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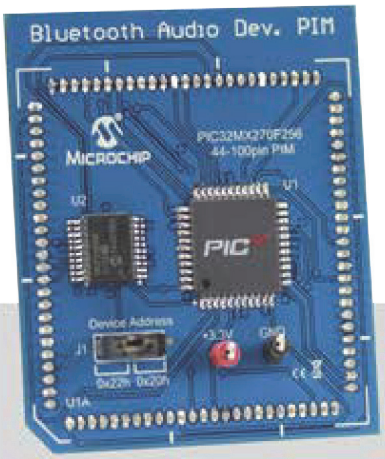

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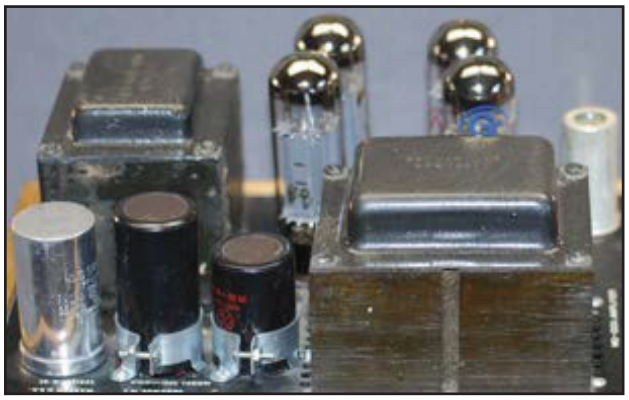

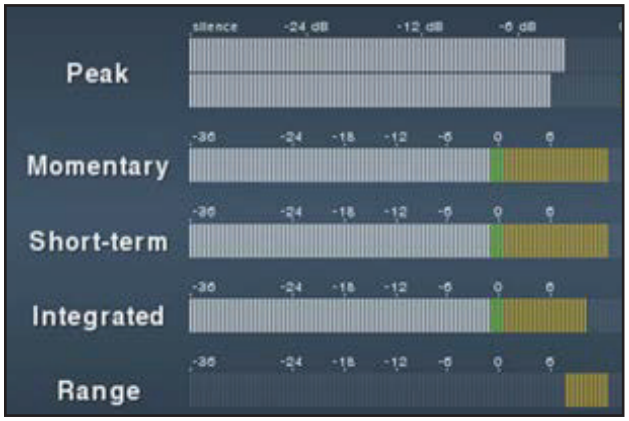

Features

Glass Audio Special Features

True Bass Rides Again (Part 2)

The Power Question

In the first in a two-part series, I described my efforts to recreate the true bass sound I once achieved in a former home. In this article, we discuss how to construct and attain the power needed to complete that sound system.

By
Thomas Perazella
(United States)

There is no doubt that high levels of very clean amplifier power are available at reasonable costs in the current market. That has allowed the successful use of speakers with lower sensitivity. Even with these advances you can rapidly reach a point where the need for amplifier power becomes prohibitive. If you stay out of the area of driver compression, for every 3 dB of additional acoustical output, you need double the electrical power. So if one driver is 3 dB more sensitive than another, it can produce the same acoustic output as the other with only half the power.

Using multiple drivers can help in the sensitivity issue. However, there is some snake oil that frequently pops up in this area. The often-quoted figure of a 6-dB increase by paralleling two of the same drivers is somewhat misleading as it assumes that the amplifier can deliver twice the power into the resulting half impedance. There are few amplifiers that can double the available power for each halving of the load impedance. Even if an amplifier could achieve the doubling, the power would in reality double, resulting in only a 3 dB increase per actual watt. That is an improvement but not as much as appears at first glance.

This situation is aggravated by the common practice of using a sensitivity figure based on 2.83 V being delivered to the speaker instead of 1 W. The problem is that voltage level would represent 1 W for an 8-Ω load, 2 W for a 4-Ω load, and 4 W for a 2-Ω load. In this case, a 2-Ω driver would have an apparent sensitivity 6 dB higher than an 8-Ω driver, which is not true because it is actually receiving four times the power at that voltage. Beware of creative "specsmanship." The availability of good relatively low-cost amplifier power is a plus, but you should take care in identifying how much power you will need, given the real sensitivity of the selected drivers. Also remember that sensitivity is specified at a distance of 1 m. Most people listen at greater distances so the levels at the listening position will be correspondingly lower.

