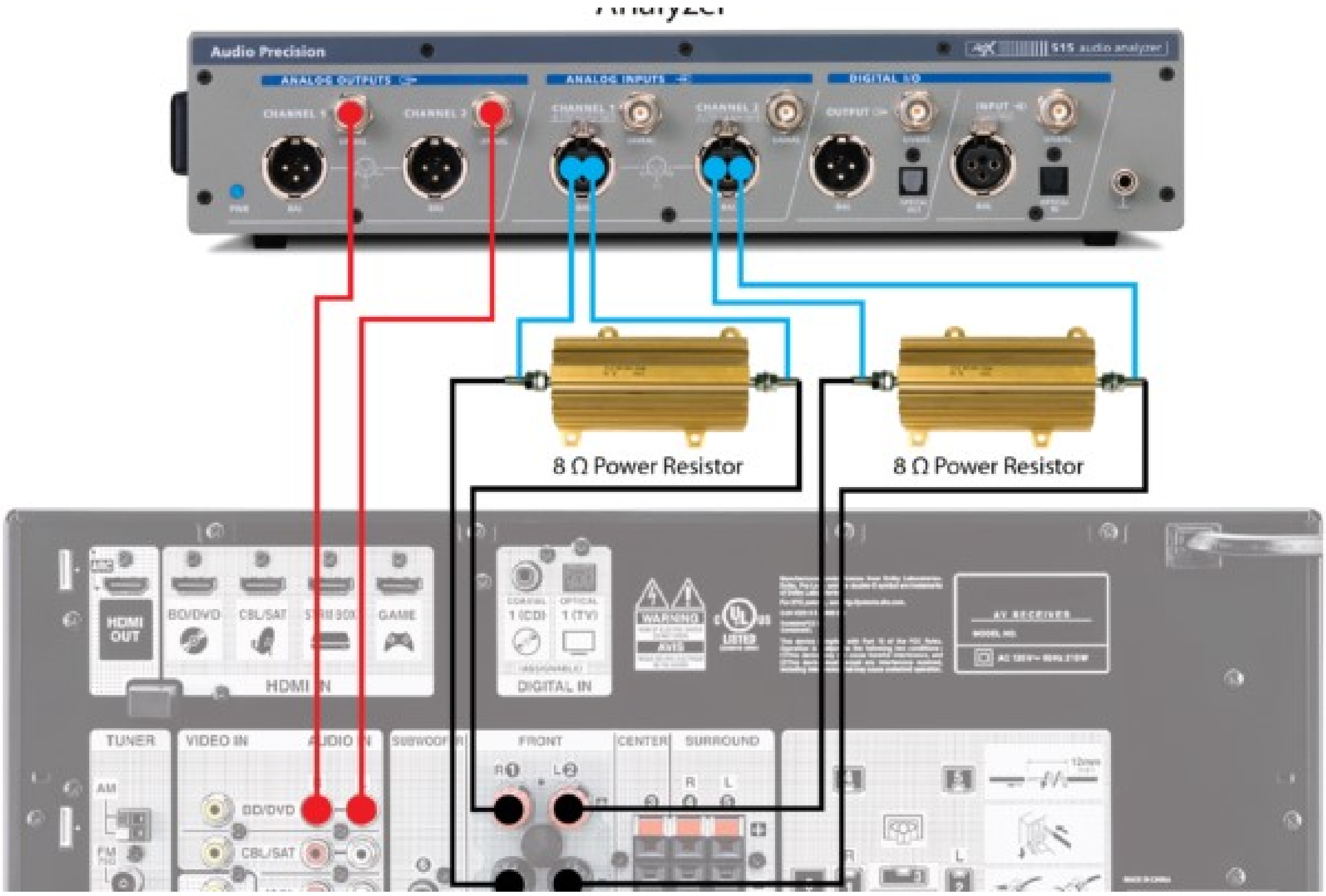
Introduction to the Six Basic Audio Measurements: Part 1

Julien Happich



Technology News | October 26, 2016

By Julien Happich

When reduced to its fundamentals, audio measurement is concerned with a select number of performance benchmarks:

• Level

• Frequency Response

• THD+N (Total Harmonic Distortion plus Noise)

• Phase

• Crosstalk

• SNR (Signal-to-Noise Ratio)

In this article, we'll look at what testing is required for different audio devices, choose a device to test and a signal path, discuss basic setup considerations, and look at how to proceed with the first couple of tests in detail, using your analyzer's meters and one frequency sweep. In the second part of this article, we'll examine the final four tests.

