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Audio Precision's APx1701 Transducer Interface

Learn more about Audio Precision's APx1701, which when combined with an APx500-series analyzer, creates a test center suitable for measuring speakers, headphones, and microphones, as well as electronics.

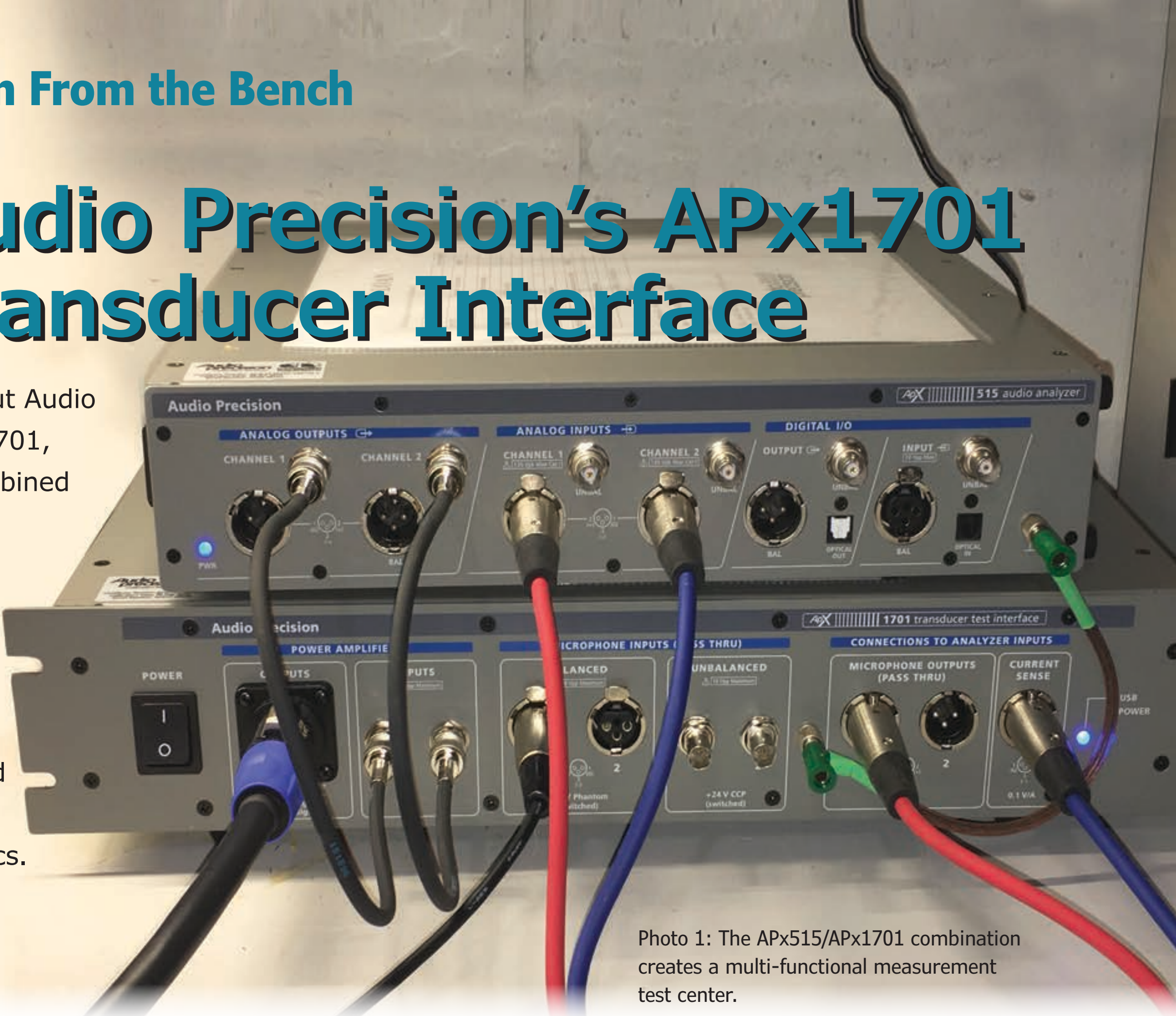

Photo 1: The APx515/APx1701 combination creates a multi-functional measurement test center.

By
Stuart Yaniger
(United States)

Without question, the traditional gold standard in audio test gear has come from Audio Precision, based in Beaverton, OR. Its test gear has been the go-to choice for the past 30 years, and any serious engineer has made extensive use of the equipment for characterizing the electronics end of the audio production and reproduction chains. Audio Precision's founder, Bruce Hofer, is one of the best creative minds in audio test and measurement.

The trade-off for performance has, as expected, been complexity and difficulty. Although I've never personally owned a System One or a System Two, my friends who have them universally praise the performance and universally condemn the difficulty of setup and use.

Audio Precision's next generation of gear, the 2722, has improved in both areas, but in return it is an expensive and complex piece of equipment, suitable for setup by engineers comfortable with GPIB interfacing or LabVIEW. Audio Precision introduced the APx500 series as a lower cost alternative with improved user-friendliness, and my experience has borne this out—in less than an hour I had unpacked the APx515 and was getting good measurements.

Although acoustic measurement is built into the APx500 software, in addition to an APx515 (or other analyzers in the '500 product line), the user needs to supply a power amplifier to drive the speakers or headphones under test and microphone preamplifiers. To perform impedance measurements, a series resistor and differential amplifier are also needed. Each of these must be accounted for in the calibration process, and any adjustments of volume using their controls will require that the calibration be rerun. And of course, low-noise and low-distortion electronics for the microphone and loudspeaker end of the measurement are not inexpensive.

