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By Fernando Rodrigues

You Can DIY!

True Bass in a Small Space A Subwoofer Project with Dayton Audio's Ultimax 18"

By Thomas Perazella

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Build a Low-Power, Class-A Power Amplifier (Part 2)

By George Ntanavaras

Questions & Answers

Interview with Nancy Moon at MOON Amplification

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True Bass in a Small Space

There is a common misconception that in order to get truly deep, clean bass you must have a lot of space for the enclosure. There are three conditions that I think are necessary to achieve "true bass"—wide bandwidth, high dynamic range, and low distortion. In this article, we discover how to achieve true bass in a small area.

By
Thomas Perazella
(United States)

Photo 1: Dayton Audio Ultimax 18" subwoofer is purpose-built to move tons of air and create clean, articulate, and fast bass.

When evaluating the size/bass relationship, the correct situation was summed up by Josef Anton Hofmann whose name represented the "K" in the firm name KLH. There are three interrelated considerations—low bass extension, small box size, and high sensitivity. You can pick any two of the three conditions but will have to sacrifice the other.

This situation was described in detail in my last *audioXpress* speaker article titled "True Bass Rides Again" (April and May 2015). As I approached the end of that project, I became aware of a new driver from Dayton Audio, the Ultimax 18". I mentioned, that it could be a game changer in how we look at low bass reproduction. My guess was that one of those drivers in a medium-sized sealed box could replace two of my 15" drivers in two larger sealed boxes.

Fortunately, I have had the chance to test a kit that Parts Express introduced that contains the Ultimax 18" driver, a 1,200-W switch mode plate amplifier with integral DSP, and an easy-to-assemble sealed box kit to house both. The one I tested from Parts Express came pre-assembled and finished (see **Photo 1**).

The Kit

To make life easy, the kit contains everything you need to implement the new 18" Ultimax into a complete subwoofer. The kit (Part number 300-7200) contains one Ultimax 18" driver (Part number 295-518), a plate amplifier SPA1200DSP (Part number 300-8000), a modified knock-down sealed subwoofer housing (Part number 300-7079) with cutouts for the Ultimax 18" driver and plate amp with display, and four 1 lb bags of Acousta Stuf Polyfill material (Part number 260-317). The only other things I needed to assemble and complete the kit were glue, clamps, paint, and feet or spikes. This subwoofer is no lightweight with a shipping weight for the assembled unit of 130 lbs. At the time of writing, the price for the kit was $899.88.

Monster Driver

When I first saw the 18" Ultimax, I thought to myself what a monster. My 15" DVC drivers looked positively small in comparison. Pictures definitely do not do justice to the imposing effect this driver has visually. The 18" cone is a Nomex honeycomb coupled with fiberglass outer skins to produce a very rigid structure that is definitely not run-of-the-mill in appearance (see **Photo 2**).

To me the most impressive specification is the 22 mm Xmax. That, coupled with the large cone, means this driver can move gobs of air in a linear fashion. The frame is cast and two spiders are used to prevent rocking of the cone or voice coil during large excursions (see **Photo 3**).

The driver has two 2 Ω voice coils that can be wired in series or parallel. In this application, they are wired in series for a 4 Ω impedance. The Vas is actually low for a driver of this size at 7.5 ft^3 so that a relatively "small" box can be used. However, the sensitivity is stated at 88.6 dB at 2.83 V. Given that the impedance is 4 Ω that actually works out to be 85.6 dB at 1 W. This is a hungry driver. All the specs are available on the Parts Express website (www.parts-express.com).

The Amplifier

Given the driver's low sensitivity, a substantial amplifier is needed to achieve maximum performance. That amplifier takes the form of the SPA1200DSP. It is a switch mode amplifier for high efficiency with a rating of 1,200 W into the 4 Ω load of the Ultimax 18″ driver. That is sufficient power for almost any conceivable musical situation that will be encountered by this subwoofer. It is notable that many low-cost switched mode amplifiers do not reach their rated power output without clipping. When I tested this amplifier, it never failed to produce at least 1,200 W into the driver's 4 Ω load at any frequency above 15 Hz. Impressive.

