Construction project:

HIGHER POWER SUB-WOOFER DESIGN

Rated at around 200 watts, this new sub-woofer speaker design should satisfy those with the thirst for high levels of low bass energy. It uses an extremely rugged 300mm speaker in a double-chamber 'bandpass' enclosure, and has an inherent frequency response of 30Hz to 100Hz (-3dB).

By ROB EVANS

Well, you asked for it! Since our last sub-woofer design was published in the June 1992 issue of *Electronics Australia*, we've received a flood of letters from readers requesting a larger, more powerful unit. While the previous design offered excellent performance from a relatively small enclosure, using a 200mm driver, the nominal power rating was a mere(!) 80 watts — which was clearly not enough for some readers...

So with the need established, we set about tracking down a high-powered driver which would be suitable for the same bandpass-style of enclosure as used in the last design. Our search ended with a hefty 300mm unit from Jaycar Electronics, which is the largest in their 'Re/sponse' brand range. Listed as catalog number CW-2145, this driver carries a generous 200W RMS power rating and is priced at $199 — not bad, when you consider that this is the main outlay for the new sub-woofer.

After testing a sample unit kindly sent to us by Jaycar, we established that it had a free air resonance (Fo) of about 29Hz, a total Q-factor (Qts) of 0.34, an 'equivalent compliance volume' (Vas) of around 190 litres, and a very encouraging sensitivity figure of 93dB (for 1W at 1m).

Physically, the driver offers a 'woven carbon fibre' cone, a stout 1.4kg magnet assembly, and interestingly, a *dual* 'kapton' voice coil which allows you to connect it as an 8-ohm or 4-ohm unit.

We initially regarded this latter feature as a significant advantage for sub-woofer applications, since many amplifiers are able to deliver a much higher power level into a 4-ohm speaker, which ultimately adds up to a more cost-efficient arrangement.

Rather strangely however, further testing revealed that the driver's Qts figure

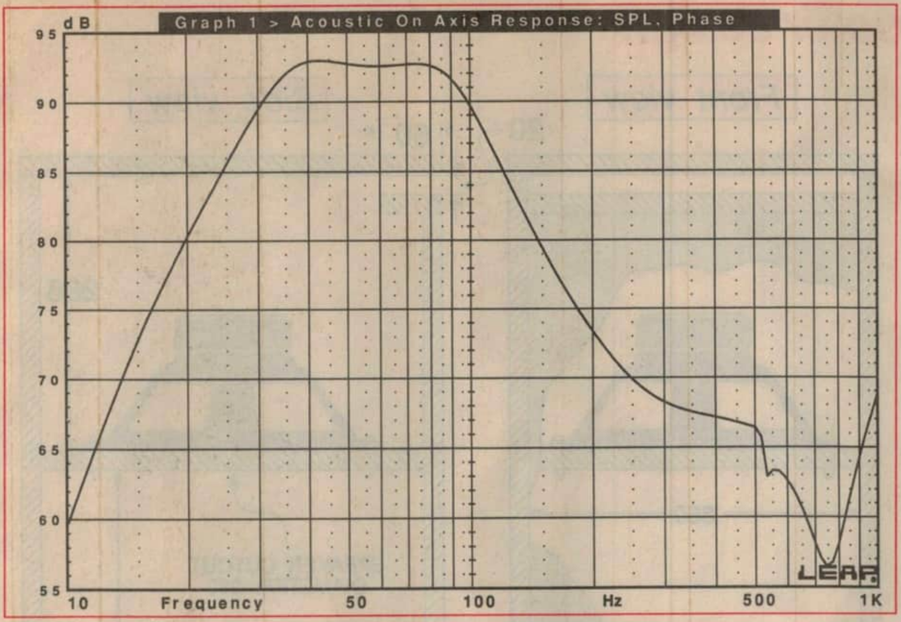

Fig.1: The sub-woofer's projected frequency response at 1W/1m. The slight aberration at around 500Hz is due to reflections inside the enclosure's ports.

rose to 0.68 when connected as a 4-ohm unit — *double* the 8-ohm figure. And to put it bluntly, a driver with such a high Q factor was just not suitable for our purposes (or too many others, for that matter).

Curiosity aroused, we had a closer look at the measurements for the driver in its 4-ohm configuration, and noticed that the fundamental 'BL' factor (which has a direct bearing on the driver's Q) was half of that measured in the 8-ohm tests. Now, since a driver's BL figure represents the length of wire in the magnetic field multiplied by the field density (in Tesla-metres), it seems that there must be half the amount of wire used in the 4-ohm configuration — since clearly, the magnetic field density remains the same.

