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Concepts, Products, and Circuits for Audio • Analog / Digital

Unlocking the Full Power of Audio Measurements

Application Note AN-5

by Christopher Moore

Listening and viewing during audio testing will greatly increase testing usefulness

While there are many ways to determine the quality of an audio process or system, one of the most popular is to use an audio analyzer to measure distortion, noise, and frequency response. An audio analyzer can be operated manually or semi-automatically and produces a quantity of numerical data which can be evaluated against expected performance levels. However, serious pitfalls await the unwary user who simply notes readings from a display

Anyone measuring audio system performance should be listening to and looking at the quantities being measured during the test. Doing so will reveal a great deal about the system's performance and anomalies; not doing so can lead to serious measurement errors:

- A distortion measurement can appear high when in reality other forms of contamination, such as demodulated RFI (radio frequency interference), are being picked up and measured along with the actual distortion products.
- Serious design problems, such as oscillating circuits or interfering clock signals, can go undetected, only to show up later when corrections are more costly.

Using your eyes and ears

Our hearing and vision are indeed impressive. We can pick out a signal even when it is buried in noise, and we can lock onto disturbing patterns that cannot easily be measured. Audio analyzers tend to reduce the reality of audio degradations to simple numbers on digital displays, or to small spikes on FFT plots. To really know how a system is going wrong, it is invaluable to augment the measurement by seeing and hearing the distortion itself

In the total harmonic distortion and noise measurement, the analyzer eliminates the test signal from the system output, leaving only the anomalies added by the system. Listening to the distortion output lets you hear in great detail all the imperfections present while the system is being probed with the test signal. It is as though you have a magnifying glass with which to spy on all the grunge of the audio system. Viewing the signal and the distortion on the scope also reveals the phase and frequency relationships between them. Another advantage of an audio monitor is that you will hear intermittent misbehaviors of the circuit even if you are not attending visually to the instrumentation when they occur.

How to set up a measurement system

Assuming you are already using an audio analyzer (made by Audio Precision, hp, Amber, Tektronix, Neutrik, or Sound Technology), you only need to add a dual trace scope and a powered loudspeaker. You will use the scope to display the system output, the distortion residual, and sometimes the system input. You will use the powered loudspeaker to listen to the system output and the distortion residual.

You don't need, or even want, a wideband scope for this job. Too much bandwidth will permit noise to obscure the audio signals, so even a 10MHz scope will do. The scope must have an external trigger input and must not be a digital scope (you don't want a sampling process and screen refresh issues blurring your view of these audio signals). Perhaps the most important characteristic of the scope is that it be chained to the analyzer and always available. Have a second scope, with a bandwidth 100MHz or more, to use for general purpose observations.

Hopefully, your audio analyzer will have the three outputs that you need:

- audio analyzer monitor output (a gain normalized version of the signal present at the audio analyzer input)
- audio analyzer distortion output (a gain normalized version of the quantity being measured, after all filters and processing)
- audio oscillator sync output (a fixed high level version of the output signal sent to the system under test)

You should connect the monitor output to scope channel 1, the distortion output to scope channel 2, and the sync output to the scope external sync input. You should also connect the distortion output to the input of the powered speaker. If your analyzer does not provide one or more of these outputs, you will have to improvise. If there is no sync output, you can trigger the scope from channel 1, the monitor output. If your analyzer has no monitor output, you can connect the audio output from the system under test to channel 1 via a Y connector (although you will lose the benefit of gain normalization).

This test and monitoring setup will allow you to view both the monitor output and the distortion output without having to constantly adjust the scope's sensitivity and trigger controls

Triggering the scope with the fixed level sync output will ensure that the display is stable even when very low level and/or low frequency audio signals are being analyzed.

What to listen and look for

In a well-designed audio system, the electronics will approach the classic goal of a straight wire with gain. In a good system, degradations should be restricted to the addition of a small amount of noise, noise that is characterless and independent of the signal. This augmented test setup will help you determine how close you have come to perfection and what has gone wrong. Here are some of the things you may find:

- *power line hum* Hum from the local AC mains will be noticeable on the scope because it won't synchronize to the audio source yet will synchronize when the scope trigger selector is moved to the line position. Both the waveform and the sound will indicate if the hum is at the fundamental frequency, the second harmonic, or is rich in harmonics.
- *TV sync hum* Hum that changes in level and walks slowly when the scope is synchronized to the local AC mains may be coming from demodulated TV signals which are synchronized to a signal slightly less than 30Hz.
- *demodulated rfi* Your ears will tell you if the system is picking up a modulated carrier (AM or FM broadcast, CB radio, etc.), and the scope display will be a distinctive, changing, unsynchronized waveform.
- *interference from other system components* If the audio system is part of a computer or a product with an embedded controller, listening and watching while various peripherals are activated can reveal troublesome coupling mechanisms. Energy from the operation of peripherals can couple into the audio system through ground or power systems, or through stray capacitance or inductance. Be sure to listen and measure while peripherals (mouse, display monitor, network adapters, disk drives, and keyboard) are active. If the product is a piece of consumer equipment, check the interaction of user remote controls, CD mechanisms, etc.
- *oscillations of system electronics* It's rare that analog electronics are unstable at audio frequencies, but they can be oscillating at supersonic or RF frequencies without being detected. Symptoms include excess noise and spurious tones due to beats with other high frequency signals in the system (clocks for digital audio circuits, switching power supplies, etc.). Gently touch ICs and traces with your finger, listening for changes in the noise, or for beat frequencies.
- *clipping* Clipping will gradually appear, first on signal peaks, as the audio level is raised. The rich harmonic structure will remain in sync on the scope. The gain structure of the system under test may be such that an internal node can be clipping before the input or output stages.
- *Motorboating* This low frequency instability, being subsonic, will not be audible per se, but you can often hear a slow, rhythmic pumping of background noise. A periodic pulsation in the reading will show up on the scope and analyzer display.
- *1/f noise* Analog circuits can introduce excess noise at subsonic frequencies if there are problems with transistors or ICs. This kind of noise sounds like popping or sputtering.
- *crossover distortion* Distortion products which remain constant in amplitude as the signal level varies will produce the pernicious effect known as crossover distortion. The scope display will reveal minor kinks increasing to major distortion as the signal level drops.
- *AD/DA converters* Digital audio has a host of interesting distortion mechanisms, some of which will be clearer using this monitoring setup. Low level idle tones in some oversampled ADCs can best be discovered by listening through a distortion monitor. Problems with missing codes and other non-linearities will stand out on the scope and the powered speaker.
- *phase errors* Because the scope is synchronized to the audio analyzer signal source, the monitor and distortion outputs will reflect the phase relationship of the system under test's signal path.

Mission statement of Seven Woods Audio

I am an electrical engineering consultant specializing in the conception and design of products and circuits used in audio applications. My company, Seven Woods Audio, is committed to helping manufacturers quickly create digital or analog audio products that generate a good return on investment, work right the first time, sound excellent, and please the end user. Seven Woods Audio works with manufacturers of professional audio, consumer audio, broadcast, telecommunications, and computer equipment.

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