Introduction to the Six Basic Audio Measurements: Part 2

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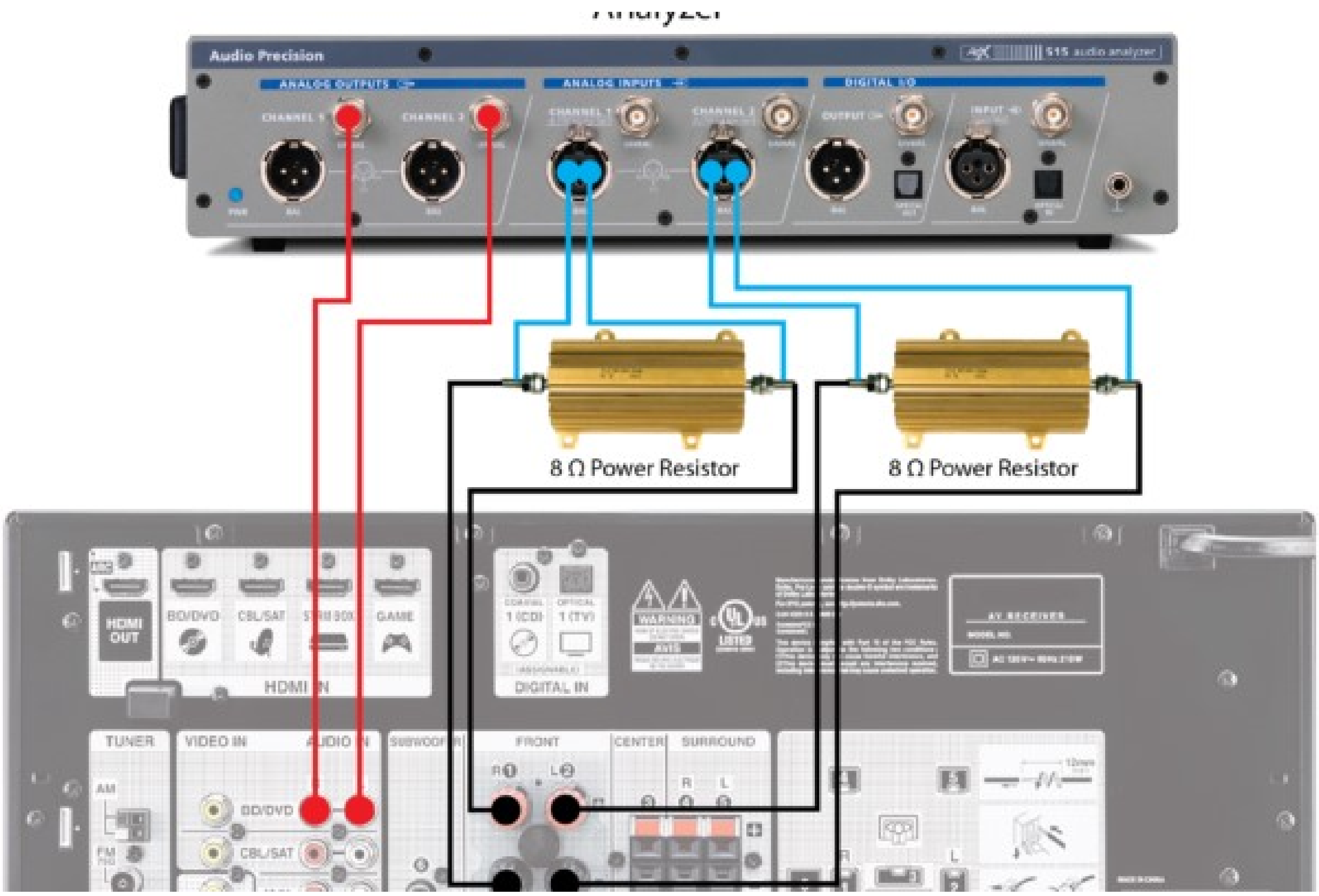

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By Julien Happich

As explained in the first part of this article, the process of audio test and measurement is fundamentally about six performance benchmarks, often referred to as 'the Big Six': Level, Frequency Response, Total Harmonic Distortion plus Noise (THD+N), Phase, Crosstalk, and Signal-to-Noise Ratio (SNR). In the first installment of this piece, we looked at the different kinds of testing required for different audio devices, explored the right signal path for connecting an analyzer to carry out test and measurement on a particular 'device under test' (or DUT — in these articles, a home theater receiver was used), and discussed the first couple of tests in detail. In this, the second and final part of this article, we'll look at the final four tests in similar detail.

