AudioQuest Technical Paper

Evaluation of Digital Devices

Proper Warm-Up for Ideal Listening and Measurement Evaluations

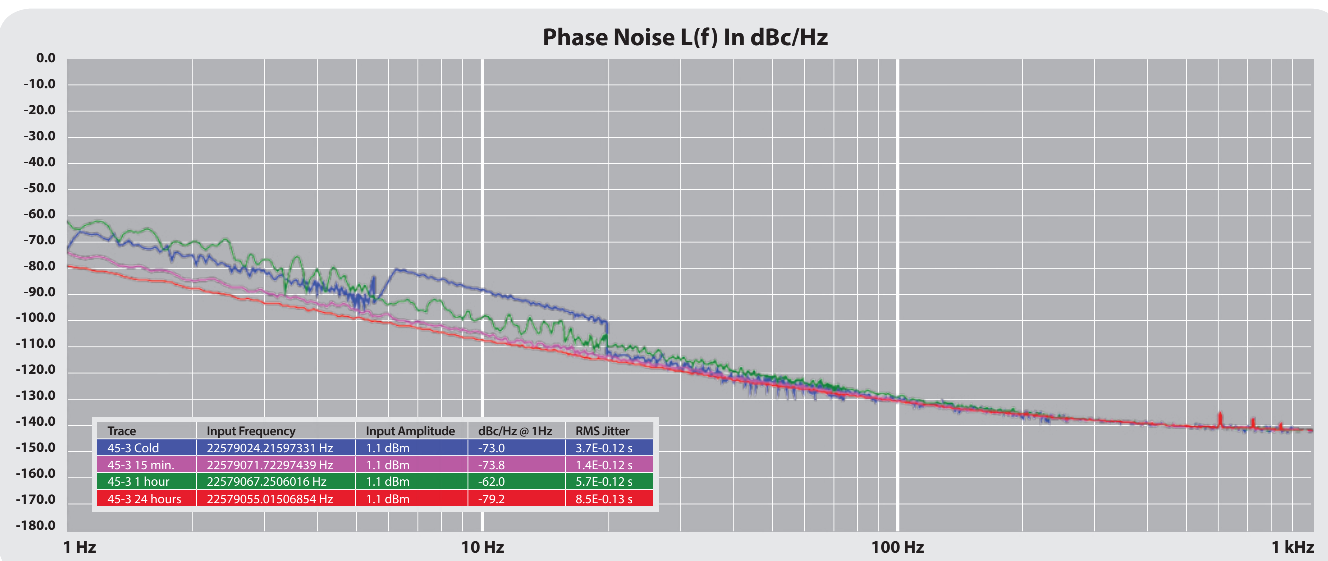
A market that at the end of the last century seemed all but extinct is once again at the conversational forefront. Thanks in part to audiophiles' rapid acceptance of digital music, and in part to the average consumer's increased interest in desktop and computer-based audio, the digital-to-analog converter is once again a significant part of the audio ecology. DACs are definitely back. Along with this welcome return comes the likelihood (among consumers) to purchase, (among dealers) to evaluate, and (among journalists) to review just about every DAC that comes down the pike. As we reestablish our interest in this unique component category, we must also reestablish certain basics of auditioning. One of the most critical aspects in the auditioning of any digital device is ***proper pre-evaluation warm-up***.

The purpose of this paper is to call attention to the changes in audible and measurable performance that occurs to ***any*** DAC over a 24-hour period. Listening to a cold digital device (any DAC that has been unplugged for one hour or more) will significantly shortchange the experience and negatively impact the desired outcome. However, a 24-hour warm-up period can – and most often will – significantly improve DAC performance. Moreover, comparisons between a suitably warm DAC and one that is cold can result in invalid findings.

Phase Noise

In an ideal world, a perfect digital oscillator would generate a pure square wave at its intended frequency, and the signal would have power at only that single frequency. However, in reality, all real-world oscillators are imperfect and have phase-modulated noise which spreads the power into and across various sidebands. This noise can spread across the entire frequency spectrum; it is a significant cause of unwanted jitter. Here's a simple formula, illustrating how phase noise correlates with jitter: ***Jitter = Phase error (degrees) / 360 x Frequency (hertz)*** *(Jitter is a numerical output represented in seconds or, in our case, picoseconds (pS), or xxx E-12.)*

Interestingly, this phase noise is not necessarily constant; phase noise may constitute differing levels of distortion at various frequencies. But the real message of this paper is that phase noise tends to be significantly higher when a DAC is cold; a 24-hour warm-up period significantly reduces phase noise. Additionally, you will see in the following measurements that there can be a period of settling, during which measurable phase noise oscillates up and down before it finally settles to its lowest and most stable level.



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Time Period	Frequency	Phase Noise	Jitter @ 1Hz
Cold	22.579024MHZ	-73dBc	3.7pSeconds
15 min.	22.579071MHZ	-73.8dBc	1.4pSeconds
1 hour	22.579067MHZ	-62.0dBc	5.7pSeconds
24 hours	22.579055MHZ	-79.2dBc	0.85pSeconds

For the purposes of providing valid measurements, a DragonFly DAC was used on a Symetricon Phase Noise Test Device. The Symetricon is one of, if not the most, accurate pieces of test equipment. Tests were run at the following increments:

- Cold/"Zero Minute" (as soon as the DAC was plugged in)
- 15 minutes after plug-in
- 1 hour after plug-in
- 24 hours after plug-in

Cold — At startup, we see at 1Hz, a dBc (decibels relative to the carrier signal) of -73. However, notice the spike from 6Hz to 11Hz. There is a significant rise in phase noise within this range. Also notice how ragged the response is from 1Hz to 100Hz. This volatility will have effects on the DAC chip's ability to recreate an accurate waveform. Jitter is measured at 3.7pSeconds.

15 Minutes — Here we begin to see a slight drop in noise at 1Hz (-.8dBc), as well as a reduction of the cold-related spike (6Hz to 11Hz). Things appear as though they're about to begin tracking nicely. Jitter is measured at 1.4pSeconds.

1 Hour — We begin to see the settling process occur. The measured performance takes a significant turn for the worse. At 1Hz, phase noise has risen by 11dBc. However, the good news is that the initial spike from 6 to 11Hz has not returned. But overall, we are seeing a much noisier signal. Additionally, notice that the response is more ragged than it was when tested in the 15-minute range. This will have a very negative impact on the DAC's ability to output an accurate (and pleasant) musical signal. Jitter has risen significantly to 5.7pSeconds.

24 Hours — At this point and beyond, the DAC appears to have reached a stasis. Notice that the response is now very stable, that there is a smooth line from 1Hz all the way out to 1kHz. At its greatest point, the delta in phase noise has improved by 17.2dBc over the initial cold test. We can now begin to critically listen to this DAC, confident that our findings will be accurate and illuminating. Jitter is dropped and settled at an astonishingly low level of 0.85pSeconds.

Audio-based jitter is most accurately measured from 1Hz to 100Hz range. This is where averaging cannot correct or hide errors as easily as it does at say 1KHz. Ironically, most published jitter measurements are given at this frequency range.

How does a high level of phase noise affect our music? While it's hard to draw a simple conclusion that will apply to all DACs, it's absolutely clear that higher levels of phase noise create higher levels of jitter. And higher levels of jitter correlate to poor sound; the more jitter, the worse the sound.

If you're auditioning a new DAC – whether for personal purchase, store merchandise, or critical review – be patient and give that contestant a day to warm up, so that it can truly strut its stuff.