Dayton Audio Test System (DATS) V3

Photo 1: DATS V3 is an ultra-portable audio test system that provides a reliable method for collection of Thiele-Small parameters and component measurements.

Rise of the Ultra-Portable Woofer Tester

After a decade of widespread use, the Dayton Audio Test System (DATS) has acquired an impressive reputation for fast and accurate testing. Now, Dayton Audio has taken the easy-to-use audio test system and improved it in almost every way when creating the DATS V3 Computer-Based Audio Component Test System (see **Photo 1**). David Logvin has been a user of the solution and reviews the latest iteration for *audioXpress*.

By
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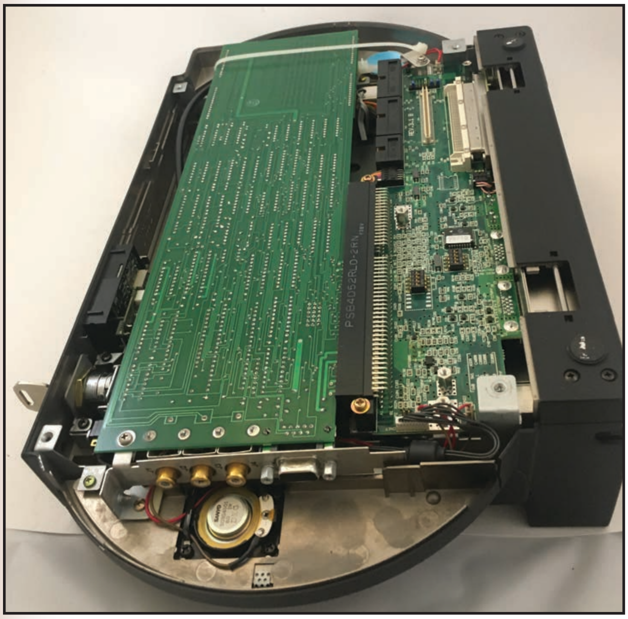

Photo 2: In the 1990s, a MLSSA measurement system was the industry standard method for measuring Thiele-Small parameters. It is shown here mounted in the author's ThinkPad Dock 1 Expansion Unit as an early example of test hardware portability.

For as long as I have been working in audio and acoustics, portability has been at the top of the desired feature list for measurement systems. And there has been a steady and noticeable evolution in hardware: from the awkward laptop docking stations making 13" ISA-cards (see **Photo 2**) slightly portable, to the more palatable options like Liberty Audio's Praxis or Dayton Audio's OmniMic, and more recently with Audiomatica's Pocket Clio,[1] this downsizing trend is quite clear.

While most manufacturers have streamlined and reduced the footprint of their measurement hardware, a few companies have focused on the "ultra-portable" market. These are devices about the size of a compact mobile phone, but with unique measurement capability that goes beyond the limited world of audio measurement on iOS or Android platforms.

Dayton Audio's Digital Audio Test System Version 3 (DATS V3) is one such device. On initial inspection, it appears to be a simple and compact impedance analyzer, but it actually offers a host of additional signal analysis and generation tools. Curiously, despite the "V3" suffix in the name of this device, this is actually the fourth iteration of this design.

The original DATS was dubbed "WT3," and was a simple USB-based hardware device that provided an easy method to measure Thiele-Small (T-S) parameters and impedance curves. It was useful for troubleshooting finished systems and prototypes, as well as designing new woofer boxes, using the derived parameters for force factor, compliance, and so forth.

The original device was launched as the WT3 Woofer Tester in 2007. The hardware and software are both the design of True Audio's John L. Murphy, a veteran acoustics engineer and author.[2] A few years later, it was replaced with an identical-looking device, but rebadged and improved as the Digital Audio Test System (DATS). This new version featured a faster start-up time, as well as new signal generator and oscilloscope modes. In 2014, the DATS v2 hardware and software was updated again. This version introduced a new rub and buzz test for advanced diagnosis of discrepant woofers.

Fast forward to 2019, and the latest generation, DATS V3, was released. This new iteration of software and hardware provides improved measurement accuracy, an interesting new linearity test, as well as dramatic improvements to the mechanicals.