As a result, most engineers I know keep two separate measurement systems on hand, one for electronics and one for transducers. While effective, this is redundant, clumsy, and unnecessarily expensive. From my point of view, a major stumbling block is having to learn the peculiarities of two separate software systems.

Meet the APx1701

To fill this gap, Audio Precision has introduced the APx1701 Transducer Interface. In combination with an APx500-series analyzer, the APx1701 creates a test center suitable for measuring speakers, headphones, microphones, and electronics (see **Photo 1**).

The APx1701 comprises two XLR balanced microphone inputs with 48 V phantom power (note that these are pass-through inputs, i.e., they will provide phantom power, but send the signal directly to the APx500-series analyzer's analog inputs for amplification) and two unbalanced BNC microphone inputs set up as 4 mA constant current for powering microphones such as the PCB Piezotronics microphones I recently reviewed (see *audioXpress,* December 2016) or Audio Precision's new line of test microphones.

The microphone inputs are TEDS-compliant and will read identification and calibration data from IEEE1451.4-compatible microphones and pass it to the APx500 software. The microphone preamp pass-through output is a balanced signal sent to two XLR jacks, irrespective of whether a balanced microphone or a constant current microphone is used.

The APx1701 also comprises two medium power (60 to 100 W, depending on the load) low noise and low distortion amplifiers. The amplifiers have unbalanced BNC input jacks, and output is taken through a SpeakOn connector. Their specified gain is fixed at 20 dB, and current is limited to 6 A. Rated signal-to-noise is 134 dB, referred to the maximum 30 V output. Total harmonic distortion plus noise (THD+N) is specified at -106 dB from 10 Hz to 20 kHz, but the specification does not mention the power level for that rating.

An additional feature of the APx1701 is a small (100 mΩ) resistor in series with the (-) power

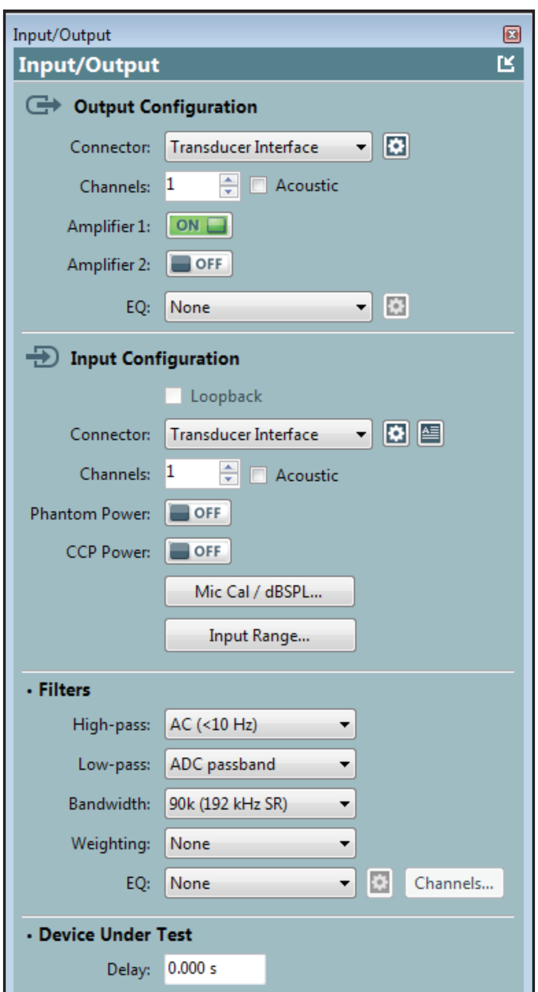

Figure 1: The inputs and outputs are controlled by a selection screen using drop-down menus.

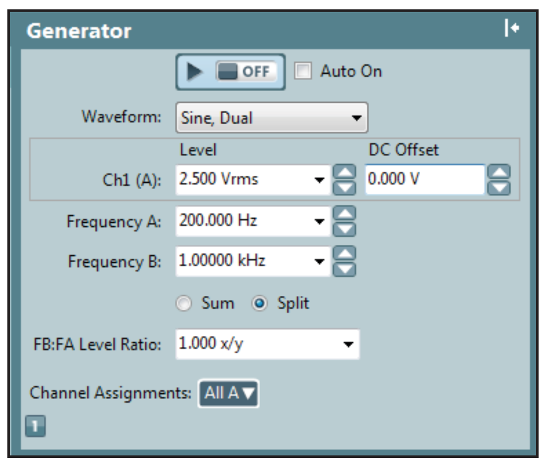

Figure 2: The Generator screen enables the user to select waveforms, levels, and channel assignments for the APx1701 integrated with an APx500 series analyzer.

Parameter	Value	Lower Limit	Upper Limit
F_S	47.02 Hz	----	----
Q_{MS}	4.74	----	----
Q_{ES}	0.69	----	----
Q_{TS}	0.60	----	----
S_D	226.98 cm²	----	----
R_E	8.45 Ω	----	----
L_E	0.66 mH	----	----
R_2	---- Ω	----	----
L_2	---- mH	----	----
K_{rm}	----	----	----
E_{rm}	----	----	----
K_{xm}	----	----	----
E_{xm}	----	----	----
R_{MS}	1.58 Ns/m	----	----
C_{MS}	0.45 mm/N	----	----
M_{MS}	25.41 g	----	----
V_{AS}	32.96 l	----	----
Bl	9.60 Tm	----	----
η_0	0.47 %	----	----

Figure 3: The APx1701 allows rapid acquisition of Thiele-Small (T-S) parameters. The data is for a 170 mm driver under test, using the added mass method.