All switched mode amplifiers have a level of ultrasonic idle tone at the output. This amplifier had a low 1.8 V level of 360 kHz idle tone, which corresponds to a negligible 0.8 W of power.

Already having several amplifiers that can produce such a prodigious amount of power, that rating did not pique my attention nearly as much as this amplifier's advanced DSP capabilities. My experiences with several audio products that have DSP have shown what amazingly good results can be achieved by proper application of the controls available through DSP. In this regard, the SPA1200DSP is quite well featured. To get a good overview, you need to look at the block diagram of the amplifier (see **Figure 1**). There are three main functional blocks in the diagram—the signal processing section, the power amplifier section, and the display and manual control section.

DSP at Work

At the heart of the DSP function in this amplifier is an Analog Devices ADSP21479 processor, which is quite a powerful unit for a subwoofer plate amplifier. For Wi-Fi, it uses a Microchip MRF24WG0MA chip that provides 2.4 GHz 802.11 b/g connectivity. Looking at the DSP section, you can see the huge flexibility of signal processing in this amplifier. **Figure 2** shows a flow chart of the signal through the various stages of processing. Signal inputs include a microphone connection for room correction. The amplifier comes

Photo 2: This is a front view of the 18″ Ultimax driver.

Photo 3: Here is a side view of the 18″ Ultimax driver.

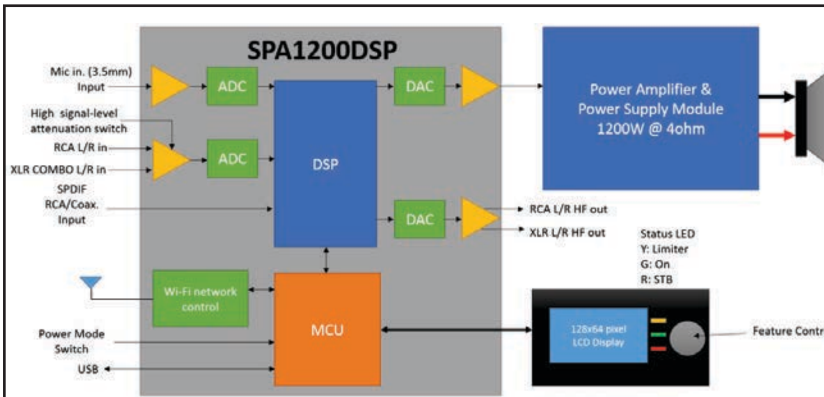

Figure 1: The block diagram of an SPA1200DSP amplifier provides a good overview.

DSP processing block diagram

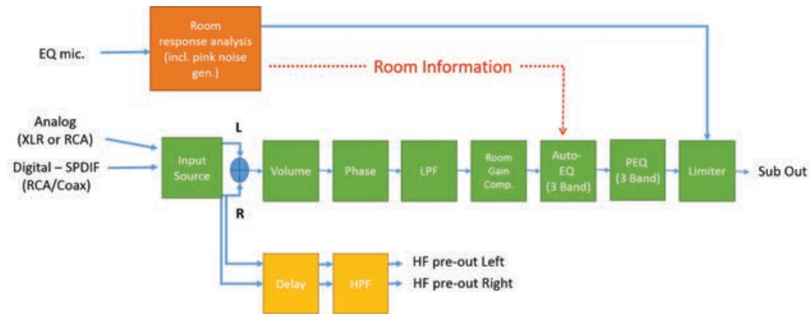

Figure 2: The flow chart shows the SPA1200DSP's signal path as it passes through various stages of processing.

with a microphone and stand adapter. Other analog inputs include both unbalanced RCA jacks and balanced XLR jacks. For analog inputs, a switch is available to select normal level for the unbalanced input or high level for the balanced input. The digital audio input is a coaxial SPDIF connector. There is also a USB connector to connect the amplifier to a PC, enabling the use of the supplied GUI software to effect control of various parameters. For iPhone junkies, there is also a built-in wireless connection that enables you to use your iPhone coupled with a Dayton Audio SubRemote iPhone Control app to perform the functions. There are general controls for volume, input choice, Wi-Fi configuration, and more. **Table 1** shows the various controls available on the amplifier and their values.