Upgraded Hardware

The prior three generations of DATS all featured a simple plastic housing with non-detachable USB cable and test leads (see **Photo 3**). With the new V3 hardware, the device is significantly upgraded with an aluminum extrusion body and endcaps (both with a nice brushed and anodized finish). A USB port and banana jacks now provide for removable cable options and standard test probes for convenience and simple field replacement. Also included with each DATS V3 is a set of rubber feet for table top use, as well as brackets so it can be mounted under a benchtop.

Quick Setup

In prior DATS versions, a separate 1 kΩ calibration resistor was used to calibrate the test system. In the V3 hardware, the resistor is now permanently mounted inside the aluminum chassis and turret connectors provide a reliable test point for making the connections.

Standard procedure would be to first zero out your probes by shorting them to determine the internal probe impedance. Then, measure the reference resistor impedance and store this value into memory and are you are now ready to collect calibrated impedance and Thiele-Small (T-S) data.

With the latest generation, DATS V3 users have access to the following features: T-S parameter measurement, impedance analyzer, RLC meter, rub and buzz failure mode testing, and a unique linearity test unique to this software, as well as the signal generator and oscilloscope modes shown (see **Figure 1**).

T-S Measurement Techniques

Conveniently, DATS V3 offers four different methods to derive T-S parameters: Added (delta) mass, Test box (delta) compliance, Specified SPL, and Specified Mmd (cone mass). The choice of

Photo 3: Three generations of DATS are shown, including the WT3 (left), the DATS V2 (right), and the DATS V3 (center).

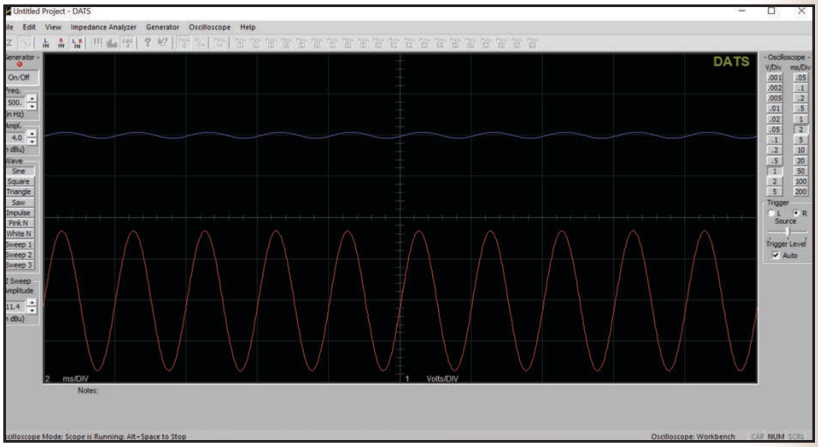

Figure 1: DATS V3 users have access to the following features: the Thiele-Small parameter measurements, an impedance analyzer, an RLC meter, rub and buzz failure mode testing, and a linearity test unique to this software, as well as the signal generator and the oscilloscope modes shown.

About the Author

David Logvin is an acoustics engineer at TDK InvenSense, working in the MEMS microphone division. With more than 20 years of experience, he has designed loudspeakers and other products for Snell Acoustics, Outlaw Audio, ClearView Audio, Cambridge Sound Management, and others. During his 14 years at Snell Acoustics, he developed and designed dozens of high-end loudspeakers and amplifiers, as well as helped to create loudspeaker standards in close collaboration with THX. David then focused his efforts on R&D, creating innovative, award-winning piezo-driven membrane loudspeakers with ClearView Audio (formerly known as Emo Labs). At Cambridge Sound Management, he put his skills in room acoustics to use in the field of sound masking for corporate applications. Most recently, he rejoined his fellow Snell Acoustics alumni, Dr. Joseph D'Appolito, to design several new loudspeakers for Outlaw Audio. In addition to his lifelong love of music and acoustics, David is an active participant in the Boston tabletop game design community. He is a member of the Audio Engineering Society (AES) and the Boston AES Section and lives in Lowell, MA with his family.

Photo 4: The DUT is tested using the Vas Added Mass method (a) and the DUT is tested using the Vas Test Box method (b).

