

The advantages of DXD for SACD

A new format, DXD (Digital eXtreme Definition for high quality and low noise recording and editing for SACD), has recently been acknowledged by Philips and Sony. DXD was initially developed for Merging's Pyramix DSD workstation and recognised as one of the best formats for DSD source recording. Now that the first A-D and D-A convertors are available for converting direct into DXD, Digital Audio Denmark MD MIKAEL VEST gives a general overview of recording for SACD with an outline of the pros and cons of DXD.

THE SUPER AUDIO CD (SACD) was introduced by Sony and Philips in 2000 as a proposal for a next generation music format providing ultra-high sound quality, as well as multichannel sound, text and graphics, plus backward compatibility with the traditional CD players. The technology has now been adopted and is a reality in all parts of the music production and consumer 'food chain' and you could say that there are now no real obstacles, either commercially or technically, in just releasing music as SACD. Indeed with the large base of surround music systems sold to consumers, and many DVD players being able to play SACD, the multichannel capability of SACD offers a challenge to artists and music producers to move music perception beyond stereo to multichannel making consumers enjoy music even more.

Many existing titles have been remastered to SACD and new original productions are beginning to emerge. This leads to the main topic of this article, which is the actual recording formats for SACD, and in particular the new recording format DXD. But before dwelling on this, it would be in order also to mention DVD-A.

Having two almost similar formats on the market tends to slow down the adaptation of technology, and this has been seen before with VHS and Betamax video tapes. Eventually one or both formats will win. The major value-added difference between SACD and DVD-A is in the copy protection scheme, making SACD a more secure media, but on the other hand more complex to handle in the recording and authoring phase. Sound quality-wise SA-CD has a higher bandwidth enabling a more precise representation of music impulses. The difference is, however, marginal and both formats are far better than CD.

The key advantages of SACD are: efficient copy protection; the media has an optional CD layer for backwards compatibility; the playing time is comparable to conventional CD; stereo and multichannel 5.1 mixes are available on the disk; significantly improved sound quality compared to CD; compatible with analogue recordings archived in DSD.

In terms of technical solutions for music recording studios, manufacturers now offer a variety of equipment suitable for SA-CD production, which can be used with existing equipment. To enable the recording and editing of the highest quality of material, Sony and Philips acknowledged a new editing format called Digital eXtreme Definition (DXD). DXD is a proposal for a 'highest common denominator' format, where the actual editing is not compromised in terms of quality by being limited to a 1-bit DSD signal, which is the format of the final audio of the SACD. A parallel to DXD and DSD in the PCM world is that audio is recorded and processed in 24-bit or more, and in the



mastering process is dithered to 16 bit.

The major points for technical evaluation in terms of defining the overall quality of a SACD recording system/set-up has to be based on technical specifications (i.e. measurements) and perceptual evaluation of sound quality. The primary specifications, apart from the ones normally applying to PCM, are the Pulse response of the recording system, and the out of band noise spectrum of the mastered DSD audio signal.

The audio data format on SACD is called DSD and is a one bit representation of the audio sampled at 64 times the sample frequency of 44.1kHz giving a data rate of 2.8224Mbit/s. This format is called DSD64. When representing the multichannel data the format is also DSD64 but with a lossless coding scheme called DST [1]. The very big advantage of DSD is that the audio bandwidth is equivalent to 2.8224MHz and the pulse response of the digital representation of the signal is not compromised by the conversion process, as is the

case with conventional PCM even up to 192kHz sampling. The noise spectrum of the DSD signal, however, increases above 22kHz because a noise shaping process is used to obtain the dynamic range of 120dB of the primary audio band — 20Hz-20kHz. A double resolution DSD format is also defined where audio is sampled at 128 times the sample frequency giving a data rate of 5.6448Mbit/s. This format is called DSD128. The benefit of the higher sample frequency is that the format will have an out-of-band noise also at the double frequencies i.e. above 44kHz. Due to the double requirement for storing capacity DSD128 is not used directly as a format for the SACD. (For more details on the DSD format refer to [2]). Figure 1 to Figure 3 show the A-D conversion characteristics of the sampling formats DSD64, DSD128, PCM at different sample-rates, and finally DXD.

To set the DXD format in perspective, it is relevant to address the initial motivation for actually defining the DSD format. There are basically two approaches to DSD. One uses DSD only as the actual audio data format on the SACD, while the other uses DSD as an acquisition format i.e. a format in which the initial sampling of the analogue audio is made.

Acquiring audio data in DSD makes sense in some recording applications, but the initial reason for introducing the format was the need for Sony Music to archive numerous analogue tapes in a digital format. For that purpose the DSD data format was used as the — at that point in time — best way of generically representing digital audio data.