SPA1200DSP Values		
Level 1 Function	**Level 2 Function or Value**	**Level 3 Function or Value**
Volume	0 to -100 dB in 1 dB steps	
Low-pass filter	On/Off	On/Off
	Frequency	31, 40, 50, 63, 80,100, 125 Hz
	Slope	12 dB, 24 dB/octave
High-pass filter	On/Off	On/Off
	Frequency	31, 40, 50, 63, 80, 100, 125 Hz
	Slope	12 dB, 24 dB/octave
Phase degree	0 to 180 in 1 degree steps	
High-pass delay	0 to 10 ms in 0.1 ms steps	
Room gain	On/Off	On/Off
	Frequency	25, 31, 40 Hz
	Slope	-6, -12 dB/octave
Subwoofer Tune	Sealed, 16 Hz, 25 Hz	
PEQ—all 5 bands	Disable	On/Off
	Frequency	20 to 200 Hz in 1 Hz steps
	Level	-12 to 6 dB in 0.1 dB steps
	Q	0.4 to 11 in 0.1 steps
Limiter	Threshold	-12 to 0 dB in 0.1 dB steps
	Attack	0.1 to 100 ms in 0.1 ms steps
	Release time	5 to 5000 ms in 0.1 ms steps
Input Source	Analog, Digital	

Table 1: Various controls are available on the SPA1200DSP amplifier.

High Pass at Its Best

One function that stood out was the amplifier's control abilities for satellite speakers. In most plate amplifiers, the input analog audio signal, at speaker level, is passed back out to the speakers themselves through a simple 6 dB/octave high pass consisting of a capacitor. If the signal is at line level, it is passed back out to an amplifier that can control the main speakers either unchanged or perhaps through a simple fixed capacitor/resistor 6 dB/octave high-pass filter. Having worked with a lot of subwoofer/satellite speaker combinations, I have come to realize that the greatest benefit of a high-pass filter is the unloading of low frequencies from the satellites.

There is a striking improvement of overall sound when the demands of low-frequency reproduction are removed from the main speakers. Most main speakers do not have sufficient linear volume displacement to handle even moderate levels of very low-frequency content. The result is that the distortion in the bass or bass/mid drivers dramatically increases. To get the most improvement, the speakers must be high passed at frequencies and crossover slopes that prevent excursions of the drivers outside of their linear operating areas. A 6 dB/octave crossover slope will generally not cut it. With that slope, excursion continues to increase even below the crossover point. At least 12 dB/octave is needed to prevent increased excursion below the crossover point.

With this amplifier, the input signal is digitized and fed to the DSP section. Within that section, one of the functions is control of the high-pass parameters that will control the main speakers. Slope and crossover point as well as time delay can be controlled. For all the various controls, you can feed the full frequency spectrum to the mains, but I cannot see a reason to pass the unmodified signal through the amplifier for that condition. You can then pick the parameters that work best for your main speakers, including slopes of 12 dB/octave and above. This is a powerful feature and will greatly help in achieving the best melding of the subwoofer with the mains and reduction of intermodulation distortion in the mains.

Low-Frequency Controls

Gain of the woofer amplifier is set on the main control panel in 1 dB increments. The low-frequency

Figure 3: The parametric EQ screen shows the result with no EQ applied.

rollover frequency and slope can be set for the woofer. Phase can be controlled in both directions. An unusual setting is an adjustment for room gain. You can pick a frequency and slope for the adjustment and then add attenuation. A feature with an unusual name is the "Subwoofer Tune." In reality, it is a selectable cutoff filter with three choices. The first is called "Sealed" where the signal is passed unattenuated to the woofer. There are two other selections for cutoffs at 16 Hz and 25 Hz. The slopes are not specified, but this feature is designed to protect woofers from excessive excursions where they are used in vented boxes and would become unloaded below the port resonance frequency.