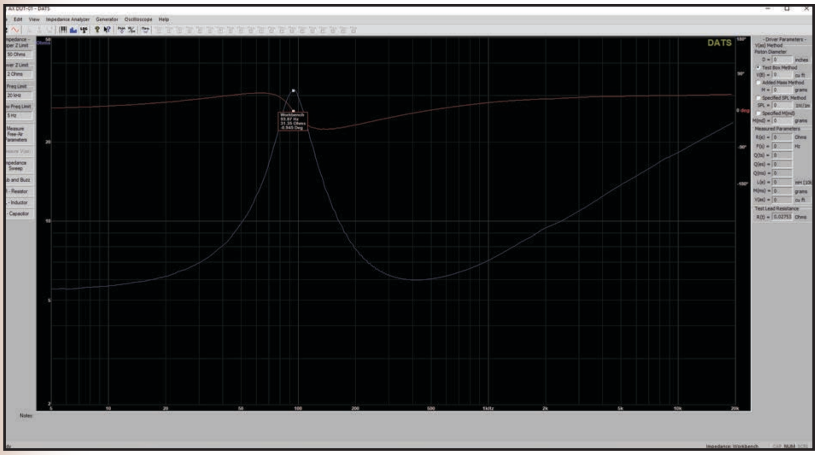

Figure 2: The main software UI is shown where all DATS V3 tests can be accessed and set up. The highly-efficient Impedance Sweep function was used to plot impedance magnitude and phase for the Peerless 850102 SDS.

method depends on auxiliary equipment, user preference, and if any manufacturer specifications are available for the device under test (DUT).

The first two listed methods are traditional and rely upon taking a free air impedance curve and then carefully shifting the resonant frequency using either a delta mass or delta compliance approach. If you have access to a precision grams scale, the delta mass method is often the easiest, although if you already have a sealed test box of a known and suitable volume, then the delta compliance (aka "Test Box" method) can also be convenient.

For delta mass testing, after collecting the free air impedance data, you will add mass (known to at least one significant figure of precision) to the cone that will result in a minimum of a 25% shift downward in resonance. The other classical method for measurement of T-S uses a delta compliance method. After the free-air resonance impedance curve is taken, the DUT is placed into a known volume that will result in an upward resonance shift of at least 50%. The delta compliance method could be particularly useful if you don't have a known mass handy, or if the installation of the mass loading itself tends to temporarily shift the resonance and you don't want to wait for the suspension to recover and return to equilibrium (see **Photo 4**).

To investigate the T-S methodologies, I selected a Peerless 4" mid-woofer, the 850102 SDS. The results for the delta mass measurement (and the three other methods, see **Figures 2–4**) are shown and correlate well with the published manufacturer specifications (see **Table 1**). It is worth noting that this particular driver's Fs is over 20% higher than the datasheet, so if it was going to be used in an actual design, a driver break-in program should be performed to exercise the suspension and ensure that the parameter values have settled to their final values.

The other two methods are "quick-look" and rely upon having access to the most basic of driver parameters (either the nominal sensitivity or the cone mass). Both rely on the accuracy of the manufacturer's supplied data for either Known Sensitivity (at 1 W/1 m or 2.83 V/1 m) or a known cone mass (Mmd). Many manufacturers will supply this basic data, even if they choose not to share their T-S parameters.

These two methods are less accurate than the traditional methods (delta mass and delta compliance), as they assume the test speaker is close in tolerance to the published parameters. While this might be true for a good working unit, it wouldn't be useful if you were trying to troubleshoot a defective unit. These methods only require a single measurement to be taken, and can provide meaningful data for rapid evaluation of drivers, at the cost of introducing more measurement error into the collected data.

To utilize the Specified SPL method, you need only measure the free-air impedance curve and enter the standard sensitivity in dB SPL at 1 W/1 m, as well as the piston diameter. It is standard practice to measure the piston diameter using half to one-third of the surround roll, if this dimension isn't listed on the datasheet.

The other efficient method is the Specified Mmd method. Similarly, you need to measure the free air impedance of the DUT, and enter the piston diameter, as well as the Mmd (cone mass) from the datasheet.

