators feature a new topology, with power sequencing achieved through a power management IC for tighter and more flexible control of supply activation and deactivation.

Additional regulation for analogue supplies: An additional level of regulation has been provided for the analogue supplies for the balanced output stage to further reduce common mode noise on that output, improving analogue performance.

Supporting DAC performance with the Varèse Core

In tandem with developing our first Mono DACs, we have created a new component – the Varèse Core – to support our goal of further elevating DAC performance.

Other dCS multi-component systems such as the Vivaldi feature a dedicated Upsampler - a unit external to the DAC which carries out a large portion of the digital-to-digital conversions, filtering and DSP required as part of the oversampling process. This configuration was informed by our experience developing professional audio equipment, where we discovered that offloading a large amount of this processing to an external unit separate from the DAC provided a significant lift in performance.

In the Varèse Music System, the majority of DSP is carried out by the Varèse Core. This means the FPGAs inside the DACs have less work to do with fewer operations running on them. This, in turn, means there are less micro-drains on the power supply, further improving the performance of each Mono DAC.

The Varèse Core takes any incoming PCM source material and oversamples it to 705.6 or 768kS/s, digitally filtering the signal to remove Nyquist images. The listener can then select an optional DSD mode when playing PCM source material. This mode converts this signal to DSD (from standard DSD/64 up to DSD/512). The oversampled, filtered digital audio signal is then sent to the Mono DACs via ACTUS, where it is modulated to the 5-bit ~6MHz signal that is fed to the Ring DAC.

dCS ACTUS: A Unified Interface

Along with the new DAC architecture noted above, and the addition of the Core, dCS Varèse presents a radical new approach to sending audio, control and timing signals between components. Our engineers have developed a new protocol that has enabled us to simplify system setup and control whilst ensuring listeners experience the best possible sound quality...

In an ideal music system, each component should be able to communicate with all others in the system, allowing important information and commands to be sent between them - allowing the system to behave as one.

With Vivaldi, this is accomplished through a 3-way RS232 interconnect and through Dual AES connections. By utilising the RS232 connection and sending tunnel commands embedded within the Dual AES connections from DAC to Upsampler and Transport to Upsampler, the Vivaldi system is able to have seamless control of settings of each unit, volume control, source changes, and so forth. Audio is sent synchronously via Dual AES. These connections mean a Vivaldi DAC, Clock and Upsampler require 3 AES cables, 4 BNC cables and an RS232 cable to connect together for audio, control and timing signals.

In the Varèse system, this is achieved through a bespoke interface, dCS **ACTUS** (**A**udio **C**ontrol and **T**iming **U**nified **S**ystem). ACTUS comprises of a combination of proprietary dCS hardware and software. It allows components to be connected with a single cable running from each unit to the Core. The interface includes asynchronous and error-corrected digital audio, control signals, and a master clock signal sent via our proprietary dCS Tomix technology.

The connector used on the cable and Varèse units is bespoke to dCS. As no existing cable or connector met our requirements for crosstalk between connector pins, shielding between cable cores, maximum lengths of cable run and ease of connectivity, we decided to create our own solution.

The connector is keyed, meaning it can only be inserted the correct way. The cable itself is non-directional and can be used anywhere in the system, meaning the same cable can be swapped between the Varèse User Interface and Core, to the Core and a Mono DAC. This makes setting up a Varèse system incredibly simple. The only specific requirement regarding cables is that the Varèse Master Clock must be connected to the Core via the port labelled 'Clock'.

The ACTUS cable consists of six twisted pairs of copper cable, carrying out the following duties:

- 1 twisted pair carries the 44.1k Tomix signal
- 1 twisted pair carries the 48k Tomix signal
- 4 twisted pairs form a high-bandwidth link

The high-bandwidth link connects each Varèse unit to the Varèse Core. This allows the system to have complete control, allowing for information, settings changes, and other control information to be sent seamlessly between units with no need for additional control interfaces such as RS232. This level of control is very useful for system fault finding. The system can intelligently inform the user that the Left Mono DAC is not corrected, for example, or that the Clock has been connected to the wrong ACTUS port on the Core.