This was done by directly storing the 1-bit output of the delta sigma modulator of the A-D convertor. Applying the DSD format as the format of the bit streams on the SACD disc therefore also made sense for publishing the archived stereo material requiring almost no editing, which at that time was also not possible in the 1-bit domain. In other words this makes fine sense when remastering already existing audio material to SACD. However, it is important to realise that recording set-ups are different for a variety of reasons when doing original recordings for SACD production, and another set of tradeoffs have to be made to get the most benefit of the sonic advantage of DSD.

If you investigate the initial technical white papers made by Philips [2], the DSD signal was initially defined as a consumer format for an efficient representation of digital audio data on a SACD.

For recording for SACD production there are currently three different approaches in terms of A-D conversion and the hardware: DSD recording; PCM recording; and DXD recording.

On a DSD recording, the material is converted using a true DSD A-DC providing the DSD64 signal. No editing can be made on the contents, due to the

mathematical nature of the 1-bit signal, without converting the data to an edit format. Normally the recordings are edited and mixed with the signal converted to a PCM-like signal having a higher number of bits than one. This will theoretically involve a noise shaping process, thus introducing some degradation to the pulse response and the noise curve of the signal.

A PCM recording can be made in the usual way, where the material is A-D converted to PCM, recorded and editing at one of the standard sample-rates of 44.1 kHz, 88.2kHz or 176.4kHz followed by an appropriate DSD formatting system. This can use DSD A-D convertors, real-time format conversion software (as a plug-in), or a software 'offline' process.

The DXD recording is based on an A-D convertor directly outputting the DXD audio signal. The advantage of this type of recording is that the DXD signal can be edited directly thus being a higher resolution format than DSD. A benefit of this is that the out-of-band noise level is significantly lower than with the DSD signal. The editing process is relatively insensitive to changes in the dynamic range relations between the recording channels and in the final mixed music.

DXD is acknowledged by Philips and Sony as a high sample rate and multi-bit processing format for recording and editing for SACD productions. DXD is defined as a 24-bit signal sampled at 352.8kHz. The advantage of DXD is that the signal is not limited to a one bit representation like the DSD format. A-D convertors can therefore be used having a higher order delta sigma modulator of 5 bit, for example. Using higher order modulators in fact makes it possible to have a significantly lower level of high frequency noise, thus improving the conversion quality. Since the sample rate of DXD is 8 times 44.1kHz, the signal is easily up-sampled to DSD without any degradation. The data rate for a DXD mono signal is 24bit times 352.8kHz, which is 8467.2MHz, being three times the data rate of the DSD64 signal.

As with any recording system, the sonic quality is the most important parameter and recording engineers and artists will have to decide on the perceptual quality. In terms of technical specifications there are two measurements of particular interest for qualifying the performance of the recording set-up — out of band noise and pulse response.

The following curves are generated from computer models of the different formats, based on the basic theory and actual performance of convertors from Digital Audio Denmark and Merging Technologies [3] [4].

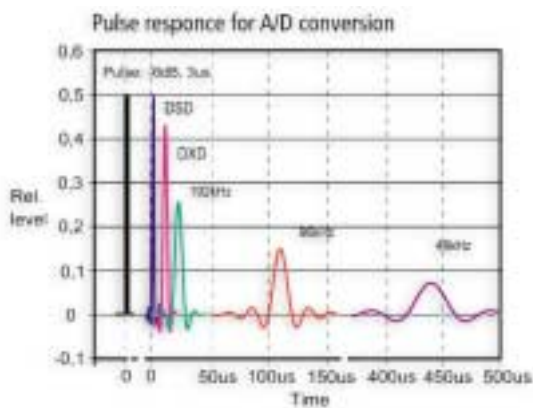


Figure 1 shows the pulse response for the AD conversion, which is a measure of the timing precision of the digital representation of the signal.

Two factors define the pulse response — the roll-off frequency of the sampling filter (anti-alias filter) and the slope of the filter roll-off. A high roll-off frequency gives a high amplitude pulse because of more high frequency content being present. A slow roll-off slope will produce less pre and post ringing of the pulse and thus a more precise time point for the pulse.

Due to its relaxed filter slope and high bandwidth DSD has a perfect pulse transparency. The results are different for the different PCM rates. These have a higher pulse when the sample-frequency increases, but the steep filters needed to comply to Nyquist (i.e. having full attenuation around the half sample frequency) will have the effect of pre and post ringing. At the higher rates a more relaxed approach can be made towards the filter steepness since the risk of having audio contents folded down is very small as the efficient amplitude of the audio is very low at rates beyond 50kHz, for example.

