by **Vance Dickason**
on **Voice Coil Test Bench**
Article

Test Bench-Purifi Audio’s PTT5.25X04-NFA-01 Midbass Woofer

January 25 2023, 17:10

The Purifi Audio 5.25” midbass driver is the third Purifi woofer to be examined in Test Bench (see **Voice Coil July 2021**, for the 6.5” PTT6.5X04-NFA-01 and the **November 2021 issue**, for the 4” PTT4.0X04-NFA-01 woofers). As I said in the previous explications, there is no question that this OEM driver manufacturer’s background is impressive and that Purifi’s transducer technology is some of the most advanced and out-of-the-box thinking in the current paradigm. (The Scan-Speak Ellipticor line is another example of out of the box transducer thinking.) More can be read about this interesting Danish loudspeaker and amplifier company in three articles published in *audioXpress*: “**Purifi Audio Promises to Reduce Distortion in Speakers and Amplifiers**” (April 18, 2019 by J. Martins); “**Purifi Audio: A Conversation About Amplifiers and Speakers**” (June 6, 2019 by J. Martins); and “**Purifi Audio - A Straight Wire to the Soul of Music**” (October 23, 2019 by Jan Didden).

Photo 1: The Purifi PTT5.25X-NFA-01 5.25” home audio woofer.

Purifi Audio’s 5.25” diameter PTT5.25X04-NFC-01 4Ω midbass driver (Photo 1) is the newest member of the Purifi midbass woofer family of drivers, and indeed, the specifications are currently listed as a “preview” on the Purifi Audio website (**www.purifi-audio.com**). The PTT5.25X’s technology is pretty much identical to the PTT6.5X and the PTT4.0X, and includes the same constant Sd surround and low magnetic hysteresis motor design.

The feature set for the PTT5.25X begins with a proprietary eight-spoke cast-aluminum frame, comprised of narrow (about 9.5-6mm) tapered spokes, and is completely open below the spider (damper) mounting shelf for cooling (Photo 2). Additional cooling for this driver is provided by 12 oval-shaped 5mm × 3mm vents surrounding the cone neck joint beneath the dust cap, with no pole vent.

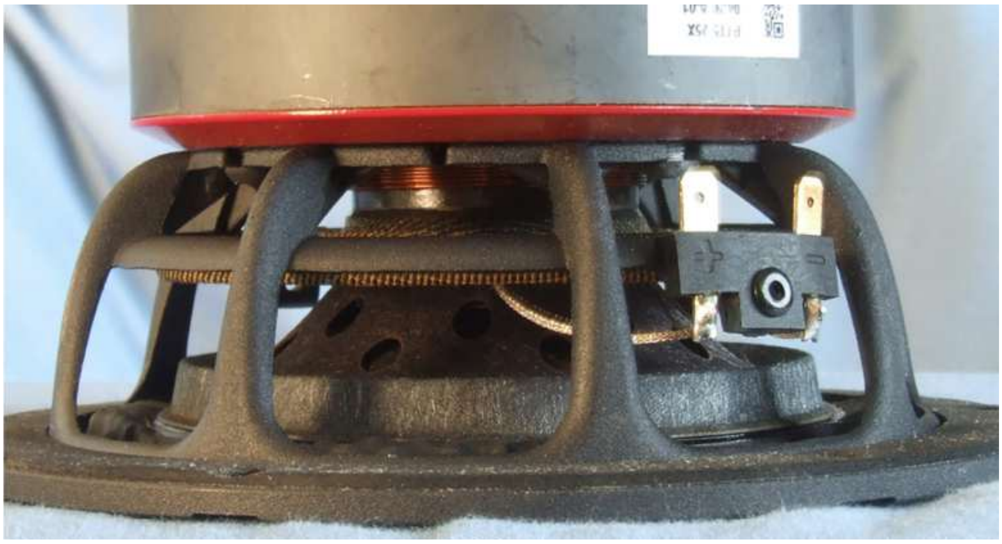

Photo 2: Close-up view of the Purifi PTT5.25X-NFA-01 motor/cone assembly.

The cone assembly consists of a slightly curvilinear profile paper cone made with a proprietary fiber mix, a 2.8” concave dust cap that covers about 90% of the cone surface, plus the addition of a rather large V-shaped edge reinforcing ring glued around the outside rim of the back side of the cone (also seen in Photo 2). This reinforcing ring makes the cone edge extremely stiff, and would obviously severely dampen cone edge resonances. This adds a substantial amount of mass to the cone assembly, but I am quite certain that this is a well-thought-out trade-off.

Compliance is provided by a NBR surround, which as with the PTT6.5X and the PTT4.0X surround is an entire story in itself. Looking at Photo 1, this is like no other surround in the history of woofer development. Surrounds, besides providing compliance and centering, are indeed a source of noise and distortion as well as a tool for damping the outside rim of a cone. It is not a surprise that surrounds have been the subject of numerous patents that offer solutions based on shape, material, and complex material thickness, but I have yet to see anything this articulated.

The PTT5.25X, as with all the drivers in the Purifi line-up, has a surround configuration that is a combination of alternating sections of both reverse roll and positive roll, plus some interesting undulations within the alternating sections. Note that the positive roll has an obvious left/right asymmetry, which yields a positive/negative going articulation on either end of the reverser roll sections. Here is Purifi’s co-founder Lars Risbo’s comment on the Purifi surround technology:

“The surround geometry serves multiple purposes: the strange shape ensures that its radiating area Sd is kept constant over its full stroke (eliminating a strong IMD source). It further tames the usual cone edge breakup (together with the stiffening ring below the cone edge) and is very resilient to the back pressure from a small box. Finally, it is excellent at keeping the coil centered even at large excursions. The combined result is that the IMD hovers around the theoretical Doppler limit."

Remaining compliance is provided by a 3.5" diameter symmetrical roll flat spider. (Note that he individual rolls themselves are asymmetrically shaped.)

The motor consists of an FEA-optimized 100mm × 25mm ferrite ring magnet with milled and tapered plates, the front plate having a red coating and the back plate having a black emissive coating, plus a pole piece comprised of a neodymium pole magnet sandwiched between steel sections that serves to linearize the Bl.