The link is also responsible for transmitting audio between Varèse units. Instead of using a synchronous interface such as AES3 or S/PDIF, ACTUS sends the audio via an asynchronous error corrected interface, meaning there is no possibility of timing or data integrity errors. ACTUS does not use established industry standards for sending audio over IP, such as AES67 – the reasons for this are detailed further on in this document.

Mono DAC Clocking: Challenges & Solutions

Operating Mono DACs brings a unique challenge when it comes to clocking. In a traditional digital audio system with a stereo DAC, the DAC has circuitry inside which generates a clock signal. This clock signal is fed to both the left and right DAC channels simultaneously, meaning both channels convert the digital audio sample to an analogue voltage at the same time. In a Mono DAC configuration, we have two dedicated DACs, each with their own casework, power supply, DAC circuitry, and clock circuitry.

With mono DACs, the two DACs must convert the audio samples at the same time. If the DACs convert the samples for the left and right channels at different times, there will be a significant and unacceptable drop in the audio quality, due to a time delay between the left and right audio channels.

When running Mono DACs, we must therefore ensure that the rising edges in each DAC's clock signal are aligned (the term rising edges refers to the change in the square wave that constitutes the clock signal, where the voltage changes from a low state such as 0V to a high state such as 5V). Ensuring these rising edges are aligned is vital if we wish to ensure that audio samples are converted at the right time.

> "We're always looking at ways we can further improve performance, but it's not always possible to deliver these with existing hardware. Some of the implementations that have come out of this - ACTUS, Tomix and the Differential Ring DAC – are some of our most complex innovations to date. I'm really pleased to be able to offer these developments and so much more with Varèse."
>
> **Chris Hales,** Product Development Director, dCS

This alone does not guarantee perfect synchronisation. Even if the two clock signals across the left and right DACs have perfectly aligned rising edges, the left DAC could still be for example running one sample ahead of the right DAC. In this case, the DACs are converting samples at the same time, but they are not each converting the same sample. Again, this would harm the sound quality of the system. The two DACs therefore must be tightly aligned when it comes to clocking, with both clocks generating a rising edge that is at the same time and converting the same sample with this synchronised clock signal.

When developing Varèse we explored several existing solutions in our efforts to address this problem. We investigated using traditional interfaces such as an AES or SPDIF signal. However, these interfaces did not have the bandwidth required to work in the way Varèse needs. They also created a higher radiated power (electromagnetic energy radiated from the ACTUS cable when the signal is sent through it) than we deemed appropriate, which risked introducing electromagnetic interference into receiver devices such as the Varèse Mono DACs.

We also looked into using established Audio over IP interfaces such as AES67. While AES67 does have the bandwidth required and does address the issue of synchronising the left and right DACs, this interface reconstructs its clock from a network clock. This is far less optimal than using a clock signal generated by audio-rate quartz crystal oscillators situated inside the DAC itself.

After exploring all available options, we opted instead to develop a unique solution that would allow us to tightly synchronise the clocks of two separate products, while utilising the local high quality VCXO based clock circuitry inside each DAC to control the respective Ring DAC circuitry. The solution we developed is dCS Tomix.