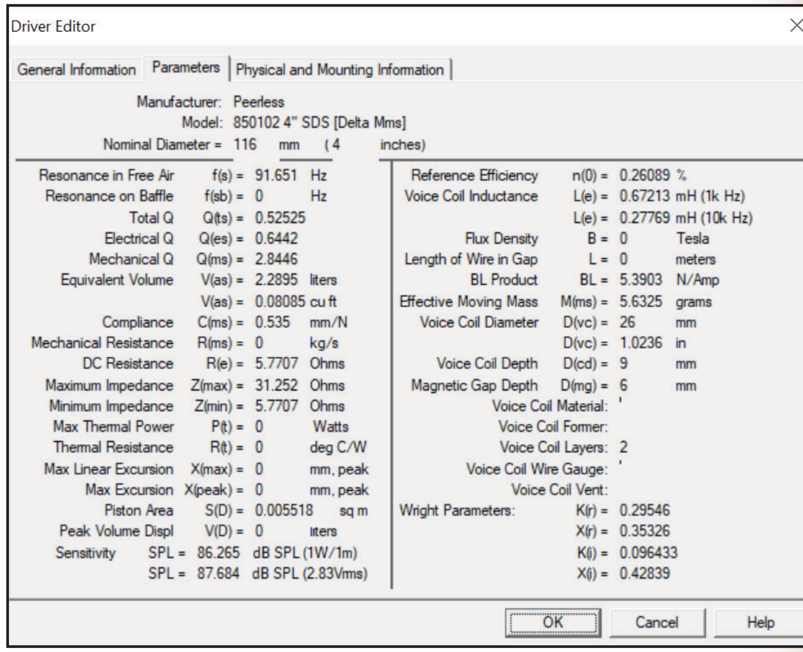

Figure 3: The Driver Editor panel is shown for Vas Delta Mass testing. Derived T-S and Wright parameters are listed and user notes can be added to the records.

Rub and Buzz and Linearity

Most traditional acoustic analyzers can be "trained" to detect rub and buzz failures in cone drivers with failure modes due to particle contaminant in the magnetic gap, or a rubbing voice coil. The basic detection scheme relies upon spectral analysis of the sixth through the 10th-order harmonics that are present in the defective units.

While DATS V3 does rely upon a human to guide and teach the algorithm the limits (using a known "Golden Sample" to verify the pass target), the DATS detection scheme is quite different than the harmonic distortion techniques utilized by other acoustic test systems.

Elegantly, the DATS rub and buzz algorithm is looking for shifts in resonance. If the resonance dramatically shifts, the loudspeaker driver is either no longer operating in the small-signal, linear range or a failure mode has been detected such as a rocking mode causing a rubbing voice coil or a tinsel wire tapping against the underside of the cone. Highly intermittent failures (from such things as contaminants in the magnetic gap) will be more difficult to detect using the DATS methodology.

As this hardware is running off a USB 5V DC bus, it typically is capable of staying in the small signal domain for most drivers. If you are dealing with microdrivers, then you may need to exercise some judicious level setting (30 dB to 40 dB below the typical DATS sweep amplitude of +4 dBu) to keep it out of the large signal domain.

In the panel shown in **Figure 5a**, you can see the set-up panel for rub and buzz detection for signal level, resonance, and impedance maximum (Zmax) tolerance. Then you need to connect DATS V3 to a known good unit, free from any unusual distortion and possessing a nominal impedance curve. This is the teaching method that requires some "pre-work" in both the selection of this "Golden Unit," as well as appropriate level setting based on the power handling capabilities. Interactive prompts will guide the operator to change to a different unit in order to determine if any rub or buzz issues exist (see **Figure 5b** and **Figure 5c**).

While the rub and buzz test was first developed for the DATSv2 hardware, the linearity test is a new (but related) test developed for the V3 release.

By relying upon the principle of small signal performance and judicious setting of input drive levels, some preliminary analysis of power handling capability is available. As with the rub and buzz test, you need to properly set the drive levels. But unlike that particular test, no golden unit is required in order to take advantage of this test method. Full control over the drive range, the number of sweeps, as well as if you want to sweep from high-to-low or low-to-high amplitude levels provides maximum flexibility. This is a quite interesting use of the DATS V3 as an impedance analyzer, as linearity is typically measured using amplitude data (see **Figure 6**).