Driving the cone assembly is a 39mm (1.54") diameter substantially four-layer voice coil wound with round aluminum wire on a non-conducting fiberglass former. Like the surround, this four-layer coil also exhibits some very unique engineering. Unlike a winding that has the same width across its full length, this four-layer coil as it has alternating two- and four-layer sections on the length of the coil with varying widths of two- and four-layer sections as seen in Photo 3.

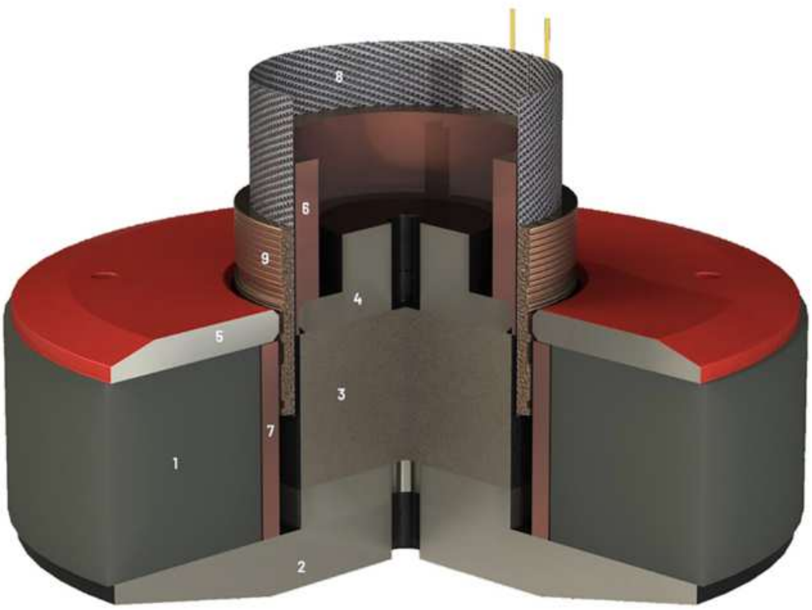

Photo 3: Cut-away diagram of the Purifi ultra-low distortion motor structure.

As can be seen in the Purifi motor rendering, most of the pole (3) is replaced by a strong neodymium magnet. This reduces the coil inductance significantly as well as the inductance vs. position gradient all the way to DC. (This cannot be achieved by shorting rings since they only work above a certain frequency determined by their cross sectional area.) An iron pole piece extension (hat) (4) is optimized to flatten the inductance vs. position further. This virtually eliminates the current dependency of the Bl factor as well as the position dependency of the coil impedance — two major nonlinear sources of IMD (changing the Bl or coil impedance modulates the sensitivity of the speaker leading to amplitude modulation).

Two very thick copper shorting rings (6) and (7) are surrounding the coil within its full linear stroke. The purpose of these is to further lower the inductance and shield the iron from the AC field of the coil. Such an AC field in the iron is a major source of distortion (hysteresis and BH saturation). Note that the top ring (6) extends through the gap since the AC field induced in the iron concentrates at surfaces close to the coil and thus needs the most shielding. The pole ventilation is through holes in the cone assembly to get enough venting area to eliminate air rushing noises.

Much of this technology came from an Audio Engineering Society (AES) convention paper presented by Morten Halvorsen and Carsten Tinggaard (both members of the Purifi team) and Finn T. Agerkvist, titled "Flux Modulation in the Electrodynamic Loudspeaker," (presented at the 138th AES Convention, May 6, 2015, paper #9317). This effectiveness of an articulated coil winding at reducing dynamic inductance will also be revealed in the Klippel L(X) curve.

Also noteworthy is the 250W IEC 268-5 18.2 long-term power handling rating, which is very impressive for a 5.25" transducer. Last, the voice coil copper braid lead wires are terminated to gold-plated solderable terminals located on one side of the frame.

I began testing the Purifi PTT5.25X woofer using the LinearX LMS analyzer and the Physical LAB IMP Box (the same type of fixture as a LinearX VIBox) to create both voltage and admittance (current) curves with the driver clamped to a rigid test fixture in free-air at 0.3V, 1V, 3V, 6V, 10V, and 15V, with the oscillator on time between sweeps to simulate the actual thermal process over time. The 15V curves were sufficiently linear to get an adequate curve fit and were used to calculate the Thiele-Small parameters (TSP) for this driver. This is maybe the second 5.25" in the last 20 years of Test Bench that is able to produce usable impedance data out to 15V (the Dayton Epique 5.5" E150HE also performed this well).

Following my established protocol, I no longer use a single added mass measurement and instead use the company supplied Mmd data (22.65 grams for the PTT5.25X). The collected data, in this case the 12 550-point (0.3V-15V) sine wave sweeps for each Purifi sample were post-processed and the voltage curves divided by the current curves to generate impedance curves, with the phase derived using the LMS calculation method. The data, along with the accompanying voltage curves, was imported to the LEAP 5 Enclosure Shop software. Figure 1 shows the 1V free-air impedance curve. Table 1 compares the LEAP 5 LTD/TSL TSP data and factory parameters for both of Purifi PTT5.25X04-NFC-01 samples.