For simplicity, the examples given here will assume you're making all the measurements in the analog domain using a typical audio analyzer, and testing a common audio device. The concepts and approaches shown here can be extended to the digital domain, to cross-domain measurements and to other types of audio equipment.

Device Under Test & Signal Path

The equipment you want to test may be a receiver for a home theater, an audio power amplifier, a DVD player, or one of hundreds of other devices that require audio testing, such as ADCs, DACs, semiconductor devices, mobile phone and telecommunications equipment, etc. When discussing a measurement, we refer to the equipment to be measured as the Device Under Test, or DUT.

Signal Paths & Connections

Different DUTs may require different signal paths. Let's look at the signal paths associated with the three types of devices mentioned above. For example:

• A home theater receiver has many inputs and outputs, and you must choose which you are going to test. Inputs and outputs may be either analog or digital.

• An audio power amplifier has both inputs and outputs. The inputs may be analog or digital, with the output usually analog.

• A stand-alone DVD player has no audio inputs, only outputs. The audio outputs may be carried as analog audio or as digital audio.

For the examples in this article, we will use a home theater receiver as the DUT. This receiver has many inputs and outputs, but by way of providing a test example, let's assume we have chosen to test the path from the CD Left and Right analog inputs to the Left and Right power amplifier outputs.

In most cases, DUTs with different signal paths will be tested using very similar techniques, simply reconnecting cables or using the digital domain generator or analyzer. Playback-only devices (such as a stand-alone DVD player) require the use of discs or other media with pre-recorded test signals and external sweep or external source measurement techniques.

Connecting the DUT to the Analyzer

Most professional, industrial and broadcast audio devices use balanced analog inputs and outputs; consumer analog equipment is typically unbalanced. Whether or not your DUT has balanced or unbalanced inputs or outputs will determine your selection of generator and analyzer connections and the type of cables you must use. Our home theater receiver has unbalanced inputs, but its power amplifier outputs are balanced. This is not always the case, but power amplifier outputs are often balanced, even in consumer systems.

Using Terminating Loads

Certain DUTs must have their outputs terminated in a specific load impedance to perform as designed or to match specified measurement conditions. An obvious example is the power amplifier, which in use must deliver its output voltage at the current drawn by its load (the loudspeaker). For amplifier measurement, the loudspeaker is typically replaced by a power resistor of the specified resistance, usually 8 Ω.

Choosing a Measurement Level

Most audio equipment has a nominal operating level within a few decibels of 1 Vrms. Specialized equipment such as microphone preamplifiers or high-power amplifiers are designed to operate well below or above this range, and certain tests may require very low or very high levels. Our home theater receiver has the typical 1 Vrms nominal input levels, and power amplifier stages that can deliver up to 100 W at each speaker output.

Choosing DUT Gain & Effects Settings

Some DUTs have no settings at all, just input and output connections. Others may have gain controls, equalization or bass and treble controls, even surround and reverberation effects accomplished using internal digital signal processing (DSP). These settings will affect the measurements you make, so you must be careful to set them properly for testing (usually by disabling them). The gain or volume control should typically be set to a nominal operating level, and other effects and controls should be set to their 'Off' or 'Neutral' positions. Other gain settings may be specified or necessary for certain tests, and in rare cases there may be a reason to set other controls or effects to 'On'. See below for more information.

Setup

So, let's set up our example home theater receiver. We will use this setup (with one minor change for input/output phase) for making all the measurements.

Connecting the DUT in the Measurement Signal Path

We have chosen to use the CD inputs in the measurement signal path for our receiver. These are unbalanced RCA jacks, and we're assuming they have a typical nominal operating level of 1 Vrms. We will connect these to the unbalanced analog outputs on our analyzer or signal generator, and measure the DUT at its power amplifier outputs (speaker connections), using the left and right channels. For our test we will ignore the surround and subwoofer channels, connect the left and right outputs to a pair of 8 Ω power resistors as a terminating load, and connect parallel lines from the resistors to the balanced analog inputs on our analyzer.