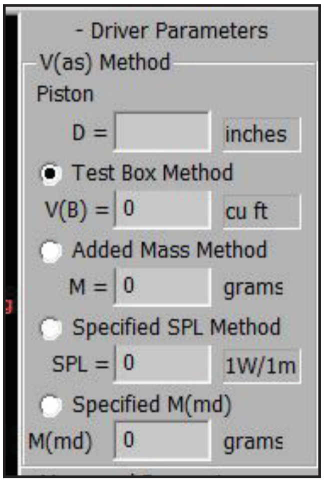

Figure 4: The four different test methods for Vas are shown: Test Box, Added Mass, Specified SPL, and Specified M(md).

Software Integration

DATS V3 directly integrates with several other software packages for maximum flexibility. In addition to the option to export a native file *.zma or *.txt format, it is also possible to export impedance data as a text file with a CLIO compatible header. Once T-S driver parameters have been computed, they can be saved either as a native DATS file or as a WinSpeakerz driver file

	Datasheet	Added Mass	Test Box	Specified SPL	Specified Mmd
Zmin	6.2 Ω	5.7707 Ω	5.7707 Ω	5.7707 Ω	5.7707 Ω
Zo	31.6 Ω	31.252 Ω	31.252 Ω	31.252 Ω	31.252 Ω
Re	5.6 Ω	5.7707 Ω	5.7707 Ω	5.7707 Ω	5.7707 Ω
Le	0.9 mH	0.67213 mH	0.67213 mH	0.67213 mH	0.67213 mH
Fs	74.2 Hz	91.651 Hz	91.651 Hz	91.651 Hz	91.651 Hz
Qms	2.41	2.8446	2.8446	2.8446	2.8446
Qes	0.52	0.6442	0.6442	0.6442	0.6442
Qts	0.43	0.52525	0.52525	0.52525	0.52525
Vas	3.4 ltr	2.2895 ltr	2.0052 ltr	1.83 ltr	2.1 ltr
Cms	0.74 mm/N	0.535 mm/N	0.469 mm/N	0.428 mm/N	0.486 mm/N
Bl	5.6	5.3903	5.7598	6.0268	5.6575
Mms	6.2 g	5.6325 g	6.4312 g	7.0411 g	6.2 g
Sensitivity (2.83 V/1 m)	86.7 dB SPL	87.684 dB SPL	87.108 dB SPL	86.7 dB SPL	87.264 dB SPL

Table 1: The T-S parameters for the Peerless 4" SDS are collected from the manufacturer's official datasheet, as well as the measured parameters using each of the four available test methods for DATS V3.