dCS Tomix: A novel approach to Mono DAC synchronisation

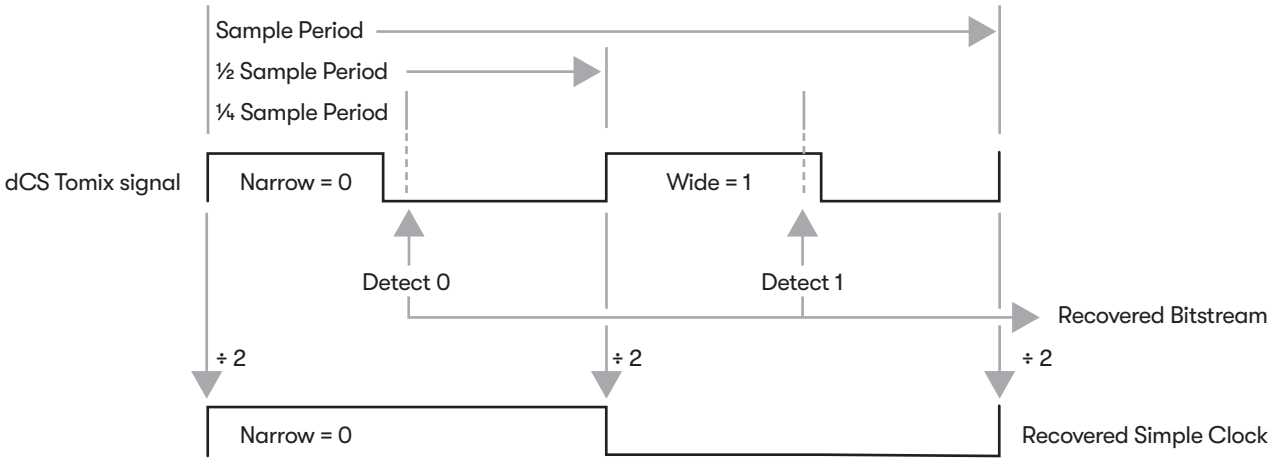
Tomix is a new approach to clock synchronisation within a Mono DAC configuration, which allows us to harness the benefits of Mono DACs whilst maintaining the highest degree of clocking accuracy.

Here, the Varèse Core acts in much the same way as a Master Clock would in a traditional audio system. It feeds a clock signal to each Mono DAC, ensuring the DACs clocks run at the same rate on average. However, this in itself does not solve the problem of ensuring the DACs work in perfect lockstep when converting samples.

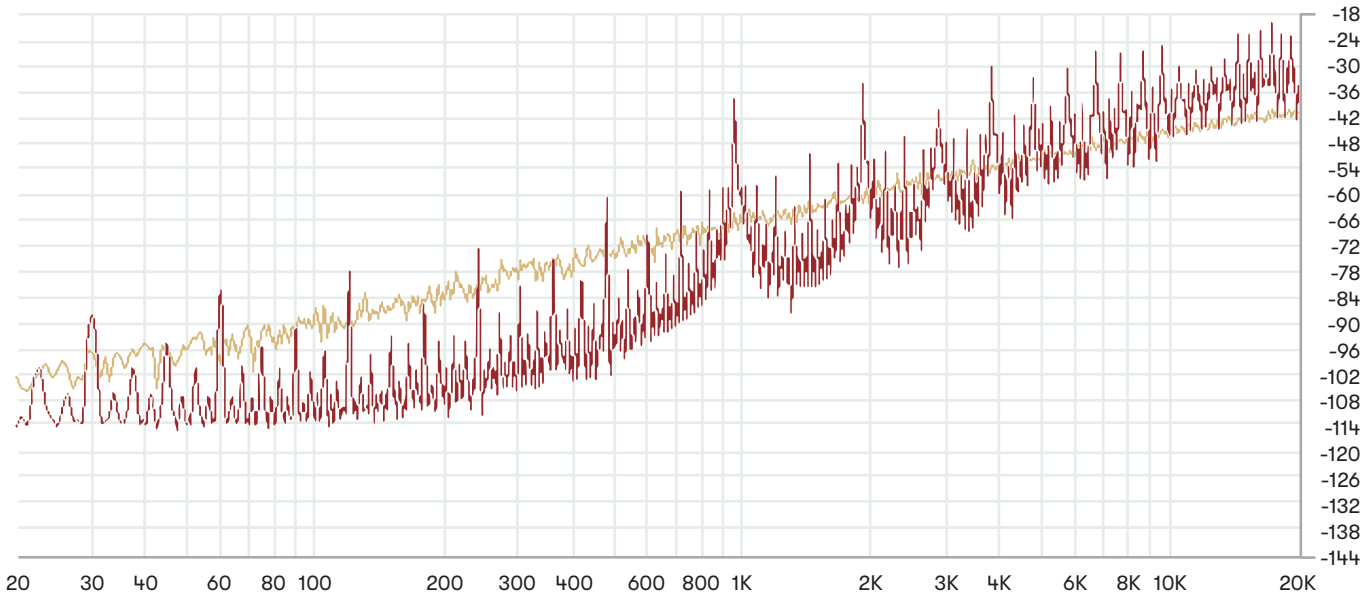
The Core is the hub of the Varèse system, and any audio and clock signals always go through it – no matter the source, system configuration and settings. The Core adds a time stamp to each audio sample before sending the sample to the Varèse Mono DACs via ACTUS. When the sample arrives at the DACs, the FPGA in each DAC is presented with the timestamp. Each DAC then knows exactly when the sample was sent, but it also needs to know exactly what time it is currently to ensure it converts the sample to analogue at the correct time. This is where Tomix comes in.

