The Art of the Mid-Woofer

BY JERRY NIEBUR

11 TOP MIDBASS WOOFERS FACE-OFF!

Pictured: Pioneer Stage4 TS-C172PRS

Approximately 80% of all high-end aftermarket mobile audio systems consist of a two-way (mid-woofer& tweeter) front stage with some type of bass supplementation in the rear of the vehicle. Consumers wishing to attain a level of superior musical reproduction, one that would equal a decent home audio system, typically look at purchasing products with exotic materials and certain published specifications associated with "high" performance; usually aligning certain brand names with specific parameters suggesting superior engineering and build quality.

We set out to find superior performance midbass drivers capable of producing accurate midrange frequencies while still producing authoritative, yet tonally accurate, midbass. The midbass performance is critical to high quality music playback as the speaker is asked to play 5 full octaves of music and in some cases 6 octaves! Additionally, the ability of the midbass to dig deep in the lower frequencies is critical to getting a subwoofer to blend correctly in the system. Excellent midbass performance compliments proper musical balance while minimizing the localization of the subwoofer and potential smearing in these critical lower frequencies.

11 high quality midbass drivers were chosen for this test. The mix of brands was based on any of the following criteria or a combination of the following: brand reputation, performance (company published specifications), price attributes, use in the mobile audio competition scene, and implementation of the latest technological innovations. You will also notice that we chose to test 6.5" – 7" woofers, as these are the most popular sizes. Drivers of this size typically have the ability to go deeper into the bass region and present a full soundstage upfront. The list of brands chosen is quite impressive; some of these brands garner great respect, not only in mobile audio, but also in some of the highest regarded home/professional drivers available. You might be wondering why some brands are missing from this test? At the request of two popular manufacturers, we agreed to not include their drivers in this very competitive test.

The following drivers were selected for this test (in alphabetical order):

- **Audio Technology C-Quenze 18H**
- **Dynaudio Esotar$_2$ e650**
- **Eighteen Sound 6ND430**
- **Exodus Ex-Anarchy**
- **Hybrid Audio Technologies L6SE**
- **JBL 660GTi**
- **PHASS MD0790**
- **Pioneer TS-C172PRS**
- **Scan-Speak 18WU/4741T-00**
- **Seas Excel W18NX-001**
- **Vifa NE180W-04**

WHAT IS A MID-WOOFER?

A mid-woofer (also know as a midbass) is any speaker that is capable of playing both midrange and midbass frequencies at the same time. The mid-woofer is usually used in a component speaker system consisting of the woofer, tweeter, and passive crossover. In a 2-way component system, a typical mid-woofer is usually responsible at least six octaves, ranging from 80Hz to 2.5kHz and sometimes higher. In a 3-way component system, a mid-woofer usually is used as a dedicated mid-bass and responsible for a general range between 80Hz and 250Hz, while some still go as high as 1000Hz (usually when a smaller midrange is used). The mid-woofer can range in size from 5.25" to 8" in diameter, with some exceptions. The typical car audio mid-woofer that is the most popular is 6.5" to 7" in diameter and used in the lower front door of most vehicles.

TEST METHODOLOGY

As with our first monumental test – The Ultimate Midrange Shootout, strict but statistically accurate guidelines were used in our testing methodology. Various methods (as outlined in detail in this section) were employed to prevent biased data reporting, errors in reporting and influence from external variables, which could skew actual performance of each midbass driver.

PHYSICAL ENVIRONMENT

Careful consideration was placed in the physical testing environment, the associated equipment, and with the actual testers. To further the accuracy of the test Mr. Doug Van Sloun, owner and engineer of Focus Mastering, was recruited to assist in this test. Doug donated his time, expertise and his sophisticated, state of the art recording studio. Focus Mastering utilizes velocity-type bass trapping as well as the new RPG pressure zone bass trapping for smooth, extended low frequency response. The reflection free zone extends all the way to the client couch and provides a wide, accurate, and enveloping sound field. The quality of the room allowed the test to be conducted on the mid-woofers themselves, without the room adding any coloration, making for a near perfect physical test environment.

Focus Mastering's state of the art studio

TEST EQUIPMENT

As you will see from the impressive equipment list below, considerable attention was paid to the associated test equipment, further fostering the best performance playback for each midbass in the test.

One of the most difficult choices was finding a suitable reference level tweeter. After much research the Dynaudio's Esotar T330D was chosen. This tweeter is known as one of the best tweeters ever made and has been used in the highest-end offerings from Dynaudio as well as other loudspeaker manufacturers worldwide. The Esotar Tweeter exhibits an extremely low resonant frequency (fs) of 750 Hz, which allows it to mate very well with all the mid-woofers tested.

Dynaudio Esotar T-330D

Focus Mastering also boasts an impressive equipment list (please visit www.focusmastering.com and select the "equipment" tab for a complete list) including a Krell KSA-250 Class "A" amplifier, which was used to power the test drivers. Class "A" has been long regarded as the best amplifier topology for high-end sound reproduction. This model from Krell has 250 watts per channel available for the test drivers.

Midwest Sound & Lighting, in Omaha, NE donated two DBX 240 DriveRack complete equalization and loudspeaker management processors for the test. These units were used to perform all crossover and individual speaker level duties.

Balanced XLR cables were used throughout the entire signal chain ensuring a strong, clean signal, and all the speaker wire used was high-end oxygen free copper (OFC) wire.

SPEAKER ENVIRONMENT

It was decided to test the mid-woofers in sealed enclosures, which were made to mimic the approximate size and shape of a typical vehicle door where most mid-woofers are mounted. It is ideal to test all drivers in an ideal enclosure size, giving the drivers a Q_{TC} of .707, which is considered to provide optimum transient response. Since it is impractical to build a specific test enclosure for all mid-woofers tested, the enclosure was constructed large enough to have little overall effect on the "Q" of the speaker and designed more to emulate a typical automotive sealed door environment. The enclosures were constructed from ¾" medium-density fibreboard (MDF), used for its strength and very dense properties, and heavy internal bracing was used to minimize cabinet resonance. The enclosures were made with 3 cubic feet internal airspace and measured 6" deep, emulating the depth of most vehicle doors. To prevent speaker cone break-up due to standing waves and enclosure resonance, Cascade Audio Engineering Deflex PowerPads were installed behind the mid-woofers (in an up-coming article, we will discuss the science behind these pads). All of the mid-woofers were mounted to ¾" MDF trim rings that were sealed air tight to the enclosure using gasketing foam.

One of the test enclosures pictured

ELECTRONIC ENVIRONMENT

With one goal of this test being to minimize possible variances that could skew the results, a passband that favorable to all drivers was selected. The passband is the frequency range over which the mid-woofers would be played. Before selecting the passband, manufacturers data was review to ensure each driver was operating in a passband well within the limits of the driver.

Typically, using an 80 Hz crossover point will allow the woofer to mesh well with the subwoofer, while going low enough to facilitate the illusion of upfront bass. 80 Hz allows the mid-woofer to play authoritative midbass, while still protecting the speaker from over excursion, which can introduce

large amounts of distortion and/or damage the speaker. A sealed enclosure is known to roll-off (meaning volume attenuates) at 12dB/octave, so applying an electronic crossover slope of 12dB/octave yields an acoustically in phase 4th-order Linkwitz-Riley impulse response.

The low-pass crossover was selected based on the physics of dynamic drivers. It is known that all drivers begin to narrow their dispersion of sound, or "beam", at higher frequencies. The frequencies at which they begin to beam is related to their cone diameter. This phenomenon is an inescapable fact in physics, and cannot be engineered out of drivers. For 6.5" to 7" drivers, beaming becomes significant at around 2,678 Hz, based on the actual diameter of the cone. Since we are mating the mid-woofer with a tweeter that has an extremely low resonant frequency of 750 Hz, it made sense to set the low-pass at 2,500 Hz. Is it generally accepted in most audio circles to set a 12dB/octave slope between the mid-woofer and the tweeter for a more natural blending between the two drivers.

The drivers were tested in the passband of 80 Hz and 2,500 Hz with 12dB/octave electronic crossover slopes, and all drivers were properly broken in using pink noise and random music offerings for the manufacturers recommended time frame and volume.

