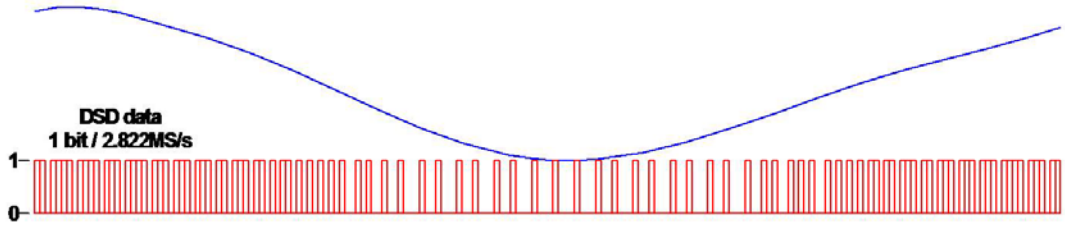
Playback of DSD Audio over USB – A Suggested Open Standard

The purpose of this paper is to present the dCS solution to achieving high quality playback of DSD audio over USB. It is our goal to develop an open standard that any audio playback software developer or DAC manufacturer can implement and this paper highlights the technical challenges the solution overcomes and how the solution should be implemented.

Direct Stream Digital – An Overview

DSD is the abbreviation for **Direct Stream Digital**, this is the data format used for Super Audio CDs (SACDs). DSD is a stream of 1-bit audio data at 2.822MS/s, with one stream for each channel.

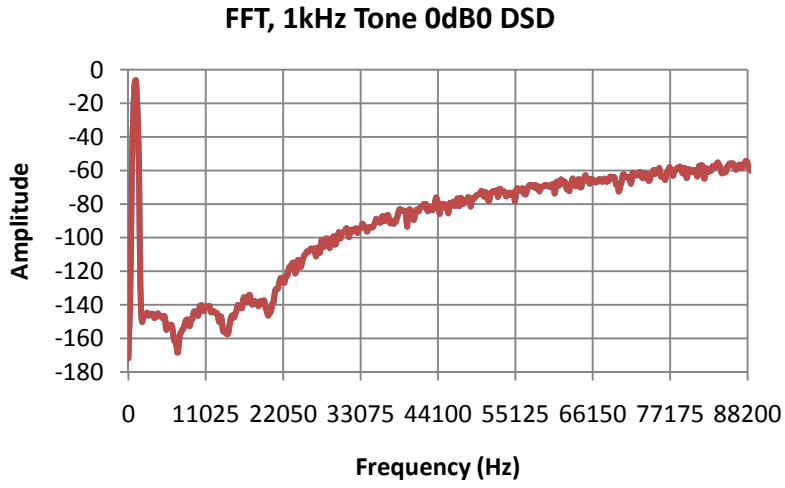
From a technical perspective DSD data gives you 24 bit performance in the audio band and an extended high frequency response that rolls off gently. This helps preserve clean transients and results in the huge improvement in musicality that DSD offers over regular Redbook CD. With DSD, a signal peak is represented by a high density of pulses, while a signal trough is represented by a low density of pulses, see Fig. 1 below:



[Figure 1 – DSD stream in red, original analogue signal in blue]

DSD being 1-bit data it has only 2 states: 0 or 1. Although the data is very crude, the sample rate of DSD data is huge – 64 times that of CD data.

In such simple data, the noise level is even higher than the full-scale signal level. Aggressive Noise Shaping is used to overcome this and give a clean audio band, at the expense of a large bulge in the noise level above 20 kHz (see Fig. 2). However, this noise cannot be heard, provided the processing makes it sufficiently random.



[Figure 2 – DSD spectrum]

DSD Playback

There remains a plethora of wonderful SACD recordings, especially in the classical genre. The sound quality of the majority of these works is far superior to their Red Book counterpart. Unfortunately, the SACD format is in decline for a number of commercial rather than technical reasons.

dCS has a history of innovation and world firsts in the audio world, we have pioneered the development and implementation of high resolution sample rates including the world's first 24/96 and 24/192 A-D and D-A Converters. dCS were also part of the working group that invented the DSD format, we supplied PCM to DSD converters to both Sony and Philips to help them develop the original SACD technology.

As well as a large catalogue of SACD material available on silver disc there exists a number of native DSD recordings, typically in the .DFF and .DST file format.

With the steady advances being made in computer audio playback, an opportunity exists to **develop and implement an open standard for the transmission and playback of DSD files from computer to DAC via USB.**

Technical Challenges

The technical challenges to this project were numerous.

- There are no open interfaces for allowing the streaming of DSD source material
- No USB class supporting DSD currently exists
- No operating system support for playing back DSD exists
- As DSD is fundamentally different from PCM, utilising an existing interface has dangers if the wrong mode can be selected by the user (for example this could result in high-level wideband noise)
- Any solution needs to ensure easy implementation for playback software developers
- Any solution should ensure there is no need for special drivers (other than USB audio class 2)
- Most importantly the solution must ensure that playback quality is of the highest standard

Solution

Working together with Amarra (Sonic Studio) and Pure Music (Channel D), the dCS team specified a method of packaging the DSD data so that any DAC with 24/176.4 capability could in principle be modified to accept it.

The solution is based around the fact that DSD has a sample rate 64 times that of CD, but each sample is 16 times smaller, giving a data rate of 4 times CD, which may be packed into 16/176.4. This means that we can utilise a "standard" PCM sample rate of 176.4k, and if each sample is 24 bit wide, then we can utilise 16 bits for the raw DSD, and another 8 bits to allow the receiving DAC to establish that it is receiving DSD rather than PCM, as follows:

23			Marker				16	15		DSD Data	0
1	0	1	0	1	0	1	0	L_n	L_{n+1}	...	L_{n+15}
1	0	1	0	1	0	1	0	R_n	R_{n+1}	...	R_{n+15}

[Figure 3 – DSD packing structure]

As you can see, the top 8 bits of each sample are 0xAA. This represents a negative DC offset, which won't be seen in real-life audio, so we can use it as an indicator for the DAC that the data it is receiving is DSD rather than 24/176.4 PCM. Additionally, it means that if we try and play the DSD stream via a DAC that doesn't support it, the output is noise, but it is 48dB down - the user can tell they are playing back an unsupported format, but not in a speaker-destroying way. For PC-audio based solutions, if the playback software is DSD-aware, it can output 0xAAAAAA samples by default to represent a safe DSD mute.

The first dCS product to be modified to accept DSD over USB is the Debussy DAC. To modify the DAC, we leveraged the inherent flexibility in the dCS Signal Processing architecture, by modifying the FPGA that deals with signal processing to look out for the special indicator samples. When these are detected, the samples are unpacked into native DSD, and fed into the DSD processing block that Debussy shares with the other DSD-capable dCS DACs.

This briefing was prepared by the dCS Research & Development Team. It is targeted at engineers developing audio playback software or D-A converters. Any detailed technical questions should be forwarded to dCS at info@dcsltd.co.uk