Setting the DUT Controls

Turn the DUT on and set its Volume control to the minimum position. All audio processing options on the receiver (such as Stadium, Theater, Club and so on) and equalization should be disabled; these settings would all add processing that would adversely affect measurement. Similarly, any surround mode that adds processing should be avoided, so that the stereo input signal is unaltered while in the receiver.

Level

Each DUT may have a number of level measurements that are of interest. You must choose which level you are seeking. Target levels include:

• an input level that produces a given output level, such as 1 Vrms, or 1 W, or unity gain (see below for a discussion of DUT gain);

• an input level that produces a certain output distortion, such as 1% THD+N;

• a level that provides good noise performance with comfortable headroom, often called the operating level;

• an input or output level specified in a testing document.

Any of these levels may be used as a reference level on which we can base further measurements. Frequency response measurements, for example, are expressed relative to the level of a mid-band frequency; THD+N measurements are made at specified levels, which should be reported in the results.

Gain Considerations for Level Measurements

The ratio of a DUT's output voltage level to its input voltage level is the voltage gain of the DUT. For example, in a DUT with a gain of 2, an applied input of 2 Vrms will produce an output of 4 Vrms. A gain of 1, where the output voltage equals the input voltage, is called *unity gain*. Some DUTs offer no gain adjustments, and are said to have fixed gain. The gain may be fixed at unity, or at some other value.

Measuring Level in Variable Gain DUTs

A DUT with a volume control or other setting that affects gain is a variable gain device. When setting and measuring level, it is essential to consider whether or not the DUT gain is variable (not only volume controls, but tone controls and other settings can change gain), and, if it is, how to set the DUT controls for the desired test results.

Making Level Measurements

We will make level measurements using three different methods that produce results that are commonly used in audio specifications. Using your analyzer to generate a 1 Vrms applied signal, we will set the volume control to the position that produces 1 Vrms at the speaker outputs (actually, across the 8 Ω terminating load resistors). Then we will readjust the volume control to produce 1 W in the load, and then we will drive the amplifier into distortion to find the level in watts at 1% THD+N.

Initial Setup

Set your analyzer to output a 1 kHz sine wave at a level of 1 Vrms. While watching the Level meters on your analyzer, slowly increase the DUT volume until you have a reading of about 1 Vrms. Since we know our input is 1 Vrms, this volume setting produces unity gain.