Ultimax UM12–22 12"		Titanic MK 4 12"		Dayton DVC15 15"		Dayton DVC15 15" (Two parallel)	
Acoustic Output (Decibels)	Power (Watts)	Acoustic Output (Decibels)	Power (Watts)	Acoustic Output (Decibels)	Power (Watts)	Acoustic Output (Decibels)	Power (Watts)
84 dB	1 W	86.6 dB	1 W	90 dB	1 W	93 dB	1 W
87 dB	2 W	89.6 dB	2 W	93 dB	2 W	96 dB	2 W
90 dB	4 W	92.6 dB	4 W	96 dB	4 W	99 dB	4 W
93 dB	8 W	95.6 dB	8 W	99 dB	8 W	102 dB	8 W
96 dB	16 W	98.6 dB	16 W	102 dB	16 W	105 dB	16 W
99 dB	32 W	101.6 dB	32 W	105 dB	32 W	108 dB	32 W
102 dB	64 W	104.6 dB	64 W	108 dB	64 W	111 dB	64 W
105 dB	128 W	107.6 dB	128 W	111 dB	128 W	114 dB	128 W
108 dB	256 W	110.6 dB	256 W	114 dB	256 W	117 dB	256 W
111 dB	512 W	113.6 dB	512 W	117 dB	512 W	120 dB	512 W
114 dB	1,024 W	116.6 dB	1,024 W	120 dB	1,024 W	123 dB	1,024 W

Table 1: Here we compare the power input vs. the acoustic output.

Determine Relative Power Requirements

A convenient way to determine the relative power requirements of different drivers is to create a chart of acoustic level vs. input power for the drivers I examined (see **Table 1**). For each driver, there are two columns. The first is the acoustic output and the second is the power input necessary to achieve that output. In addition, that same scenario is repeated for the two 15" drivers that I used to show the advantage of multiple drivers in parallel. A good example is to look at how much power is required to reach 102 dB.

Looking at the Ultimax, 64 W is needed for a level of 102 dB. Because of the Titanic's higher sensitivity, only about 32 W is needed. For the 15" Dayton, it can get by with 16 W. When paralleled, a measly 8 W is required. Considering the ear sensitivity at lower frequencies, over 110 dB is not an unreasonable expectation from a subwoofer. Re-examining the three drivers, to achieve 114 dB, you would need 1,024 W for the Ultimax, approximately 512 W for the Titanic, and 256 W for the 15" Dayton. Now, the numbers really start to hit home. At some point, low sensitivity becomes the 800-lb gorilla in the corner. If you are going to use EQ to flatten the response below resonance, the situation gets even worse.

Building the Boxes

Information on assembling the 2-ft^3 boxes for the 12" drivers is provided on the Parts Express website (www.parts-express.com). The assembly was very straightforward.

The 5-ft^3 boxes were a little more complicated because I decided to make them asymmetrical allowing me to put them back to back, if desired. In addition, I rear mounted the drivers for a cleaner look so I made the back panels removable. Instead of plate amplifiers, I decided to power them with an external amplifier. I removed the plate amps in the existing subwoofers and filled the holes with