Photo 2: I used the APx515/APx1701 combination to take a nearfield measurement of a 170 mm woofer.

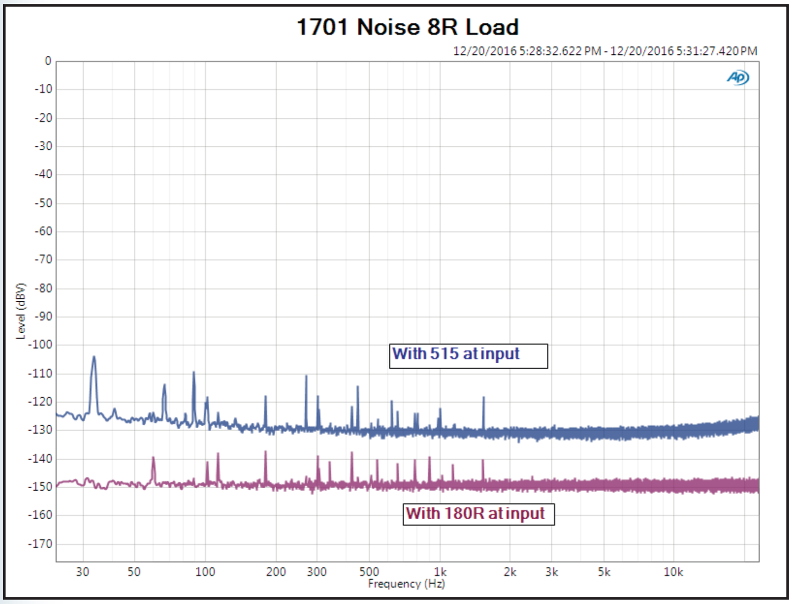

Figure 4: The upper curve of this graph shows the noise floor of the APx515/APx1701 combination and the lower curve shows the APx1701 alone, with the APx1701 terminated in an 8R (8 Ω) load.

amplifier output—this resistor develops a voltage across it proportional to the amplifier's output current. A built-in differential amplifier measures the voltage across this resistor and sends it to an XLR jack on the front panel marked "Current Sense." The Current Sense is most commonly used for impedance measurements, but can also be used for any other sort of measurement where current to the transducer needs to be analyzed. The retail price of the APx1701 is approximately $3,600.

Integration

Figure 1 shows the input and the output selection screen. When "Transducer Interface" is chosen, the software automatically accounts for the APx1701's power amplifier gain of 20 dB when driving its input and looking at the output. It can also turn each amplifier channel on and off. Likewise, when the output voltage is set from the Generator screen (see **Figure 2**), the software adjusts the analyzer output to get the correct voltage at the output of the APx1701.

At the input side of things, the microphone inputs can be selected (unbalanced constant current or balanced) and the phantom power turned on and off via the selection screen. Microphone calibration and sensitivity can be input through a menu choice on the Input Configuration screen so that sound pressure levels can be shown in decibels as well as volts.

The software will enable selection of either acoustic or impedance measurements. There are two basic software modes—Bench and Sequence. The former is, unsurprisingly, aimed at engineering and development work, the latter targets production testing. For Sequence, you can program in Pass/Fail criteria, enabling the instrument to be used by non-engineering personnel on a production floor. The two environments provided by these modes seems intuitive, but there's a few examples of where placement is (to me) non-intuitive. The most glaring is impedance measurements, which seem like something useful for bench testing, but are actually part of the Sequence environment. This caused me some head-scratching until I asked Audio Precision's tech service to take pity on me. They patiently walked me through this and were nice enough not to mention that I could have figured this out for myself if I had just consulted the manual.

Once that was explained, I was getting accurate impedance measurements in minutes. The APx515/APx1701 combination made obtaining Thiele-Small (T-S) parameters a snap—in Sequence mode, of course! You can use either the added mass or

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known-volume box method, and the entire process is two button pushes—one free air and one in the box (or one without and one with added mass). **Figure 3** shows an example output screen for a high-quality 170 mm driver that I have been testing for use in my next speaker design—this was obtained using the added mass method. The test setup is shown in **Photo 2**.