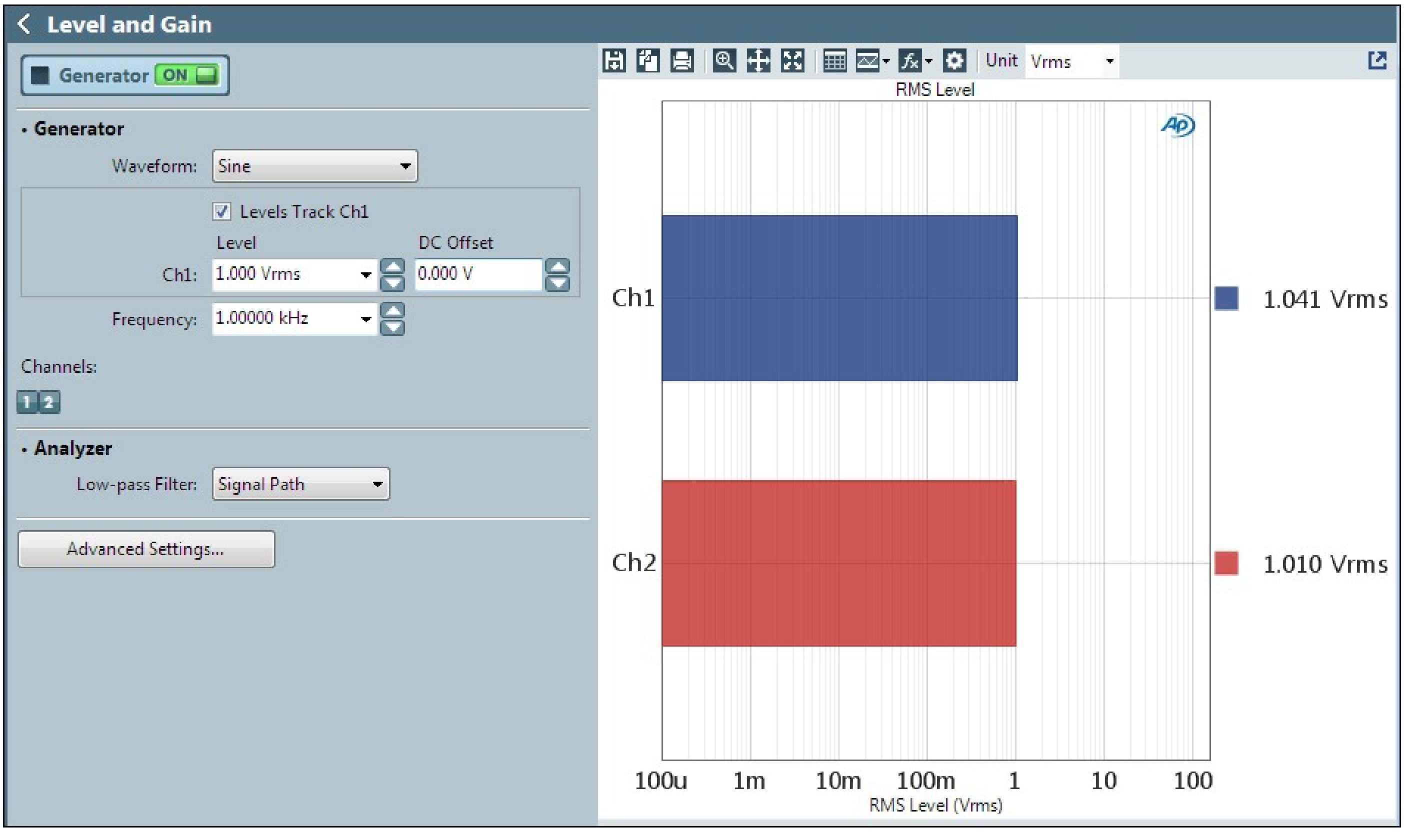


Figure SEQ Figure * ARABIC 1. Setting Level at Unity Gain.

Adjust DUT for 1 W

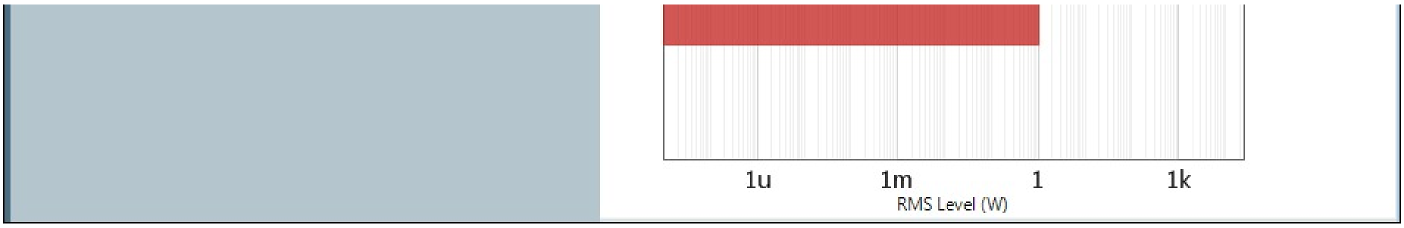


Figure 2. Setting level at 1 watt output.

If you can, reset your analyzer to give an output level reading in Watts, which will require that you provide the load resistance value; 8 Ω, in our case. Observing the Level meters, slowly increase the DUT volume until you have a reading of about 1 W.