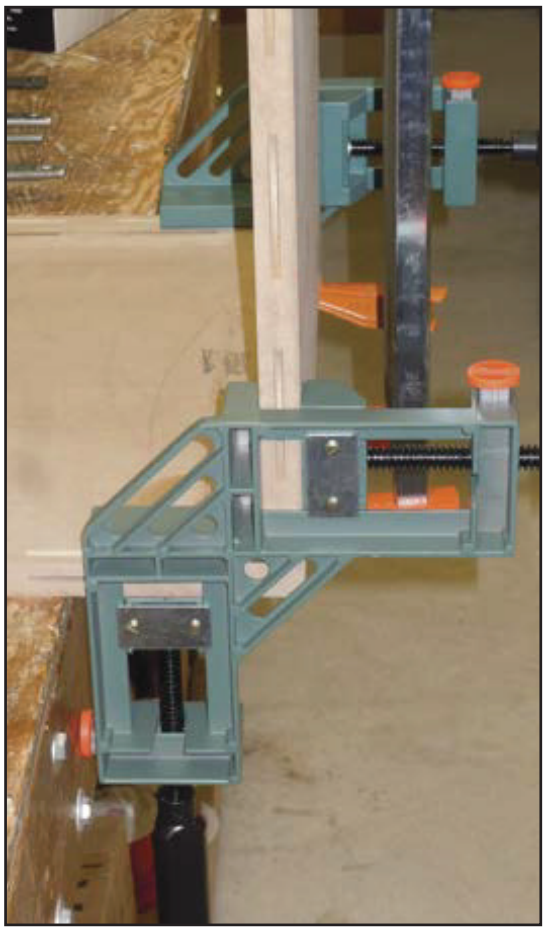

Photo 1: Corner clamps maintain true right angle joints.

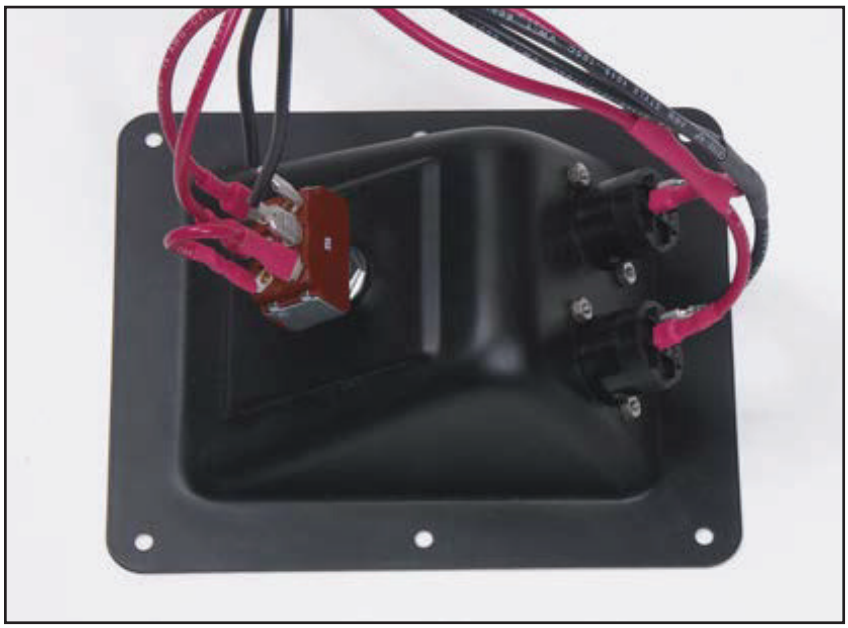

Photo 2: The rear view of the input dish shows the connectors, the switch, and the wiring.

0.75" MDF patches. Making two additional same-sized boxes to add to the existing boxes was easier than building two new 10-ft^3 boxes. It also made it possible for one person to move them with the drivers installed and provided flexibility in placement.

Another decision that added flexibility was to provide switching, enabling the use of the two 8-Ω voice coils of each 15" driver either in a series or in a parallel configuration. That provided a choice of 4- or 16-Ω operation. If a subwoofer is independently used, the 4-Ω configuration is a better choice. If two are used in parallel, the 16-Ω setting is better. Paralleled, the impedance is then 8 Ω, but with the 3-dB gain in sensitivity, the resulting sound pressure level (SPL) is the same but with double the volume displacement capability.

I used 0.75" MDF assembled with biscuits and Titebond II wood glue for the construction material. This method resulted in strong airtight joints, which I have discussed in previous articles and will not repeat here. One tool worth mentioning is a corner clamp that I purchased from Harbor Freight. It is a low-cost convenient way to hold adjoining pieces at right angles while the glue dries (see **Photo 1**).

Photo 3: The hanger bolt is installed in MDF near the driver opening.

To provide connectivity to the subwoofers, I chose Speakon connectors. They are the standard speaker connection for professional applications and have the advantage of being a locking connector with no exposed electrical connections. I decided to mount the subwoofers behind my large planar arrays with limited access so I could not afford to have loose connections.

To mount them, I used some metal input dishes specifically made with mounting holes for the connectors. They come in different configurations. I used the one that had openings for two connectors. I could then configure an "in and out" scheme connecting the two subwoofers on each side to one run of speaker cable. I drilled holes in the plates to mount the double pole, double throw switches needed for impedance conversion. **Photo 2** shows the rear of the input dish with the connectors and switch mounted and wired for later assembly into a finished cabinet.