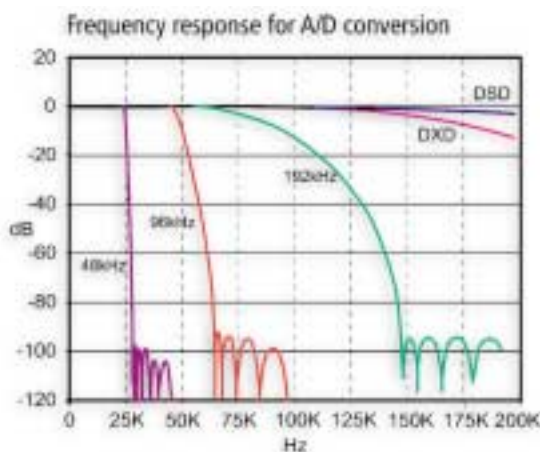


Figure 2 shows the frequency response of the different formats. Figure 3 shows the out of band noise spectrum as an FFT.

This clearly indicates that A-D conversion in DSD at 64fs, has a high noise level that adds up when more channels are recorded and mixed. As can be seen DXD has a lower noise spectrum than DSD, which at 60kHz is 50dB lower.

The Scarlet Book is a set of technical specification for SACD media, the digital audio signal stored on the media, and specifications for the equipment playing the audio and data off the SACD. The Scarlet Book is equivalent to the Red Book specification for CD.

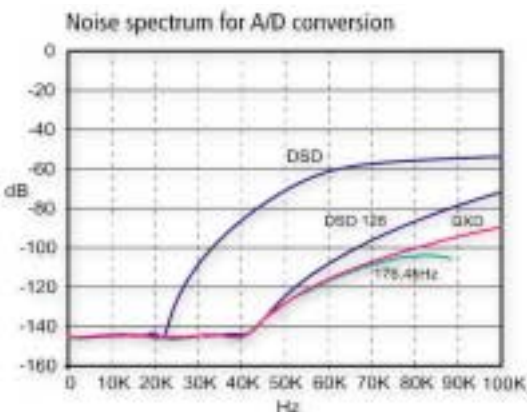


Figure 3. In terms of specifications for the audio signal, a limit is set for the noise spectrum of the DSD signal on the SACD disc. The accumulated RMS noise in the

frequency band between 40kHz and 100kHz with 30dB/oct slopes must not exceed -20dB (SACD level) [5]. This specification is close to what can be achieved by most DSD A-D convertors and therefore very sensitive to any noise deterioration in the editing system. The DSD noise curve in Figure 3 has an RMS noise of -23.5dB.

So how do you make the ideal recording for SACD? Because of the technical aspects of DXD, DXD is the most suited format for recording a signal with the highest quality. Since DXD is a PCM-like signal, editing can be made using conventional lossless digital processing, just operating at 8 times FS. The signal can be converted to DSD for authoring the SACD. DXD can also be converted to the standard PCM rates using sample-rate conversion still maintaining that the final mastering format will set the quality standard for the music production. One drawback of DXD is the high data rate of the signal as it is 8 times FS but with the evolution of workstations this is only a temporary limitation. Today 16 channels of DXD can be recorded and edited [4].

DSD64 is not, on the other hand, so well suited to multichannel recording, because the DSD out-of-band noise will significantly contribute to the overall noise performance of the production, depending on the actual mix and the relationship in terms of dynamic range between the channels. As specified in the Scarlet Book, there is a requirement for the final SACD production to respect the limits for the out-of-band noise. This specification can be difficult to comply with, when noise is adding up from more channels.

Sampling in DSD128 does make a significant improvement in the noise of the recording. However, it is still necessary to format convert the signal just as with DSD64 to do editing and thereby gives a degradation to the overall recording.

A more pragmatic solution would be to record at 88.2kHz PCM if the final mix has to be SACD or 96kHz if it has to be DVD-A. In the case of SACD the PCM mix can be DSD converted in the authoring process. The recording in general will, of course, be limited to the pulse response of 88.2kHz PCM, but on the other hand depending on the actual music being recorded (i.e. the high frequency response of the material) this might not be a real problem. This type of recording will not have problems in complying with the Scarlet Book requirements.

The conclusion is actually very simple. For music recording studios to decide on practical implementations, the DSD, the PCM and the DXD approaches can be used separately or combined. To qualify a SACD recording system, you need to evaluate the system performance in terms of out-of-band noise and pulse response, and the perceptual sound quality.

Various implementations can be made of the basic three SACD recording set-ups, and most of them give very good quality when used correctly. However, DXD should be considered seriously when setting up systems for the absolute highest sound quality. ■

References

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- [3] www.digitalaudio.dk, AXION audio convertor
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