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The KISS Bass Project

By Tom Perazella

Sometimes smaller and simpler is better, as in the case of this sub project, which produces amazingly clean bass.

There is no doubt that the science of speaker design has grown dramatically since the time I first started in Hi-Fi. In the early days, there were few tools to predict the final results of a project. In many cases, speaker design was a case of trial and error. Although experience helped, using what seemed to be similar drivers in the same types of enclosures did not give the same results.

Without going into the whole history of speaker design, it is clear that the work of Messrs. Thiele and Small provided a predictable basis for determining key driver parameters and then using those parameters to tune the speaker enclosure. Since then, many different books and software programs have been written that can help optimize the design of a speaker. However, sometimes you just need to keep it simple. If ultimate performance is not your goal, but you want predictable performance, it would be nice to have a KISS (Keep It Simple, Stupid) method to achieve the results you are looking for.

That was the case when I wanted to produce a simple small subwoofer to take with me on an extended trip to the UK. My company was moving me there for a five-month period to work on some special projects. While there, I would be living in a small flat. I was used to a sound system that had prodigious amounts of clean bass (see "True Bass," *Speaker Builder* 5/96, p. 10). However, even if I could duplicate the ability to produce 122dB of clean bass at 16Hz like my main system, when I moved to the flat, relations would most likely soon go pear shaped with the neighbors. A more modest approach was called for.

BASIC DESIGN

While thinking about the project, I decided to see just how simple I could make it. Basically I wanted to take a small driver and put it into a sealed box. Forget vents, passive radiators, transmission lines, servos, and all the other wonderful methods that offer some advantage but require more effort. Remember that the bass requirements were quite modest. I would be using the sub to augment a pair of Sequerra Met 7s. Although I wanted reasonably deep bass, the SPL levels would not be very high.

Having spent quite a bit of time in the UK, I realized that housing space is not only quite expensive, but it is also limited. The flat I would be in was two stories, with a kitchen, dining area, living room, two bedrooms, and a bath, all totaling just about 800ft^2. All the rooms were small. In addition, my wife would be accompanying me and would not take kindly to a large sub in such small quarters.

PICKING THE DRIVERS

The first step was to pick the driver I would use. Although I had previously used larger drivers not only for their larger radiating area, but also for their usually longer linear stroke, I decided to see whether I could find a suitable 8″ driver. It is important to never forget that you must have sufficient linear volume displacement to achieve your target levels of frequency response and output level. If the driver is not capable of producing enough linear displacement at the lowest frequencies and highest levels you wish to reproduce, distortion will be high.

Volume displacement is a function of the effective driving area of the cone times its linear excursion. If the effective diameter of the cone, Sd, is not specified, a reasonable approximation is the diameter of the cone plus about one-third of the surround. The linear excursion is specified as Xmax.

Recent advances in driver design have greatly increased the Xmax that can be achieved, and, thankfully, this has extended to smaller drivers. At first glance it would seem that a small driver with a high Xmax could produce the same linear output as a larger driver with a smaller Xmax. This is true to some extent, but as they say, a funny thing happened on the way to the Forum.

To achieve higher Xmax, you must have

PHOTO 1: Typical large Xmax driver.

an increase in the ability of the surround to travel in a linear fashion over greater distances. That translates to a larger surround. **Photo 1** shows the large roll surround on a typical large Xmax driver. So, for a given outer diameter of the driver, greater Xmax means a larger surround and a correspondingly smaller cone diameter. Because the surround does not contribute as much to sound generation as the cone, the driver will generate less SPL for the same excursion.

For example, the Vifa M21WO-39-08 8″ driver, which is representative of a conventional woofer, has an Xmax of 6mm and an Sd of 235cm^2. The Tang Band W8-740C 8″ driver (**Photo 2**) has an Xmax of 12mm but an Sd of only 220cm^2. The TC Sounds 2574 8″ driver (**Photo 3**) has an Xmax of 16mm and an Sd of only 190cm^2. Therefore, although the Tang Band has twice the excursion as the Vifa, the displacement is not quite twice, but only 1.87 times due to the smaller effective cone area caused by the larger surround. The TC Sounds has an Xmax that is 2.67 times the Vifa but only 2.15 times the displacement.

There is no doubt that either the Tang Band or TC Sounds driver has higher linear displacement than the Vifa. However—and this is especially true with smaller diameter drivers—increasing Xmax for a given basket size does not result in a proportionately higher displacement. It's something to keep in mind when comparing drivers.