Holes in the box pieces for the input dishes and drivers were cut before assembly. I used a sabre saw to cut the dishes and a Jasper Circle Jig Model 200 for the driver holes. I chose hanger bolts, which combine wood and machine screw threads on a single shaft, to mount the drivers. This enabled me to drive the hanger bolt into the MDF and use machine nuts and washers to secure the drivers. **Photo 3** shows one of the hanger bolts near a driver opening.

To assemble the panel, I applied glue into the biscuit slots on both sides of the pieces to be joined and inserted the biscuits, ensuring the mating surfaces (including the sides of the biscuits) were also covered with glue. Next, I tightly clamped the parts together and wiped up any excess glue that had been forced out of the joints. I always let the glue dry for 24 hours before moving on to the next pieces. The more clamps you have, the more pieces you can glue at the same time.

The main part of the box consisted of the four sides and a front plate. Since the back was removable, I cut the back piece about 0.125" (1/8") smaller in each dimension for an easy fit. To keep the back located and secure, I glued four strips of MDF into place at an appropriate depth inside the box's rear opening to act as a mating surface for the back plate. I drilled recessed clearance holes into the back plate and matching pilot holes into the support strips.

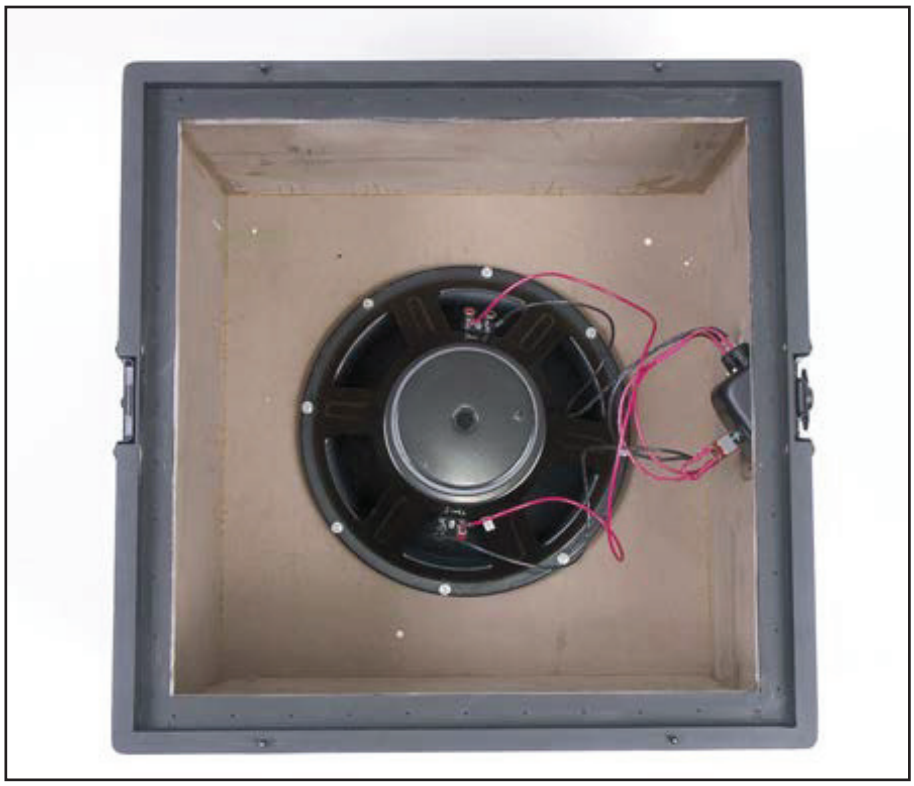

Photo 4: The DVC 15″ driver has been mounted and wired.

When the glue on all the panels was set, I routed the driver opening and all front and side corners with an edge bit. This step improves the looks and helps prevent damage to the sharp edges of the MDF panels, which can easily knick. Next, I sanded all the surfaces in preparation for paint. With MDF, it is important to use a solvent-based primer before painting with water-based paints. The primer not only provides a strong base for paint adhesion to MDF but also forms a barrier to the water in the paint. MDF is sensitive to water and can swell from the paint if not properly primed. I have found that Zinsser Bin works well for my projects.