Adjust DUT for 1% THD+N

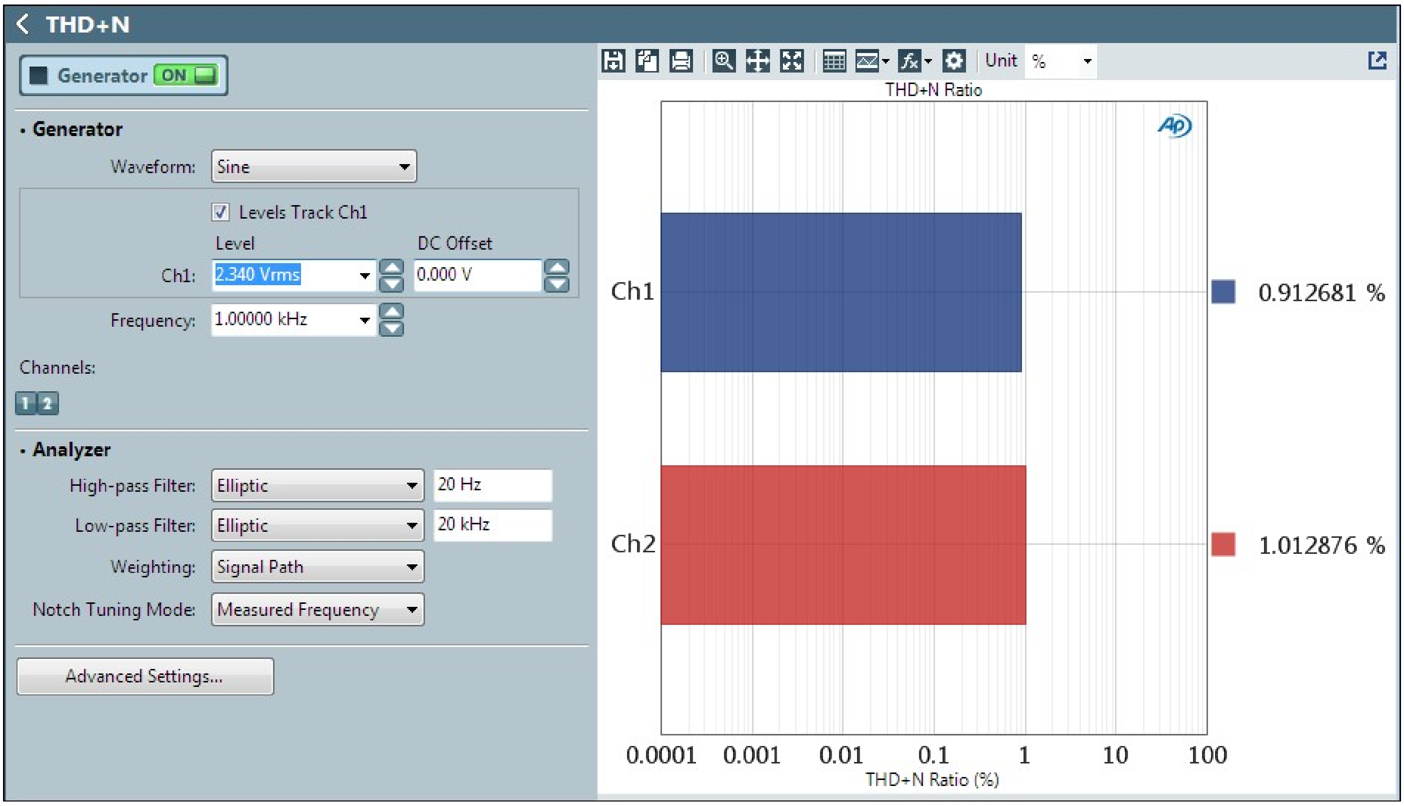
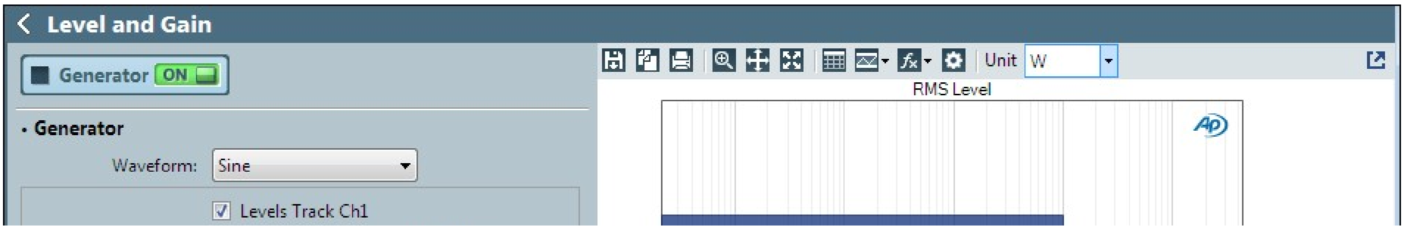


Figure 3. Finding Gen Level for MOL (1% THD+N).