As previously discussed, it is not sufficient to simply have the rising edges of the clock signal fed from the Processor to the DACs line up; the DACs have to utilise the **same** rising edge. To achieve this, Tomix is deterministic in time: the clock signal is itself timestamped. This timestamp allows the DACs to agree upon an overall system latency, so that their outputs can be lined up.

The method through which the clock signal is timestamped is critical to audio performance. The DACs need to be able to perfectly recover the original clock signal, to also recover the timestamp information, and to do so without introducing detrimental levels of noise or interference to the DAC. The Tomix signal is either generated by the Varèse Master Clock, or the Varèse Core if there is no Master Clock in use.



With Tomix, the base frequency of the clock signal is doubled – so an example clock signal of 44.1k would be doubled to 88.2k. The rising edges of the Tomix clock signal are not changed, as these are what the DACs will use for clock recovery. The falling edges of the Tomix clock signal are encoded with the timestamp information. This is done by either narrowing or widening the pulse width of the signal, bringing the falling edge of the Tomix signal before or after the detection point (the same frequency as the Tomix signal but out of phase by 180 degrees). If the falling edge is before the detection point, the DAC will recover a 0 from the Tomix signal. If the falling edge is after the detection point, the DAC will recover a 1 from the Tomix signal.



The recovered bitstream is used by the DAC to timestamp the recovered clock signal, allowing the DACs to tightly synchronise. Simply sending the timestamp information encoded onto the clock signal would introduce patterns and correlations in the data, which would mean the electrical noise created by the Tomix signal would become problematic in the DACs.

The above graph shows two traces. The red is the noise created by the Tomix clock signal if the timestamp data is simply a linear counter encoded onto the rising edges as described above. For example, rising edges would be timestamped with 1, 2, 3, 4 and so on. The gold trace shows the noise created when the timestamp data is instead a counter based on the type of counter used in Tomix.

The above graph cannot fully show the audible impacts of these effects. But it does show how the linear counter (the red trace) produces a series of discrete frequency components, which are above the gold trace for much of the audible band and not behaving like random noise. This would therefore interfere with the audio circuitry within the Varèse Mono DAC, degrading performance.

The number generator needs to have a carefully controlled frequency spectrum with no discrete frequency components within the audio band, whist still being able to carry the deterministic timing data. For this purpose, a specialised counter is used in Tomix. It generates a data stream which is repeatable in so much as it has a finite number of outputs and when these have all been run through it will restart, but the data is random enough that the resultant noise is decorrelated and spread in a linear fashion, compared to the periodic noise produced by a linear counter.

The result of this is that Tomix, a patented dCS technology, allows the Varèse Mono DACs to have tightly synchronised clocks, ensuring the Mono Ring DACs convert the left and right channels of the same audio samples at exactly the same time. This happens while still using the dedicated clock circuitry inside each Mono DAC to control the respective Ring DAC circuitry. Tomix enables the Varèse system to utilise Mono DACs while maintaining the dCS signature high clocking performance and maintaining excellent time-alignment between channels.

"I've been at dCS for over 30 years .... I think it's fair to say that Varèse is the most complicated and challenging project I've been involved in, but I can't begin to tell you how proud I am of the team and the system they have created."

Andy McHarg, Technical Director – dCS

dCS Insights & Innovation

dCS Varèse New Features, Innovations & Technologies

dcsaudio.com | **@dCSonlythemusic** | **info@dcsaudio.com**

Data Conversion Systems Ltd.
Unit 1, Buckingway Business Park, Anderson Road,
Swavesey, Cambridge, CB24 4AE, UK

dCS
ONLY THE MUSIC