Parametric EQ

An extremely valuable feature of the DSP is three channels of parametric EQ. My first experience with parametric EQ goes way back to a pair of Orban 672A equalizers that I used to tame some speaker and room resonances. Having the flexibility of parametric EQ was a real eye and ear opener for me. Since then, I have used digital parametric EQ extensively in all my main speaker systems.

The three channels of parametric EQ are accessible through the

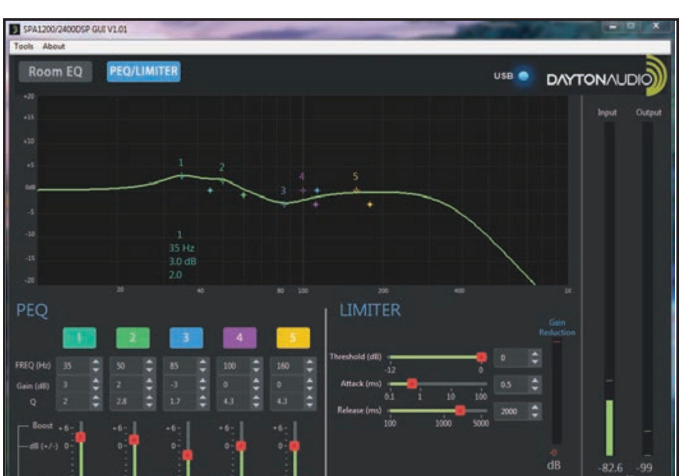

Figure 4: Parametric EQ is shown after I made some manual adjustments.

Photo 4: This is my in-room measurement equipment.

Figure 5: The Auto Room EQ screen shows the original and adjusted curves.

GUI and your PC or the iPhone app. I don't have an iPhone so I will only show the PC version. **Figure 3** shows the screen with no EQ applied. With the parametric EQ you can control the center frequency, the gain, and the Q or bandwidth. Values can be directly input into the appropriate fields or arrows can be used to increment or decrement the values. **Figure 4** shows the additional manual adjustments I made in the room after the basic auto room EQ had been done.

Automatic Room EQ

Every room has some nodes that either reinforce or cancel certain frequencies. To some extent, especially with very low frequencies these can be adjusted to improve performance. The SPA1200DSP is supplied with a microphone and a holder so that in-room measurements can be made and then problems ameliorated. The process entails selecting the Room EQ button in the GUI, placing the microphone at the first of three locations and then selecting the Start Position 1 button. Measurements will be made and then you will be asked to move the microphone to position 2 where another set of measurements will be made. This is repeated at a third position of your choice, and all three positions averaged to come up with a final EQ curve.

Photo 4 shows all the measurement equipment I used for both the Auto Room EQ and distortion measurements done with the program LAUD from Liberty Audio. You can see the small microphone on the left arm of my listening couch, which was the first position. In the center of the couch is the ACO Pacific 7012 measurement microphone I use to feed LAUD. Both the pre and post measurement curves are displayed in **Figure 5**. The pre EQ curve is shown in grey and the post EQ curve with corrections is shown in blue. Below the curves are the EQ values that were used to modify the response.

Measurements

Normally, the first measurement I make on a subwoofer is a closed mic'd frequency response. To do that LAUD needs to work with an amplifier where the signal and the speaker leads on the amplifier are both at ground potential. Laud measures the level of each test frequency from the amplifier and compares it to the microphone output of SPL. That way if the amplifier has any frequency fluctuations, they are removed from the speaker measurement.

This amplifier has a bridged output so the negative speaker lead is not at ground potential, preventing me from doing true frequency response measurements. However, I have not found any

Table 2: I compared the linear volume of the Ultimax 18 and the DVC 15.

