What is S/MUX?

S/MUX is our shorthand for Sample Multiplexing. Multiplexing is the process of combining multiple streams into one stream (in this case, the streams are audio samples). Demultiplexing is the opposite process of splitting a single stream into multiple streams.

The basic idea of S/MUX is to join together multiple audio channels in order to represent a single higher bandwidth channel. Unlike current bit-splitting technology, with S/MUX each sample is contained within one of the 'bonded' channels (*bchans*), not spread out among them. The audio channels joined together thus determine the resolution of the S/MUX channels (*schans*). If they are 24 bits, the S/MUX channels are 24 bits. If they're 20 bits, the S/MUX channels are 20 bits, and so on. All the bonded channels (*bchans*) are of course the same resolution.

This simple idea is made practical through a few conventions:

1. The lowest numbered *bchan* has the earliest-time sample.
2. The next-lowest *bchan* has the next-earliest sample, and so on.
3. The S/MUX channel (*schan*) sample rate is an integer multiple (*N*) of the *bchan* rate (e.g. 2x, 3x, 4x, etc.)
4. The oversampling multiplier *N* is called the *order* of the *schans*, notated S/MUX^N (e.g. S/MUX^2 for a 2x, 48KHz to 96KHz system).
5. The first group of *bchans {1..N}* represent the first *schan*.
6. The second group of *bchans {N+1..2N}* represent the second *schan*, and so on.
7. Though any integer N can be used for the order, powers of two are recommended (2, 4, 8, 16, etc.)
8. No non-audio signaling will be present in the audio streams. Though this means the user (or system) needs to make not of the S/MUX order, it also means maximum possible fidelity (using every bit for audio data) as well as simplicity of implementation.
9. It is possible to use *schans* of different orders simultaneously though care should be taken to avoid confusion.
10. S/MUX compatible systems must not filter the audio in any way. Since each channel only sees a fraction (1/N) of the total *schan* data, any filtering would be invalid (e.g. lowpass, bandpass, highpass filters).
11. Though ADAT lightpipe is the first implementation, the concept is applicable to any digital audio format. In fact, the AES is working on a standard for just such a system using AES/EBU streams.
12. S/MUX is compatible with dithering and gain changes, as long as they are done exactly the same way for each *bchan* in a *schan* group. That is, you can dither or change the gain of the *schan* by applying the processing uniformly to the *bchans.*

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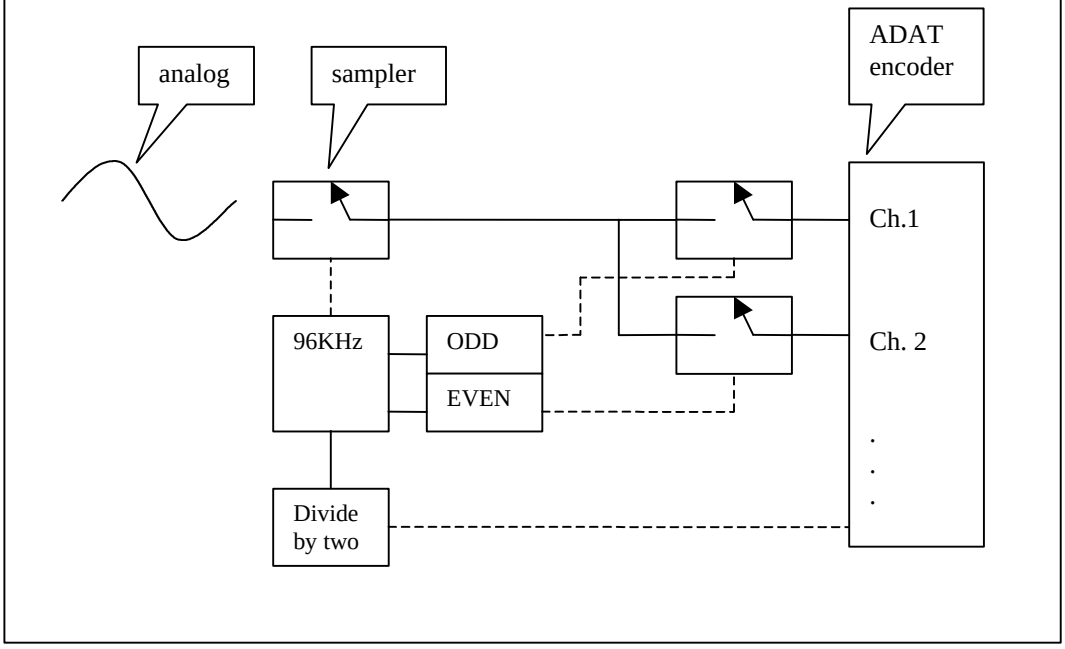
EXAMPLE SYSTEM

The DAW9624™ system recently introduced by Mytek Digital and Sonorus, Inc. is an order two S/MUX system, or S/MUX^2. We will examine the signal flow from analog in to analog out.