If your analyzer allows, reset it to show output of Total Harmonic Distortion plus Noise, or THD+N (a common analyzer measurement — more on this in the second installment of this article, as the eagle-eyed reader will have noticed that THD+N measurements are one of the Big Six that we'll be covering then). Slowly increase the DUT volume until you have a THD+N reading of about 1%. You may find that the distortion jumps suddenly from some ratio just below 1% to a very high ratio of distortion. This is caused by the onset of amplifier clipping. Find the volume that produces the highest possible distortion that is below 1%. For our example DUT, this output level was about 99 to 100 watts (about 28 Vrms in 8 Ω). This level is often called Maximum Output Level, or MOL.



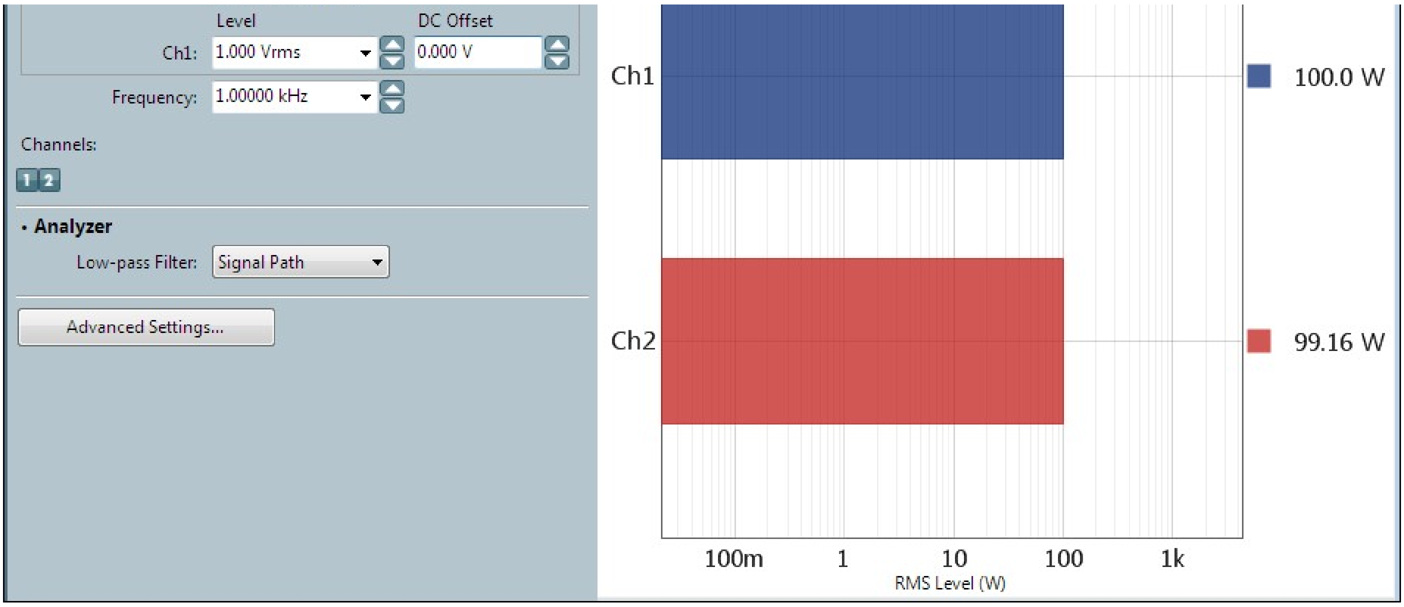


Figure 4. Amplifier output at MOL.

Note: At this level, the amplifier will be producing its greatest undistorted output. Depending upon the design of the DUT and its output rating, this condition may stress the amplifier, and may heat the amplifier heat sinks and the terminating load resistors. Be sure that your load resistors are designed to safely handle the rated output of your DUT, and that they are well ventilated. Leaving the amplifier at its maximum output may damage the amplifier and load resistors, and may be a fire hazard. Generally, you should make maximum output levels tests brief, and be sure you turn the generator off and/or the volume control down as soon as you have your measurement.