TEST PROCEDURES

Test procedures guarantee the actual test was performed accurately to ensure all the results are reliable and all the mid-woofers were tested using the same methods.

Vifa's pentacone cone technology midbass

Exodus Ex-Anarchy & ScanSpeak 18WU

LEVEL MATCHING

Industry experts generally agree that components under evaluation should be level matched to within 0.2 deciBels (dB). To ensure that all drivers were precisely level matched, a real time analyzer (RTA) was used to verify the volume of the drivers tested. The RTA's microphone was positioned 10 feet centered between both drivers to measure the total sound pressure level (SPL) while pink noise (20 to 20k Hz, Alpine Speed of Sound CD, Pink Noise –Ref -0dB) was played. Each mid-woofer was level matched with the tweeter (due to the variance of the sensitivity of the mid-woofer) before the overall volume was precisely adjusted so its total un-weighted SPL was 82.0dB ± 0.2dB. This volume was derived from considerable experimentation and evaluation before the test began. It's also important to note that no equalization was used and no other drivers, other than the tweeters already mentioned, were used in conjunction with the mid-woofers drivers tested.

LISTENING TEST

The listening test consisted of a single blind listening session and technical measurements of all the drivers. The drivers were covered with acoustically transparent grill cloth so that none of the blind listeners could see the drivers and the testers were required to leave the room for each speaker change; even the Hybrid Audio's beautiful copper colored phase plug was not visible, essentially guaranteeing there was no bias. The drivers were assigned a random number and a control driver was chosen at random and re-played during the testing session to validate the tester's ability to accurately rate each set of drivers (the control driver scored identically all times it was tested thereby validating the listeners' accuracy and repeatability). The testers were given score sheets to judge the drivers based on various aspects with a section to write down thoughts and opinions.

ELECTRICAL TESTING

All drivers were individually tested in free air and each driver was measured in the listening standardized test enclosure using the Dayton

WHAT IS BEAMING & HOW DO YOU CALCULATE IT?

Hybrid Audio L6SE

The upper crossover limit for a woofer is governed principally by its polar response. At frequencies corresponding to wavelengths that are large relative to the woofer's diameter, the sonic radiation pattern is spherical. As the frequencies rise, and their corresponding wavelengths become smaller relative to the woofer's diameter, the radiation pattern begins to narrow with increasing frequencies. This phenomenon is commonly called beaming, and is known to occur when the wavelength of sound is approximately equal to the circumference of the driver. This narrowing dispersion can adversely affect how the woofer integrates with the dispersion pattern of its companion tweeter, given it is generally accepted that the dispersion patterns of both drivers should be as identical as possible. Since the tweeter's dispersion at typical crossover

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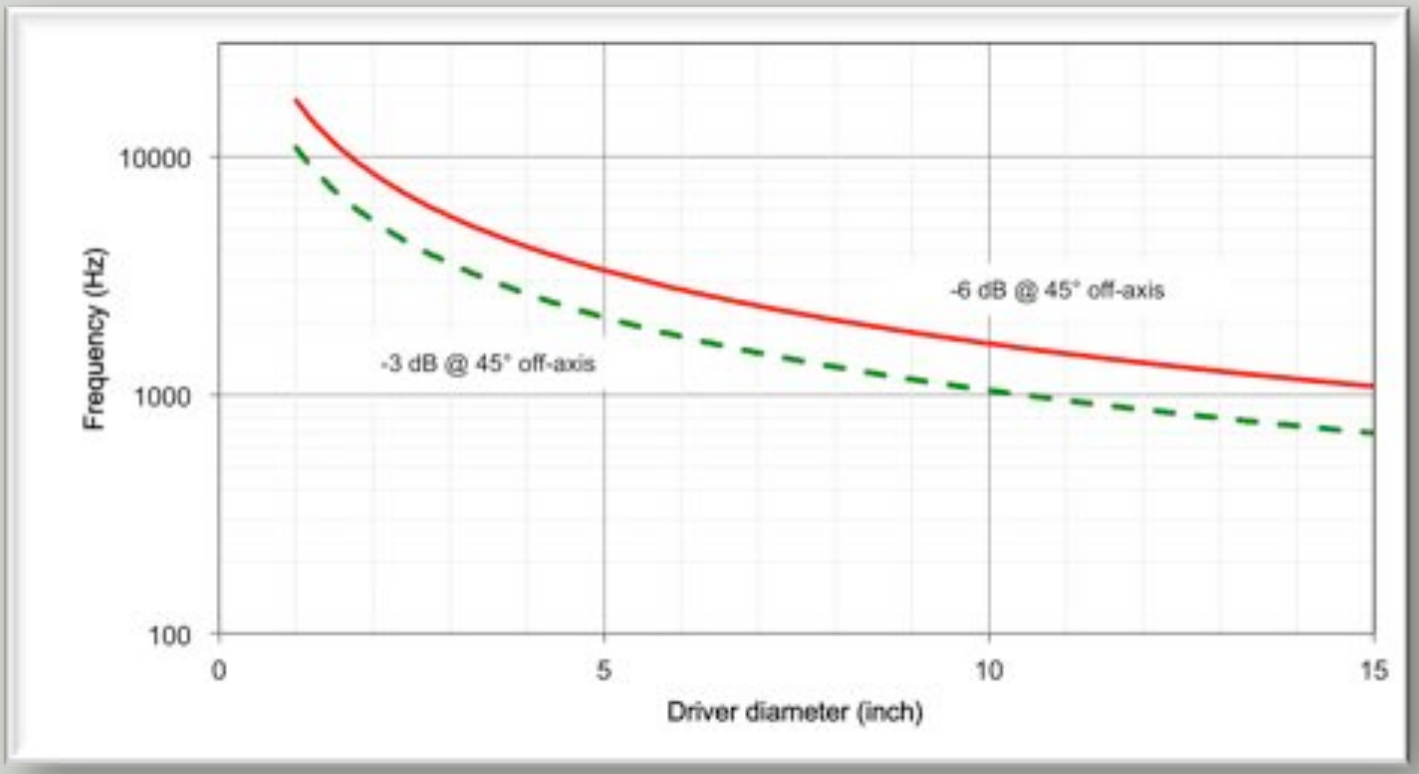
frequencies is essentially spherical, it is desirable that the woofer's dispersion also be spherical.

One useful criterion for determining the extent of beaming defines the amount of allowable attenuation at 45 degrees off axis. It is generally accepted that attenuation ranging from -3 to -6 dB at 45 degrees off axis is an acceptable amount of attenuation to limit the audible effects of beaming. Vance Dickason presented both polar plots of directivity and tabulated data defining reasonable upper limits for low-pass crossover frequencies.[1] Vance's tabulated data was fitted with a smooth function and transformed into graphical form as shown in the figure below:



The chart above shows the independent variable, driver diameter in inches, on the abscissa, and the dependent variable, frequency in Hertz, on the ordinate. The solid red line represents the upper limit for the low-pass crossover frequency based on the less stringent criterion of -6 dB, while the dotted green curve represents the more stringent criterion of -3 dB. The graph clearly illustrates that a driver approximately 6 inches in diameter should be crossed-over to the tweeter no higher than about 3 kHz, and preferably at about 2 kHz, if possible. This phenomenon highlights the dilemma loudspeaker designers face: finding a tweeter with sufficiently robust performance parameters capable of withstanding the preferred crossover frequency, and thus why some manufacturers use well designed 3-way systems with cone or dome midrange speakers.

Some of the loudspeakers in this test utilize "phase plugs", devices believed to improve the high-frequency dispersion of the drivers. Research has shown that the effects of such devices are rather minimal, or even insignificant, for this purpose, thus rendering the term "phase plug" somewhat of a misnomer. Phase plugs are, however, effective at transferring heat away from the voice coil, and in some cases, are also used to mitigate the unwanted effects of a dust cap. The debate between the merits of dust caps versus phase plugs is a complex issue with proponents for each implementation.[2] In the end, either approach can be implemented effectively with appropriate engineering considerations.

