A Matter Of Time
The Audibility Of Clock Jitter
By Dave Hill

In the course of developing gear, one sometimes does experiments that do not work as planned. The resulting issues include why are things working the way they are and why the device or algorithm sounds the way it does. In the process of developing a new Digital to Analog converter(D/A), such questions arose.

The only changes being made at the time that questions were raised about were in the clocking circuits; the analog circuits were not changed.The clock jitter decreased from around 13 ps to about 2 ps.To put picoseconds in prospective, light travels approximately 12 inches in 1000 ps; in 1pS of time, light travels 0.012 inches.

The measurements indicated that the D/A was working correctly. The first listening test did not go as one expected. On the first listen, the old circuit sounded better. After listening for a short time, with one’s ears learning what the sounds are, the observation changed. The old circuit was not warmer; it was muddier, less clear and did not image as well. This raised a large number of questions (some are technical and some have to do with ear training):

- What is the threshold point where lower jitter no longer offers performance improvement?
- What does jitter sound like, can mixes be influenced by a D/A with higher than threshold jitter and how do different frequency ranges of jitter influence performance?
- Can we be fooled into thinking that a device which has poorer performance is the better converter? If so, there is an ear education problem that needs to be addressed.
- What are the limits of technology and the level of audible artifacts?

An experiment was designed that allowed making recordings with jitter that was controlled and repeatable. An important part of the experiment was to be able to record the files so they would, when time aligned and subtracted, result in an audio file in which we can hear only the jittered component. The experiment produced a set of five files (the reference and the files with induced jitter) that can be listened to with the set of four difference-only files.

The test was set up with an Avid Pro Tools system using digital I/O. The D/A used an ASRC to remove any jitter in the audio before feeding it to an A/D and back into Pro Tools.

The A/D was built so that lab equipment could be used as the clock source and this equipment could be frequency modulated to produce jitter. There were a great many problems in making this work, and once the first audio files were recorded and listened to, there was a new problem: If one did not hear what was expected, was the experiment valid? It took a fair amount of time and effort to be able to state that the experiment was valid.

Jitter can be caused by many things in clock circuits. To keep this relatively simple, we are not looking at PLLs used in word clocks and elsewhere—just oscillator circuits, the source of the clock. There are many types of oscillators and a large amount of information on the net, in books and papers that a circuit designer can make use of when developing a clock circuit. Some of the best sources of information come from amateur radio work, and in microwave and space communication. Jitter in clocking is not a new problem; technical information exists showing that since the earliest days of radio and computing circuits, many very good engineers have worked to investigate the sources and effects of jitter.

Looking at all of the data, you learn many things that are surprising. A pendulum clock is more accurate than a quartz watch. It is possible to make a quartz crystal oscillator that will outperform most other types of oscillators, including rubidium and other atomic clocks, for short-term accuracy (and the problem with clocking for audio is short-term accuracy). Rubidium is great if you need to be remain within 10 ps in 10 days—a change that no one could hear.

Digital audio clock variations (jitter) on the order of a few picoseconds or greater in a short time window, like 10 ms or 100 ms, will be audible. The largest cause of jitter is noise, which can affect any clock, no matter the type of clock base (crystal, atomic and so on). Noise increases as frequency goes down, thus LF jitter is the hardest to work with. A common example is power supply noise; in clock generation, power supply noise is more critical than for mic-pres or tape-head playback electronics.

The next problem is turning the oscillator output to a clock waveform; all approaches to this have issues. The basic problem is the need to turn a slow-moving sine wave into a very fast, sharp, vertical-edged square wave. Once we have a square wave clock, the next thing to overcome is jitter induced by logic circuits. Jitter in logic circuits, depending on the type of logic, can be very large. If you are trying to achieve sub-picosecond jitter, there are very few logic choices and the better parts are very power hungry and costly.

If the jitter is low-enough level, it will not be audible, but it is a level versus frequency relationship.

The five jittered audio files have been online since June. The phase-canceled (subtractive) files are now available. Some were played at Audio Days in Paris and the AES Convention in Rome. Listen to the source files to form an opinion first, then listen to the phase-canceled files. Think of what you might feel compelled to do with an EQ to change the sound of the jittered source. What is the result of playback on a very low jitter playback system? The effect of jitter does not sound like what most people think. If one can draw any conclusion from these experiments, it is that we all need ear training when it comes to recognizing new problems; education will help everyone.

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There’s More – Hear the audio files via prosoundnetwork.com/aug2013

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