Driver Displacement Calculations						
Driver	Area	Xmax mm	Total Linear Excursion	Individual Linear Displacement Liters	Number of Drivers	Total Displacement Liters
Dayton DVC385-88 DVC 15″	830 cm^2	15.0 mm	3.00	2.5 ltr	2	5.0 ltr
Dayton UM18-22 Ultimax 18″	1,213 cm^2	22.0 mm	4.40	5.3 ltr	1	5.3 ltr

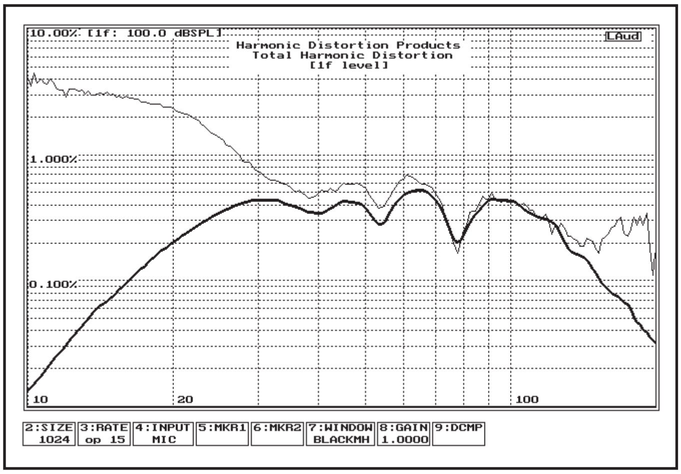

Figure 6: This is the measured Ultimax 18″ close microphone distortion.

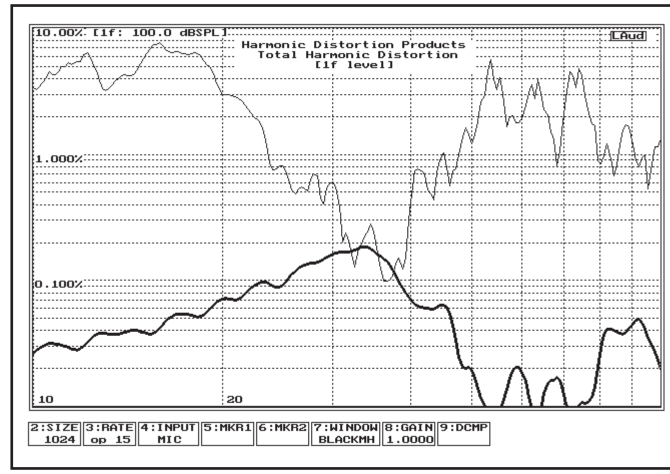

Figure 7: Here is the measured Ultimax 18″ listening position distortion.

plate amplifiers that had any significant frequency anomalies that would prevent an assumption of flat output response. During my tests, the amplifier had no low-frequency cuts programmed into the DSP.

The close mic'd harmonic distortion measurement started the series. At the end of my last article, "True Bass Rides Again," I postulated, based on mathematical considerations, that one Ultimax 18 should be able to replace two of my DVC 15s. **Table 2** shows a comparison of the linear volume displacement. The calculations show that the linear volume displacement of one Ultimax 18 is slightly higher than two DVC 15 woofers.

The Ultimax 18's closed microphone distortion was low. In fact, it was the lowest close microphone distortion of any subwoofer I have ever measured. **Figure 6** shows the distortion measurements. As you can see, at 100 dB with the microphone close to the cone, the distortion at 20 Hz was just slightly over 2% and never went above 0.7% from 30 to 200 Hz. This driver has excellent linearity.

Although I do not have an anechoic chamber, I decided to do some distortion measurements at my listening position, which is 14′ from the subwoofers at a level of 100 dB. Keep in mind that measurements in a normal room like I have are fraught with problems due to nodes, especially at frequencies over about 45 Hz. The distortion measurements are a percent of the fundamental. Suck outs at a particular fundamental frequency can result in the distortion products registering higher as a percent at that frequency.