To make sure you are playing your drivers below the point of beaming, you can calculate that point. According to NASA, the speed of sound at sea level is 1,116 ft/s (feet per second). Next take 1,116 x 12", since speakers are sold in inches. This equals 13,392 inches per second. Now all you have to do is divide 13,392 by the diameter of the "cone". A 6.5" diameter driver with a cone diameter of 5" would start to beam at 2,678Hz (13,392/5).

*The above illustrates and supports your editors' findings and conclusions derived from the "The Ultimate Midrange Shootout".

[1] V. Dickason, The Loudspeaker Design Cookbook, *6th Ed.*, Audio Amateur Press, ©2000, p. 105.

[2] http://www.diyaudio.com/forums/multi-way/192215-phase-plug.html

THIELE/SMALL DEFINED

"T/S parameters" refer to a set of electromechanical parameters that define the low frequency performance of a loudspeaker driver in a closed box, and are named after A. Neville Thiele of the Australian Broadcasting Commission, and Richard H. Small of the University of Sydney, who developed the electrical and pneumatic models that define the parameters.

There are two main types of closed-box designs: the infinite baffle ("IB") and the acoustic suspension ("AS"). Relative to the compliance of the driver's suspension, the IB enclosure utilizes a larger box containing a highly compliant volume of air, while the AS enclosure uses a much smaller, less compliant volume of air. Generally, mobile audio woofers, as typically mounted in automobile doors, would be considered IB.

T/S parameters of the driver are used as input variables to design the driver/enclosure resonance magnification factor, or Q_{tc}, which defines the composite response of the electrical, mechanical, and pneumatic behavior of the driver/enclosure system at resonance. Information regarding T/S parameters can be found elsewhere.[1]

Certain values of Q_{tc} have mathematical significance. When the Q_{tc} is equal to 0.5, the system is described as "critically damped", and the frequency response of the system rises as rapidly as possible to its asymptotic output level with no overshoot and no settling time. Mathematically speaking, a system is described as "overdamped" when Q_{tc} is less than 0.5, and "underdamped" when Q_{tc} is greater than 0.5. When the Q_{tc} is 0.707, the system is described as "optimally damped", meaning the frequency response rises as fast as possible while achieving the least amount of overshoot and settling time. It is interesting to note that maximum power handling occurs when the Q_{tc} is equal to 1.1. Q_{tc} also defines many important loudspeaker performance parameters such as the volume of the box, closed-box frequency of resonance, roll-off slope, phase angle at -3 dB output, cone excursion, group delay, impedance, and cone velocity, to name a few. Wiebell and Bywater published an excellent paper discussing the optimization of sealed-box loudspeaker systems.[2] Numerous types of computer programs and software are available to aide in the optimization of these parameters.[3]

The mathematical values of Q_{tc} also influence the subjective sound quality of the driver/enclosure system. Systems with a Q_{tc} of 0.5 are sometimes regarded as "dry", "excessively taut", or "overdamped", yet some renowned loudspeaker designers maintain that 0.5 to 0.6 is optimal. Conversely, systems with a Q_{tc} of about 1.0 sound "warm" and "robust", and many consumers find this appealing. Many commercial loudspeakers utilize Q_{tc}s ranging typically from 0.5 to 0.9, while one notable exception, and commercially successful design, used 1.2.

It is important to realize that the T/S parameters are useful for small signal (low power) predictions. The driver/enclosure system can be expected to perform according to the calculations at 1 Watt ("W") of power input. However, as the power input increases, the voice coil temperature increases, which causes significant changes to the predictions at 1 W. The maximum power input a driver can handle is limited by the driver's ability to tolerate and dissipate heat. Typical materials and adhesives used in loudspeaker transducer design can tolerate temperatures up to about 250 °C. As the temperature of the voice coil increases with increasing power input, its electrical resistance increases, consequently decreasing the damping of the system. Research has shown that a driver/enclosure system modeled to obtain a Q_{tc} of 0.707 at 1 W changes substantially with increasing power input. For instance, at 40 W, the voice coil temperature has been shown to rise to about 192 °C, and as a result, the Q_{tc} rose to 1.2. Obviously, the significant rise in Q_{tc} has a profound effect on the loudspeaker performance parameters. Since typical mobile audio systems provide tens, if not hundreds, of W to a driver, it is important to take this phenomenon into consideration. Consequently, some loudspeaker designers recommend using a lower Q_{tc} to compensate for this effect.[4]

[1] V. Dickason, The Loudspeaker Design Cookbook, *6th Ed.*, Audio Amateur Press, ©2000, pp. 23-32, 155-171.[2] H. J. Weibell and R. Bywater, *Practical Design of Optimal Sealed-Box Loudspeaker Systems*, Audio Engineering Society, reprint 2105 (C-2), 1984.[3] V. Dickason, The Loudspeaker Design Cookbook, *6th Ed.*, Audio Amateur Press, ©2000, pp. 173-183.[4] Ibid. p. 33.

An Audiophile's Dream……

Audio Test System (DATS). During the free air test the drivers were suspended to ensure a proper reading from those drivers with a vented pole piece. The 1,000 Ω reference resistor, provided with the tester, was used to calibrate the leads of the DATS system, as instructed by the manual. The DATS tests the drivers for the following Thiele/Small parameters:

R_e – Measured in Ohms (Ω), this is the DC resistance of the voice coil.
F_s - The frequency at which the combination of the moving mass and suspension compliance maximally reinforces cone motion, called the resonance frequency, measured in hertz (Hz)
Q_{ts} – Total Q factor. A unitless measurement characterizing the combined electric and mechanical damping of the driver.
Q_{es} – Electrical Q factor. A unitless measurement describing the electrical damping of the loudspeaker.
Q_{ms} – Mechanical Q factor. A unitless measurement characterizing the mechanical damping of the driver, that is, the losses in the suspension (surround and spider.)
L_e – Measured in millihenries (mH), this is the inductance of the voice coil.

RESULTS

SCORING SYSTEM

The results of this test will be represented by a 4-Tier scoring system for the 11 drivers tested. Drivers in "Tier 1" scored the highest of the test group, while drivers in "Tier 4" scored the lowest of the test group.

The scores given to the mid-woofers in the individual categories determined the final tier placement for each driver. We will not divulge the actual scoring sheets.

The mid-woofers appear in alphabetical order in the tier in which they were placed. Technical data is presented at the end in alphabetical order by the manufacturer name.

The beautiful Pioneer TS-C172PRS & JBL 660 GTi

The Results

Hybrid L6SE, Dynaudio Esotar2 650 & PHASS MD0790

TIER 4 MID-WOOFERS:

Eighteen Sound 6ND430
SEAS Excel W18NX-001

EIGHTEEN SOUND 6ND430

This company was started in Italy in 1997 and is a division of a much larger Italian company called AEB. AEB is involved in aquatics, alternative fuels, robotics, and well, you guessed it...drivers. It goes to show you that genius engineers of all types study speaker design; think about it, a speaker is an electro mechanical and magnetic device that also involves spring technology. This speaker features a neodymium magnet with an interesting surround, treated cone and a nice heat sink on the magnet assembly. It seems this baby was built for long-term abuse and sound reinforcement but their website clearly states “built for two way systems”.

These drivers finished in Tier 4 due to their poor overall performance relative to the other drivers in this test. All the testers were in consensus, stating these drivers were dead and lifeless sounding. Each tester also noted that these particular mid-woofers, while extending somewhat low, suffered from a lack of midbass impact and what they did play sounded muddy. They did not correctly replicate proper impact or loudness in varying textures of lower frequencies. The Eighteen Sound’s midrange sounded hollow and nasally, lacking a natural tonal quality. The overall presentation of music was substantially inferior to the other drivers in this test. Furthermore, the soundstage lacked depth, image placement, and lifelike presence. There was no discernable difference of opinion between on-axis and off-axis testing. For these reasons, this woofer’s sonic performance was uninvolving. Consequently, these mid-woofers would be recommended for a different type of application.

SEAS EXCEL W18NX-001

The Seas Excel hails from Norway and Seas is a well known manufacturer of raw drivers designed for use in both home and car loudspeaker systems.