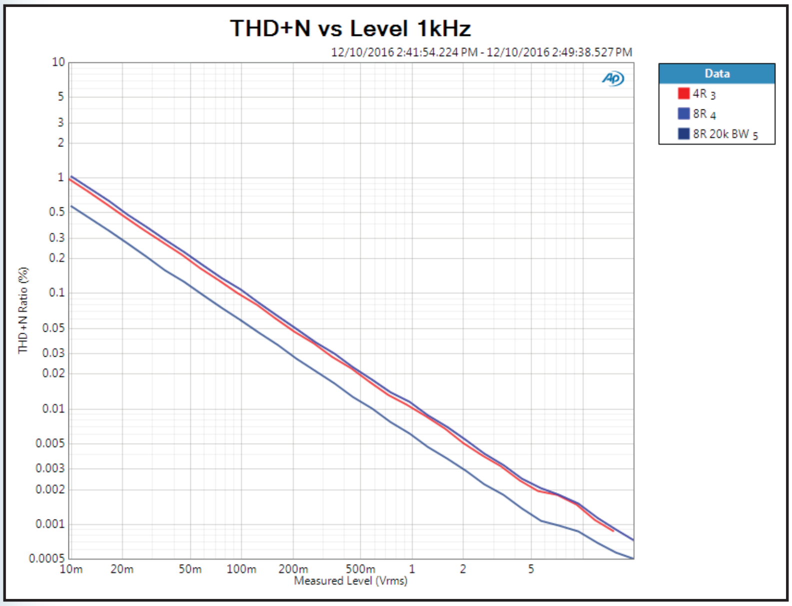

Figure 5: The THD+Noise of the APx515/APx1701 combination is extremely low and noise dominated. The upper curves are the THD+Noise vs. level for 4 Ω and 8 Ω loads, 80 kHz bandwidth, the lower curve is the same measurement for an 8 Ω load with a 20 kHz bandwidth.

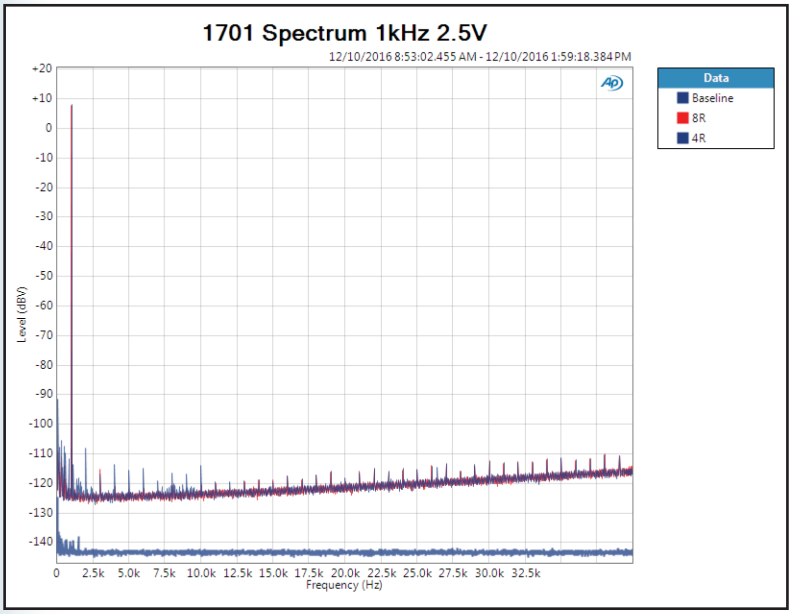

Figure 6: The distortion spectra of the APx515/APx1701 combination at 2.5 V into 4 Ω and 8 Ω loads are impeccable. The lower curve is the noise floor for the measurement.

Performance

The test setup to measure the APx1701's performance is fairly easy. I connected the APx1701 to my lab computer (a Hewlett-Packard desktop running Windows 7) via the USB port. Likewise, I connected the APx515 to the same computer, and used the supplied BNC-terminated coaxial cables to connect the APx515's outputs to the APx1701's inputs. Then, I connected the APx1701's output to a dummy load made from a 4R (4 Ω) or 8R (8 Ω) 100 W non-inductive power resistor, depending on the load measurement. I connected the APx515's input across the load using a 1× oscilloscope probe.

First, I measured the noise floor with the Y axis units being decibel level referenced to 1 V (dBV) and the output of the APx1701 connected to the 8 Ω dummy load (see **Figure 4**). The upper trace shows the noise across the dummy load with the APx515 connected, but with the signal generator turned off. The lower trace shows the noise across the dummy load, but with the input of the APx1701 shorted with a 180 Ω resistor.

These spectra show that the APx1701's noise will not be the limiting factor in a measurement, and even with the increased noise floor from connecting the APx515 analyzer, the noise is orders of magnitude below anything that is likely to be acoustically measured. Note that the 20 dB difference in the noise floors (-130 dBV vs. -150 dBV) corresponds to the 20 dB voltage gain of the APx1701.

There's a few small spikes in the spectra, probably a mix of internally generated noise from the digital circuitry and pickup from my not-at-all-quiet lab environment. That said, the noise floors are quite low, and even the worst of the spikes doesn't exceed -105 dBV (with the APx515 connected).

Figure 5 shows the THD+Noise vs. level for both the 4 Ω and the 8 Ω loads. These measurements were taken at 1 kHz, but 10 kHz measurements looked nearly identical. The top two traces were taken with an 80 kHz measurement bandwidth, the lower trace was taken with a 20 kHz bandwidth. The difference in level between these traces confirms that the measurement is dominated by noise. You can also see that the built-in protection circuit limits the voltage swing at the 4 Ω load impedance well before any distortion appears—measurements right up to the power limits of the APx1701 will be reliable.

Figure 6 shows the distortion spectrum at 2.5 V output and a 1 kHz fundamental into 4 Ω and 8 Ω loads. The 4 Ω load results show some even-order distortion not present for the 8 Ω load, but even so, at -116 dB down from the fundamental (0.00016%), the distortion is ridiculously low.

Figure 7 shows a log frequency plot of the distortion spectrum for a 2.5 V output and a 10 kHz fundamental into an 8 Ω load. The distortion is similarly low and dominated by noise (all spikes in the spectrum that do not fall at multiples of the 10 kHz fundamental are noise). In most amplifiers, distortion rises with increasing frequency because of falling open loop gain and hence lower feedback with increasing frequency. The clever engineers at Audio Precision seem to have done some circuit tricks to overcome this.