If there is a bump at a particular fundamental being measured, the distortion products will seem to be lower as a percentage of that frequency. In the distortion measurements taken of both the Ultimax and DVC drivers at the listening position, the percent distortion is the upper lighter trace and the fundamental level is the lower heavier trace. You can see the effect I mentioned as the fundamental

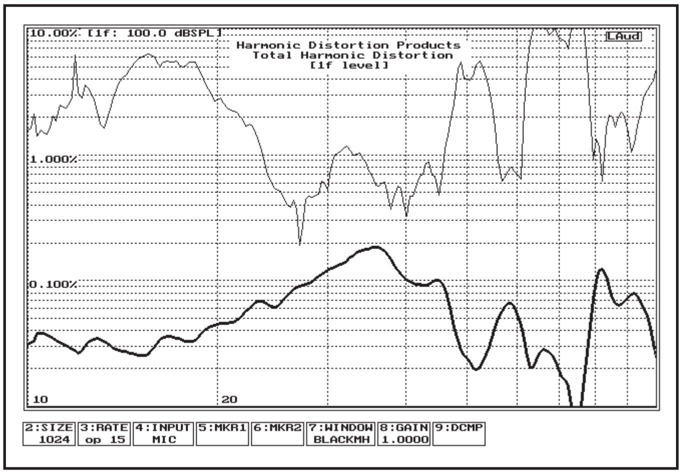

Figure 8: I also measured the DVC 15″ listening position distortion.

Photo 5: I placed the Ultimax 18″ next to an LP for size comparison.

goes up and down in level. As the fundamental goes down, the distortion percent goes up and vice versa. Although you will have to do a little "reading between the lines," the results are still valuable in showing the very low distortion of both solutions especially at low frequencies, which would wreak havoc with most smaller drivers.

The Ultimax distortion at the listening position never exceeds 7% below 20 Hz and drops to about 0.5% by 30 Hz. For measurements at 100 dB and 14′ from the driver, this is great performance (see **Figure 7**). The two DVC 15s show similar results as expected with distortion below 20 Hz never exceeding 6% and dropping to around 0.5% at 30 Hz (see **Figure 8**). These measurements were made with no EQ being applied.

Just for grins, I decided to repeat the measurements with EQ in place. In the case of the Ultimax, the SPA1200DSP amplifier was limited to 20 Hz for corrections. In my system, I use the DEQX HDP-Express II preamplifier/processor for crossover and EQ functions. It has a lower correction limit of 10 Hz. When repeated, the distortion graphs show much flatter fundamentals with the corrections provided by the SPA1200DSP not quite reaching 10 Hz, but the DEQX reached all the way down to the 10 Hz limit resulting in flatter response. At 10 Hz, I'm not sure anyone could tell the difference, but it is nice to have that capability. To put that in perspective, the cost of the DEQX alone is $3,495, which is more than four times the cost of the complete Ultimax kit. Yes, as a preamplifier/processor the DEQX is phenomenal, but it shows the value of all the aspects of the Ultimax kit.

Figure 9 shows the distortion results of the Ultimax with the room EQ function of its amplifier.

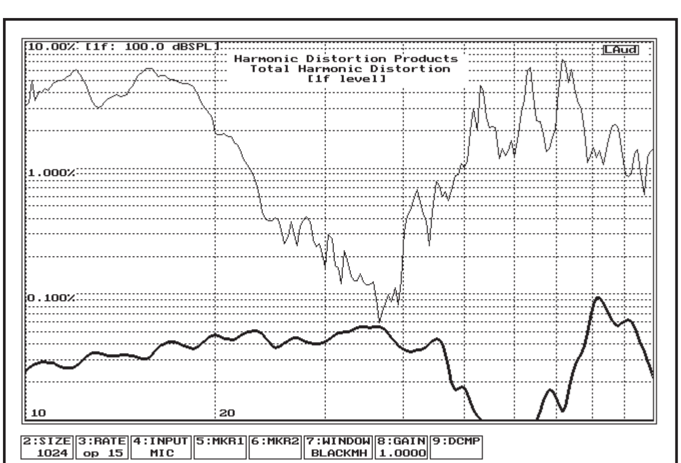

Figure 9: This is the measured Ultimax 18″ listening position distortion with EQ.