In this test they were also clearly in tier 4 with the Eighteen Sounds. The Seas Excel’s had a poor overall tonal balance. The listeners described the reproduction of the midrange frequencies as bright and brittle, and unanimously agreed these drivers exhibited a beaming quality in the upper midrange. These drivers generally lacked output and articulation in the lower midrange and midbass, sounding as if these frequencies were just missing. The sound of the Seas was so thin that many listeners thought the polarity had inadvertently been reversed. Unfortunately for the Seas, polarity was confirmed, and the drivers were indeed in phase. However, there is still the possibility of a technical issue with these particular drivers. The testers also noted that these drivers were very dry and clinical sounding, lacking in musicality, validating the above characteristics. The Soundstage depth was considered poor and seemed to suffer from the overbearing high frequency information, causing the singer to get lost amongst

the other instruments. Additionally, there was an inconsistency in the varying musical tracks on the top frequencies. Considering the performance of the other drivers in this test, these performed well below average. Given all the attributes at all frequencies, these drivers do not receive our recommendation as a top performance midbass and you are best served by another choice.

TIER 3 MID-WOOFERS:

Audio Technology C-QUENZE 18H
JBL 660GTI
Vifa NE180W-04

Audio Technology C-QUENZE 18H

The Audio Technology C-Quenze 18H is also manufactured in Denmark, along with the Dynaudio, Vifa and Scan-Speak brands. Drivers made by Audio Technology enjoy a prestigious pedigree; its founder is known for his experience and long history of loudspeaker design and innovation.

Surprisingly, relative to the other drivers in this test, these drivers faired only reasonably well, earning a Tier 3 rating. These mid-woofers lacked fullness to the midbass, especially in male vocals and varying drum tracks. In addition, articulation in the lower midrange lacked the finesse associated with a high quality driver. What midbass these drivers did have sounded a tad muddy and smeared. Where this speaker did do well was upper midrange, which is surprising considering it looks like a very heavy-duty driver; its robust stature would suggest incredible midbass impact, which was not the case. Interestingly, this driver performed well in the upper midrange. The presentation and staging also suffered due to the tonal inaccuracies in the lower registers. These drivers made the soundstage sound much smaller than it actually was, but the placement of images within the soundstage was reasonably well defined. Overall, these drivers were not impressive, and consequently, the sound was characterized as rather boring and uninvolving. It is noteworthy that Audio Technology offers customized products; you can actually tailor the Thiele/Small parameters and have them build a driver to your specifications, which is pretty cool.

JBL 660GTi

James B. Lansing founded JBL, which is now owned by Harmon International. JBL makes a variety of highly regarded products and has a vast history in speaker building. They are successful not only in the consumer market, but also in the professional and sound reinforcement. They have engineered a number of well-respected woofers using their own Aquaplas coating system and the Bi-Radial® horn-loaded drivers. During the early 1990's, they took much of what they had learned in the professional arena and applied it to their mobile products, creating what was known as the GTi series. Since then, the GTi line has grown into a full line of drivers. The JBL 660GTi midbass was designed to be the reference level mobile product.

Despite its lofty heritage, the 660 GTi was another woofer whose sonic performance was uninvolving enough to land it in Tier 3. Its overall presentation was mellow and what some judges reported as flat. Midbass frequencies sounded dull and lacked the impact of better scoring drivers. With these drivers, drums lacked slam and sounded muddy. Like the Audio Technology, they had reasonably good upper mid-range detail and sounded best on acoustical guitar passages, but the low extension even on acoustic guitar was missing the necessary harmonics to move it up in the ranks. Overall, most instruments lacked life, sounding dull and emotionless. Nonetheless, the 660GTi's exhibited reasonably good soundstage depth, height, and width. Due to its overall somewhat lacking overall performance, the judges unanimously agreed the JBL driver deserved a Tier 3 ranking.

Vifa NE180W-04

Vifa is also another brand hailing out of Denmark and has a long history of building drivers used in many DIY home audio kits. They manufacture a myriad of drivers with a wide range of parameters. This particular driver, like the Scan- Speak, uses a unique basket design allowing for well-directed airflow around the coil, while at the same time minimizing air turbulence from the spider-cone-magnet structure. This air turbulence, if not properly controlled and minimized, can create noise in the driver thus increasing audible distortion. Vifa and Scan-Speak have successfully developed their own technological approach to address the design challenges associated with turbulences. The driver's cone also employs a unique geometry and wood pulp material developed by Vifa.

Even with all this technology, the Vifa NE180W-04 mid-woofers earned a Tier 3 ranking. This drivers exhibited poor low-frequency extension combined with inadequate midbass impact and heft. In more complicated passages, the midbass was further muddied and somewhat compressed sounding. Midrange frequencies also sounded harsh at times, sounding rather sharp and a bit beamy in the upper midrange. One common characteristic among Tier 3 woofers was the lack of articulation and involvement during playback; very dull from top to bottom. Its score on staging and imaging were VERY poor and one of the worst in the test. The testers unanimously agreed the stage depth was poor. The soundstage sounded rather one-dimensional with everything running together on a flat plane. This speaker could have been ranked in Tier 4, but the performance characteristics of the Tier 4 drivers were much worse than the Vifa.

TIER 2 MID-WOOFERS:

Exodus Ex-Anarchy
Hybrid Audio Technologies L6SE
Pioneer TS-C172PRS

Exodus Ex-Anarchy

The Exodus Ex-Anarchy mid-woofers came from a website that sells high-end cables named www.DIYcable.com. They are mostly a do-it-yourself website and the future for these drivers seems uncertain as per their website. From the website and the Exodus Audio data sheet, the driver appears

to have been designed by Dan Wiggins at Acoustic Development International. This thing is a beast in both size and heft. The manufacturer claims significantmidbass output, while minimizing associated turbulence and noises created from the mechanics of the driver. Given its commendable sonic performance at its affordable price point, this driver is undoubtedly the high value winner of this test. At $180 a pair, they are the bargain.

These mid-woofers scored well in the test. One of their best attributes was the even balance throughout the frequency range. As their beefy size might indicate, they excelled in midbass performance. The midbass had good impact, although it was a tad muddy, and at times, it sounded more like test tones than natural sounding midbass. Its midrange reproduction was good, although not impressive. There was some upper-end midrange resonance apparent during many of the songs especially during complex musical passages. Separation was poor throughout the entire frequency range, as many instruments and frequencies seemed to blend into one during the more demanding musical passages. The Exodus threw a large soundstage and scored well in height, depth, and width with all the testers. Overall, these drivers were solid performers and ranked well among the other drivers. As discussed in the "Ultimate Midrange Shootout", a product like the Exodus, and a few others in this test, would greatly benefit from a dedicated midrange. In the midrange test, we had some high-value offerings that would compliment this driver quite well.

Hybrid Audio Technologies L6SE

Hybrid Audio Technologies was founded in 2005 by Scott Buwalda, a multi-time champion in car audio sound quality competitions. The Hybrid Audio Technologies L6SE mid-woofers are the company's top-of-the-line, reference-quality Special Edition. This gorgeous driver features a copper phase plug, a lightweight paper cone, and superb quality-related details.

This driver did many things well during this test. The midbass was detailed but didn't quite match the superb impact and volume typical of Tier 1 drivers. The midbass frequencies simply needed more output and impact in the lower octaves. The female voices sounded airy and smooth, but the male voices sounded a little flat and lacked the visceral presentation of some of the higher scoring drivers. Instruments had good separation and the acoustic guitar sounded lively and palpable, due to its good midrange articulation and speed. These mid-woofers had great upper end detail and impact throughout the midrange frequencies, but at times sounded a bit strained. The main thing these drivers lacked was fullness to the sound, sounding accurate and correct, but falling short in the lower octaves. The testers unanimously agreed the soundstage was good, rendering it of proper size and height, depth, and width. The HAT L6SE overall performance was very good but just missing some presentation in lower octaves, sometimes sounding as if it would do better as a dedicated mid-range. In this test a great overall driver.

Pioneer TS-C172PRS

Pioneer has long history of leadership in producing reference level mobile audio products. These mid-woofers are part of Pioneer's newest Stage 4 reference level component set, which consists of mid-woofers, tweeters, and crossovers. Pioneer also offers a full electronic compliment (source unit and amplifier) as part of Stage 4. We are also very curious about their amplifiers [hmmm … future test? hint, hint].