PHOTO 2: Tang Band W-8-740C driver.

PHOTO 3: TC Sounds 2574 driver.

At the time I was searching for drivers for this project, these Tang Band and TC Sounds drivers were at the top of the list. Why did I choose two? First, there was a huge difference in the pricing. The Tang Band was $39 and the TC Sounds was around $250. The price was an estimate for the TC Sounds because it was not yet available to the public. That's a big price difference for about 18% more displacement.

But, there was another reason to look at the TC Sounds. In a sealed box, all else being equal (which never really happens), the stiffer the suspension, the smaller the box that you can use. The equivalent volume of the driver, Vas, depends on the effective area of the cone and the compliance. The relationship of the Vas to the box volume determines the degree of change of free air parameters of the driver such as Fs and Qts once the driver is mounted in a box and results in the new

parameters Fb and Qb.

For example, if you have two drivers with the same free air resonance, but one has a Vas that is twice the other, then for the same change in resonant frequency when mounted in a box, the driver with the higher Vas will need a box volume of twice that of the driver having half the Vas. This also has a significant impact on overall box size.

The Tang Band has a Vas of 23 liters and the TC Sounds has a Vas of 14.2 liters. Therefore, to achieve the same change in parameters, the TC Sounds can go into a smaller sealed box. Refer to the *aX* website (www.audioXpress.com) for the specifications of the TC Sounds and Tang Band drivers.

To understand the reasons for some of the differences in the pricing of these drivers, you must look at the construction. **Photo 4** shows the TC Sounds in relationship to the Vifa. For many reasons, the TC Sounds is physically huge compared to the Vifa, including those that have to do with the need to keep efficiency up while extending Xmax, having a relatively low Fs and low compliance. **Photo 5** shows the Tang Band in relationship to the Vifa. Here again, the difference with the Vifa is dramatic if not as large as the TC Sounds comparison. Finally, **Photo 6** shows the TC Sounds compared to the Tang Band.

Although beyond the scope of this article, note that given the right motor structure, electronic means can be used to modify the passive effects that are caused by box volume and Vas. Utilizing those methods, however, would put this well be-

PHOTO 4: TC Sounds in relationship to the Vifa.

PHOTO 5: Tang Band in relationship to the Vifa.

yond a "keep it simple" project.

SIZING THE BOX

The next step was to determine the box volume. Again, to keep it simple I just plugged in the T/S parameters from the manufacturers into a spreadsheet I developed. That spreadsheet, along with instructions, is available from the *audioXpress* website (www.audioxpress.com). The goal was to have an Fb of 40Hz. With the TC Sounds, that resulted in a box volume of about 0.5ft^3.

Because this was such a small volume and the driver motor was quite large, I slightly upsized the box to 0.6ft^3 to allow for the volume lost to the motor and basket structure. For the Tang Band, the box volume was about 0.8ft^3. At this point, it was such a close call between the box volumes I realized that to really decide, I'd need to build them both. It would be a good example of trade-offs.

POWERING THE SUB

Deciding the power source was a no brainer. We are blessed today to have self-contained subwoofer amplifiers, sometimes called plate amplifiers—not to be confused with vacuum tube terminology—that have outstanding performance and are excellent values. Everything you need to drive the sub is included in one piece, including power amp, summing network, auto on sensing, crossover, and equalization. All these components come attached to a metal plate that is mounted into a cutout in the sub cabinet, making life easy.

PHOTO 6: TC Sounds compared to the Tang Band.

PHOTO 7: Parts Express 300-794.

I chose the 300-794 from Parts Express (**Photo 7**). At the 4Ω impedance of the drivers, it is rated at 250W, more than adequate for the levels I was looking for. The circuitry for this amplifier is shown in **Photo 8**.

BUILDING THE BOX

Looking at the suggested cutout for the amplifier, I had an idea. Why have a cutout at all? Because the boxes were so small, if I chose the dimensions correctly, the amplifier could become the rear wall of the box. So, that is what I did. As a result, the box consisted of only five pieces—four sides and a front

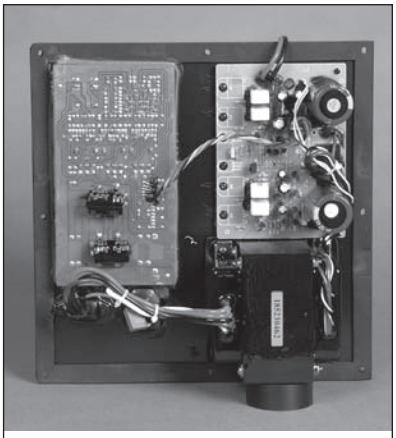

PHOTO 8: Amplifier circuitry.

mounting piece.

