Designing Speakers

Part 9 – WD18BR – A Bass Reflex Project

This month we start our first project, appropriately enough with the most popular enclosure type in hi-fi speakers. Peter Comeau explains.

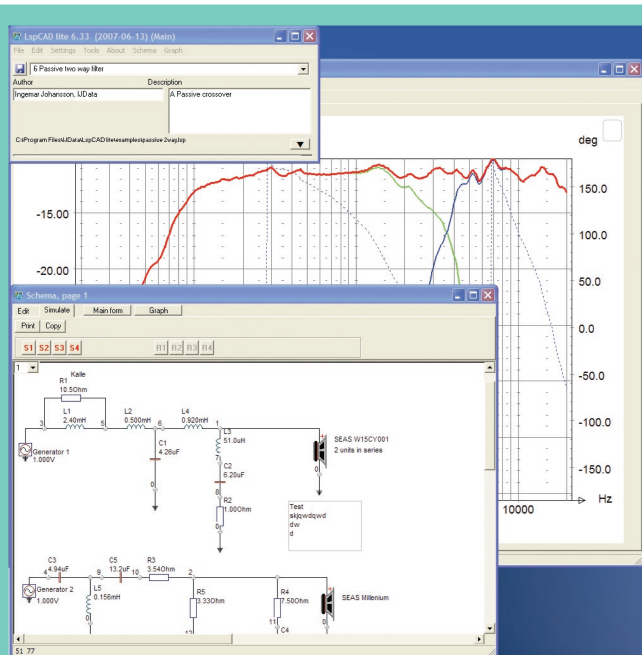
Last month we discussed ways and means of measuring your loudspeakers with some of the more affordable software tools. I mentioned then that my favourite tool is LspCAD but that this is at the 'high-end' of speaker design software and, therefore, priced accordingly.

Well I am delighted to inform you that Hi-Fi World and World Designs have persuaded IJData, the originators of LspCAD, to produce a 'lite' version of the latest version 6. This is a fully working tool that does everything the amateur needs and will really speed up your design process – see the LspCAD6 lite box for further details of how to download this innovative program.

So, as we work through our first project, I am going to do it all in LspCAD6 lite, though many of the initial design processes can be run in a similar fashion in other software.

The first thing to do is select our drive units. Obviously you will want to select those with as smooth a response as possible over the bandwidth you want them to cover, if only to make your crossover work easier to handle. But there are a couple of other characteristics of drive units you need to take into account.

LSPCAD6 LITE



LspCAD is more, much more, than just a speaker measurement and box calculation program. Within LspCAD6 lite you can start by designing your cabinet and trying out different drive units in it, all in a virtual lab! Then, when you have constructed the real thing, you can measure the output of your drivers, using the MLS function built into LspCAD6 lite, and start on the crossover design.

LspCAD6 lite allows you to construct both active and passive crossover configurations just by dragging and dropping components onto the page. In this way you can construct as simple, or as complex, a crossover as you like and see the results displayed on the output graphs in real time.

If you are unsure what the component values in a crossover should be, don't worry. LspCAD6 lite includes an Optimiser function which can either adjust the crossover slopes to any desired target, or just automatically adjust your crossover values to achieve a flat response.

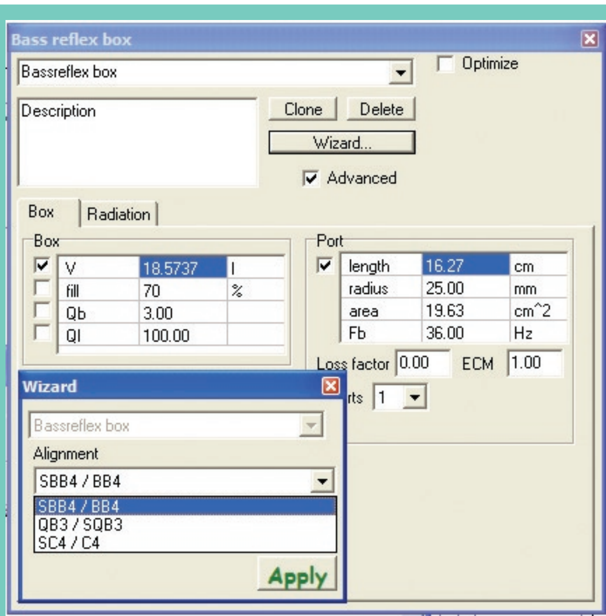
You can change the component values and characteristics easily just by typing in new values or by using your keyboard arrow keys to move the value up and down, all the time watching the effect on the output graphs.