THD+N

As mentioned in the previous article, THD+N stands for Total Harmonic Distortion plus Noise. Harmonic distortion is the unwanted addition of new tones to the audio signal. These tones are harmonically related to the original signal: when the signal is one sine wave of frequency f1, harmonic tones are f2, f3, and so on, at integral multiples of the frequency of the original tone. Total harmonic distortion is the sum of all of the harmonics measured in the DUT's bandwidth. Why THD+N? Why not just measure THD (the distortion) and N (the noise) individually? Well, in the early days of audio measurement, it was difficult to measure the THD by itself, without the noise, but it was relatively simple to measure the THD and the N together. So the accepted techniques handed down from years past specify THD+N, because that's what was practical. In addition, THD+N is a convenient and telling single-number mark of performance, widely understood and accepted.

Bandwidth & THD+N

The measured THD+N of a device will vary with the measurement bandwidth. You will almost always want to restrict the measurement bandwidth using high-pass and low-pass filters, if your analyzer offers them, and you must include the bandwidth used when you state the result. THD+N is typically measured and reported in a 20 Hz-20 kHz bandwidth, which is what we'll use and refer to here.

Level & THD+N

The measured THD+N of a device will also vary with level and the frequency of the applied signal. Audio THD+N is typically measured and reported at a mid-range frequency (1 kHz or so) at the either the device's nominal operating level or at its maximum output level (MOL).