I used flat black latex paint, which I allowed to thoroughly dry before installing the wired input dishes and the drivers.

The original subwoofers had latches placed on both sides to hold two of them together in a back-to-back configuration, if desired. I kept those latches even though I ultimately placed the subwoofers one on top of the other in a forward facing arrangement. **Photo 4** shows a mounted and wired driver.

Next, I fluffed up 5 lb of Acousta-stuff polyfill damping material and placed it into each box before mounting the back and screwing it shut. I attached rubber feet and put half-round foam weather stripping on the MDF back support strips to act as a seal. The subwoofers were then ready to go. **Photo 5** shows a side-by-side comparison of the cabinet sizes used for the 12″ and the 15″ drivers.

Listening Tests

I conducted all the listening tests with the subwoofers driven by a Crown Studio Reference amplifier. Crossover duties were provided by a Behringer DCX2496. The subwoofers were crossed over to the midbass arrays at 71 Hz with a 48 dB/octave Linkwitz-Riley slope. Room and speaker correction was from a Behringer DEQ2496. To compensate for the bass falloff of the subwoofers below 30 Hz, I applied a 1.5-dB boost at 25 Hz and a 2.5-dB boost at 20 Hz to all. I used source

Photo 5: The differing sizes of the finished 2-ft^3 and 5-ft^3 enclosures with the drivers mounted are shown for comparison.

material from .wav files stored on my laptop, which I played through an XMOS USB to SPDIF converter connected to the DEQ2496's AES/EBU input through a Canare Balun. The link between the DEQ2496 and the DCX2496 was through their AES/EBU connections to avoid multiple changes between analog and digital domains.

Group/ Performer	Album	Musical Piece	CD
Boston Audio Society	*Test CD 1*	Charles-Camille Saint-Saëns: "Organ Symphony"	CD-1
Boston Audio Society	*Test CD 1*	Giuseppe Verdi: "Requiem"	CD-1
Dallas Wind Symphony	*Fiesta*	Herbert Own Reed: "Prelude and Aztec Dance"	Reference Recordings RR-38CD
Jean Guillou	*Pictures at an Exhibition*	"Gnomus"	Dorian DOR-90117
Legacy Audio	*Music Sampler*	"Dynamic Drums"	Volume 1
Sergio Mendes	*Brasileiro*	"What is This"	Elektra 9 61315-2
Pink Floyd	*The Wall*	"Another Brick in the Wall Part 2"	Columbia C2K68519
Talking Heads	*Stop Making Sense*	"Slippery People"	Sire 9 25186-2
Clark Terry	*Live at the Village Gate*	"Hey Mr. Mumbles"	Chesky JD49
Turtle Creek Chorale	*Testament*	"We Fight Not for Glory"	Reference Recordings RR-49CD

Table 2: This is a list of the music I used in the tests.

Midbass duties were provided by my two dipole arrays consisting of six each 10" Peerless woofers driven by a QSC USA1310 amplifier. High frequencies came from my two Bohlender Graebener RD75 dipole mounted planar magnetic drivers, which were driven by a Crown Macro Reference amplifier. The mid to high crossover was provided by the DCX2496 at 303 Hz, with a 48 dB/octave Linkwitz-Riley slope. As you can imagine the mid- and high-frequency sections are capable of prodigious, very low distortion output, creating quite a challenge for the subwoofer section to match.

I chose 11 pieces of music that represented a mix of very low frequencies, dynamic impact, and complex bass lines to test the system. I ripped all the music from CDs in a .wav format and upsampled to 88 kHz/24 bit. **Table 2** lists the test tracks.

Ultimax Results

Charles-Camille Saint-Saëns' "Organ Symphony" piece has some strong notes at 18 Hz that are a major test for any subwoofer. The Ultimax did very well on most of the bass notes shaking the floor quite vigorously. On the lowest notes, the impact was not as strong or as clean as the reference system of the four DVCs. But, it was still quite amazing for two 12" drivers in such small boxes.

Giuseppe Verdi's "Requiem" is a killer piece not only because of the very strong bass drum but also the huge dynamic range. If you have to turn the volume down to prevent gross distortion on the bass, you will miss the subtle sounds of the solo vocalist at the end of the piece. The drum whacks were very forceful with no audible distortion.