The intermodulation distortion (IMD) results are similarly impressive. **Figure 8** shows the spectrum for a 10 kHz and 11 kHz tone pair at 10 V output into 4 Ω and 8 Ω loads. Intermodulation products appear at 1 kHz multiples, with the largest being at 13 kHz with a level of -125 dB (referenced to the signal for the 4 Ω load. Again, this is outstanding performance, with the distortion absolutely negligible compared to that of any transducer.

Example Applications

When the legendary speaker company NHT was going through one of its many corporate restructurings, I inherited a couple dozen Peerless 170 mm woofers in varying condition. I had tried using them in a few prototype speakers, but never got quite the results I wanted. The bass always sounded rather murky and uncertain. Of course, I had run measurements on their T-S parameters during development, using my sound card setup, and used these measurements to design the boxes. My measurements were repeatable, so I never understood why my results weren't better. Hating a mystery the way I do, the first thing I did with the APx1701 was re-run those measurements.

One of the cool features of the integration is that the amplifier output voltage can be selected from a drop-down menu—no knob-twiddling or external voltmeter measurements needed. So in less than two minutes, I was able to see how the impedance curve varied as a function of drive level, varying the drive from 250 mV to 2.5 V. The test setup was straightforward. I connected the output of the APx1701 to the woofer, and connected the Current Sense output of the APx1701 to one of the balanced inputs of the APx515 analyzer. The APx500 software then uses the current and applied voltage to calculate the impedance, which is then displayed.

The results are shown in **Figure 9**. As much as we always hear the disclaimer that T-S parameters are small signal, the level at which they are taken is not standardized, and this graph shows that indeed something as basic as resonant frequency is a strong function of drive level. With increasing

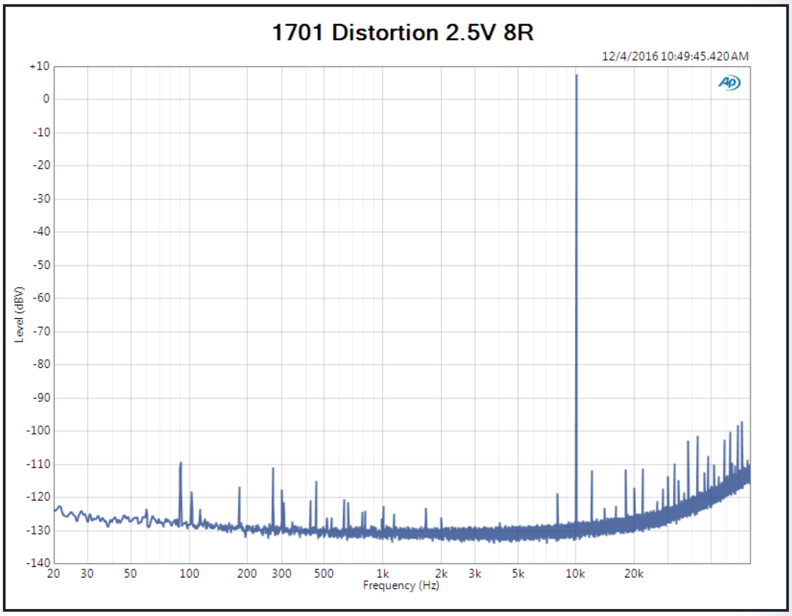

Figure 7: The distortion spectrum of the APx515/APx1701 combination at 10 kHz is dominated by low levels of noise—as with the 1 kHz results, the distortion is remarkably low.

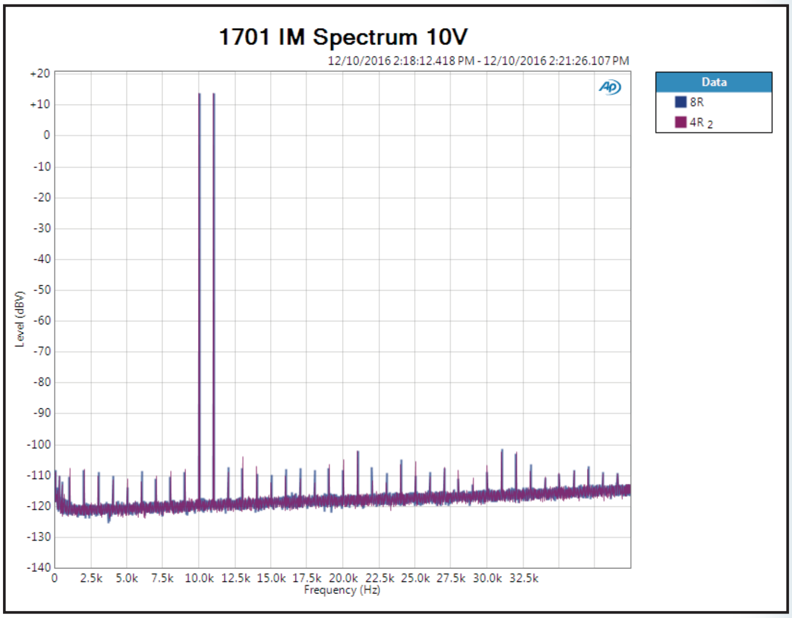

Figure 8: The10 kHz/11 kHz intermodulation distortion at 10 V output into 4 Ω and 8 Ω loads is astonishingly low, with the largest component at -125 dB (<0.0001%) relative to the signal.