This really is a boon when you are 'fine tuning' a crossover. For example you can listen to your crossover, change some of the components to make it sound 'better' then immediately adjust those components in LspCAD6 lite to see what effect they have on the output graphs. Once you've measured your drive units there is no need to re-measure the speakers again – LspCAD shows you exactly what is happening automatically.

The output graphs show frequency response, impedance, crossover transfer function, phase, group delay, cone excursion and port air speed, in fact everything you need to know about how your speaker is going to behave as you finalise the design.

LspCAD6 lite is available now from www.world-designs.co.uk. You can try it out as a fully functioning demo for 15 days before purchase. Price is £59 including VAT.

BASS ALIGNMENTS



There are many ways that you can tune a Bass Reflex loudspeaker and there is no such thing as 'perfect' tuning. Each driver and cabinet requires fine tuning to reach its optimum performance, but you can start with some basic, suggested, alignments to begin with.

The alignment that I usually settle on is SBB4 (Super 4th Order Boom Box). This isn't, as its name seems to suggest, a heavy power house but actually delivers a good balance of LF extension and nicely damped performance with accurate transient response. It has a low tuning frequency from a slightly larger enclosure volume with a longish port.

SC4 (4th Order Sub-Chebyshev) requires similar enclosure characteristics as SBB4 but has a tuning which has greater LF power, uses a shorter port, together with a slightly degraded transient performance.

QB3 (Quasi 3rd Order Butterworth) is frequently seen in commercial designs because it often requires a smaller enclosure than SBB4, but note that it has relatively poor transient performance.

First of all you need to check the suitability for the type of enclosure you want to design. Generally, if the Qts (driver Total Q) value is lower than 0.5 then the driver may suit a bass reflex, and if Qts is higher than 0.3 then it may be suitable for Closed Box operation.

Now there is obviously a degree of overlap here, so we can look a bit further into this with a quick calculation. Richard Small (whose work led to the design calculations we now use) suggested a quick rule of thumb for checking whether a bass driver is ideal for bass reflex or closed box. He called this the Efficiency Bandwith Product (EBP) which is the Driver Resonant Frequency (fs)/Driver Electrical Q (Qes).

Drivers with an EBP > 80 are suitable for bass reflex enclosures, whilst those with an EBP <60 will suit a Closed Box.

So look up the TS (Thiele-Small) parameters for the drivers you are thinking of using and divide Fs by Qes to see if they are suitable. Let's look at the SEAS H1215 – a nice 18cm (7") driver which has a Qts of 0.35, so it is not obvious which camp it falls into. But if we divide its Fs of 36Hz by its Qes of 0.43 we get an

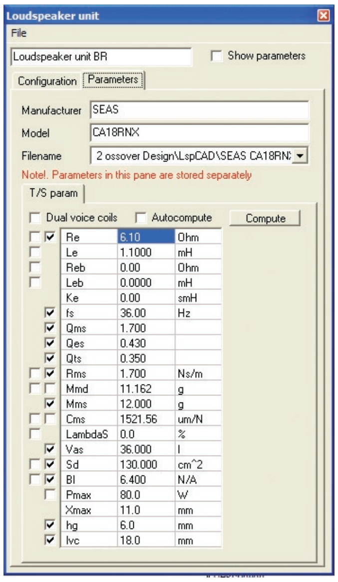


Illustration:lspcad6c.tif
Caption: Entering the driver's TS Parameters into a Loudspeaker Unit file.

EBP of 84 – clearly it is suitable for a bass reflex.