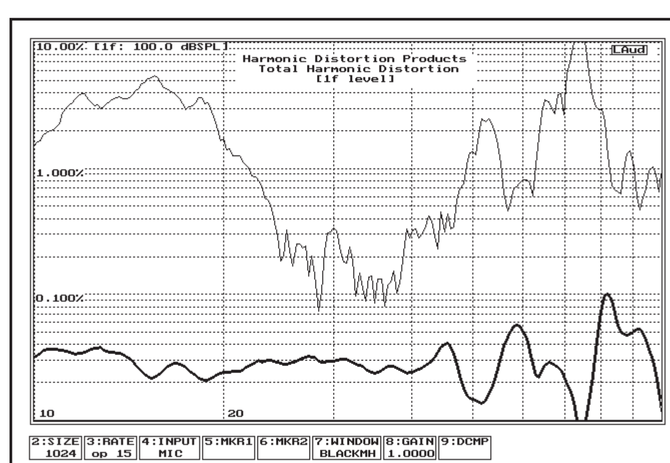

Figure 10: This is the DVC 15″ listening position distortion with EQ.

Although the distortion measurements are similar, you can see the fundamentals are much flatter. **Figure 10** shows the distortion results of the two DVC woofers with the DEQX correction. The fundamentals are impressively flat from 10 Hz to around 45 Hz.

Size Comparison

The primary goal of this exercise was to see if a substantial size reduction of the subwoofer could be achieved with the same acoustic performance. **Photo 5** shows the Ultimax subwoofer next to an LP for size comparison. Even though the subwoofer is substantial, you can see that the majority of the front surface area is taken up by the massive driver. In reality, the total volume is actually small in relation to the prodigious bass output.

For comparison, I also placed the Ultimax next to two of the DVC subwoofers I currently use. **Photo 6** shows the size comparison. As you can see, there is a tremendous difference in size between the two DVC subwoofers and the Ultimax. **Photo 7** shows the Ultimax in position behind my mid bass and mid/high speaker sections. Compared to them, the subwoofer virtually disappears. If the outputs are similar in level, distortion, and character, from a size standpoint, using the Ultimax would result in a significant reduction in room space utilization and visual impact.

Measured distortion levels at the same output already confirmed the similarities in the single Ultimax compared to the two DVCs. The final test was to actual listen to some music to determine the character of the different approaches.

Listening

Selecting appropriate source material for testing truly high performing subwoofers can be tricky. There are a lot of sources claiming to contain killer bass that are actually quite anemic. In addition, there are a lot of rumors about how low certain tracks go. Many of those are inaccurate. I have a few selections that I have found contain very low bass and at high amplitudes. I chose four main selections—"Bass I Love You" from Bass Mekanik, "Helicopter" from the Revue du Son test disk, "Saint-Seans Organ Symphony" from the Boston Audio Society test disk, and "Shuttle Launch" recorded by Bob Katz using DPA mikes supplied by a friend, Mike Morgan.

It is important to know this last cut that I received from Morgan is the original two-channel feed. The cut available from Katz's site is a multi-channel mix using other mikes in addition to the DPA microphones. They sound slightly different but both are exceptional.

Photo 6: I placed the Ultimax 18" subwoofer next to equivalent DVC subwoofers for comparison.

These pieces are not suitable for normal speakers as at best the low frequencies will not be reproduced and at worst they can destroy woofers. If you plan to use any of the above samples do so with great caution. To make sure they really contain low bass, I used the application Audicity to determine the true low-frequency content.

I fed the cuts into Audicity and placed time markers at the beginning and end of the lowest

Photo 7: For the listening test, I placed the Ultimax behind my mid bass and mid/high speaker sections.