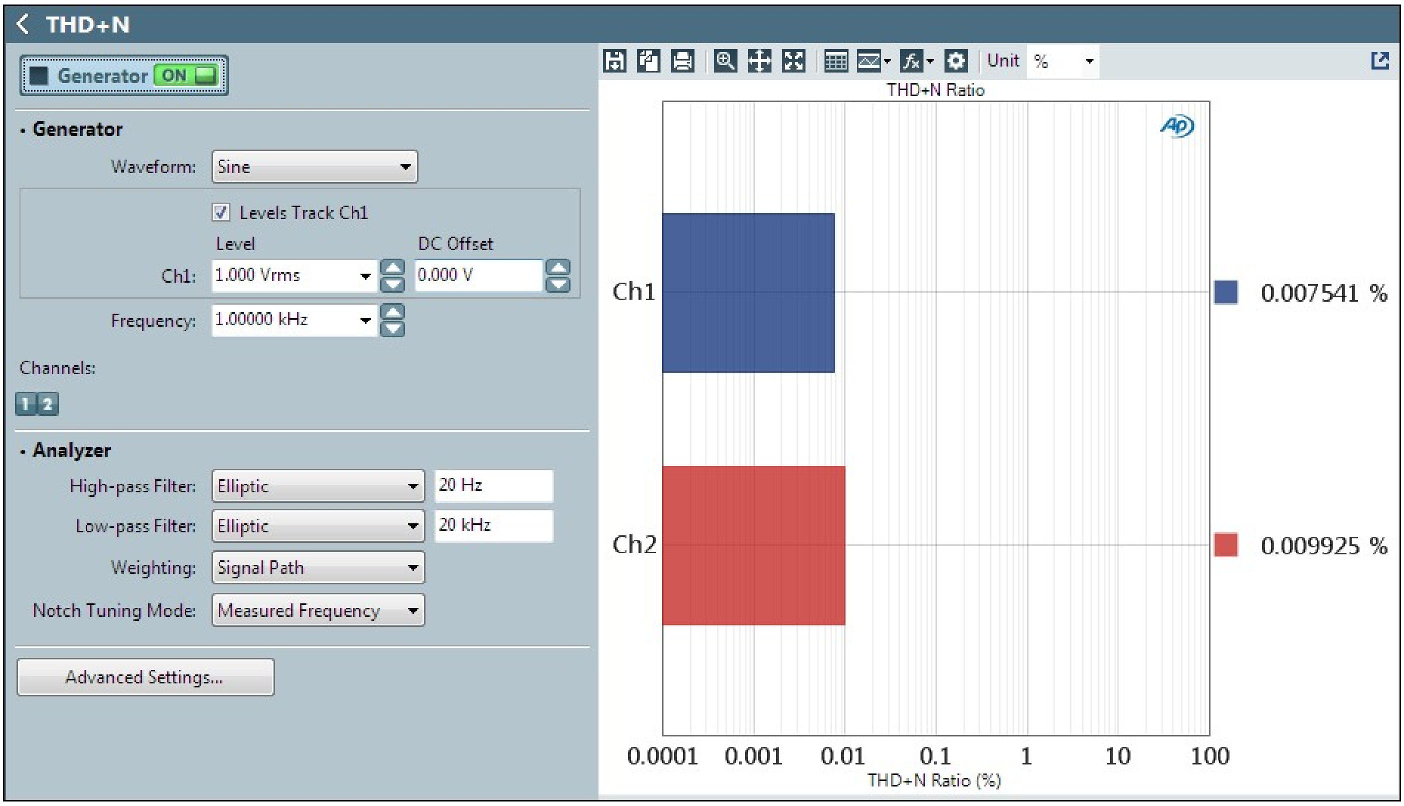

Figure 8. THD+N ratio measurement at nominal operating level.

Making a THD+N Measurement

Set the generator level to the DUT's nominal operating level (1 Vrms). Set high-pass and low-pass filter selections to define the measurement bandwidth at 20 Hz to 20 kHz. You should then be able to adjust your analyzer to give you a THD+N reading as a percentage, with a 1 kHz stimulus signal. In the test carried out on the home theater receiver for this article, our DUT gave a reading of 0.007541% on channel one, and 0.009925% on channel two.

Other THD+N Techniques

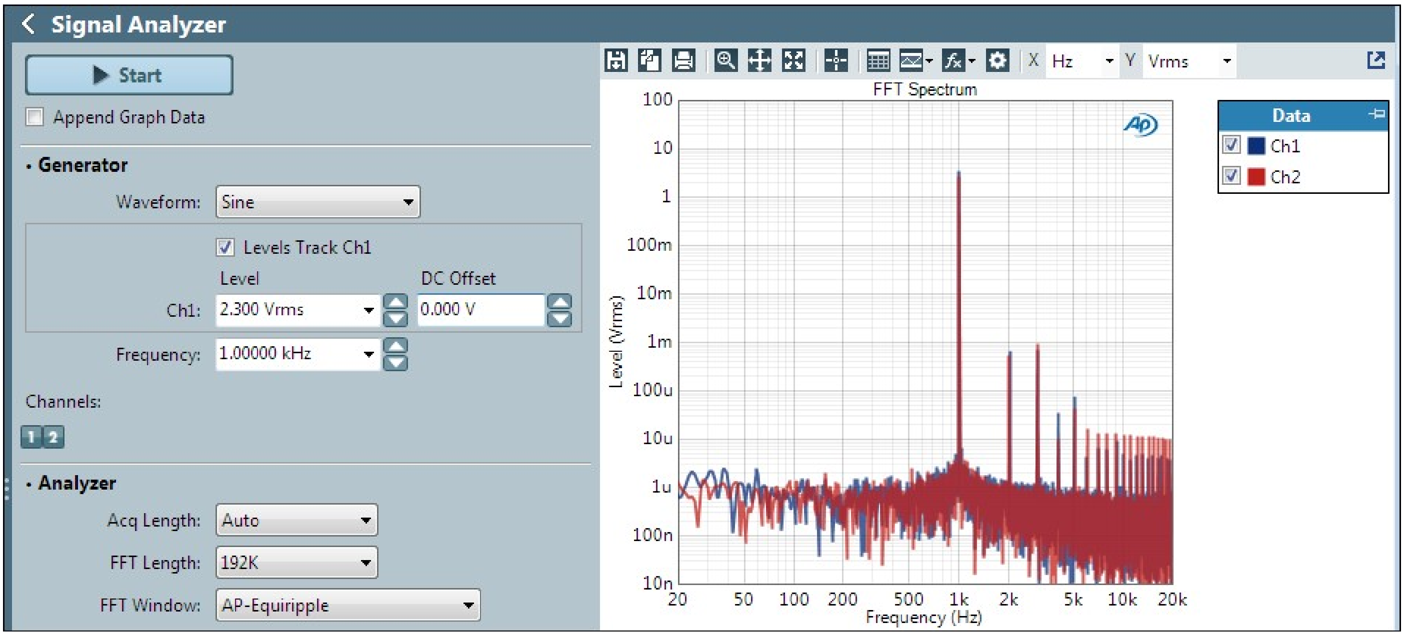

Figure 9. THD+N spectrum measurement at MOL.