Resource

S. Yaniger, "Innovative Measurement Microphones from PCB Piezotronics," *audioXpress*, December 2016.

Source

APx515/APx1701 combination
Audio Precision, Inc. | www.ap.com

drive, the resonant frequency drops significantly. Note that all of these voltage levels are relatively low, so the woofer is certainly not being stressed.

The shift in resonant frequency with drive is an indication of nonlinearity of the suspension (and possibly the motor), and it's evident that the frequency response of the driver in a box would shift around considerably when playing music. No wonder I was dissatisfied with the sound!

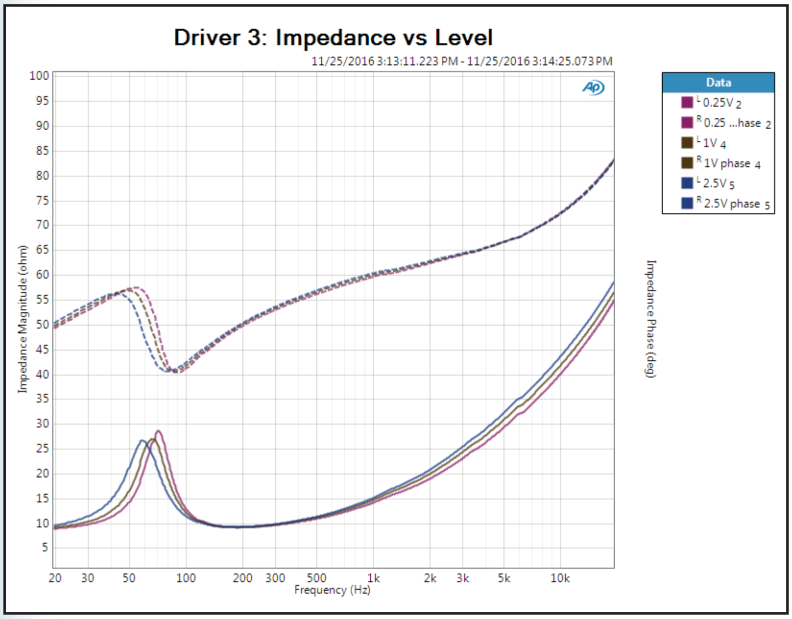

Figure 9: The impedance of a 170 mm Peerless woofer is shown for drive levels of 0.25 V, 1 V, and 2.5 V. Note the significant shift in resonant frequency with drive.

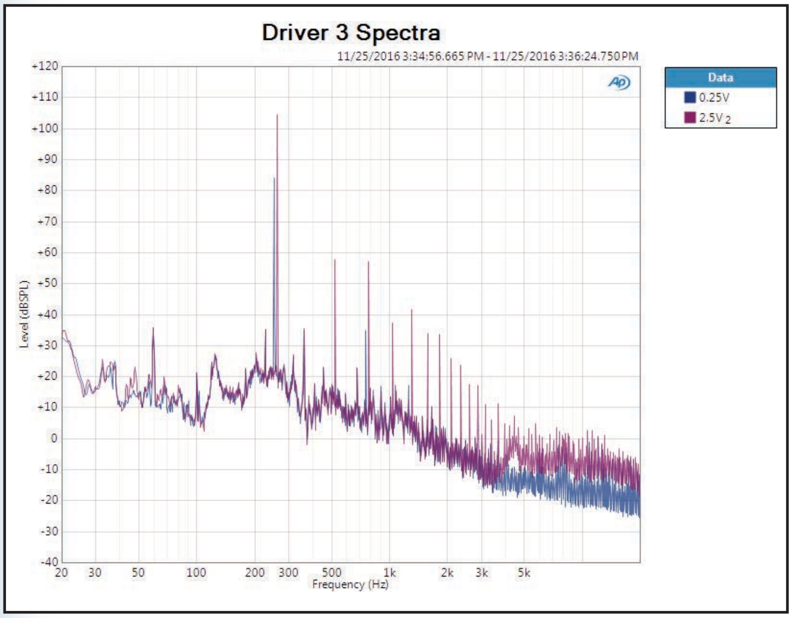

Figure 10: The distortion spectrum of the same 170 mm woofer from Figure 9 at two drive levels shows the distortion changes predicted from the resonant frequency shift.

An indication of this effect is evident in the distortion spectra, which are shown in **Figure 10** for two drive levels (250 mV and 2.5 V) at approximately 250 Hz. I altered the frequency slightly between the two different levels so that the spectra could each be seen and compared. The setup for this measurement was also straightforward. I connected the woofer to the output of the APx1701. Next, I placed my test microphone (an iSEMcon EMX-7501) about 3 cm away from the woofer cone and connected it to the APx1701's balanced microphone input, which provided the phantom power and passed the microphone signal to the APx515 analyzer.

Note that at 250 mV drive, the third harmonic is dominant at about -50 dB relative to the 250 Hz fundamental. Any symmetrical nonlinearity will have the odd-order harmonics predominate, and we can see that this is the case here. When the drive is increased to 2.5 V, the second harmonic at 500 Hz appears at a level comparable to that of the third harmonic, indicating an asymmetric nonlinearity (i.e., the cone's forward and backward motions are not equal). We can also see the appearance of other even harmonics (e.g., the fourth at 1 kHz) characteristic of an issue with the suspension or motor.