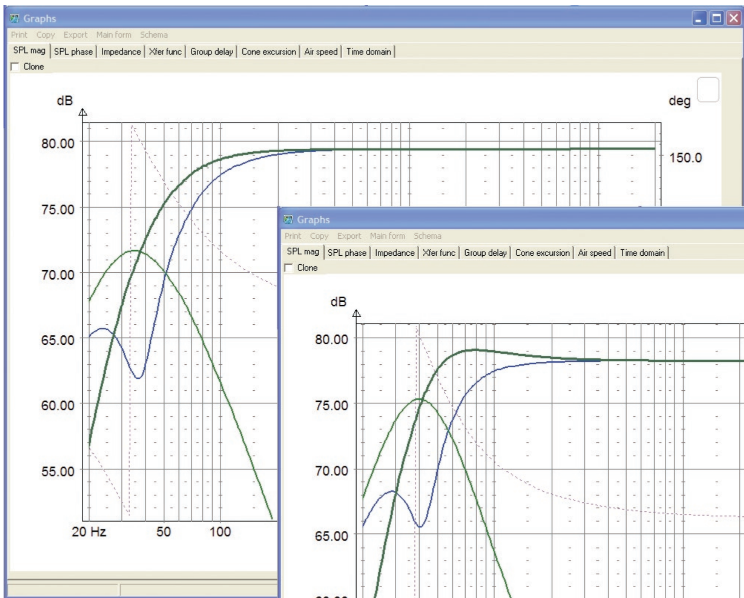
Sometimes things don't work out so well. For example the SEAS H1217 we suggested in our last article has a Qts of 0.45, again an indeterminate figure. And if we divide its Fs of 40Hz by its Qes of 0.58 we get an EBP of 69, neither one thing nor the other.

So the second check we need to do is to actually work out how the driver is going to behave in our prototype enclosure. Of course we could actually build several different cabinets and try the drivers out in them, but our software tools can save us a lot of time and woodwork!

Open up your software Enclosure Designer, and here we are going to use LspCAD6 lite, and enter the TS parameters of your driver. Depending on which software you are using you can either enter the details of the enclosure size and port dimensions of the cabinet you want to use or get the software to suggest it for you.

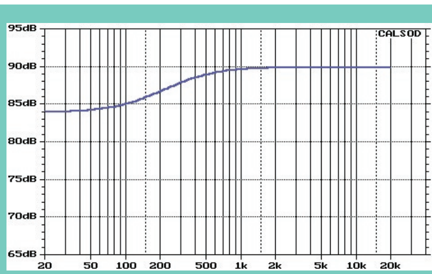
LspCAD6 lite has a 'Wizard' button that can suggest enclosure sizes for the three, major, bass reflex alignments, SBB4, SC4 and QB3. You can see more info on these in the Alignments box, but I usually choose SBB4 as a good starting point.

With the SEAS H1215 we see a very smooth and well damped alignment in an 18 litre enclosure tuned to 36Hz – the ideal result. Plug in H1217 and we can see that the bass extension is much greater



Comparison graphs of SEAS H1215 & H1217 bass alignments

BAFFLE STEP



I went over the Baffle Step issue earlier in the series but, in case you have forgotten it or just didn't see that article, I'm going to explain it again.

If the driver is placed, say, in a wall then it is effectively radiating into half a sphere. The surface of a sphere is given by 4 π r2 so we call this half sphere radiation 2 π for short.

Now when we put the drive unit on a baffle it only radiates into this 2 π space as long as the baffle is bigger than the half wavelength of sound radiated. I've put that in bold because it is a very important aspect of speaker design. Below the frequency where the wavelength is twice the baffle dimension the speaker is effectively radiating into the whole spherical 4 π space.

What does this mean in practice? It means that below the frequency where the wavelength is twice the baffle dimension the output of your drive unit will effectively drop by 6dB. We call this step in the measured response of the forward radiation the 'baffle step'.

You can easily calculate the baffle step frequency in the equation f3=17200/Wb where Wb is the baffle width.

In our speaker design a narrow baffle width of 20cm will give a baffle step at 850Hz – rather high to compensate for in our crossover and requiring a large value inductor to bring the upper midrange level down.

If we increase the baffle width to 30cm the baffle step goes down to 575Hz, which is a bit more manageable in our crossover.

Of course we've only looked at baffle width as the narrowest dimension. In reality the baffle step is smoothed by the larger dimension of the height of the baffle. For example a baffle height of 50cm gives the lower edge of the baffle step at 345Hz, so the driver on a baffle of 30cm x 50cm will show a smooth transition from a gradual drop in output at 575Hz to a -6dB point around 345Hz.