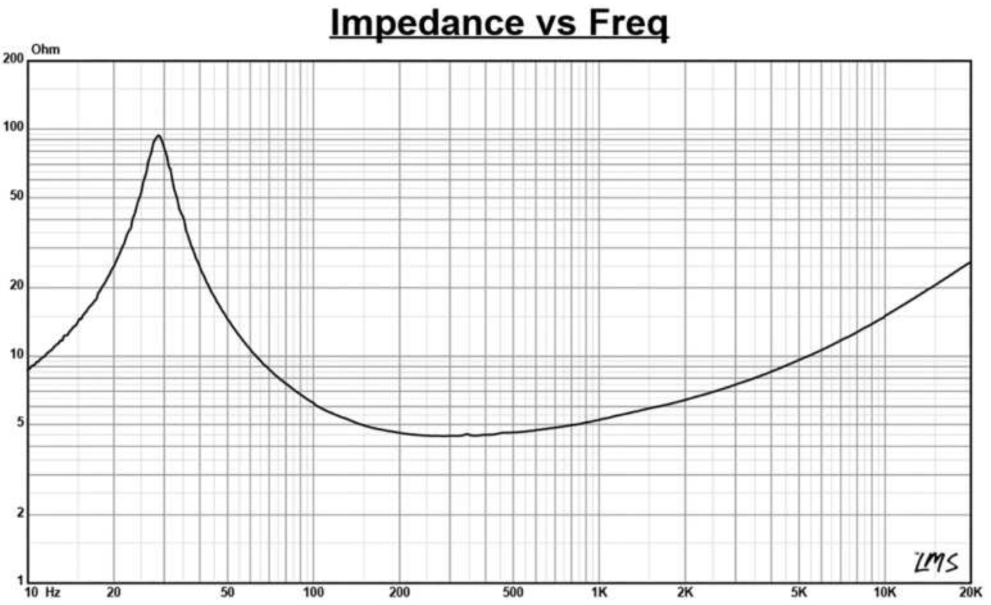

Figure 1: Purifi PTT5.25X-NFA-01 1V free-air impedance plot.

	TSL Model		LTD Model		Factory
	Sample 1	Sample 2	Sample 1	Sample 2	
F_S	28.3Hz	29.2Hz	27.2Hz	27.9Hz	29Hz
R_{EVC}	3.63	3.62	3.63	3.62	3.8
Sd cm^2	84.9	84.9	84.9	84.9	84.9
Q_{MS}	5.25	5.85	5.25	5.62	6.70
Q_{ES}	0.21	0.22	0.23	0.23	0.27
Q_{TS}	0.20	0.21	0.22	0.22	0.26
V_{AS}	14.1 ltr	13.2 ltr	15.2 ltr	14.5 ltr	13.0 ltr
SPL 2.83 V	83.7dB	83.6dB	83.1dB	83.2dB	85.7dB
X_{MAX}	9.8mm	9.8mm	9.8mm	9.8mm	9.8mm

Table 1: Comparison data for the Purifi PTT5.25X-NFA-01 5.25" woofer.

LEAP LTD and TSL parameter calculation results for the Purifi woofer correlated reasonably well with the published factory data, with a 2dB difference in 2.83V sensitivity. My number is a TSP calculation result, and Purifi uses a 300Hz to 800Hz measurement referenced to 20µPa. As usual, I followed my established protocol and set up computer enclosure simulations using the LEAP LTD parameters for Sample 1. Two simulated enclosures were programmed into the LEAP 5 software, one Butterworth Qtc=0.7 sealed box with 96in3 air volume with 50% damping material (fiberglass).

Like the PTT6.5X and the PTT4.0X, the TSPs for the PTT5.25X produced a small enclosure that is tuned fairly low, making a vent of sufficient diameter to be nearly impossible to realize. Fortunately, Purifi makes a matching 6.5" passive radiator (the PTT6.5PR-NF1-01) using the same type surround as used on the Purifi 6.5" (similar to the PTT6.5X-NFA-01 driver cone assembly featured July 2021). Using the Purifi PR parameters for Mms and compliance (80 grams and 133 mm/N respectively), I simulated a Chebychev passive radiator alignment in a 403in3 enclosure volume with 15% damping material tuned to 17Hz.

Figure 2 displays the box simulation results for the PTT5.25X woofer in the sealed and drone enclosures at 2.83V and at a voltage level that achieves excursion equal to Xmax + 15% (11.3mm for the PTT5.25X). This resulted in a F3 of 83Hz (-6dB=66Hz) with a Qtc=0.67 for the closed box and a -3dB for the passive radiator simulation of 40Hz (-6dB= 36.5Hz).

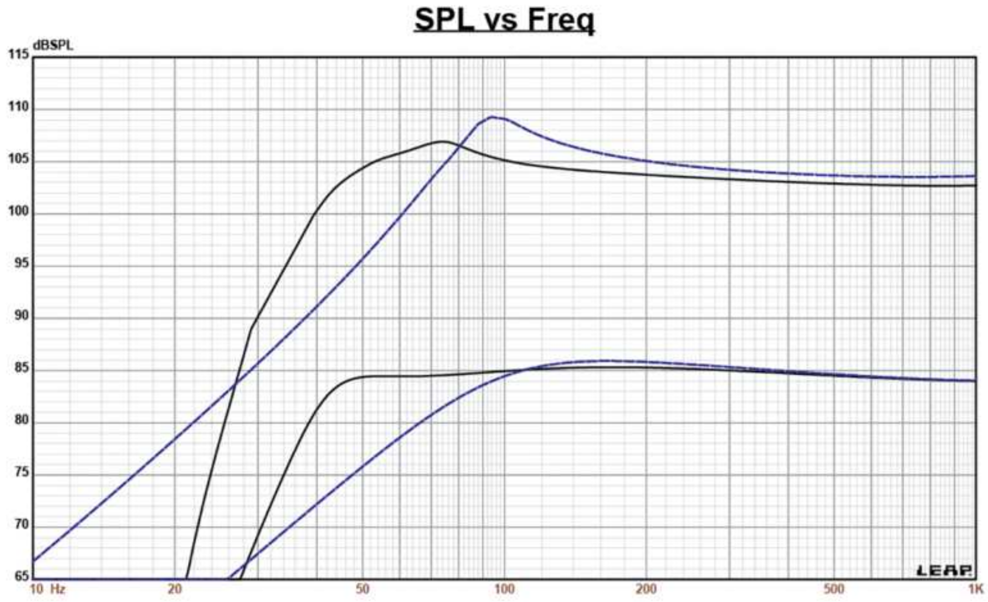

Figure 2: Purifi PTT5.25X-NFA-01 computer box simulations (black solid = sealed @ 2.83V; blue dash = PR @ 2.83V; black solid = sealed @ 36V; blue dash= PR @ 31V).

Increasing the voltage input to the simulations until the Xmax +15% excursion was reached resulted in 109dB at 53V for the sealed enclosure simulation and 107dB with a 36V input level for the larger PR box. Figure 3 shows the 2.83V group delay curves. Figure 4 shows the 53V/36V excursion curves. As usual, a steep high-pass filter on the vented enclosure would prevent over excursion at higher voltage levels.