Actually, after looking at the drivers, I made one concession to aesthetics with the TC Sounds box. I cut another piece the same outline size as the front piece to be used as a trim plate and make it look as though the driver were flush-mounted. That driver has a nice-looking rubber trim ring on the front of the basket and the idea worked well. The Tang Band is a little more utilitarian-looking on the front with a more traditional mounting piece, so I decided to rear-mount that driver.

Because the rear opening was determined by the amplifier, the only differences in the boxes were their lengths. The piece dimensions and final box sizes with amplifier are shown in **Table 1**. I built the box with ¾″ MDF, using glue and biscuits. I could have just as well used screws, but I prefer biscuit joints.

Table 1 Box Dimensions

Note: All material is ¾″ MDF.

Box Pieces for TC 2574

Qty	Description	Length	Width
2	Side panels	12″	9¼″
2	Top and bottom panels	12″	10¾″
2	Front panel and trim	10¾″	10¾″

Box Pieces for TB W8-740C

Qty	Description	Length	Width
2	Side panels	16″	9¼″
2	Top and bottom panels	16″	10¾″
1	Front panel and trim	10¾″	10¾″

Finished Sizes Including Amplifier

Driver	Length	Width	Height
TC 2574	14½″	10¾″	10¾″
TB W8-740C	17¾″	10¾″	10¾″

If you have never built wood projects using biscuits, you owe it to yourself to try. Not only are the joints extremely strong, assembly is very simple. In case you are not aware of the technique, biscuits are small flat pieces of wood in the shape of a "squashed" biscuit (**Photo 9**). The alignment of the grain in the biscuits is such that maximum strength results when they join the plates. Slots are cut in the facing plates that are to be joined to receive the biscuits (**Photo 10**).

The use of a plate joiner to cut the slots for the biscuits is not only fast, but it also results in precise positioning of the pieces when they are assembled. A typical plate joiner (**Photo 11**) has a rotating cutter wheel mounted in a frame that allows precise height, depth, and angular adjustments. **Photo 12** shows the cutter wheel in relation to the frame that positions it to the piece being cut.

The biscuits—when inserted into these slots—keep the pieces in alignment during the assembly and add strength to the joint. Glue is added to the slots for the biscuits and the facing area of the plates. The biscuits are put into their slots and the plates pressed together. If done with a little care, the resulting joints are flush to the point that you cannot feel the seam.

The first step was to lay out the pieces and cut them out on a table saw. **Photo 13** shows the four sidepieces for the TC Sounds box. **Photo 14** shows the front plate after I cut slots for the biscuits, but before cutting the mounting hole. Next, I applied glue to the four sides of the box, added biscuits, assembled the sides, and clamped them in place. **Photo 15** shows the resulting box ready for mounting of the front plate. I cut the driver mounting hole using a router and then mounted the plate to the box. For the TC Sounds driver box, I cut the decorative trim plate, which I routed and glued to the front plate. The process was the same for the Tang Band box except that no trim plate was used.

FINISHING THE BOX

Once each box was assembled, I rounded all external edges with a router, except those on the back face. After sanding, I primed and painted the boxes. I had decided to use black paint, but while looking at the various paints available, I ran across a textured paint from Rust-oleum®. I decided to try it and purchased #7220, which is textured black.

This paint was easy to apply, and after drying had a nice, fine texture. The appearance is not like a flat finish, which can sometimes appear to pick up different tones depending on the light angle. It also does not have the coarseness of the older style wrinkle finishes. Overall, I was very pleased with the results. The finished box did not have a homemade look that you sometimes get with normal paint finishes.

The next step was to drill the mounting holes for the driver. The TC Sounds driver has very substantial push-type mount-

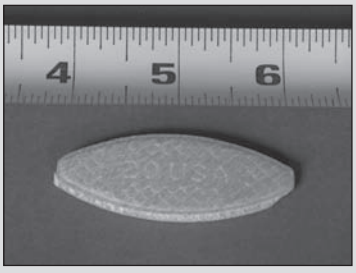

PHOTO 9: Biscuit.