One might guess that this nonlinearity correlates with the previously noted shift in resonant frequency with drive, proving a purely electrical way to predict driver distortion. Using the Audio Precision system, I was quickly able to evaluate several different driver types to see if this is the case—I will elaborate on this in a future article.

I tested six of the Peerless drivers and found similar results. However, despite having frequency response, impedance, and distortion similar to the other woofers, Driver 3 subjectively sounded different and worse than the others—the difference wasn't huge, but it was noticeable. What could be the cause? My first step was to look at the impulse response of the drivers. I obtained this using the log frequency sweep as a stimulus and the same setup as described for the distortion measurements

About the Author

Stuart Yaniger has been designing and building audio equipment for nearly half a century, and currently works as a technical director for a large industrial company. His professional research interests have spanned theoretical physics, electronics, chemistry, spectroscopy, aerospace, biology, and sensory science. One day, he will figure out what he would like to be when he grows up.

above. **Figure 11** shows the impulse responses of Drivers 1 and 3, with 2.5 V of drive signal. On casual inspection, they look pretty similar. To see if there are any issues with delayed energy, the impulse response was transformed to give the Energy Time Curve (see **Figure 12**). The drivers don't show much difference there, either. Quite a mystery!

Audio Precision also has a proprietary signal processing function to detect voice coil rub and buzz. Could this shed light on the mystery?

Figure 13 shows the rub and buzz measurements. We can see that Driver 3 has significant peaks at a series of discrete frequencies compared to Driver 1 (and indeed, all the other woofers tested), suggesting that the sonic difference I heard is related to mechanical issues in the woofer's motor. This function could be a very useful quality control tool when looking at a population of drivers.

Negatives

My wife likes to say, "Perfection is a good starting point." In that spirit, there's still a few things I'd want to see improved. First, there's noise.

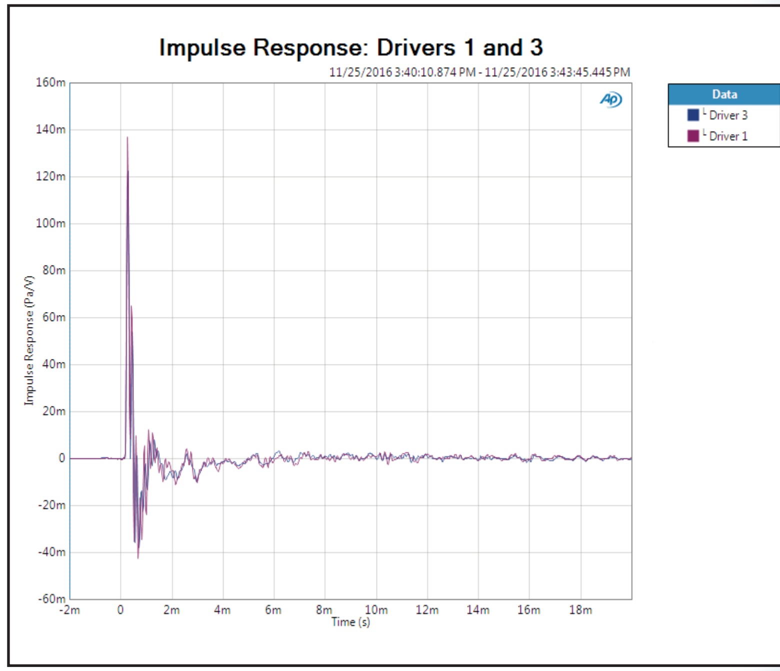

Figure 11: The impulse responses of two 170 mm woofers derived from a log frequency sweep do not show much difference between them, despite some differences in sound.

Not electrical, which was quite low, but mechanical. The fan was loud enough to interfere with some low-level speaker measurements I was trying to do. The workaround is to use a long microphone cable and position the interface and the analyzer in a separate room, but this was rather inconvenient since my electronics test bench and speaker measurement area are in the same room.

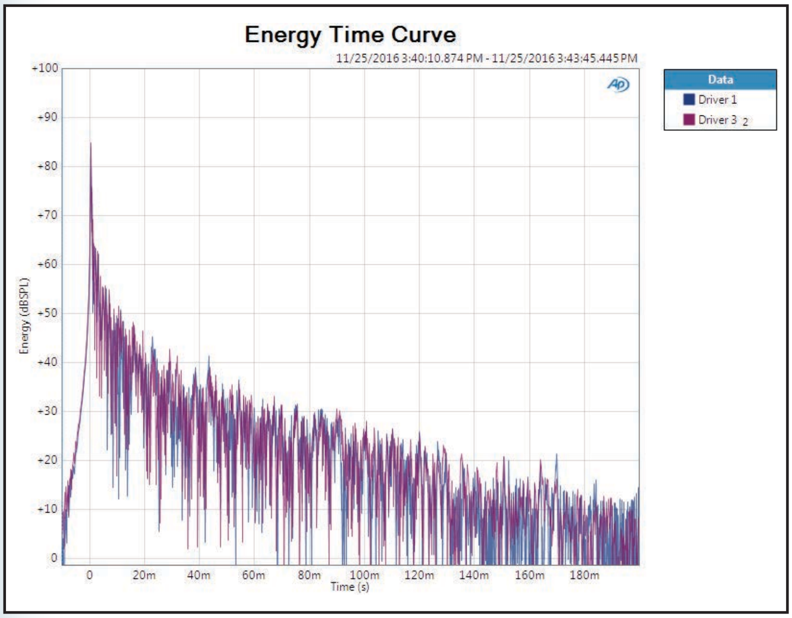

Figure 12: The APx515/APx1701 combination enables rapid acquisition of energy-time curves. This graph is derived from the impulse responses shown in Figure 11.