Bass Frequency Determination							
Music	**Times**	**Segment 1**	**Segment 2**	**Segment 3**	**Segment 4**	**Segment 5**	**Average**
Bass Mekanik	Finish	12.518	20.94	29.36	37.78	71.465	
"Bass I Love You"	Start	12.368	20.79	29.21	37.63	71.315	
	Duration	0.15	0.15	0.15	0.15	0.15	
	Frequency	6.66666667	6.66666667	6.66666667	6.66666667	6.66666667	6.666667
Revue du Son	Finish	59.649	59.853	60.005	60.161	60.313	
"Helicopter"	Start	59.597	59.802	59.954	60.11	60.263	
	Duration	0.052	0.051	0.051	0.051	0.05	
	Frequency	19.2307692	19.6078431	19.6078431	19.6078431	20	19.61086
Boston Audio Society	Finish	28.9	29.072	29.772	113.838	116.458	
Saint-Saens Organ Symphony	Start	28.841	29.015	29.713	113.78	116.399	
	Duration	0.059	0.057	0.059	0.058	0.059	
	Frequency	16.9491525	17.5438596	16.9491525	17.2413793	16.9491525	17.12654
Mike Morgan	Finish	28.22	29.828	30.29	31.923	32.649	
Shuttle launch	Start	28.097	29.689	30.173	31.809	32.51	
	Duration	0.123	0.139	0.117	0.114	0.139	
	Frequency	8.1300813	7.1942446	8.54700855	8.77192982	7.1942446	7.967502

Table 3: Here are the results from my music frequency tests.

frequency waveforms. For each piece, five samples were taken and then put into a spreadsheet so that frequencies could be calculated for each sample and then an average of the five could be determined. **Table 3** shows the results. With frequencies from 6.7 Hz to 19.6 Hz and with high levels, these pieces will quickly reveal any limitations in subs under test.

In addition to the low bass tests, I used many other musical pieces to determine overall bass performance and integration with the mid and high sections of my speakers. The music choices included various organ recordings, jazz containing string bass, kick bass, piano, rock, and other bass rich pieces. For a list of some of those selections, refer to Table 2 in the second part of my article "True Bass Rides Again," (*audioXpress*, May 2015). During all the tests, the Ultimax was on the left side of my system and the two stacked DVCs were on the right side.

Listening tests were performed by myself and two other listeners—one male and one female. The tests consisted of two sections, the first using only one side of the subwoofers at a time with the mid and treble sections of both speakers to compare the Ultimax to the DVCs. In all tests, the associated equipment used the settings that resulted in the flattest response at the listening position. The second part of the test was to run the complete system with both subwoofer sections to determine the overall balance of the system in actual listening conditions.

The results were the same with all listeners in all tests. The subwoofers sounded the same regardless of the selections played. When both sections were used the overall balance and impact of the subwoofers was spot on. Since the actual characteristics of the DVC system was extensively covered in my May 2015 *audioXpress* article, I will not repeat the detailed results for each test piece here. The main goal was to determine if the single Ultimax 18" driver in a smaller box could replace a pair of DVC 15" drivers in individually larger boxes. In everyone's opinion, the answer is yes. This was very exciting because it confirmed two different approaches could provide the same acoustical results.

The Bottom Line

Are there any nits to pick? Yes, but they are quite small. The GUI that enables computer control of the amplifier's DSP only works with two functions—the auto room EQ and the parametric EQ. The other functions have to be addressed at the control panel, which is not as convenient. A temporary memory storage location for a setup in progress would be convenient for quick comparisons during changes to

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.

the parameters. You have unlimited setups available but they are stored in files that have to be recalled to replace the current setup in memory.

In addition, the instructions are limited and an expansion would be appreciated. I am one of those rare types who reads all the instructions provided with equipment and find that most could use significant improvement. Parts Express has taken these and other suggestions to heart and it is working on upgrades.

The bottom line is that Hofmann's Iron Law holds true. If you want deep bass in a small enclosure, you have to give up sensitivity. However, if you have a clean high-powered amplifier, you can achieve exceptional low bass in a relatively small enclosure.

This Parts Express kit provides a great driver with a powerful, flexible amplifier and a sturdy enclosure kit resulting in a solid bass performance that would cost you several times more to achieve in a commercial solution. Another advantage of the kit is you can finish it to your liking. So if you are a DIYer with a hankering for true bass, you should give serious consideration to this kit. It will be hard to beat. For more information, visit Parts Express at www.parts-express.com

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