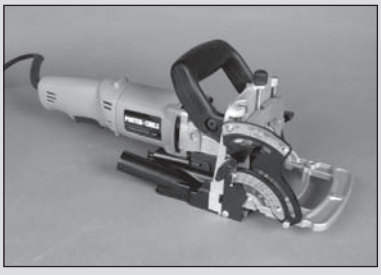

PHOTO 11: Typical plate joiner.

PHOTO 13: Four sidepieces for the TC Sounds box.

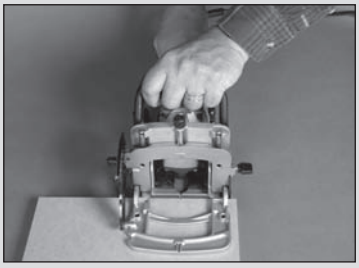

PHOTO 10: Slots cut into faceplates.

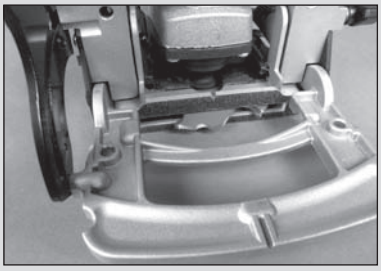

PHOTO 12: Cutter wheel.

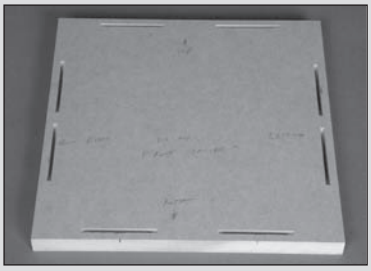

PHOTO 14: Front plate after slots cut.

ing posts for the wires. The Tang Band had polarized spade lug connectors —a larger one for the positive connection and a smaller one for the negative connection. For convenience, I decided to use a standalone push-on terminal strip fastened to the inside of the box to make the connections to the unit using the Tang Band driver, making it easier to assemble and later remove the amplifier if needed.

Mounting the terminal strip directly to the inside wall of the cabinet would have made inserting the wires a little cumbersome because the entrance holes would then be facing the inside of the box rather than the rear. To solve this problem, I cut a small piece of wood the size of the terminal base and fastened its edge on to the wall. I was then able to mount the terminal to this wood piece with the entrance holes and push buttons facing the rear. **Photo 16** shows the terminal strip inside the box used for the Tang Band driver.

Next, I mounted the drivers. As previously mentioned, I mounted the TC Sounds driver to its box from the outside, and mounted the Tang Band from the inside. Normally, I use square drive screws from McFeely's, but when I checked my supply, I did not have the right size. After using regular Phillips head screws, I decided not to let that happen again. In spite of that, I did mount the drivers. Before mounting the amplifiers, I connected the Tang Band driver to the intermediate terminal strip.

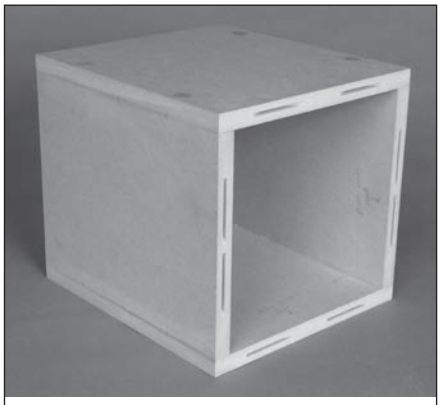

PHOTO 15: Box ready to mount front plate.

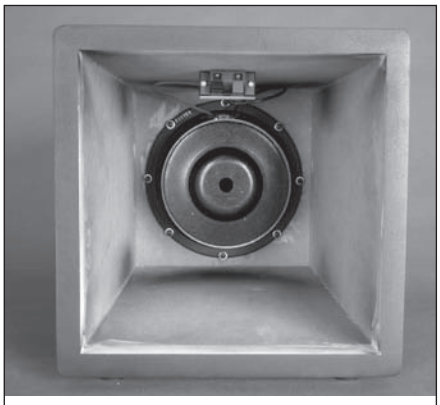

PHOTO 16: Terminal strip inside the box.

FINAL ASSEMBLY

Mounting the amplifiers is a very simple process. I first placed them in position on the back of the subs and marked for the pilot holes. After removing the amplifiers, I drilled pilot holes in the back edges of the boxes to receive the screws supplied with the amps.

