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White paper on DSD – the SACD's audio coding

Some information on the DSD format – properties, caveats, uses

The DSD (Direct Stream Digital) Audio format is used with the well-known SACD disc. The SACD has some form of copy protection implemented, thus an SACD is not easily rip-able into a computer file.

Quantizing

DSD is a digital signal which uses a 1 bit quantization of the audio signal at a sampling rate of 64 times the sampling rate of a CD (64 x 44100 = 2.8224 MHz). The CD format uses a 16 Bit quantization at a 44.1 kHz sampling rate, thus the data rate of a DSD signal is 4 times the data rate of a CD, which gives the SACD the potential to represent the audio signal more precisely.

The noise floor of a signal at 44.1kHz /16 Bit is about 16 x 6 = 96dB below full scale. With the DSD signal the noise floor is 1 x 6dB below full scale, so obviously there have to be taken some measures to get down the noise floor, else a DSD recording would be very noisy.
Here the high sampling rate of DSD comes in handy. I.e. with special filtering techniques (noise-shaping) it is possible to move the noise in the audio band (0...20kHz) out to higher frequencies above 20kHz. Thus the noise floor in the audio band can be brought down to very low levels (well below the 16 Bit noise floor of a CD) at the cost that the noise is at a fairly high level at frequencies above 20kHz.

Filtering

This high level / high frequency noise has to be suppressed before the signal hits the amplifier and speakers, in order to avoid amplifier misbehaving and/or speaker blow-up. A low pass filter is used to suppress the noise. In a native DSD D/A Converter this low pass filter has to be implemented in the analog domain which can be problematic because the non-linear phase characteristics of such a filter.
Alternatively this filter can be implemented in the digital domain where the DSD signal is converted to PCM (at e.g. 176.4 kHz / 24 Bit) and at the same time gets properly low pass filtered, e.g. with a linear phase filter which is easily achievable in the digital domain.
Very few DSD - D/A chips work on native DSD data. Often the DSD signal gets converted to PCM before conversion. One popular example which does that is the currently very popular DAC chip ES9018.

DSD uses

The DSD format initially was conceived for distribution and archiving. Later on it became more and more popular in music recording with its own set of problems as described below. DSD shows the state of the art of the 90ies. The 1 bit sigma-delta A/D and D/A converters were very popular at that time. Converter techniques have progressed though. Today the modern sigma-delta converters are multi-bit designs with e.g. 6 bits instead of 1 bit. This for good reasons of course, the 1 bit technique has some inherent problems with dithering and idle tones. If the SACD was conceived today, it would use a 6 bit format.

Processing

If a recording made in DSD has to be processed, e.g. the loudness has to be adjusted or some equalizing is required, then the DSD signal has to be converted to PCM in order to be able to do the processing. In the PCM format the signal can be processed, i.e. "produced" as required in order to get a final version. In such a case it does not make sense to do a recording in DSD to start with. A PCM recording at e.g. 88.2kHz / 24 Bit would make much more sense. After the production process the file can always be converted to DSD if required.

What is better?

The discussion whether DSD is better than PCM is moot. DSD is another variant to store music, like PCM, MP3, magnetic tape, vinyl etc. All formats are fine as long as there are people preferring one over the other for whatever reasons. A matter of taste or practical reasons as with MP3 for instance.

The future

Technically speaking, PCM from like 88.2kHz /24 bit up, is definitively better than DSD. There are attempts to enhance DSD by rising the sampling rate from 2.8824 MHz to 5.6448 MHz or even 11.2896 MHz. Some problems of DSD may be reduced with such measures, but the 1 bit quantization problem cannot be eliminated.
With the DSD downloads becoming more and more popular the DSD format is going to stay with us. A niche, but a growing one.

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