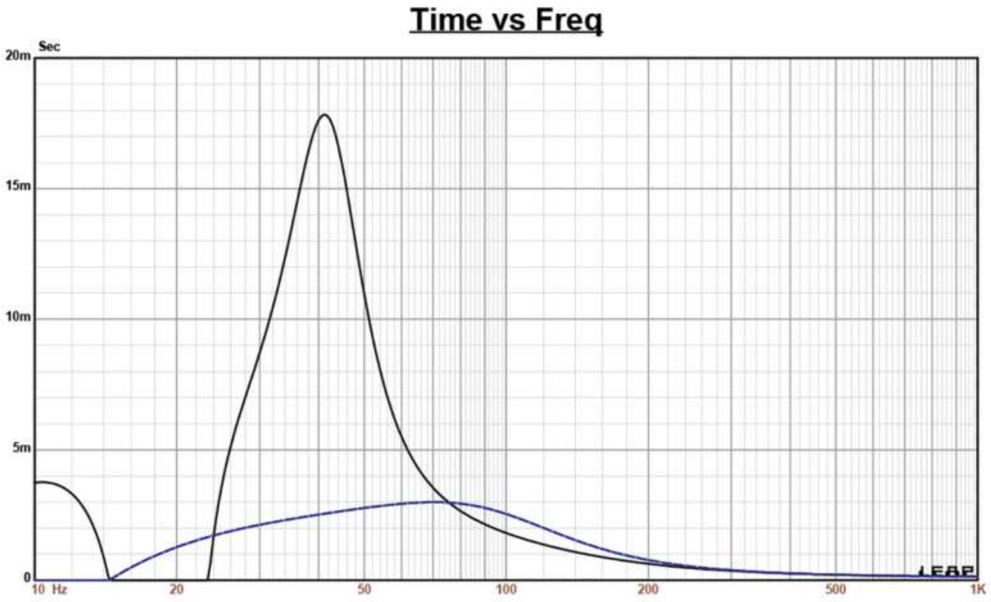

Figure 3: Group delay curves for the 2.83V curves shown in Figure 2.

Figure 4: Cone excursion curves for the 53V/36V curves curves shown in Figure 2.

Klippel analysis for the Purifi 5.25” woofer was performed by Warkwyn (Jason Cochrane performed the analysis) with the Klippel KA3 analyzer. The Bl(X) curve for PTT5.25X shown in Figure 5 is reasonably flat and broad, especially for a 5.25” driver, but with a small amount of “tilt” and offset. The Bl symmetry curve in Figure 6 shows coil-in offset of 2.1mm offset at 7mm decreasing to about 1.2mm at the 9.8mm (physical Xmax) excursion point. Not perfect, but nothing that is all that extreme either.

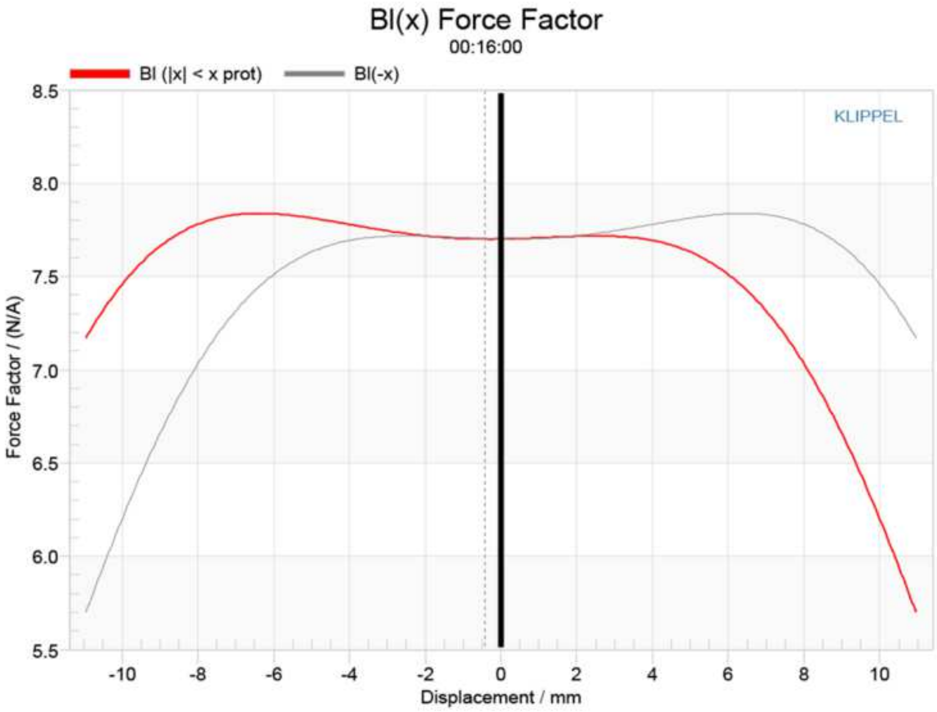

Figure 5: Klippel Analyzer Bl(X) curve for the Purifi PTT5.25X-NFA-01.