Sealing the amps to the back of the box is ensured by the foam gasket mounted around the edges of the amps. Power from the amps to the drivers is provided by one each red and black heavy gauge wires soldered directly to the circuit board. The wires were terminated with ¼″ spade lug connectors, which were removed for this application. I connected the wires to the appropriate terminals with excess wire dressed neatly, replaced the amps in posi-

tion on the backs of the boxes, and screwed them in place using a cross-tightening pattern to uniformly compress the rubber gaskets.

The final construction step was to screw four rubber bumpers to the bottoms of each box. **Photo 17** shows a three-quarter view of the complete sub using the TC Sounds driver. The rear view of the same sub is shown in **Photo 18**.

The complete Tang Band sub is shown in **Photo 19**, in which you can easily see the extra length of this sub that was required to achieve the additional volume that the larger Vas required. For a size reference, **Photo 20** shows the TC Sounds sub with an LP resting against the side. You can see that the box is lower than the album cover and only slightly longer.

TESTING

For testing purposes, I brought both subs to my friend, Tom Nousaine, who has done a huge amount of speaker testing both for himself and various publications. The primary goal was to see how well the actual box tuning matched the calculated value determined by the spreadsheet.

Figure 1 is the response of the two subs superimposed on the same graph. The sub using the TC driver is shown with a dotted line and the TB with a solid line. As you can see, the curves are virtually identical. The -3dB point is about 42Hz, certainly very close to the target goal of 40Hz. It appears that the spreadsheet did a good job of selecting box volume.

Table 2: Tang Band Q8-740C specifications

Diaphragm MTL	paper
surround MTL	foam
nominal impedance	4Ω
DCR impedance	3.2Ω
Sensitivity 1W/1m	84dB
frequency response	28-1kHz
free air resonance	28Hz
voice coil diameter	50mm
air gap height	8mm
rated power input	120W
maximum power input	240W
force factor, BL	13.35Tm
magnet weight (50 oz.)	1427g
moving mass	95g
ferrofluid enhanced	No
suspension compl.	$333MN^{-1}$
Effective piston area	$0.022M^2$
Levc	3.18mH
Zo	113.99Ω
Xmax	12mm
Vas	23 ltr
Qts	0.30
Qms	10.53
Qes	0.30

LONG-TERM RESULTS

The TC sub was the version I eventually took with me to the UK, and it worked extremely well, producing more bass than I could reasonably use in the small flat that I had. A few times I was playing it at a level that I thought might provoke the ire of my neighbors, but they exhibited the proverbial British patience and did not come knocking on the door. The British are the nicest people.

Several of my colleagues from the office came by and were astounded by the volume of clean bass coming from such a small box. They had never heard that level of performance from such a small sub.

After that trip, our primary residence moved, but I needed to keep an apartment near company headquarters for the times I was there on business. The sub has been performing well there for almost three years in conjunction with a pair of Infinity Primus 150 speakers. I'm using a pair of old Orban parametric equalizers to roll off the low frequencies going to the 150s at 80Hz with a 12dB/octave slope. This

PHOTO 17: Three-quarter view of the completed sub using TC Sounds driver.

PHOTO 18: Rear view of the same sub.

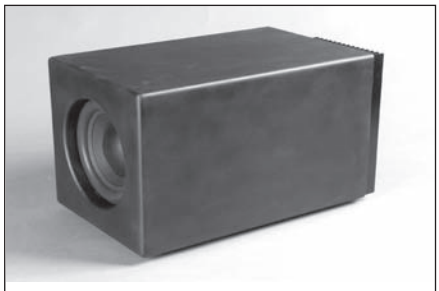

PHOTO 19: Completed Tang Band sub.

PHOTO 20: TC Sounds sub with an LP resting against the side.