Clifton William's "Fiesta," performed by the Dallas Wind Symphony, has several selections with very strong bass drum notes mixed with complicated high frequencies. On the Prelude the drum was very powerful with a musical decay. This "Symphonic Dance No. 3" also had a good rendition of the bass drum.

Modest Mussorgsky's "Gnomus," performed by Jean Guillou, is a piece with sustained pedal notes at various frequencies, levels, and durations. The lowest notes were quite strong but some of the growl was missing. The bass was a bit homogenized.

Legacy Audio's "Dynamic Drums" is one of the best pieces I have to test a system's dynamic range. There are some very low level cymbal hits and light skin taps followed by awesome kick bass whacks. This is a piece that will drive the Crown into clipping on this driver. There is no problem with the driver because if you reduce the level to just below clipping the sound is superbly clean. Volume displacement is not the issue at the higher

Driver	Area	X_{MAX}	Total Linear Excursion	Individual Linear Displacment	Number of Drivers	Total Displacement	Unit Cost	Cost per Liter	Total Cost
Dayton DVC385-88 DVC 15″	830 cm^2	15 mm	3 cm	2.5 ltr	4	10 ltr	$132.86	$53.36	$531.44
Dayton UM18-22 Ultimax 18″	1,213 cm^2	22 mm	4.4 cm	5.3 ltr	2	10.7 ltr	$266.65	$50.31	$533.30

Table 3: The Dayton DVC 15″ is compared to the Dayton Ultimax 18″.

frequencies that the kick bass produces, but rather available amplifier power given the low sensitivity. The clipping occurred at very high levels, probably higher than you would normally play but close to realistic. As with any dynamic music if you turn the volume down, you miss a lot of the low-level detail.

Sergio Mendes' "What is This?" has a very interesting bass drum that is strong and is difficult to cleanly reproduce. The Ultimax performed well with sound that was both strong and clean.

Pink Floyd's "Another Brick in the Wall" has probably had as much air time as any rock piece ever. The kick drum in this piece is interesting because it is not too deep but still round sounding. Any lack of volume displacement or amplifier power will actually make it sound sharper due to the introduction of high-frequency distortion products. With the Ultimax, it sounded great.

If you can sit still while Talking Heads' "Slippery People" is playing at high volumes, someone better call a mortician because you have probably died. This is my all-time favorite to get me totally hopping. When played on a clean system, the transients just go directly in with no stops along the way. The Ultimax was totally capable of doing justice to this piece. My notes said that "It really rocks!"

Terry Clark's "Hey Mr. Mumbles" has a combination of string bass and kick bass notes that require flat clean deep bass that is very transient to sound good. The string bass was natural, not bloated and the drums were quick and tuneful.

Turtle Creek Chorale's "We Fight Not for Glory" is another complicated dynamic piece that requires high performance from all parts of the spectrum. It starts relatively quietly but toward the end, there are some very strong bass drum whacks. If you have to turn the volume down because the drum is overloading the system, you will miss a lot of detail in the quieter passages. The Ultimax was both strong and clean giving a realistic presentation.

Titanic Results

The Saint-Saëns piece had slightly less very deep bass than the Ultimax, which is understandable given the frequency response curves of the two. However, it still shook the floor. There was no doubt there was a substantial amount of bass being produced.

The Verdi music still had a strong and tight bass drum even at the very high playback levels.

Herbert Owen Reed's "Prelude" was quite good and had a slightly better sound to the decay of the drum than the Ultimax.

"Symphonic Dance" did not have quite as much low bass as the Ultimax but was musical with lots of harmonic detail. "Gnomus" had good low pedal notes but with a bit more growl than floor shake.

"Dynamic Drums" had a great sound to the drum kit. The kick drum was very forceful. I made a note to myself describing it as a "sock in the gut." The amplifier was also a little more at ease with the transients. "What is This?" sounded clean and musical, although the lowest notes were not as strong as the Ultimax.

"Another Brick in the Wall" had a great rendition of the kick bass. It was quite tight without being sharp. While "Slippery People" was tight, a little of the rock factor was missing compared to the Ultimax. Just for grins, I bumped the EQ at 20 Hz to 4.5 dB and the rock factor increased. Because of the higher sensitivity, the amplifier did not complain.