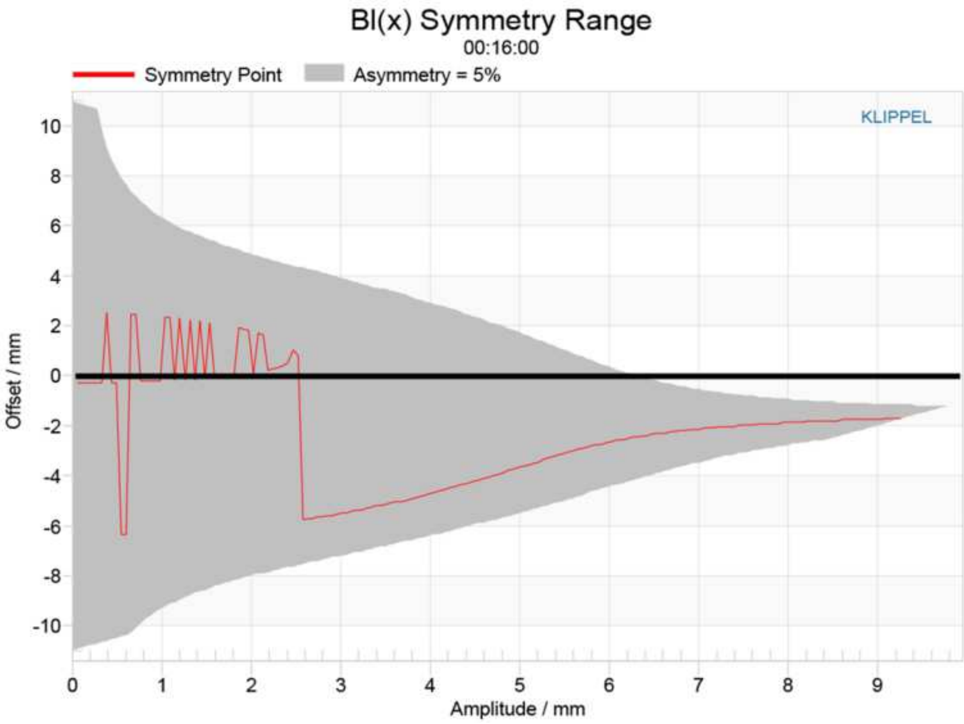

Figure 6: Klippel Analyzer Bl symmetry range curve for the Purifi PTT5.25X-NFA-01.

The Kms Stiffness of Compliance curve (Figure 7) is broad and with a degree of asymmetrical behavior along with a small degree of rearward (coil-in) offset and tilt. The Kms symmetry range curve in Figure 8 shows the coil-in offset to settle down to ≤1mm beyond 4mm of excursion, going to zero at 6mm, and increasing to a coil-out offset of less than 1mm at the 9.8mm Xmax position.

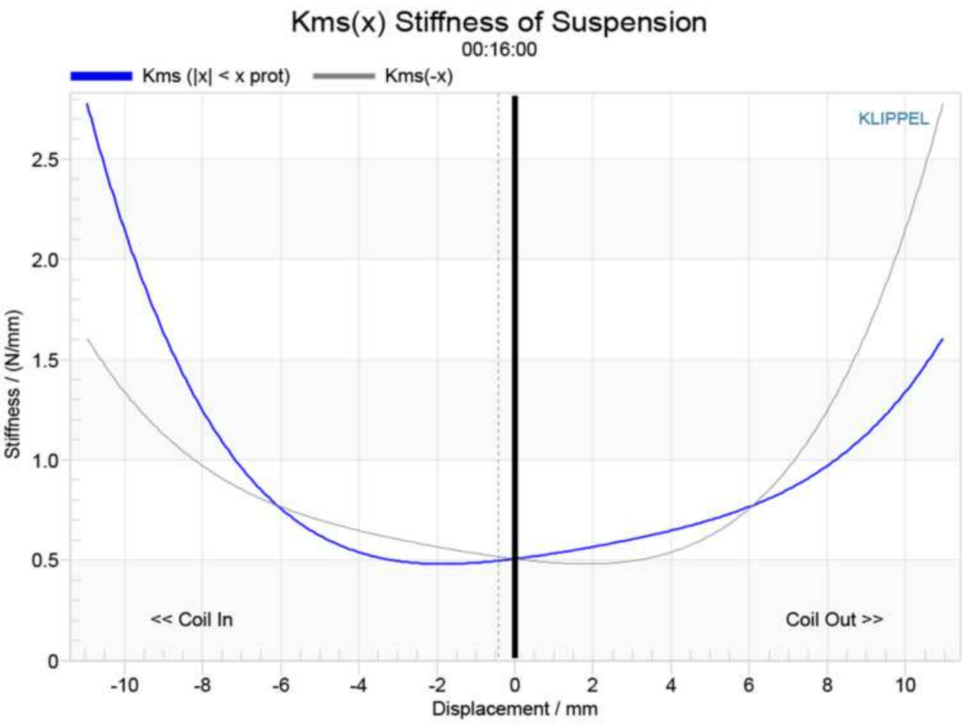

Figure 7: Klippel Analyzer Mechanical Stiffness of Suspension Kms(X) curve for the Purifi PTT5.25X-NFA-01.

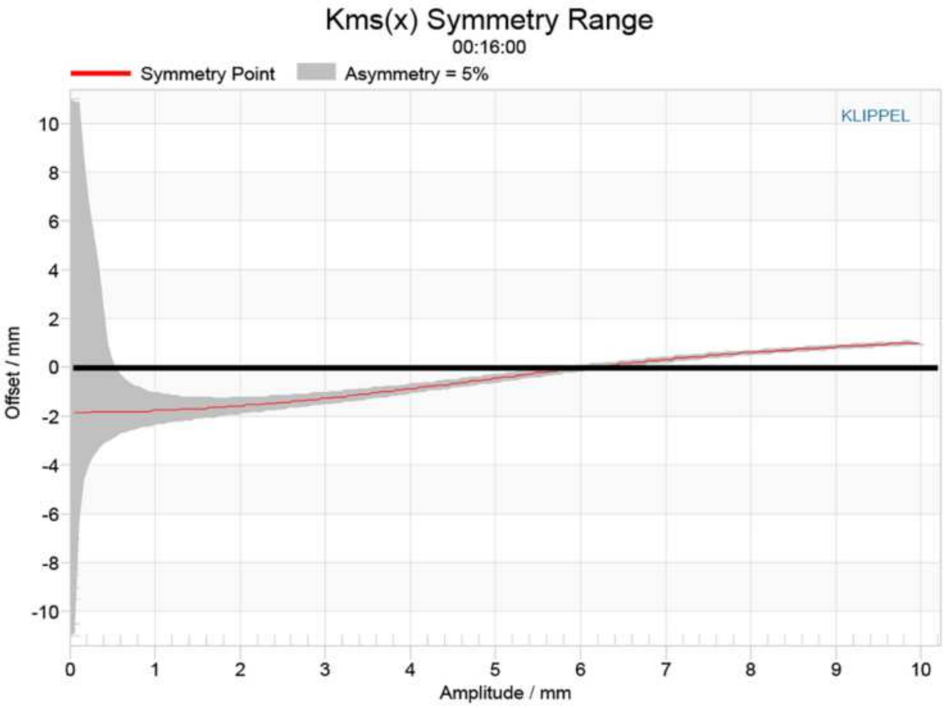

Figure 8: Klippel Analyzer Kms symmetry range curve for the Purifi PTT5.25X-NFA-01.