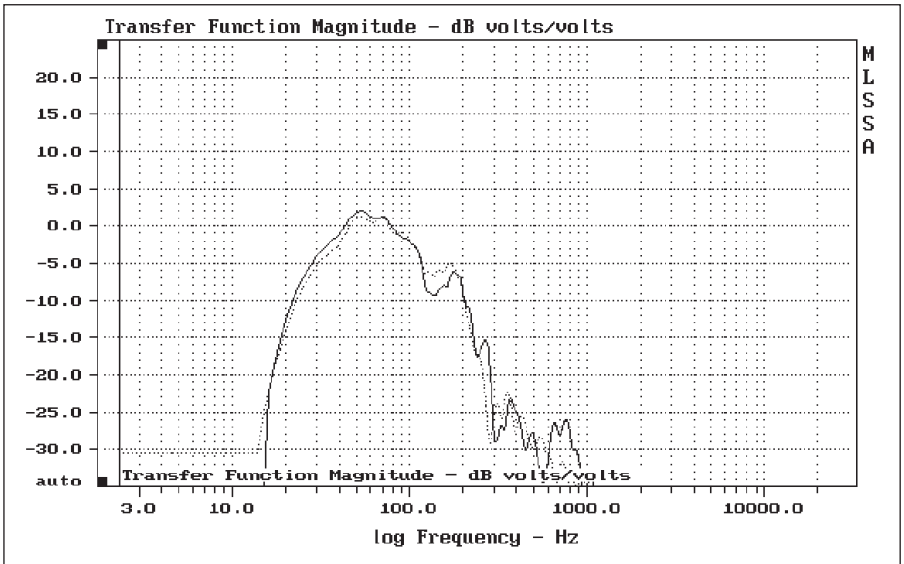

FIGURE 1: Response of two subs superimposed on the same graph.

makes their job much easier.

In addition, the Orbans did some minor room tuneup. Again, the small size of the sub makes it perfect for apartment use. **Photo 21** shows how I placed the sub under an end table with the two Orbans in front. It is effectively hidden by the table and equalizers. I gave the other sub to a friend, who is also using it with a pair of small satellites.

There is no doubt that the design fulfilled the limited requirements that I had for apartment use. If you have similar needs, this is a good way to get reasonable bass simply. Neither of these designs will fill the need for high levels of very low bass in large volumes. For that, you will need much more linear volume displacement than these drivers provide. But, if your needs are modest and you want to keep it simple, this is a good way to go.

RECENT DEVELOPMENTS

Since these subs were built, several changes have occurred in the market. Tang Band drivers are now available from Parts Express. The TB W8-740C, now listed as a W8-740P, carries the Parts Express part number 264-854 and sells for $65.37. The T/S parameters are the same, so box size should remain unchanged. The only apparent change in the new version is a higher power handling capability.

The TC Sounds 2574 has been replaced by the 8TC-1000. The good news is that most of the parameters are the same, with the exception that the Xmax is now an unbelievable 24mm, the Vas has been reduced to 12.3 ltr, and the best news, the price has been reduced to $149.

The specifications of the TC Sounds 8TC-1000 and the Tang Band W8-740P are posted on the *aX* website (www.audioXpress.com).

This sheds a whole new light on the decision process as to which driver to use. The TC is now only slightly over twice the price of the TB, but offers nearly double the linear displacement. In addition, it can be used in a smaller enclosure. It's a tougher decision now, but both are viable choices depending on your requirements.

The original amp from Parts Express is no longer available, but a good substitute would be either the SA-240 or SA-240B. The part numbers are 300-804 and 300-805, respectively, and each sells for $128.88.

As this goes to press, Parts Express has put the Tang Band W8-740P driver on sale for $38.88 through 10/31/07. If you are thinking about using this driver, now is the time to buy. *aX*

PHOTO 21: Sub under an end table with two Orbans in front.

TABLE 3: TC Sounds Thiele/Small Parameters

Qts	0.269
Qes	0.286
Qms	4.56
Fs	27Hz
Res	3.70Ω
Ls	2.48mH
Lp	3.28mH
Rp	3.15Ω
Dia	145mm
Vas	12.31
mms	105g
cms	312µm/N
bl	15.4Tm
Spl	81.6dB

TABLE 4: Tang Band W8-740P Specifications

Diaphragm MTL	paper
surround MTL	foam
nominal impedance	4Ω
DCR impedance	3.2Ω
Sensitivity 1W/1m	84dB
frequency response	28-1kHz
free air resonance	28Hz
voice coil diameter	50mm
air gap height	8mm
rated power input	150W
maximum power input	300W
force factor, BL	13.35Tm
magnet weight (50 oz.)	1427g
moving mass	95g
ferrofluid enhanced	No
suspension compl.	$333MN^{-1}$
Effective piston area	$0.022M^2$
Levc	3.18mH
Zo	113.99Ω
Xmax	12mm
Vas	23 ltr
Qts	0.30
Qms	10.53
Qes	0.30