The method just described provides a quick, single-number result for THD+N, and is often the method of choice. However, other techniques can provide much more information about a device's distortion performance. A THD+N versus frequency sweep or a THD+N versus amplitude sweeps will show how a DUT performs under varying types of stimulus. Frequency-domain fast-Fourier transform (FFT) processing or a dedicated Harmonic Distortion Analyzer (as offered by some analyzers) can even reveal details of the individual distortion products.

Phase

In audio engineering, phase measurements (expressed in degrees) are used to describe the positive or negative time offset in a cycle of a periodic waveform (such as a sine wave), measured from a reference waveform. The reference is usually the same signal at a different point in the system, or a related signal in a different channel in the system. This choice of references defines the two most common phase measurements: device input/output phase, and interchannel phase. Phase shift varies with frequency, and it is not uncommon to make phase measurements at several frequencies or to plot the phase response of a frequency sweep.

Making an Interchannel Phase Measurement

As with the tests detailed in the previous installment of this article, we have to decide on a level for the stimulus signal. Phase measurements are generally not particularly level-sensitive, as long as we are above the noise floor and below distortion. We will make our test at 1 Vrms, with the DUT set for unity gain (i.e., such that output level is also 1 Vrms). These steps assume a DUT like our home theater receiver, and that your preferred analyzer can drive multiple outputs and analyze multiple inputs simultaneously.

Initial Setup

As with the tests detailed in the first part of this article, set your analyzer to output a 1 kHz sine wave at a level of 1 Vrms, route this into two different input channels on your DUT, adjusting the Volume control on the DUT until its output also measures 1 Vrms, then have your analyzer measure the phase difference between the two signals, as measured at the DUT's outputs. In the test conducted for this article, using our default 1 kHz setting, we measured a small interchannel shift of –1.056 degrees.