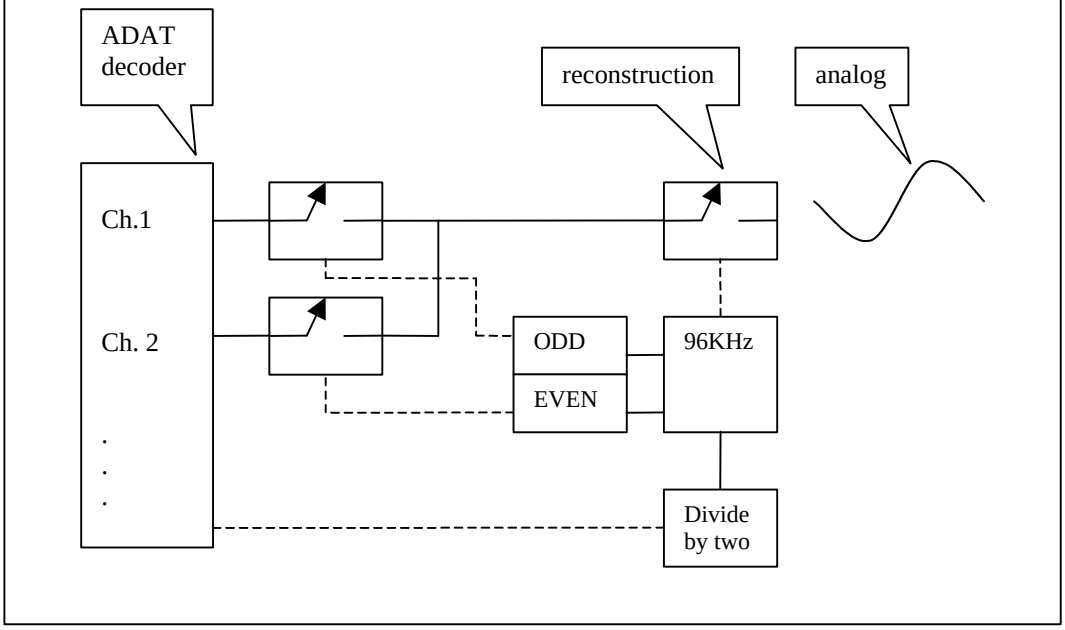
First, A/D conversion takes place at 96KHz sample rate (alternatively the system can receive double-speed AES/EBU digital audio). The 96KHz samples are then demultiplexed onto pairs of channels of two standard ADAT lightpipe outputs (the system handles 8 *schans*, equaling 16 *bchans*). Thus there is the following correspondence between 96KHz *schans* and 48KHz ADAT *bchans*:

Schan	1		2		3		4		5		6		7		8	
Bchan	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
machine	A								B							

S/MUX^2 encoding diagram



S/MUX^2 decoding diagram



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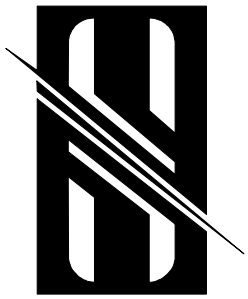

The audio is thus available on two sample-synchronous lightpipes.

At this point, the 96KHz *schans* could be recorded onto standard 16 bit ADATs, 20 bit ADATs, or with translators onto TDIF or DASH machines. Changes in bit depth are handled the same way as any other digital audio system. The DAW9624 front end (AD/9624) has noise-shaped dither, switchable to 16 or 20 bits, which is the optimum way to record at those resolutions. However, the S/MUX format is also compatible with dithering, so for example you could record to a 20-bit ADAT, and then make a 16-bit copy using the ADAT machine's built-in output dither. In fact, you can use digital gain controls as well, as long as each *bchan* in a *schan* group is exactly the same. You could even use a dynamics compressor, as long as it doesn't filter the main audio path! In our S/MUX^2 system, for example, you could use something like the dbx DDP in stereo link mode as a mono 96KHz S/MUX compressor for each channel!

For this example, however, we're going to record the audio at full 24-bit precision into Cubase VST/24. The two lightpipe outputs of the AD/9624 are connected to a STUDI/O card in our G3 Mac. Within Cubase, the 'ASIO-96K' driver is selected. Cubase is then running at 96KHz, oblivious to all the multiplexing and demultiplexing that's going on. You just record as normal, edit, process, etc. Only you're doing it all at 96KHz. And, STUDI/O now appears as an 8 channel, 96KHz audio device instead of the usual 16 channel, 48KHz device.

Inside the ASIO-96K, audio is multiplexed/demultiplexed from 96KHz Cubase buffers to 48KHz ADAT buffers. This process is also called interleaving/deinterleaving. The DSP chip on STUDI/O is designed to perform this type of operation with absolutely no extra overhead, so the driver efficiency is the same as normal – one of the benefits of the simplicity of S/MUX.

In fact, this interleaving/deinterleaving operation is very efficient on the PowerPC and Pentium II as well, meaning just about any audio driver can be adopted to be S/MUX capable.

Back in the real world, its time to play back our new Cubase recording. When this happens, the ASIO-96K driver multiplexes the 96KHz samples onto pairs of ADAT outputs, the exact reverse process of recording. The two lightpipe outputs of STUDI/O are connected to the DA/9624, which is placed in x2 mode, with ADAT as the source. The box re-multiplexes the samples to eight 96KHz streams which go to the 96KHz D/A converters (and double-speed AES/EBU). Out through the magical Mytek analog section, through your favorite power amp, speakers, air, ears, and brain!

Again, the lightpipe outputs can be recorded onto ADATs, etc. and played back later, or re-recorded, edited, etc.

Thus, it's seen that S/MUX provides the capability of high sample rates while maintaining efficiency and easy workflow, as well as allowing the use of standard-sample-rate equipment.