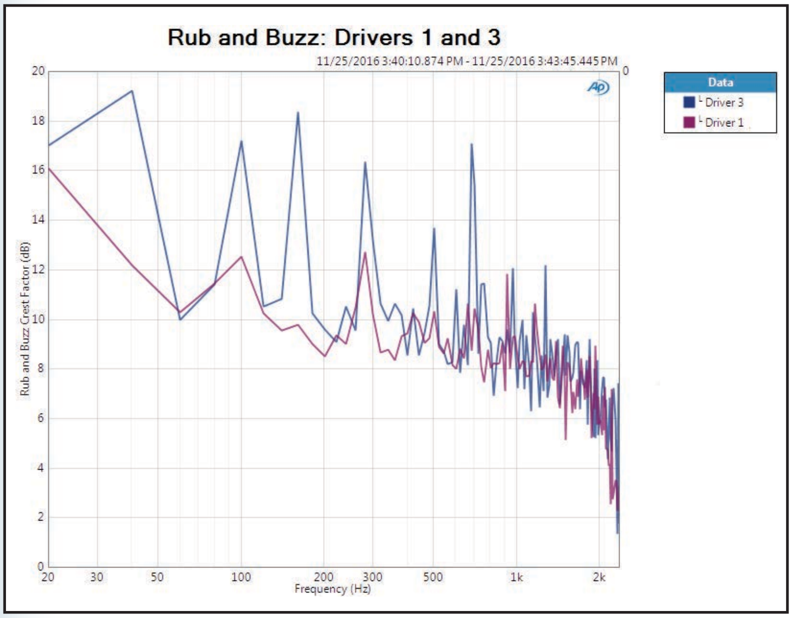

Figure 13: Audio Precision includes a proprietary rub and buzz measurement. These curves are taken from the same drivers as the previous two figures and graphically shows why Driver 3 sounded significantly worse than the others.

Second, it would be nice to have a balanced input option. The existing unbalanced connection through a BNC is fine if the unit is always getting its input from an APx500-series analyzer, but I can think of several potential measurement scenarios where a balanced input would be preferred. You could construct a simple balanced-to-single-ended converter, but I would hate to compromise this system's performance with more quotidian electronics in the signal chain.

Finally, documentation. The APx500 software's documentation is extraordinarily comprehensive (700 pages in the manual!) and clearly written. By contrast, the APx1701 comes with a rather thin pamphlet that gives some general suggestions, but doesn't share the magisterial splendor of the software's manual. It would be nice if there were more detailed explanations of how to set up the basic measurements needed for transducers beyond some spare block diagrams. It's a credit to the user-friendliness and intuitive quality of the software that I was nonetheless easily able to puzzle things out.

Reviewer Confession

Although I was supposed to be reviewing the APx1701 as part of a test and measurement system and keep my official scientist lab coat on at all times, my monkey brain got irresistibly curious. The APx515 contains a state-of-the-art DAC and pre-amplification, and the APx1701 is clearly a fantastic performer (see **Photo 3**). So I hooked it up to a pair of speakers, took some snippets of music files from my home recordings and used them as my "test" signals, with my ears as the measurement tools. Not unexpectedly, the sound was exceptional. If I were a marketing person at Audio Precision, I would be calling an engineer into my office and saying, "If we can add a pass-through function into the software that would enable users to easily play music through the APx515/1701 combination, we could have a high-end audio cult hit on our hands. After all, the price is lower than the cost of top-ranked commercial DACs or power amplifiers alone, and it's a completely integrated DAC and amplifier..."

Conclusions

The APx1701, along with the acoustic measurement software options in the AP500 system, converts a remarkably capable system for electrical measurement into an equally capable acoustic measurement system, with the added ability to acquire quantitative high-resolution impedance data. The integration is outstanding. Setup and measurement times are remarkably quick, and data that require amplification gain changes can

Photo 3: The APx1701 Transducer Test Interface is an APx accessory device that integrates instrument-grade amplifiers and microphone power supplies for designers and production test engineers seeking clear insight into the behavior of their electro-acoustic devices. And it sounds great too.

be obtained with simple menu selections. The need for additional boxes (e.g., microphone preamps and power amps) with all of their variability and calibration complexity is eliminated. The performance of the amplification is state-of-the-art and orders of magnitude better than any imaginable transducer. Given the performance, the price is remarkably modest.

My post-doctoral advisor, the late Nobelist Alan MacDiarmid, used to say, "Time is the most valuable chemical." This homily has stuck with me over the years, and perhaps explains why I have enjoyed my time with the APx515 and APx1701 combination. Sure, the performance is very fine, but the great thing was how the integration saved me so much time. Measured by the amount of high-quality data I was able to generate per hour, I'd estimate my productivity was an order of magnitude better. Moving from setup to setup or measurement type to measurement type went from an hour minimum to a minute or less. Changing measurement conditions or setting up the frequency sweeps took seconds.

Bottom line: I have been contemplating selling a kidney to pay for my own APx515/APx1701 combination, and am still ducking phone calls from Audio Precision asking for my loaner units back.