Where there is a big disparity in baffle width and height, for example in a tall, narrow floorstander, I have noticed that width tends to dominate in the baffle step effect, so don't think you can get around the width problem that way!

but has a hump in it in the 60 – 90Hz range. Now this would be ideal if you want a speaker with an 'impressive' bass for its size, but I suspect it is not going to have as articulate or accurate a bass performance as the smoother H1215.

But, in the end, the choice is yours. At least LspCAD6 lite allows you to make an informed decision between maximum extension and power and smooth, natural sounding bass.

BAFFLE SIZE

Having chosen our drive unit we can now see the optimum enclosure internal volume for the bass driver. This does not have to be adhered to absolutely. In practice, because of your ability to change the internal filling and so on you can increase the volume by 20% without affecting the tuning too much. It is not recommended to go much smaller, however, as we will almost certainly want to fit internal bracing, damping pads and crossover, all of which will take up some of the much-needed internal space.

So, with the predicted 18.5 litres given by LspCAD, I would aim for a true internal enclosure volume of 20 litres to allow for the volume taken up by braces and the rear of the drive unit itself. Now you can start to think about the baffle size.

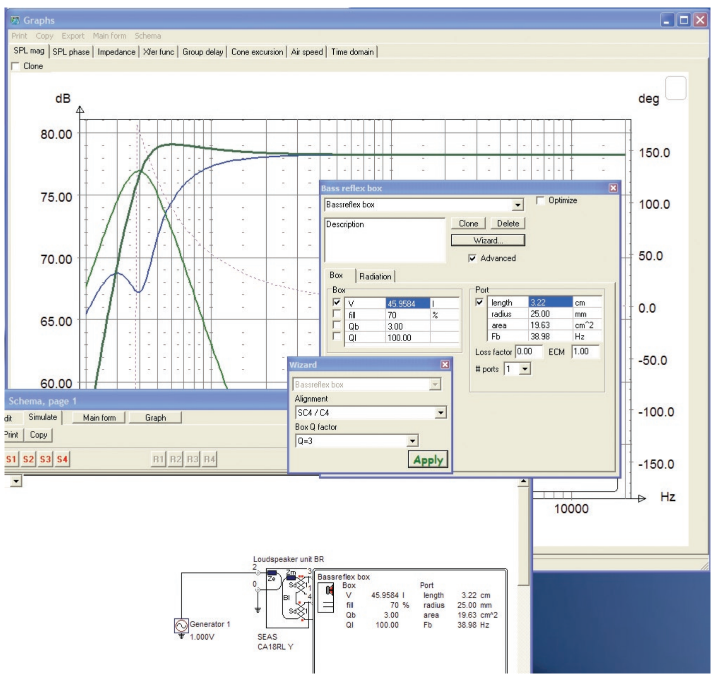
As this is an 18cm unit and the cabinet volume is relatively low it is tempting to go for the current fashion of as narrow a width as possible. But please bear in mind that, by slavishly following this fashion, you will raise the frequency of the baffle step, making crossover design that bit more difficult, and almost certainly lower the sensitivity of the speaker.

Of course, you are the designer, and are free to accept these limitations if you wish. But me? I'm going for the wider baffle look as I know it is going to make my crossover design easier and maximise the sensitivity of the driver as well as provide good coupling with the room back wall (which is something I like to do to enhance speaker-room integration).

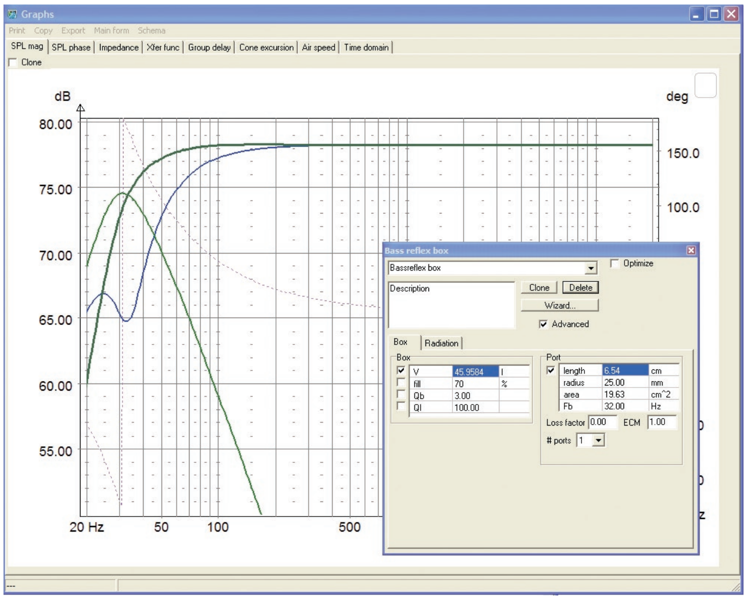
Now a nice box size that I have worked with in the past is 265W x 470H x 235D mm. I like the aspect ratio and it gives me an internal volume (without braces) of 20 litres. How did I calculate that? Subtract twice the enclosure wood thickness from each external dimension and then multiply together. So, assuming a wood thickness of 18mm, the internal dims are 229 x 434 x 199 = 19777814/ 1000000 = 19.78 litres (1 litre= 1000000mm3)..