Displacement limiting numbers calculated by the Klippel analyzer for the using the full-range woofer criteria for Bl was XBl @ 82% (Bl dropping to 82% of its maximum value) equal 9.8mm for the prescribed 10% distortion level. For the compliance, XC @ 75% Cms minimum was only 4.6mm, which means that for the Purifi woofer, the compliance is the more limiting factor for getting to the 10% distortion level. However, if we use the less conservative 20% distortion criteria, XBl @ 70% greater than >11mm and XC @ 50%=7.2mm, showing the Cms number closer to the physical Xmax of the driver.

Figure 9 gives the inductance curve Le(X) for this transducer. Motor inductance will typically increase in the rear direction from the zero rest position as the voice coil covers more of pole in a conventional motor, which is not exactly what you see in this graph, but this is also not a conventional motor. More importantly, the inductive “swing” from maximum inductance to minimum inductance gives a maximum inductive change of only 0.012-0.018mH, which is seriously excellent performance.

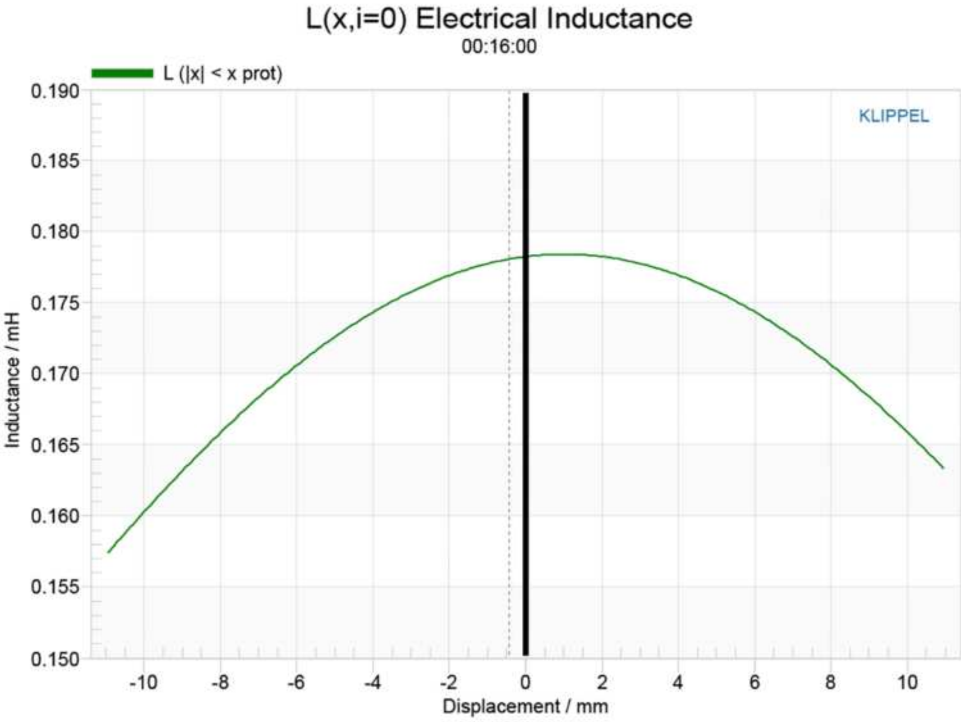

Figure 9: Klippel Analyzer L(X) curve for the Purifi PTT5.25X-NFA-01.

For the remaining test procedures, I mounted the Purifi PTT5.25X 5.25” woofer in a foam-filled enclosure that had a 15” × 6” baffle and then measured the device under test (DUT), using the Loudsoft FINE R+D analyzer and the GRAS 46BE microphone (courtesy of Loudsoft and GRAS Sound & Vibration). I measured them both on and off-axis from 200Hz to 20kHz at 2.0V/0.5m normalized to 2.83V/1m, using the cosine windowed FFT method. All of these SPL measurements also included a 1/6 octave smoothing. (This is done to mimic the frequency response resolution I published for years using the LinearX LMS analyzer with 100 point sweeps.)

Figure 10 gives the Purifi PTT5.25X’s on-axis response indicating a rather smooth response with no break-up modes or peaking that is ±2dB out to about 6kHz where the driver begins its low-pass roll-off. Figure 11 displays the on- and off-axis frequency response at 0°, 15°, 30°, and 45° degrees, -3dB at 30°, with respect to the on-axis curve that occurs at 3.5kHz, so a cross point in that vicinity or lower should be work well to achieve a good power response and directivity index curve. Figure 12 gives the normalized version of Figure 11, while Figure 13 displays the CLIO pocket horizontal polar plot (in 10° increments). And finally, Figure 14 gives the two-sample SPL comparisons for the PTT5.25X, showing a close match (≤ 0.9dB) throughout the operating range of the driver.

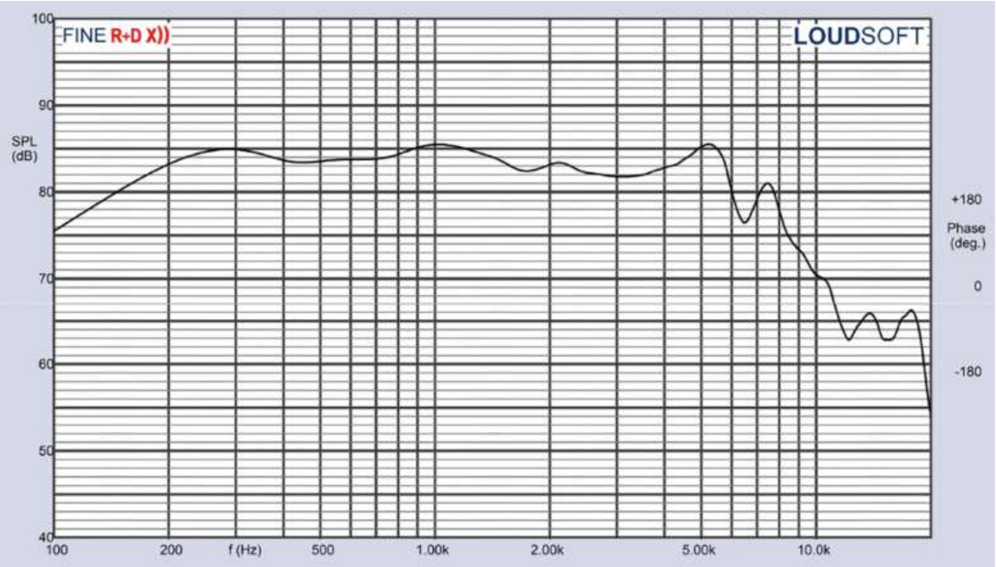

Figure 10: Purifi PTT5.25X-NFA-01 on-axis frequency response.