Setting a Reference Testing Level

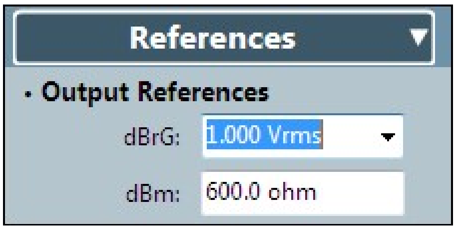


Figure 5. Setting a Generator Reference

Depending on the design of your analyzer, once you have found a useful level using one of the above methods, you may be able to store it as a reference in your analyzer's memory. If you're able to do this, don't forget that since the DUT gain setting affects level, you should make note of the DUT volume setting as a reference as well.

Frequency Response

A frequency response measurement reports the output levels of a DUT when stimulated with different frequencies of known level. The simplest of all frequency response measurements consists of only two or three tones, the first near the middle of a device's usable frequency range, and followed by a tone near the higher extreme of the range and sometimes a tone near the lower extreme. Assuming the tones are all generated at the same level, the DUT's output levels describe its response to these different frequencies.

Full-range frequency response measurements can be made by a number of different methods, the classic being a sweep of a sine wave from the lowest frequency in the range to the highest, with the results plotted on a graph. A 'flat' response describes the shape of a graph where the DUT responds equally at all frequencies, producing a trace with a slope of 0 and with minimal variations.

Making a Frequency Response Measurement

As mentioned above, it is possible to make a basic response measurement using only two or three tones.

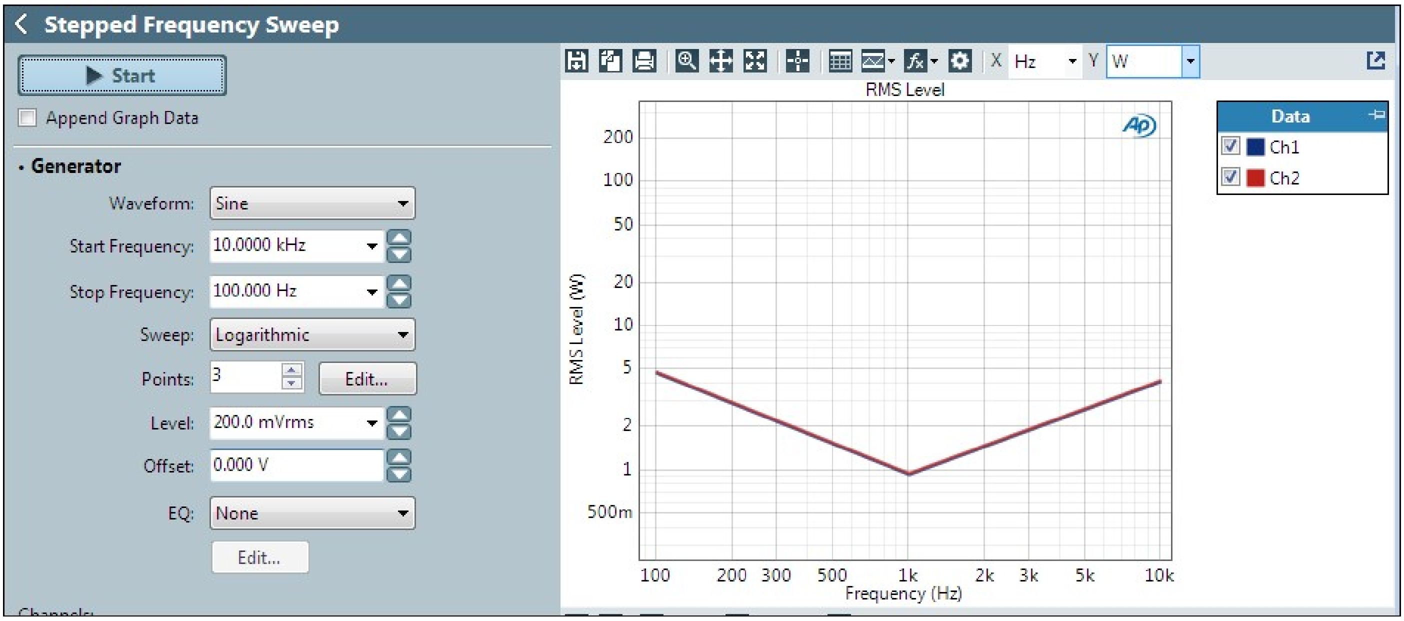


Figure 6. Three-point frequency response measurement.