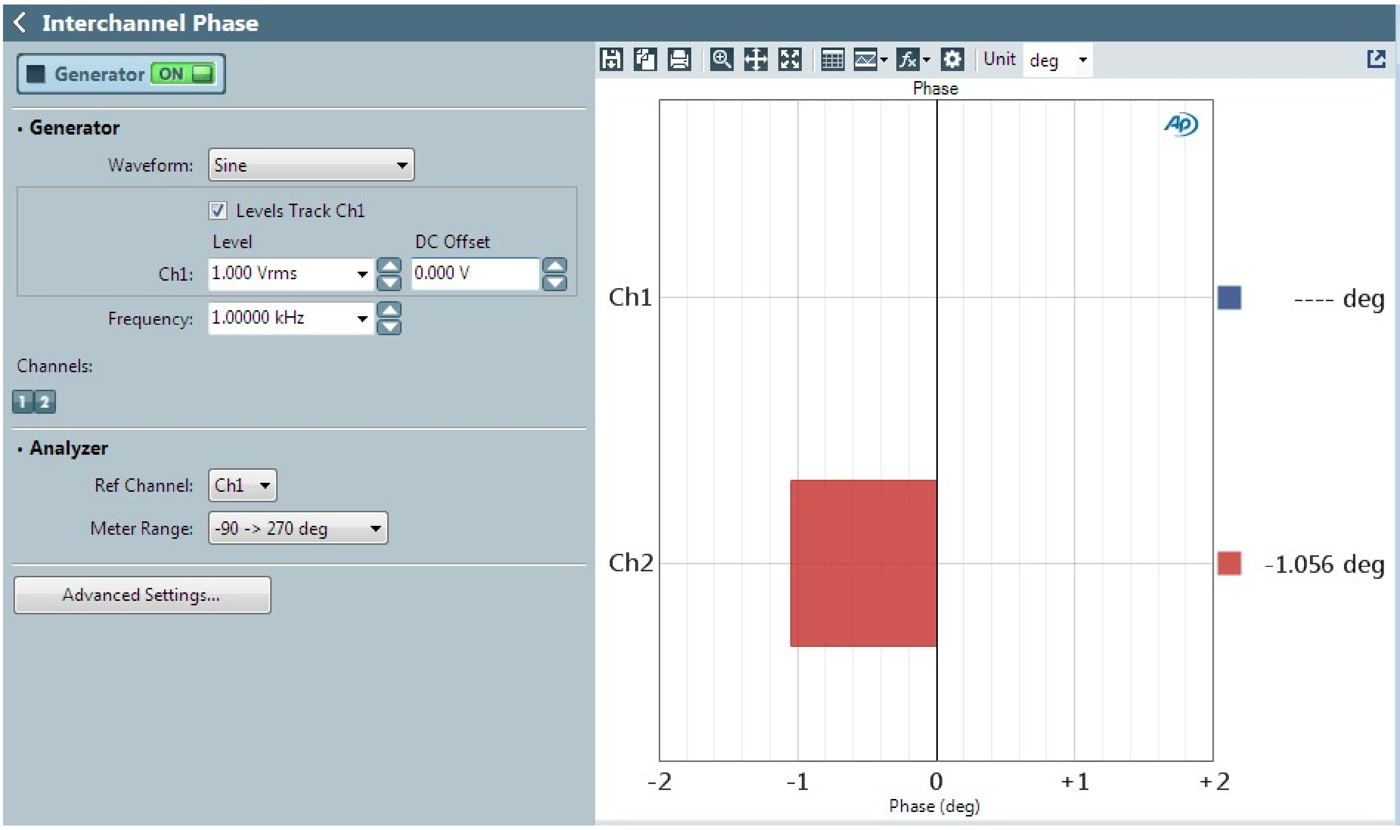

Figure 10. Interchannel Phase at 1 kHz.

However, phase shift between channels often varies with frequency, as you will see if you change the frequency of your stimulus signal to 100 Hz, and then to 10 kHz. Doing this for the purposes of this article gave slightly varying results: a –0.583 degree phase shift at 100 Hz, and –0.103 degrees at 10 kHz. To view a complete phase response, a sweep measurement plotting interchannel phase versus frequency is often made.

Making an Input/Output Phase Measurement

The other common phase measurement compares the phase of the signal at the input of the DUT to the phase of the same signal at its output. Again, provided your analyzer can handle multiple inputs and outputs simultaneously, this is straightforward.

A simple way to make this measurement for the DUT's Left channel is to simultaneously route the signal generator output from your analyzer into the input of your DUT, and also back into an input channel of your analyzer without passing through the DUT. Some analyzers can patch the latter routing internally. The left channel output of your DUT then needs to be routed back into a separate input channels on your analyzer, and the analyzer set to measure the phase difference between the two channels, one of which has passed through the DUT while the other has not.