FLOORSTANDER

This size of cabinet will also raise the treble unit to seated ear level when placed on some standard height stands. But what if you want a floorstander? One simple answer is just to build the enclosure as the top half of a floorstanding cabinet. You could use the bottom half to hold the crossover and, perhaps, some dry sand (in a sealed polythene bag) to



SEAS H1217 in a SC4 Bass Alignment.



Detuning the SC4 Bass Alignment.

provide stability and cabinet damping.

But you might also like to consider an alternative driver, the H1217. Load the TS parameters into LspCAD6 lite and we will start playing with the options.

Now click on the Wizard button and choose an SC4 alignment. This gives us an internal volume of 46 litres and a significant amount of bass power. To my mind it looks a bit peaky in the lower bass. By the time we have added in room gain (as the frequency gets lower so the contribution to the overall sound from reflections from walls, floor and ceiling increases) the bass could well be overpowering.

But we don't have to stick with what the Wizard tells us. It is only a recommendation based on the 'classic' alignments and you can fine tune the system any way you want.

So let's do that in our simulation. The classic way to 'detune' a reflex box is to lower the box tuning frequency Fb. So double-click in the Fb box and use your down arrow on your keyboard to lower the frequency. You'll see how the response changes in the graph as you do it. See how it smooths out as you get down to 32Hz?

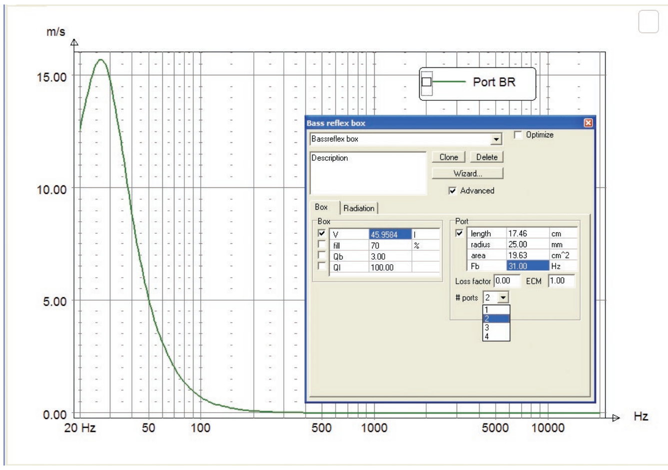
Obviously we can play around to our heart's content, but how do you know when you've got it right? Short of listening to it (and we haven't constructed our cabinet yet) you can get a fairly good idea of the right 'tuning spot' by looking at the impedance graph.

Click on the impedance tab and you'll see the typical double humped graph for a reflex box. What you are looking at is the impedance of the drive unit only. At the box tuning frequency the port will be doing all the work and the driver will hardly be moving at all, so the driver impedance will fall to a minimum at this point.