"Hey Mr. Mumbles" also sounded good with much the same rendition as the Ultimax. "We Fight Not for Glory" also had a clean bass drum but not quite as deep as the Ultimax.

DVC Results

To make a long story short, the four DVCs were superior to the two 12" in every test. Gee, what a surprise that more than 2.5 times the linear displacement makes a difference! If I were going to summarize, I would say the DVCs were more relaxed and realistic with every test piece. Here are just a few specifics.

The pedal notes in the Saint-Saëns were superbly clean and although the floor was shaking more than with the others, those notes were not as obtrusive and never interfered with the rest of the instruments.

The "Gnomus" had both the very deep bass and the growl. A friend that builds high-quality vacuum tube amps stopped by when I was playing this piece and he commented, "This is the way it is supposed to sound!" It really sounded like an organ. All the other pieces had the same quality—taking you closer to the performance.

The Bottom Line

There is no getting around the fact that like everything else in life, building subwoofers is a matter of making the correct choices. There are always compromises. And, there is no substitute for lots of linear volume displacement. Modern drivers have come a long way in reducing distortions while working in their linear range. However, once X_{MAX} is exceeded, all those improvements are for naught. Looking at the distortion graphs of all three drivers, it is apparent that distortion may vary slightly in the linear operating range between the drivers, but once X_{MAX} is exceeded distortion rises at a very high rate.

Probably the most amazing result was the high degree of performance that was available from both the 12" drivers in the small boxes. I would venture

Building Supplies

Part	Source	Part Number
Pittsburg corner clamp	Harbor Freight, www.harborfreight.com	38661
Speakon cable connector	Parts Express, www.parts-express.com	092-058
Speakon chassis connector	Parts Express, www.parts-express.com	092-059
Input metal dishes	Parts Express, www.parts-express.com	262-838
Jasper Jig	Parts Express, www.parts-express.com	365-250
Zinsser Bin	Rustoleum, www.rustoleum.com	shellac-base primer
Acousta-stuf	Parts Express, www.parts-express.com	260-330

Speaker System

Part	Source	Part Number
Behringer DCX2496	Parts Express, www.parts-express.com	248-669
Behringer DEQ2496	Parts Express, www.parts-express.com	248-661
Ultimax 18	Parts Express, www.parts-express.com	295-518

Sources

DCX2496 Loudspeaker management system and crossover and the DEQ2496 mastering processor
Behringer | www.behringer.com

RD75 Dipole mounted planar magnetic drivers
Bohlender Graebener | www.bg-speaker.de

to say that unless you are as crazy as I am, two of these drivers would probably suffice for the vast majority of any listening situations. Here is how I size up the drivers.

The Ultimax has more low bass in the small box than the Titanic. However, the sensitivity is the lowest of all the drivers. You need a lot of power if it is to achieve its full potential. If you are willing to live with that requirement, it is probably the choice for the lowest bass.

The Titanic requires less power but in that less than optimum box, the rolloff starts at a higher frequency. You can add boost below resonance, but you then need more power and negate some of the sensitivity advantage. If you don't need the very lowest bass or else can live with a bigger box, this may be the driver for you.

The DVC from a price, displacement, and sensitivity standpoint is better than the 12" drivers, but you pay the price in box size. If you can live with the size, it is the winner as far as I am concerned.

Now that we have that out of the way I will throw a monkey wrench into the mix. There is a new driver that might be the answer to the over the top approach, if you are starting from scratch. There is now an 18" version of the Ultimax with 22-mm X_{MAX} with a sensitivity rating of almost 86 dB/W. Two of these would have the same linear volume displacement as four of the DVCs but require only two 5-ft^3 boxes. It would be a good compromise between displacement, size, price, and sensitivity.

Table 3 shows a comparison of the DVC15 and the Ultimax 18. The DVC still has the sensitivity edge by 6 dB, but the smaller box size would be very tempting. It's great to have choices. If I get time next year, I may try that approach. In the meantime, this project met all my targets and sounds great. Happy building!

About the Author

Thomas Perazella is a retired IT director. He is a member of the Audio Engineering Society, the Boston Audio Society, and the DC Audio DIY group. He has authored several articles in professional audio journals.