The Pioneer TS-C172PRS mid-woofers sounded really nice overall with a pleasant balance throughout all frequencies. The lower bass capability was, like the Hybrids, lacking in the lower registers. The drivers did not have much low-frequency extension, and did get a little muddy down low, causing separation to suffer. The Pioneer's midrange frequencies were also good, having wonderful detail in the upper frequencies. The Pioneer's had threw a precise and reasonably large sound stage, with very good width, height, and width. These mid-woofers also scored well in the category of tonality. All testers were generally positive toward the Pioneer's performance but they did fall short in bottom end resolution - clearly earning them a Tier 2 slot. Overall, another good sounding mid-woofer that just didn't seem to extend very low and did not possess capabilities characteristic of the Tier 1 drivers.

TIER 1 MID-WOOFERS:

Dynaudio Esotar$_2$ e650
PHASS MD0790
Scan-Speak 18WU/4741T-00

Dynaudio Esotar$_2$ e650

Dynaudio is fully engineered and manufactured in Denmark in their state-of-the-art facility. Dynaudio became famous for the performance and quality of their drivers that were, and still are, considered to be amongst the very best. Due to their reputation for performance and quality, Dynaudio drivers were used in many high-end speaker brands like Wilson Audio, Sonus Faber and Thiel, to name a few. Among Dynaudio's many innovations in driver design, the most obvious is their proprietary magnesium silicate polymer cone, and their large, but lightweight, voice coil with internal magnets. We tested the Esotar^2 650, a mid-woofer from its flagship line of Esotar products.

Does all this extra effort in engineering, production and design pay off for Dynaudio? In a word YES. The Esotar^2 650's performed very well in this test with excellent extension in the lower registers. The midbass extension went very low, with very good midbass impact, articulation and detail. The performance in the midbass was effortless - even when going deep it still maintained its composure. Additionally, even in complex musical passages, the driver never strained. Midrange detail was exceptional, with subtleties much more noticeable throughout. Upper vocals sounded airy and natural, while lower vocals were strong and energetic, but still sounded true to life. Everything in a musical passage was played correctly and accurately. The actual descriptive comments from testes were – it 's lifelike, non-fatiguing, full-bodied, and awesome. The overall soundstage was expansive and precise with excellent height, width and depth that created a 3-dimentional, almost holographic, soundstage with pinpoint images. Overall, this was an excellent sounding driver well deserving of its Tier 1 ranking.

PHASS MD0790

Phass is manufactured in Japan and first began as an amplifier company manufacturing a unique, but very serious, RE line of amplifiers. Their powerful solid-state amps utilize topology usually found in high-end tube amplifiers. At that time they offered two more high-end series amplifier families, one of which was the entry AP series which won a few awards and accolades for their performance. 1996 was the official beginning for Phass, and about a year later they began selling loudspeaker drivers.

The MD0790 is Phass' top reference level offering and we are happy to report they have succeeded. This is a wonderful driver that utilizes a lightweight paper cone, high-density resin basket, and rare alnico magnet. These mid-woofers also scored very well in this test and ended up in the top tier. Tier 1 placement is impressive, as this company is more know for it high end amps [upcoming test? hint - details to be released]. The seriousness of this driver's performance was immediately obvious. These mid-woofers sounded very full in their delivery, exhibiting very good low-end extension, with good impact in the lower mid-range frequencies. The driver's deficit to the top two was due to its inability to convey the proper impact and drive like the Scan-Speak and Dynaudio. The Phass had good detail and separation throughout the entire passband, allowing the testers to easily hear the individual instruments. The midrange was pleasing and lifelike, and the stage presentation had good height, width, and depth, with good instrument separation and proper placement. The music played through the PHASS MD0790 is realistic sounding and tonally accurate. Well done!!

Scan-Speak 18WU/4741T-00

Scan-Speak, like Dynaudio, is one of the world's premier loudspeaker manufactures and arguably one of the best. The company started production in 1970 and quickly became sought after because of the performance, low distortion and quality construction. Designed and manufactured in Denmark, Scan-Speak is known world wide for its careful manufacturing and quality control. You will find that Scan-Speak also has some automotive offerings but for this test we wanted the best from their Illuminator product line.

The Scan-Speak 18WU's midbass performance was also stellar, earning a Tier 1 placement. Its performance in these lower registers was also effortless and clean. It was punchy and authoritative when it needed to be, and gently refined when the music called for those subtleties. Like the other two in this tier you can keep on listening, it was tonally right. The midrange was also amazing with tremendous timbral accuracy, and an appropriate sense of air. The only nitpick was absence of upper-end detail. Other than that, this was one of the top performing drivers of the test. The soundstage was precise and three-dimensional, with incredible height, width, and depth that made the stage came alive with well-separated instruments and vocals. These drivers had good detail throughout most of the passband with a very nice, rich texture. These mid-woofers were full of energy and presence, while sounding tonally accurate and lifelike. Overall, this was a superb sounding mid-woofer that did almost everything right.

CONCLUSION

"High performance" or "reference" is thrown around too easily these days and those designations seem to be driven more by marketing than solid engineering and superior build quality. Further confusing the decision process can be the vast information available on the internet. While the internet serves as an excellent starting guideline for product research, it is also filled with unverifiable verdicts and opinions. We were resolute in our unbiased testing to find superior performing midbass drivers. As always, consider your own priorities, installation limits, and goals. "Tier 1" placement was reserved for drivers that played effortlessly and accurately while still maintaining their midrange resolution even at realistic volume levels. Overall this placement is reserved for outstanding performance with majority consensus amongst the judges. Any driver in "Tier 1" will reward with exceptional performance. "Tier 2" drivers are an excellent option and should still be considered. Drivers in this group did everything well but have a shortcoming to "Tier 1" drivers. The products in "Tier 3" have some good characteristics but were lacking in numerous performance variables as compared to the top two tiers. "Tier 3" drivers, and even in some instances "Tier 2" drivers, would gain performance with the addition of a dedicated midrange. It was the opinion of all the judges that "Tier 4" was not in the same caliber as the other drivers and were not to be considered. The Seas drivers in this test could have had some defect given their poor results, but given the time constraints we could not verify this. The Eighteen Sounds seems to have been designed for another purpose other than a dedicated midbass for two-way system duties.

Using the bar graphs on page 15, further visual guidance is quickly given on the performance of these drivers in this test. This section shows that some specified data doesn't correlate to expected performance especially in the lower octaves. Considering the ultimate goal for these drivers is a mobile installation, special consideration must be made to mounting depth. If your desire is to build dedicated door enclosures our graph shows which drivers work best in the smallest enclosures. Even if you choose to mount your drivers in "free air", our graph helps you select drivers designed to perform best for that application.

While there is no such thing as the perfect speaker, there are some that are far better than others: some that put a big smile on your face, some that made you wince once and a while, and some that made you question logic and intelligence - we wanted big smiles……we got them!

For any questions or comments, please email me at jerry_hdma@cox.net.

" ... loudspeaker design is still largely an art. Engineering will guide the way, but it is no substitute for good taste, good sense, and musical sensitivity. If Engineering were all it took, there would be no bad or even mediocre loudspeakers to think about."

-- Vance Dickason, The Loudspeaker Design Cookbook, 6th ed., 2000, p. 155.

Audio Technology C-Quenze 18H

MSRP $730

TIER 3

Audio Technology C-Quenze feature a solid die cast basket, hexacoil voice coil winding, vented pole piece, natural midrange reproduction, and customizable t/s parameters.