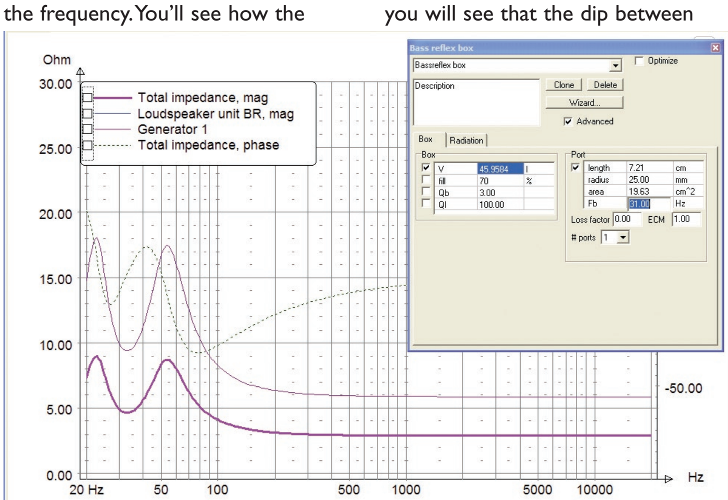
If you look closely at the graph you will see that the dip between the two peaks is exactly at the box tuning frequency Fb. What we can do is make sure that the height of the peaks either side are equal (all this really means is that the box tuning frequency exactly subdivides the impedance peak of the drive unit) which usually indicates the optimum transition between drive unit and port.

You should find that the height of the peaks are roughly equal when Fb = 31Hz. You can get a clearer picture by expanding the graph. Click on Settings in the main window and alter the Display range to 10Hz and 1000Hz.

Now we can work on the port size. I usually work with 50mm diameter ports, but you can use whatever you have available (plastic water pipe from a DIY merchant will allow you to easily cut different lengths of port for experimentation when tuning the final system). LspCAD asks for the radius of the port, so I'll put in 25mm here. (You will need to change Fb back to 31Hz after you've done that).



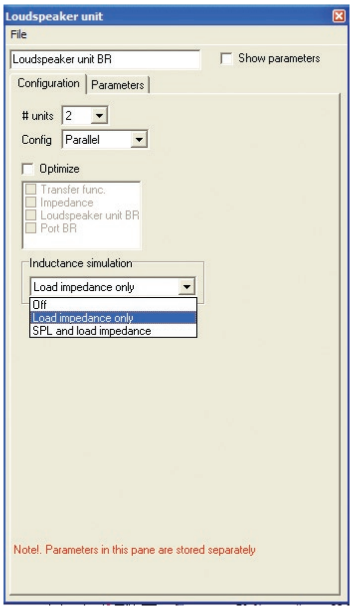
Air Speed graph with 50W input and twin ports.



Impedance of SEAS H1217 in optimum Bass Alignment.

This gives me a port length of 70mm – quite short. I can afford to go longer than that if necessary so let's have a look at the air flow in the port. Click on the Generator symbol in the layout window and set to 20V (equivalent to 50W/8 Ohms). Click on the Air Speed graph tab and you'll see it peaks at 30m/sec. This basically gives you an idea of 'chuffing' or air turbulence in the port which can add to bass distortion. This is beyond the limit of introducing audible non-linearity so I would feel safer bringing the air velocity down.

So we can either increase the port size or double the number of ports. I'll keep with the port size I have, so I click on the # Ports to enter 2, set Fb to 31Hz again and, bingo, the air velocity has reduced to 15m/s.



Configuring twin bass drivers in LspCAD6 lite.

See how easy it is to play around in this 'virtual' speaker design laboratory? So while we're having fun why not try another method of creating a floorstander?

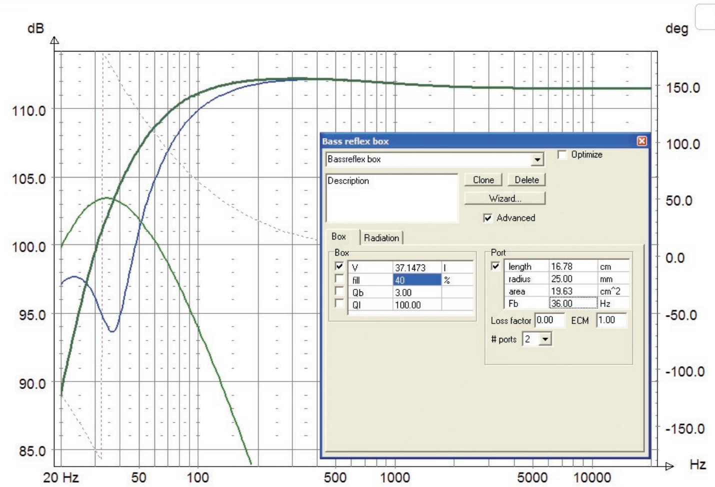
TWIN DRIVERS

One of the nice aspects of floorstanders is that they give you the opportunity to use more than one bass unit. Providing that your amplifier can drive a 4 Ohm load, and most can, you can increase your speaker sensitivity as well as use the increased internal volume of a floorstander to its maximum potential.