However, the expectation is usually a full sweep across the audio spectrum, and, assuming your analyzer can automate and output such a sweep, that's what we'll do here.

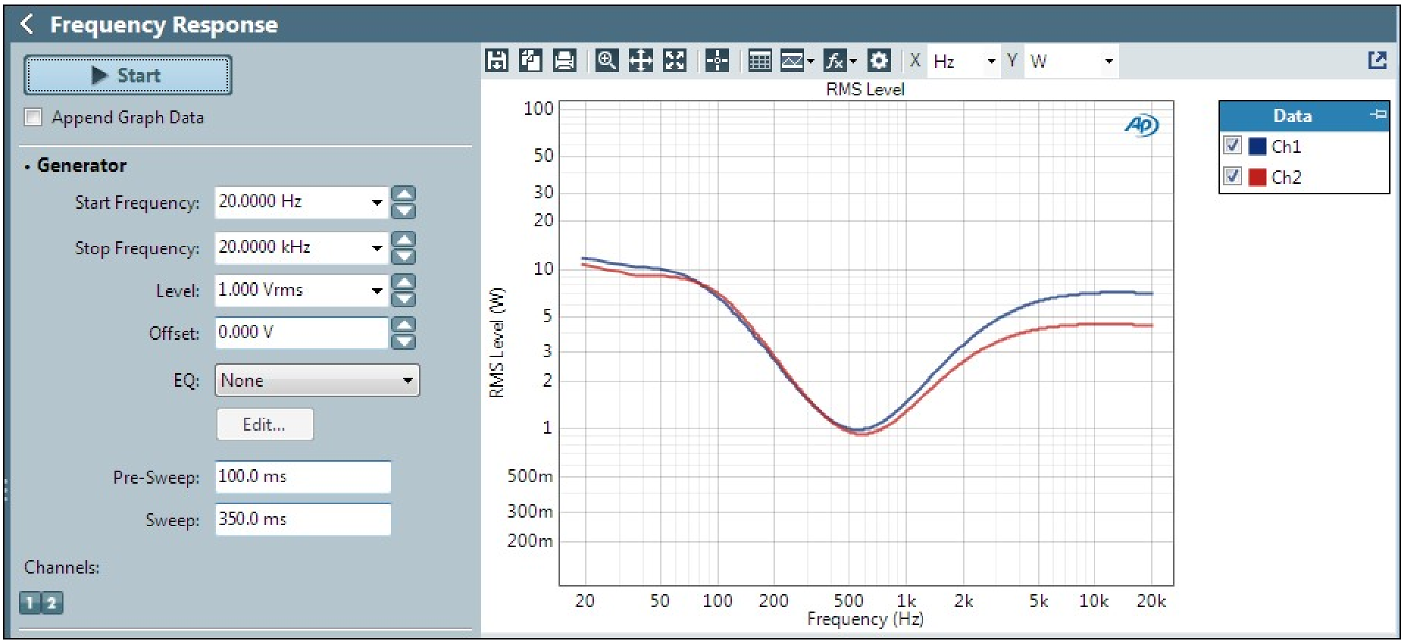


Figure 7. Frequency Response sweep measurement.

First we have to decide on a level. We could make the sweep at a very low level, but we might see noise or other spurious signals in our response. We could make it at a very high level, but then there is the possibility of amplifier distortion affecting the response. However, a common level for frequency response in a power amplifier is at the 1 W output level, so that's what we will use here.

Initial Setup

First, as before, set your analyzer to output a 1 kHz sine wave at a level of 1 Vrms. Then, if you can, set up your analyzer to display level in watts and slowly increase the DUT volume, observing the Level meters on the analyzer as you go, until you have a reading of about 1 W. Now, assuming your analyzer can automate a frequency sweep, have your analyzer record the resulting response from the DUT. If you can, have your analyzer plot the results as a graph, which gives you the complete frequency response over the range of your frequency sweep.

Next Time

We'll conclude this article in the next installment by looking at the final four of the Big Six tests: THD+N, Phase, Crosstalk, and SNR. Until then!