Figure 11: Purifi PTT5.25X-NFA-01 horizontal on- and off-axis frequency response (0°=black; 15°=blue; 30°=green; 45°=purple).

Figure 12: Purifi PTT5.25X-NFA-01 normalized on- and off-axis frequency response (0°=black; 15°=blue; 30°=green; 45°=purple).

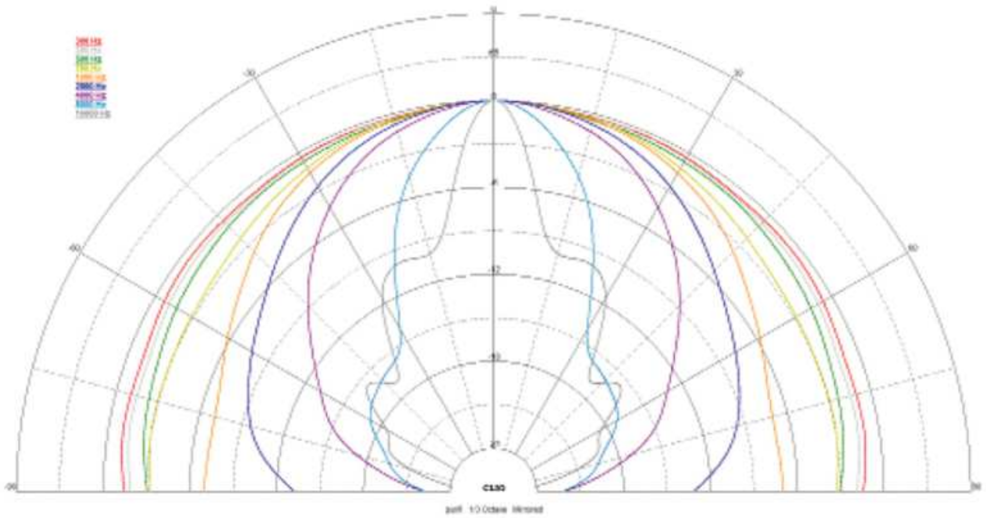

Figure 13: Purifi PTT5.25X-NFA-01 180° horizontal plane CLIO polar plot (in 10° increments).

Figure 14: Purifi PTT5.25X-NFA-01 midwoofer two-sample SPL comparison.

Next, I utilized the Listen, Inc. SoundCheck 20 software and AudioConnect analyzer with the Listen SCM microphone (supplied to Voice Coil by Listen, Inc.) to measure distortion and generate time-frequency plots. For the distortion measurement, the 5.25" driver was mounted rigidly in free-air, and the SPL was set to 94dB (my criteria for home audio transducers) at 1m (9.2V) using the built-in SoundCheck pink noise stimulus generator and SLM.

Then, I measured the distortion with the Listen microphone placed 10cm from the driver. This produced the distortion curves shown in Figure 15, which exhibits extremely low third harmonic distortion. If you compare this data to the Purifi factory data, there is variation. Note that Purifi has developed its own proprietary distortion measurement system with the data acquired in an anechoic chamber, compared to my measurements done with a background noise level of around 55dB. Either way, the distortion on all the Purifi drivers, my measurements or theirs, is very low and definitely a hallmark of their design technology.