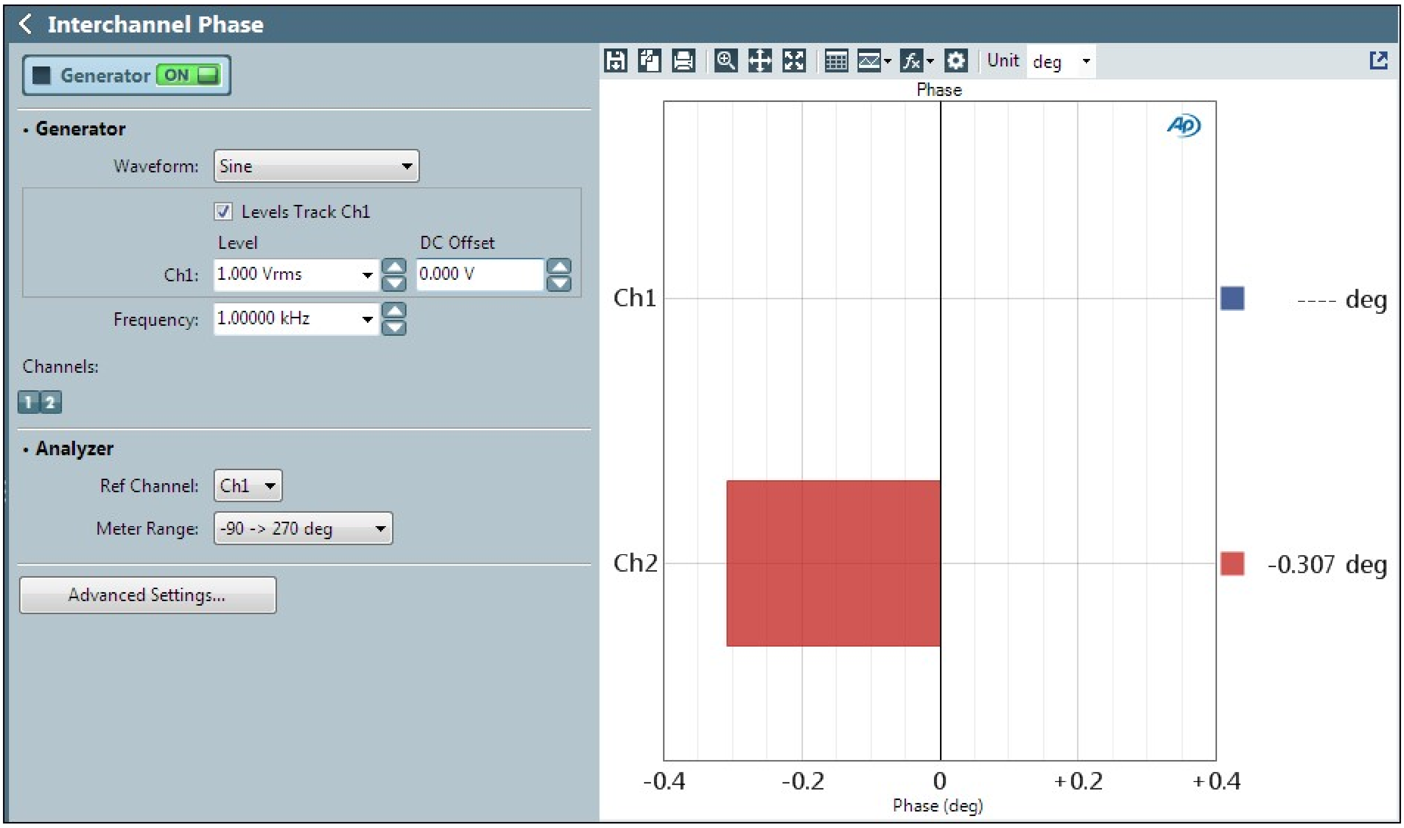

Figure 11. Input-Output Phase at 1 kHz.

The tests conducted for this article produced a phase difference of −0.307 degrees at 1 kHz, and results at 100 Hz and 10 kHz were −5.546 and −12.834 degrees, respectively.

Occasionally, you may see input-output phase results that gather around a value of 180 degrees. This indicates that the output of the DUT is out of polarity with its input (180 degrees out-of-phase at all frequencies).

Crosstalk

In audio systems with more than one channel, it is undesirable for the signal in one channel to appear in the output of another channel, even at a very reduced level. This signal leakage across channels is called crosstalk, and in practical devices it is very difficult to eliminate. Crosstalk is expressed as the ratio of the undesired signal in the unstimulated channel to the signal in the stimulated channel. Crosstalk is largely the result of capacitive coupling between channel conductors in the device, and usually exhibits a rising characteristic with frequency.

Making a Crosstalk Measurement

As with most of these tests, with crosstalk measurements you need to set reference levels for the analyzer output amplitude and the volume setting on the DUT. Unity gain, 1 Vrms or 1 W output are typical choices.