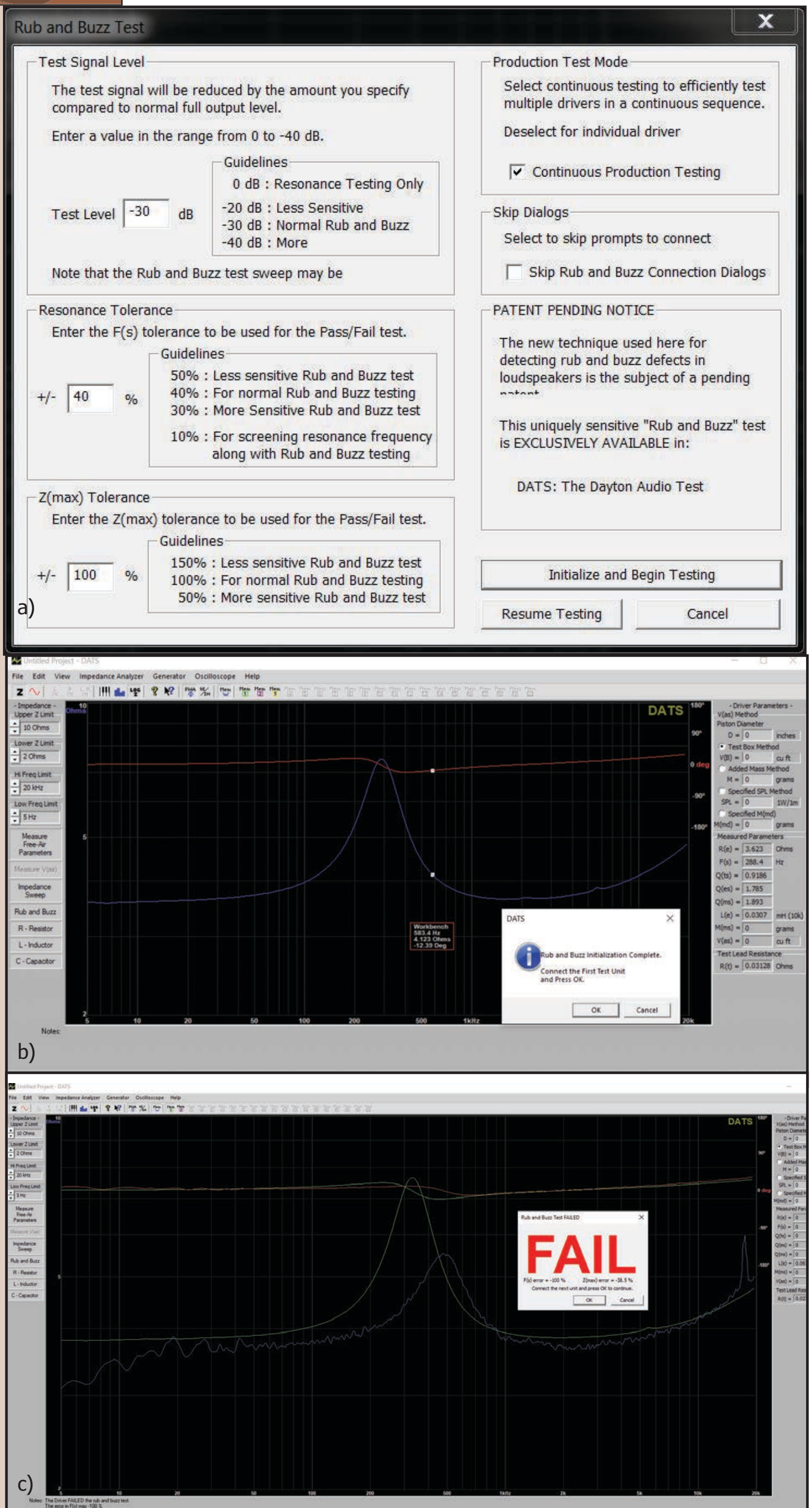

Figure 5: The set-up panel for Rub and Buzz testing provides signal level setting, tolerance setting, and the option to enable production testing (a). After entering appropriate signal levels and tolerances, the next step is to initialize the system with a known good "Golden Sample" unit to teach DATS V3 appropriate limits for rub and buzz (b). A failed unit is detected using the rub and buzz algorithm. In this case, the failure is due to a severe rocking mode (c).

to aid in woofer box simulation work. For those unfamiliar with True Audio's WinSpeakerz, it is a low-cost software package aimed at the DIY market for those users looking to design woofer boxes and passive crossover and Zobel networks.

When generating your loudspeaker driver files (using one of the four available methods), the Wright model parameters are also calculated, which provides a more representative description for the complex voice coil impedance.[3] For more details, please see the tech notes in the DATS V3 documentation.

Final Thoughts

While the acoustic measurement system world is strongly biased toward PC-based data acquisition systems, consistent demand for audio testing portability has led to the proliferation of mobile apps that offer powerful measurement capabilities that can be run on a smart phone or tablet (Studio Six's AudioTools for iOS and Bofinit's AudioTool for Android are prime examples). Even with this flexible and low-cost measurement capability, there are times when you need an impedance measurement. In those cases, there isn't "an app for that," and some specialized hardware is required in order to collect this data. And while DATS V3 is firmly rooted as a PC application, its spirit and adaptable workflow definitely have kept up with the changing expectations for today's engineers and audio enthusiasts.

It has been interesting to observe the evolution of DATS over the past 12 years. The software has consistently added interesting features that expand significant capabilities, whether you are hobbyist, mobile installer, field technician, or pro engineer far from a rack of professional measurement gear.