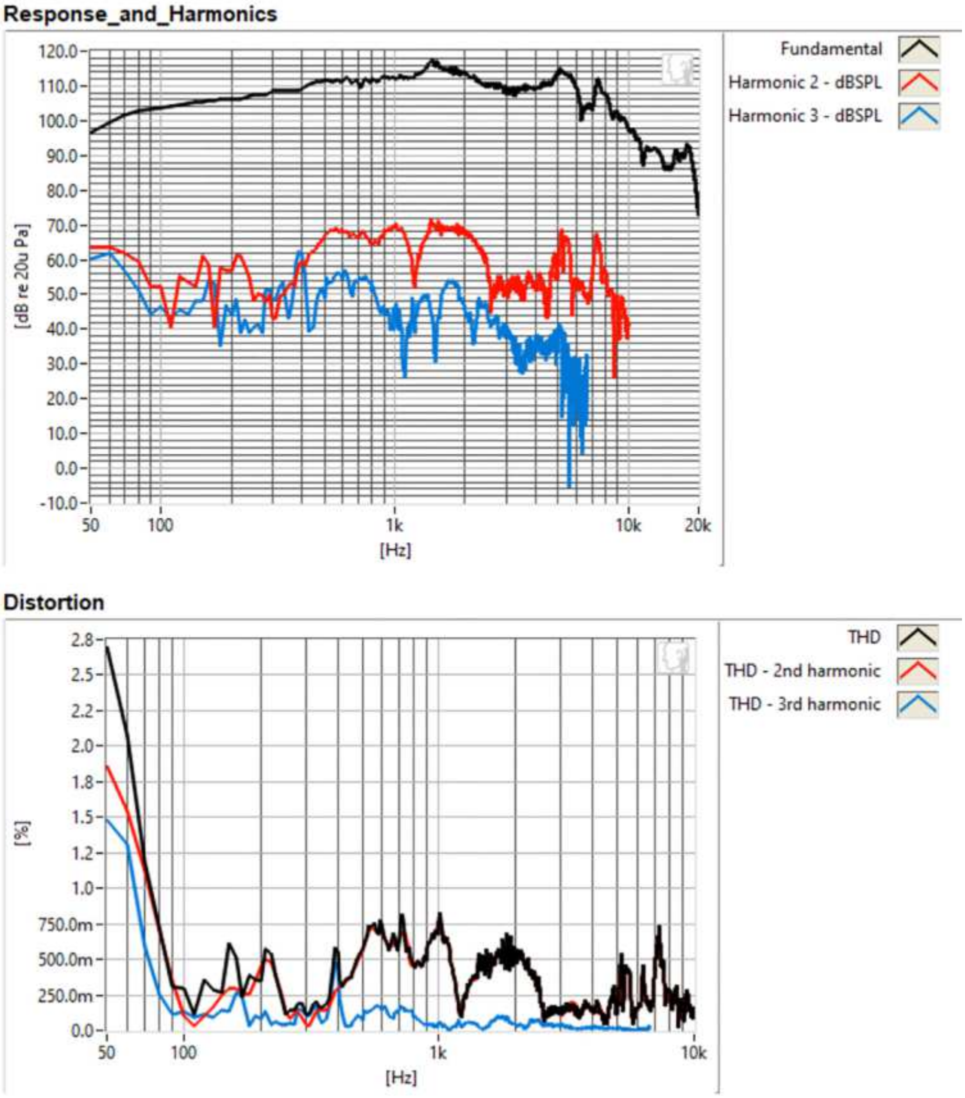

Figure 15: Purifi PTT5.25X-NFA-01 SoundCheck distortion plot.

I engaged the SoundCheck software to get a 2.83V/1m impulse response for this driver and imported the data into Listen's SoundMap Time/Frequency software. Figure 16 shows the cumulative spectral decay (CSD) waterfall plot. Figure 17 shows the Wigner-Ville plot.

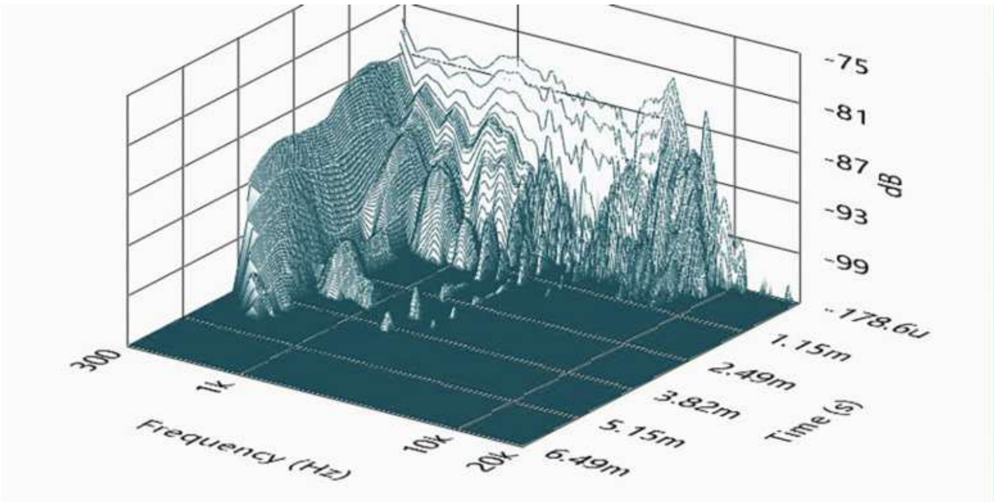

Figure 16: Purifi PTT5.25X-NFA-01 midwoofer SoundCheck CSD waterfall plot.

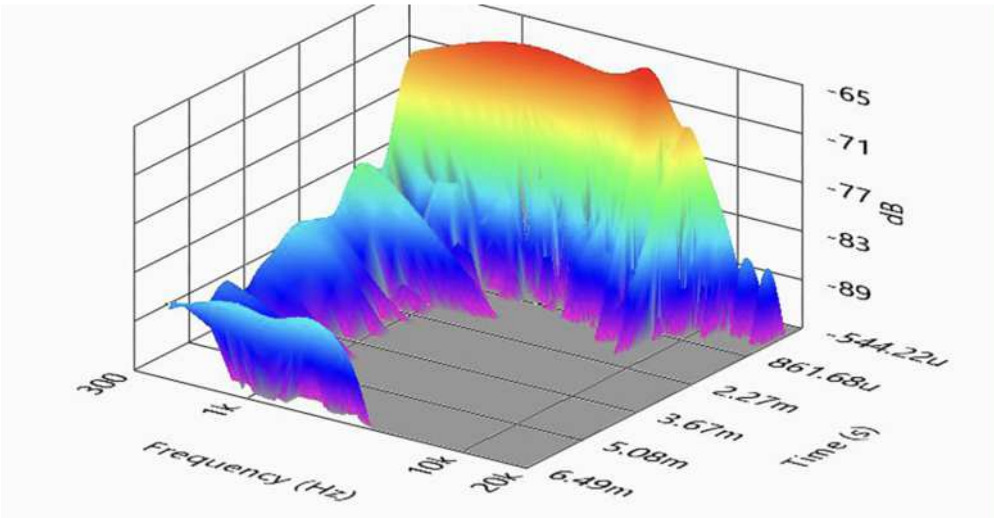

Figure 17: Purifi PTT5.25X-NFA-01 midwoofer SoundCheck Wigner-Ville plot.

Looking over the data I collected for the new Purifi PTT5.25X 5.25” midbass, there is no question that the performance is impressive, not to mention the various engineering innovations that have been described. Used in a compact two-way application in conjunction with a passive radiator, the performance is outstanding for a 5.25” transducer. I think the PTT5.25X would also be a good choice for a compact sealed-box home theater LCR/surround speaker.

For a relatively new company, Purifi Audio has unleashed an impressive ever-growing line of transducer designs and combined this with a high level of build quality. The PTT5.25X is a well-crafted midbass driver that would do well designed into the high-end two-channel hi-fi, home theater, or studio monitor markets. For more information, visit **www.purifi-audio.com**. As with all the Test Bench reports, I regret not being able to design these drivers into a system and do a proper subjective evaluation. **VC**

This article was originally published in Voice Coil, October 2022.