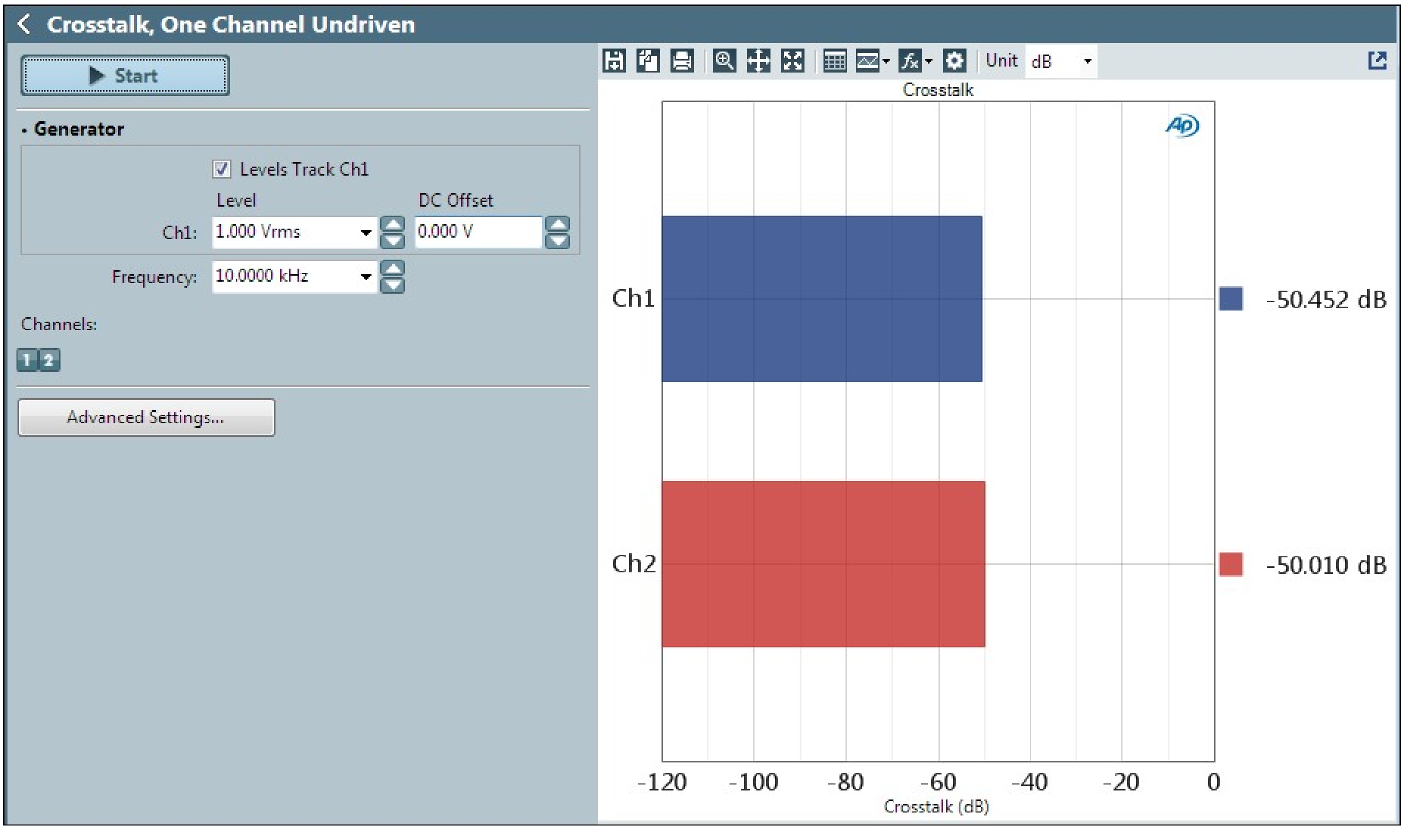

Figure 12. Crosstalk Measurement.

Essentially, the crosstalk is measured by patching the analyzer's output into an input on the DUT, and comparing this level with that measured at a different output of the DUT. In the tests conducted for this article, the crosstalk from channel two into channel one measured at –50.452 dB. The crosstalk from channel one into channel two measured at –50.010 dB.

Note: If you are testing a power amplifier using terminating resistors, be aware that your resistor connections could add capacitive coupling between the channels, increasing the measured crosstalk.

Other Crosstalk Measuring Techniques

The method just described provides a quick, single-number result for crosstalk, and is often the method of choice. However, a crosstalk versus frequency sweep will show how a DUT performs across its operating bandwidth.

Signal-to-Noise Ratio (SNR)

How much noise is too much? That all depends on how loud your signal is.

Signal-to-noise ratio (or SNR) is a measure of this difference, providing (like THD+N) a one-number mark of device performance. The signal is usually set to the nominal operating level or to the maximum operating level of the DUT. When SNR is made using the MOL, the result can also be called the dynamic range, since it describes the two extremes of level possible in the DUT. (**Note:** *dynamic range* in digital devices has a somewhat different meaning). SNR is usually stated in decibels.

Using traditional methods, SNR requires two measurements and a bit of arithmetic. First you measure the signal level, then turn off the generator (and often, terminate the DUT inputs in a low impedance as well, to fully reduce the noise in the device). Then the noise level (often called the noise floor) is measured, using filters to restrict the measurement bandwidth. The ratio between the two is the SNR.

Making SNR measurements

Since SNR is the relationship between two measurements, first we measure the value at a specified signal level. If your analyzer allows it, it's convenient to store this reference level. Then we measure the noise in the channel, using the earlier reference. This result is the SNR.