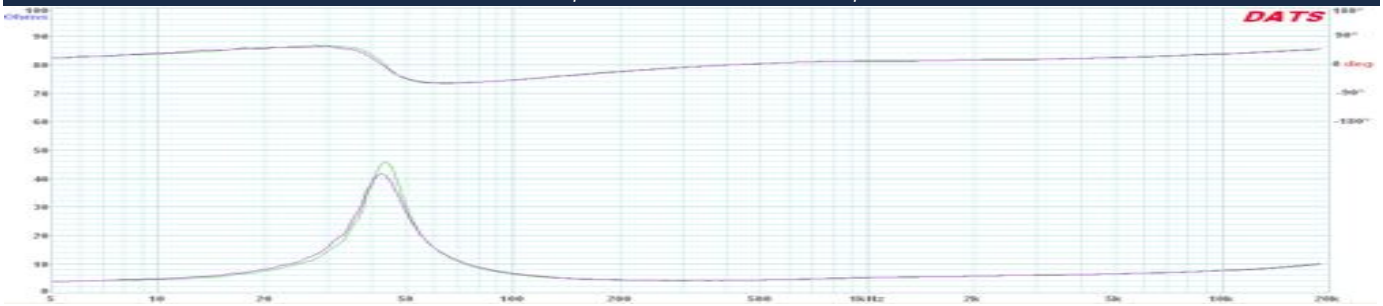
www.audiotechnology.dk

AudioTechnology

Diameter	180mm
Mounting Depth	83mm
Impedance	4 Ω

T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
R(e)	3.3494	3.4614	3.2%	N/A	3.7776	Ft^3	.26
F(s)	42.39	43.74	3.1%	40	45.09	Ltr	7.34
Q(ts)	.285	.327	12.8%	.32	.434	F(s) (Hz)	88.4
Q(es)	.31	.354	12.4%	.39	.48		
Q(ms)	3.537	4.328	18.3%	1.8	4.574		
L(e)	.111	.112	0.9%	.13	.112		

DATS Measurement Graph – Free Air Measurement of Speaker 1 & 2



Dynaudio Esotar2 e650

MSRP $1100

TIER 1

Dynaudio Esotar2 e650 features a die-cast solid aluminum frame, MSP diaphragm, 75mm voice coil, neodymium magnet, excellent transient response, and natural midrange reproduction.

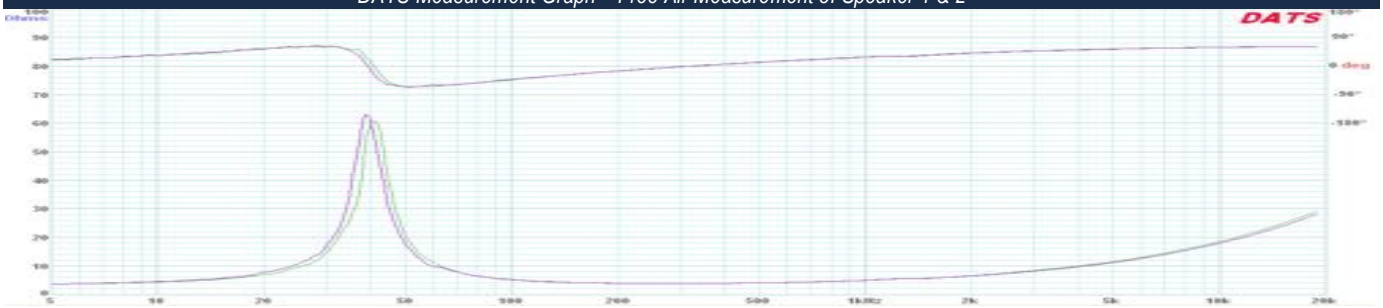
www.dynaudio.com/us

DYNAUDIO
AUTHENTIC FIDELITY

Diameter	169mm
Mounting Depth	67mm
Impedance	4 Ω

T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
R(e)	3.394	3.3541	1.2%	3.4	3.3511	Ft^3	.23
F(s)	38.36	41.05	6.6%	49.6	41.05	Ltr	6.51
Q(ts)	.374	.382	2.1%	.44	.418	F(s) (Hz)	79.7
Q(es)	.395	.404	2.2%	.47	.446		
Q(ms)	6.956	6.936	0.3%	6.2	6.608		
L(e)	.282	.292	3.4%	.33	.282		

DATS Measurement Graph – Free Air Measurement of Speaker 1 & 2



Eighteen Sound 6ND430

MSRP $299

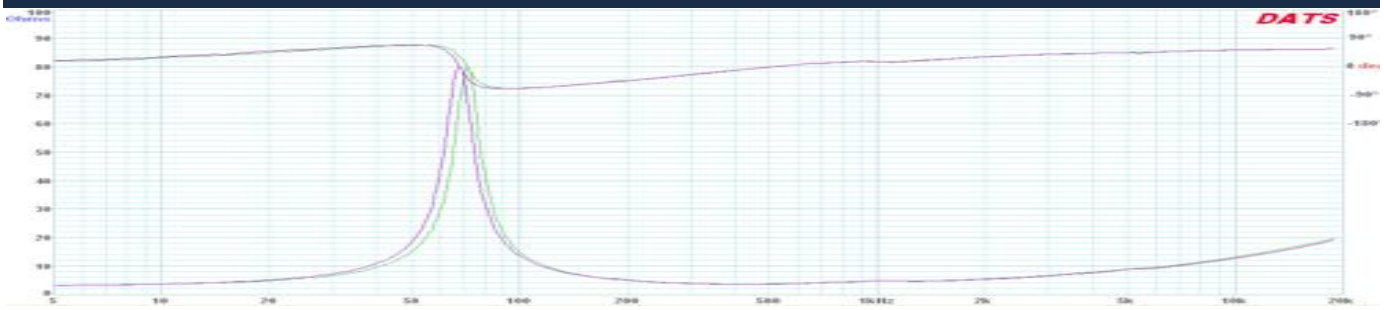
TIER 4

Eighteen Sound 6ND430 feature a lightweight neodymium magnet, weather coated cone, and is available in 4, 8, or 16 ohms.

www.eighteensound.com

Diameter	162mm
Mounting Depth	60.5mm
Impedance	4 Ω

T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
R(e)	2.9388	2.9184	0.7%	N/A	2.9369	Ft^3	.08
F(s)	71.33	67.96	5.0%	61	65.95	Ltr	2.27
Q(ts)	.279	.266	4.9%	.27	.368	F(s) (Hz)	159.7
Q(es)	.29	.276	5.1%	.28	.385		
Q(ms)	7.591	7.26	4.6%	6.5	8.42		
L(e)	.206	.198	4.0%	.28	.199		



Exodus Ex-Anarchy

MSRP $180

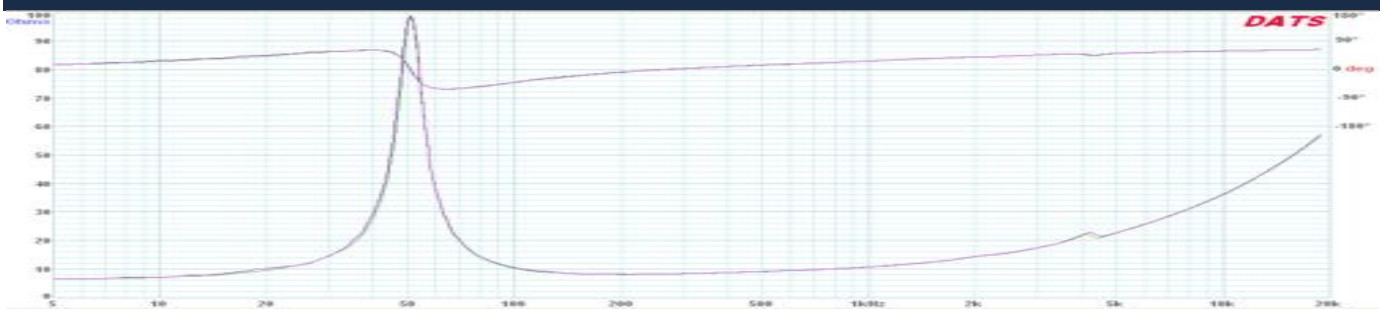
TIER 2

Exodus Ex-Anarchey feature an XBL motor, highly optimized suspension, aerodynamic performance of the spider/pole vent assembly, and 25mm peak-peak xmax.

www.diycable.com

Diameter	181.8mm
Mounting Depth	93mm
Impedance	8 Ω

T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
R(e)	6.0216	6.1028	1.3%	6.4	6.1185	Ft^3	.21
F(s)	51.14	50.47	1.3%	45.8	51.14	Ltr	5.95
Q(ts)	.459	.446	2.9%	.44	.524	F(s) (Hz)	73.6
Q(es)	.489	.475	2.9%	.48	.562		
Q(ms)	7.535	7.198	4.7%	6.37	7.631		
L(e)	.567	.571	0.7%	.84	.575		