References

[1] J. D'Appolito, "Audiomatica's CLIO Pocket Electro-Acoustical Portable Measurement System" *audioXpress*, October 2015. https://audioxpress.com/article/Audiomatica-s-CLIO-Pocket-Electro-Acoustical-Portable-Measurement-System

[2] J. L. Murphy, *Introduction to Loudspeaker Design: Second Edition*, True Audio, 1998.

[3] J. R. Wright, "An Empirical Model for Loudspeaker Motor Impedance," *Journal of the Audio Engineering Society*, Vol. 38, No. 10, October 1990.

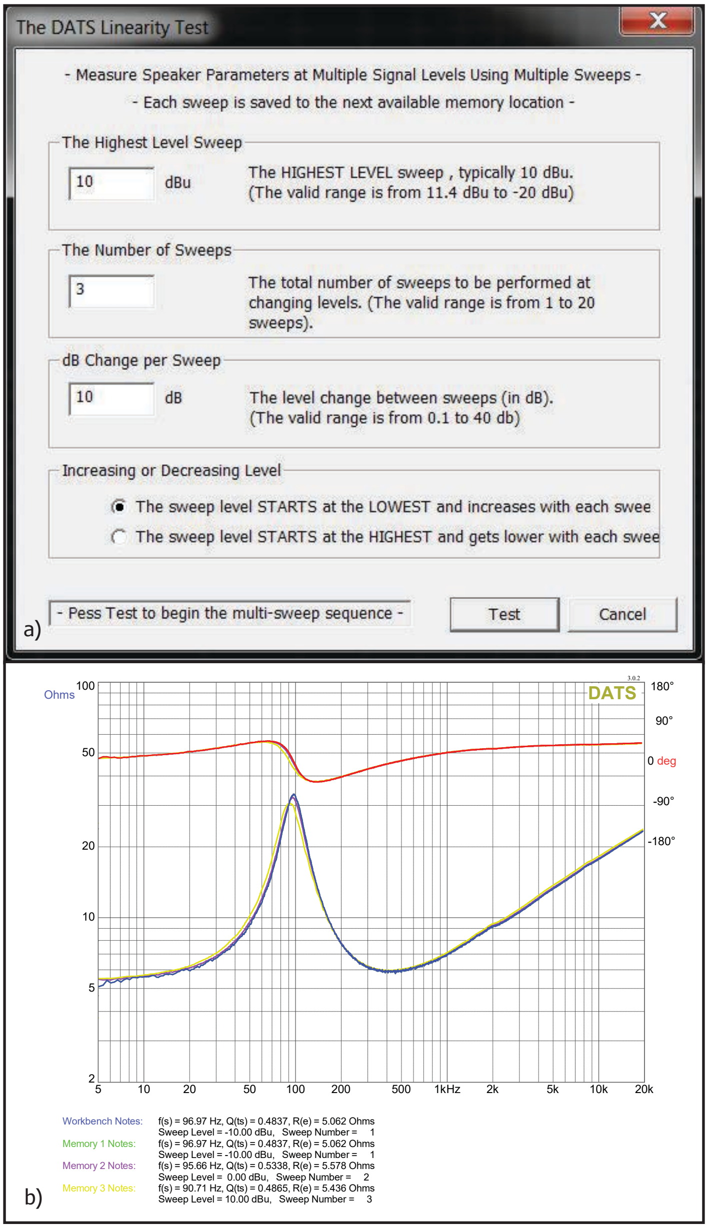

Figure 6: The set-up panel for Linearity testing provides settings for signal level, number of sweeps, and the decibel change per sweep (a). Linearity test results are plotted for three sweeps in 10 dB steps up to the maximum amplitude of +10 dBu for the Peerless 850102 (b).

Physically, it has gone from the very basic look of a low cost, specialized peripheral, to a robust and professional appearance. Feature-wise, it provides the end user with the ability to measure T-S parameters, something that can't be done with a sound card-only based test system, along with a host of other capabilities such as signal generation and linearity testing. This is a flexible tool that can be used for a variety of interesting functions unrelated to woofers, such as testing speaker cables or tweeters. Its greatest strength lies in the satisfying fact that it encourages users to use, analyze, and better understand the vast amount of information that is communicated from a humble impedance curve.