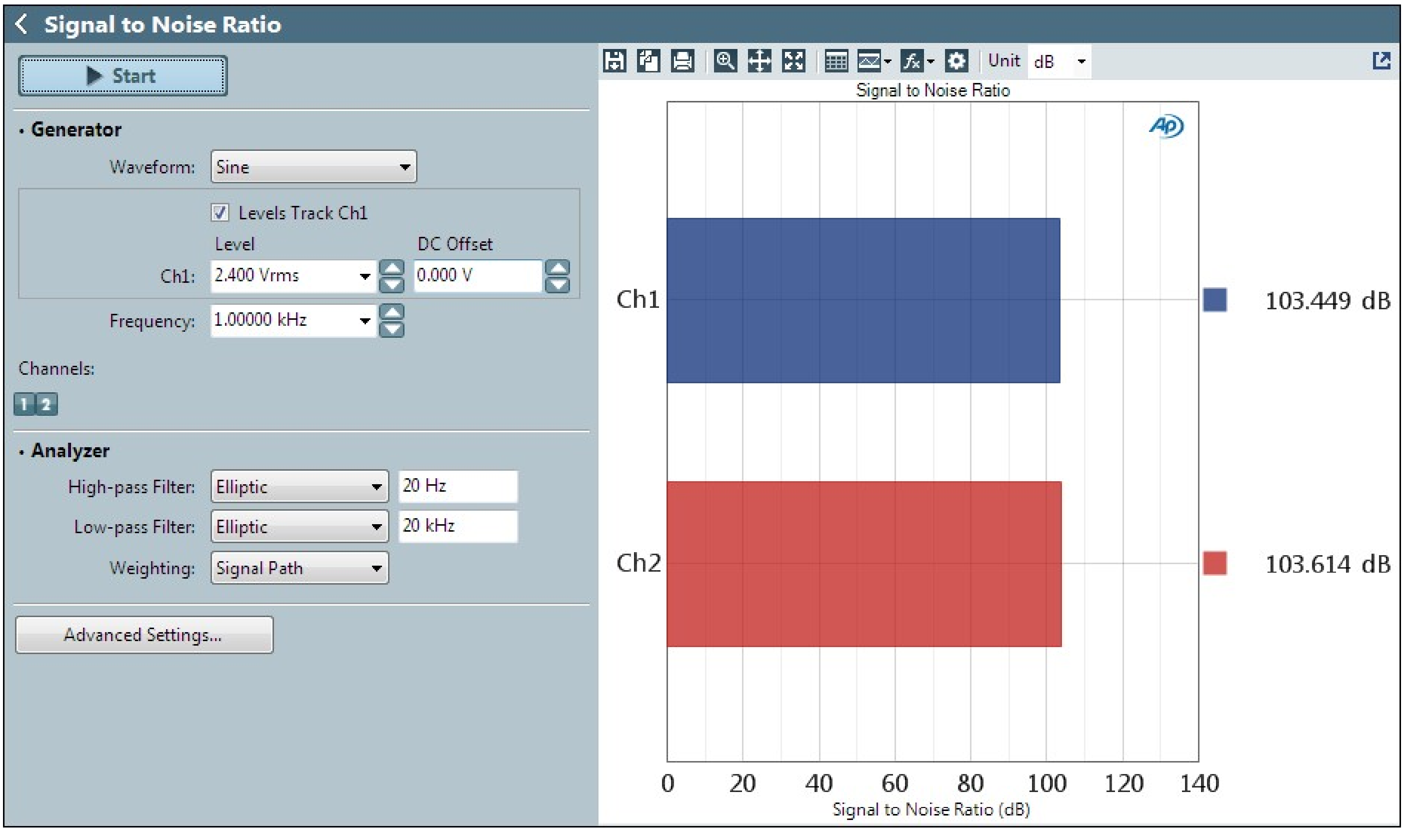

Figure 13. Signal-to-Noise Ratio Measurement

As with all of these tests, a reference level should be chosen for your SNR measurement. Maximum Operating Level or MOL is a common choice, and the one used in the tests conducted for this article. You will have to press into service high- and low-pass filters on your analyzer to define the measurement bandwidth, typically about 20 Hz to 20 kHz, and this bandwidth must be stated with the distortion result. For noise measurements, weighting filters are often used instead of bandwidth-limiting filters. In the tests conducted for this article, the SNR of the DUT was measured at about 103.5 dB.

Capturing Low Noise Measurements

Getting the best noise measurement depends upon connections and the electromagnetic environment. For best results, you should use high-quality shielded cables and test jigs, keep your analyzer, your DUT and measurement cables away from magnetic and electrical fields, and ensure that the mains power to your analyzer and your DUT is free of interfering signals. It's also a good idea to connect a large-gauge ground strap between your analyzer and your DUT.

Conclusion

Over the course of this two-part article, we've looked at easy ways to make six basic audio measurements on a home theater receiver using an analyzer of your choice. We worked in the analog domain, and confined our testing to a maximum of two channels using meter readings and a simple sweep.

The basic methods practiced here can be transferred to other types of audio devices and digital domain and cross-domain testing. While these basic approaches will often be all that is required, understanding their principles will provide an excellent framework for working with faster and more informative techniques such as FFT analysis, multitone testing and the continuous sweep (log chirp) method.

Related article:

Introduction to the Six Basic Audio Measurements: Part 1