Let us load up the H1215 again from the saved driver files. Before going any further click on the Configuration tab in the Loudspeaker Unit window. Enter # units as 2 and Config as Parallel. If you want to double check the impedance go to the Impedance Tab on the graph and hold the cursor over the minimum point between the two peaks. You can see in the bottom left corner a readout of the frequency, impedance and electrical phase. Don't worry about the minimum impedance higher up in the frequency range as, by the time you've added a few crossover components, the impedance here will rise considerably.

In fact you might not be viewing the true impedance unless you have included the inductance of the voice coil you entered in the Loudspeaker Unit Parameters. So go to that window, click on Configuration and then select Inductance Simulation – SPL and Load Impedance.

Back in the Bass Reflex Box window we click on Wizard and, for an SBB4 alignment, the required enclosure volume is 37 litres. The response is much better damped than with the H1217, in fact it is a bit over damped. So reduce the enclosure filling from 70% to 40%. Of course you can adjust this when you build the real thing, but at least you can see its effect on the response and impedance.



Bass performance of twin SEAS H1215 in a floorstander.

COMPARISONS

Can't decide which to run with – one drive unit or two? Let's make it easy to compare them, shall we? I'll show you a neat trick that LspCAD6 lite has up its sleeve to give you instant comparison of any design exercise.

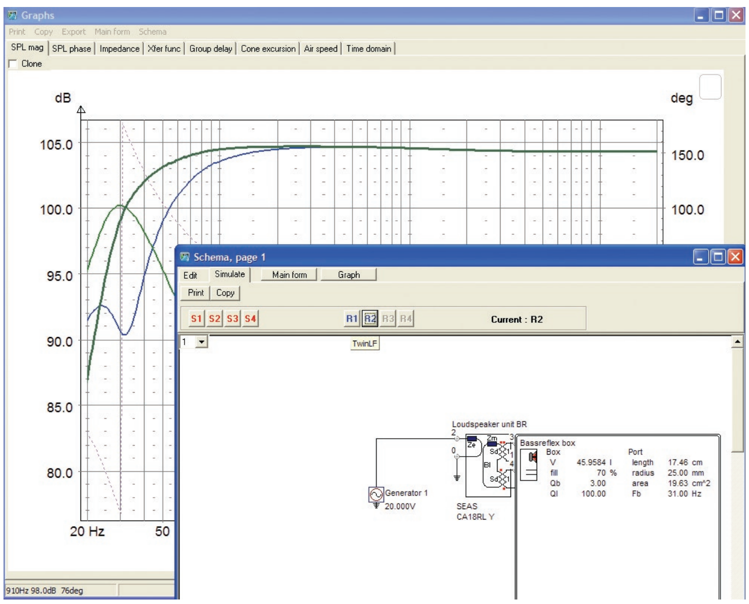
On the Schema window you'll see some buttons 'S1, S2, S3 and S4'. These buttons commit your design to memory. Click on S1, (you can give it a name so you know what it is, say TwinLF). Then change the Loudspeaker Unit back to the H1217 by loading it from the saved driver files, change the Configuration back to 1, and run the Wizard again. Then click the S2 button.

Now you can do a direct comparison between the two designs just by clicking the recall buttons R1 and R2. You can instantly see the changes to any of the graphs you wish to view. Now you can make an informed decision on any design project, loading up to four different variations into memory and comparing any of them with a button click!

Which would be my choice? Well, for a speaker that goes near a rear wall I'd choose the double H1215 as I will get quite a lot of room gain boost to the area below 100Hz which will level out the response nicely. But if I wanted a free standing design then I would use the H1217, especially as that bass lift just before roll-off is going to give me an impressive 'kick' which users of bass reflex speakers seem to like.

But why not decide for yourself? Download the trial version of LspCAD6 lite and run through this design exercise on your own computer, in your own time.

Next month: Measurements and Crossover



Using Save (S1, S2...) and Recall (R1, R2...) to compare designs.