Hybrid Audio Technologies L6SE

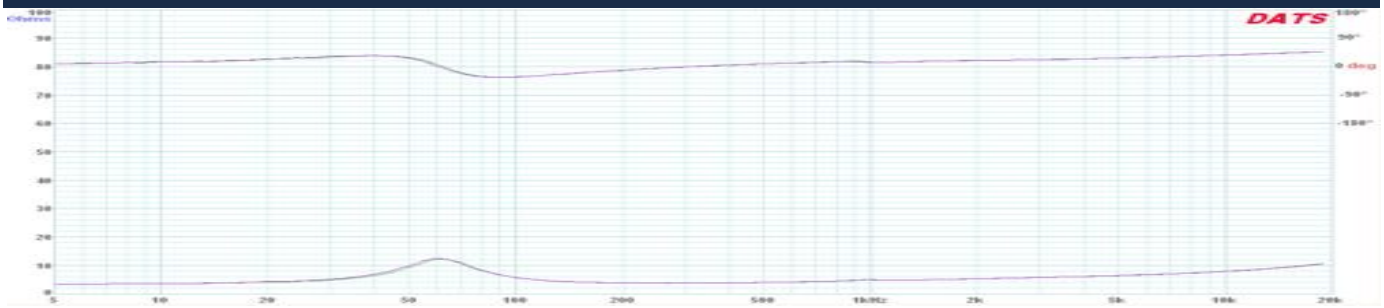
MSRP $820

TIER 2

Hybrid Audio Technologies L6SE features an opposing double stacked NdFeB magnet, 35.55mm voice coil, inverted butyl rubber surround, proprietary hybrid paper diaphragm, copper phase plug pole piece, and copper shorting cup.

www.hybrid-audio.com

		T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
		R(e)	3.22	3.18	1.3%	3.2	3.2758	Ft^3	.50
		F(s)	61.24	60.56	1.1%	50	59.22	Ltr	14.29
Diameter	181mm	Q(ts)	.576	.543	6.1%	.466	.752	F(s) (Hz)	75.9
Mounting Depth	78mm	Q(es)	.784	.731	7.3%	.612	1.039		
		Q(ms)	2.167	2.11	2.7%	1.941	2.729		
Impedance	4 Ω	L(e)	.117	.116	0.9%	N/A	.119		



JBL 660GTi

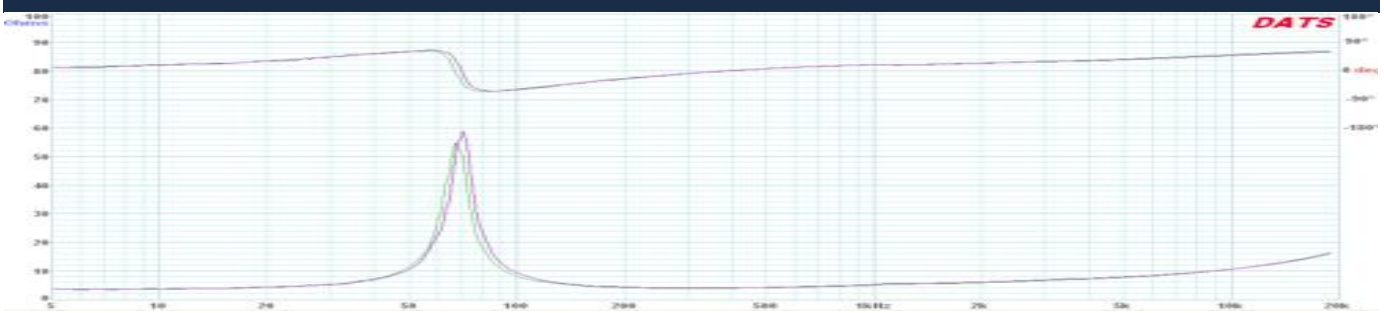
MSRP $1500*

TIER 3

JBL 660GTi feature cast aluminum basket, kevlar dust cap and cone, vented voice coil former, over-hung voice coil, copper shorting ring, neodymium magnet, polished and flared vent, copper polepiece cap, nitrile-butylene surround, and nomex spider.

www.jbl.com

		T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
		R(e)	3.2655	3.2388	0.8%	N/A	3.2528	Ft^3	.16
		F(s)	67.29	70.66	4.8%	60.8	64.6	Ltr	4.45
Diameter	176mm	Q(ts)	.5	.484	3.3%	.4	.598	F(s) (Hz)	107.5
Mounting Depth	69.1mm	Q(es)	.532	.512	3.9%	.42	.637		
		Q(ms)	8.375	8.779	4.6%	10.17	9.729		
Impedance	4 Ω	L(e)	.161	.162	0.6%	.13	.163		



PHASS MD0790

MSRP $1275

TIER 1

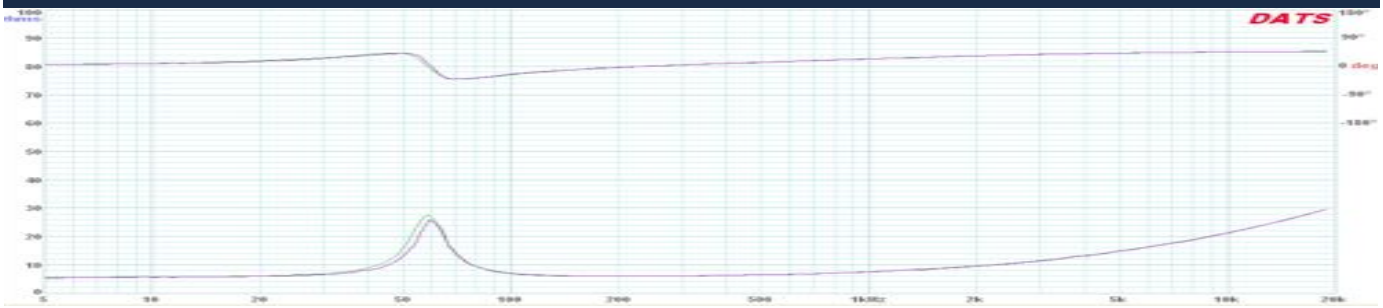
PHASS MD0790 feature a plastic basket, paper cone, alnico magnet, and ability to reproduce music with a great sense of realism and naturalness.

www.ignitionmobilehifi.com

PHASS
CAR HI-FI EQUIPMENT

Diameter	164mm
Mounting Depth	65mm
Impedance	6 Ω

T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
R(e)	5.8514	5.7828	1.2%	N/A	5.4304	Ft^3	N/A
F(s)	59.22	59.22	0.0%	N/A	57.87	Ltr	N/A
Q(ts)	1.126	1.158	2.8%	N/A	1.48	F(s) (Hz)	N/A
Q(es)	1.431	1.492	4.1%	N/A	1.946		
Q(ms)	5.292	5.168	2.4%	N/A	6.177		
L(e)	.327	.326	0.3%	N/A	.329		



Pioneer TS-C172PRS

MSRP $999*

TIER 2

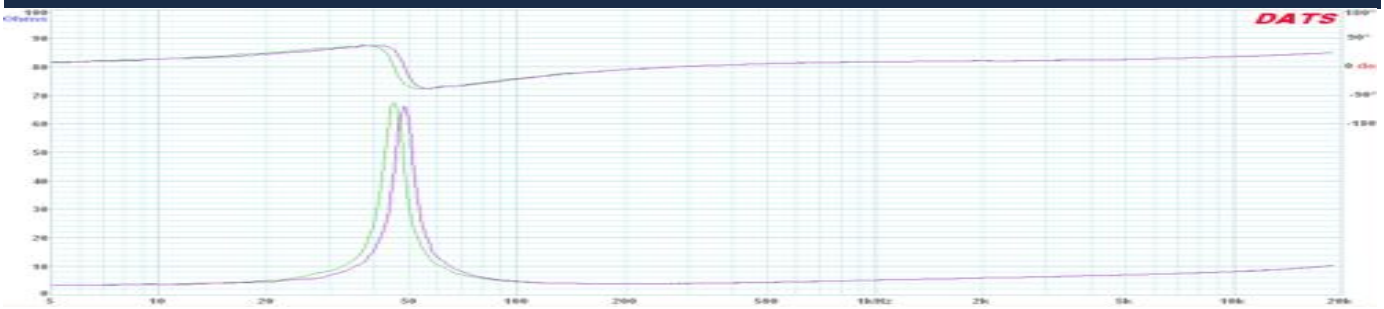
Pioneer TS-C172PRS feature open, smooth, expansive, multidimensional sound, without the dramatic dips and inconsistencies, fuller midrange fidelity and clear, accurate vocals.

www.pioneerelectronics.com

Pioneer

Diameter	183mm
Mounting Depth	67mm
Impedance	4 Ω

T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
R(e)	3.1451	3.1028	1.4%	3	3.173	Ft^3	.84
F(s)	45.09	48.45	6.9%	45	49.12	Ltr	23.71
Q(ts)	.509	.532	4.3%	.5	.632	F(s) (Hz)	63.6
Q(es)	.534	.558	1.3%	.54	.674		
Q(ms)	10.931	11.345	3.6%	5.9	10.116		
L(e)	.12	.12	0.0%	N/A	.118		



ScanSpeak 18WU/4741T-00

MSRP $683

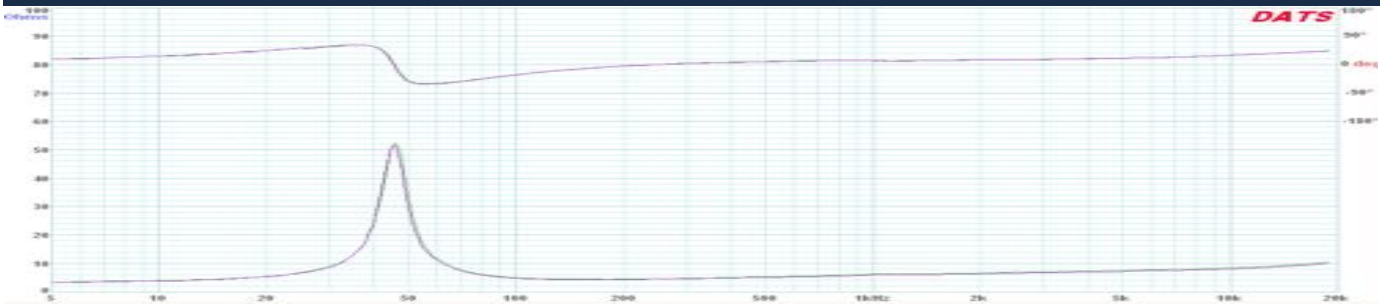
TIER 1

ScanSpeak 18WU features under-hung neodymium motor, black anodized aluminum cone, low-loss linear suspension, patented symmetrical drive, and exceptionally long linear excursion.

www.scan-speak.dk

SCANSPEAK

		T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
		R(e)	3.1918	3.2034	0.4%	3.2	3.1901	Ft^3	.35
		F(s)	45.76	45.09	1.5%	30	45.76	Ltr	9.99
Diameter	184mm	Q(ts)	.49	.497	1.4%	.29	.592	F(s) (Hz)	73.1
Mounting Depth	97.3mm	Q(es)	.522	.53	1.5%	.32	.641		
		Q(ms)	8.043	7.992	0.6%	3.56	7.646		
Impedance	4 Ω	L(e)	.127	.118	7.6%	.5	.119		



Seas Excel W18NX-001

MSRP $440

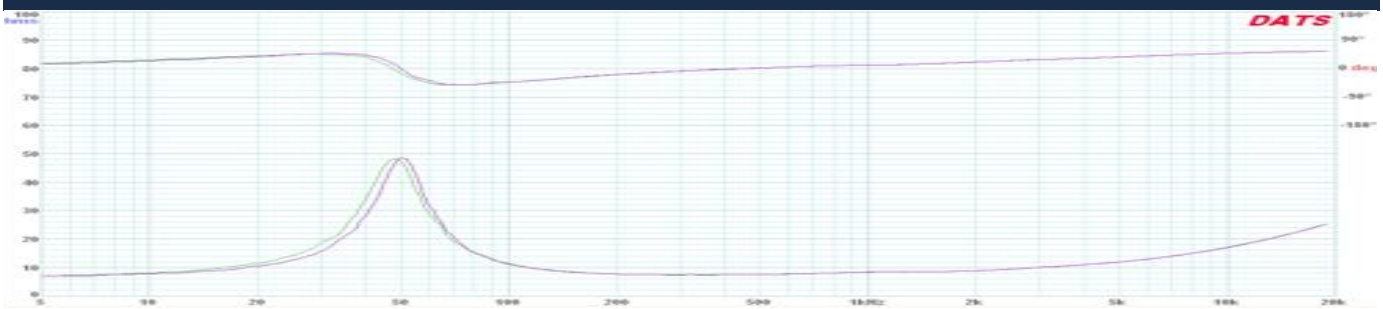
TIER 4

Seas Excel W18NX-001 feature an adaptive rubber surround, paper cone with a unique Nextel coating, large magnet system with bumped back plate, light weight CCAW voice coil, copper shorting rings, and injected metal basket.

www.seas.no

seas

		T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
		R(e)	6.2126	6.3274	1.8%	6.3	6.596	Ft^3	.25
		F(s)	47.78	49.8	4.1%	40	46.43	Ltr	7.22
Diameter	176mm	Q(ts)	.376	.418	10.0%	.34	.494	F(s) (Hz)	83.2
Mounting Depth	81mm	Q(es)	.432	.48	10.0%	.41	.572		
		Q(ms)	2.909	3.211	9.4%	2.08	3.617		
Impedance	8 Ω	L(e)	.255	.252	1.2%	.43	.253		



Vifa NE180W-04

MSRP $460

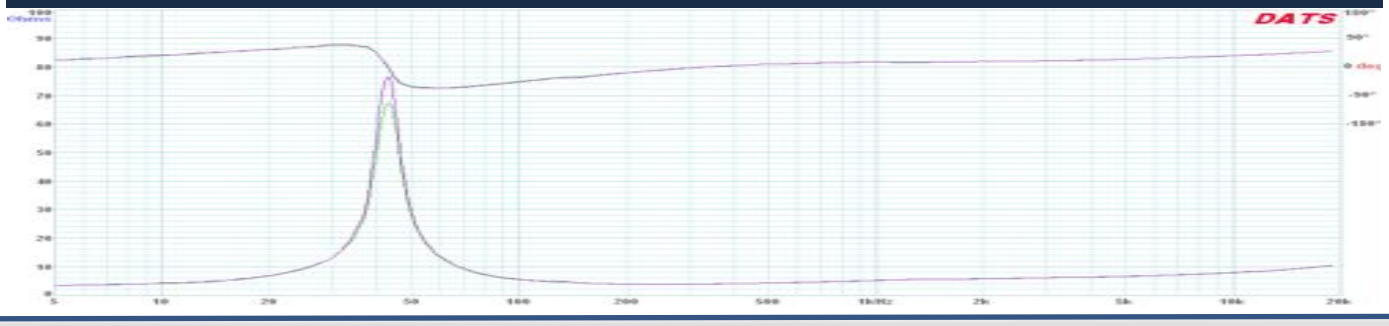
TIER 3

Vifa NE180W-04 feature a cast aluminum frame, high-strength neodymium motor, coated natural wood fiber cone, pentacone cone technology for improved frequency response, long-throw voice coil on titanium former, and copper pole piece for extended high frequency response.

www.tymphany.com

Diameter	180mm
Mounting Depth	88.29mm
Impedance	4 Ω

T/S	Measured Speaker 1	Measured Speaker 2	% Varience	Manufacturer Parameters	Measured In Enclosure	Required Enclosure .707 Qtc per WinISD	
R(e)	3.0008	3.0622	2.0%	3.3	3.1143	Ft^3	.16
F(s)	43.07	43.07	0.0%	39	44.41	Ltr	4.55
Q(ts)	.331	.33	0.3%	.29	.41	F(s) (Hz)	95.1
Q(es)	.346	.344	0.6%	.30	.434		
Q(ms)	7.435	8.239	9.8%	8.6	7.301		
L(e)	.116	.117	0.9%	.08	.117		



COMPARISON OF IMPORTANT MEASURED TESTING PARAMETERS