So in effect, the Re/sponse driver appears to have a *tapped* voice coil, and since only half of the windings are used in the magnetic gap with the 4-ohm connection, there is a resulting decrease in the voice coil's driving force. Therefore as a 'motor' unit, the coil has less control over the cone movement, which adds up to a much higher electrical Q factor. As further evidence, we noticed that the driver's sensitivity is about 3dB lower in the 4-ohm mode (90dB as opposed to 93dB).

As you have no doubt gathered then, our new enclosure design is intended for the Re/sponse driver wired as an 8-ohm unit only. The driver's parameters in this configuration are well suited to the bandpass style of enclosure, which was duly developed with the help of our resident LEAP (Loudspeaker Enclosure Analysis Program) software. The result is an enclosure of about 138 litres in volume which stands about one metre high, and radiates sound via two slotted vents positioned at the extreme ends of the front panel. In acoustic terms, it has a natural bandwidth of 30Hz to 100Hz (see Fig.1), and theoretically delivers a maximum sound pressure level (SPL) of about *115dB* at a distance of one metre.

While the double-tuned bandpass design ends up a little larger than an equivalent vented enclosure, it does offer a number of distinct advantages for sub-woofers in particular. In short, these are a lower average cone excursion and velocity, less audible overtones heard from the cone itself, and a natural high-frequency roll-off — these points were also covered in more detail in the original June 1992 article, by the way.

These features mean in turn that the bandpass design tends to sound much 'cleaner' (less distortion products), and is less demanding of the crossover filter.

So there you have it. It's big, it's powerful, and it won't break the bank. Just remember, when the neighbourhood starts complaining about seismic activity which seems to be emanating from your house, that *you* asked for the thing...

Construction

Before you start building the cabinet for the new sub-woofer, we would suggest that you read through the complete article, since as detailed later, the design may need to be slightly changed to suit your components and/or preferences.

As you can see from the assembly diagram (Fig.3), the bandpass style of enclosure is a more elaborate arrangement than the common highpass (vented or sealed) type, and consequently, will take rather more effort to construct. On the brighter side however, a precision finish is not really necessary since the cabinet will probably be painted in a dark colour, and installed in an inconspicuous location. This in turn means that simple butt joins can be used, and minor woodworking errors won't really show.

The enclosure should be constructed from 19mm (or even 25mm) high-density particle board (commonly known as

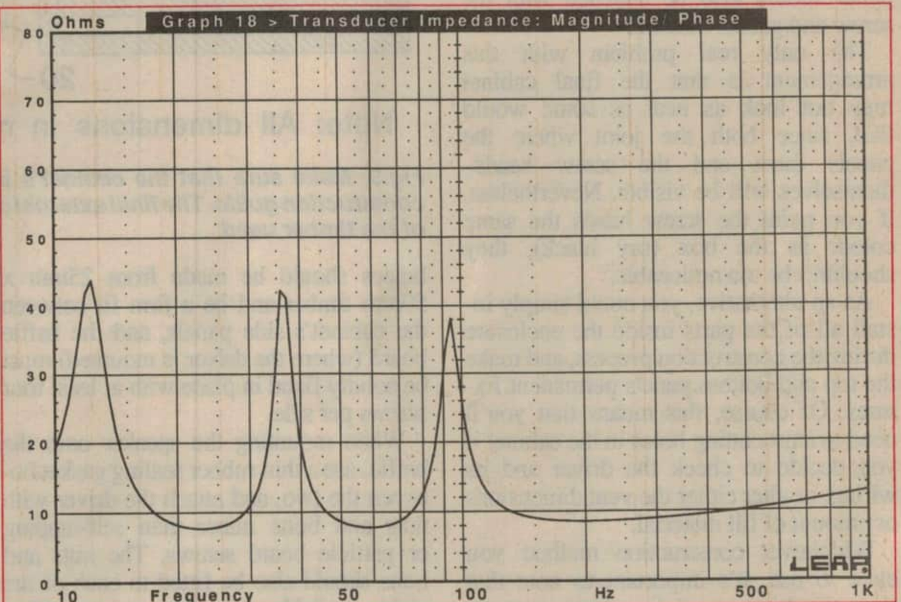

Fig.2: The impedance curve shows the distinct triple-hump characteristic of the double-tuned bandpass design — the dips represent the tuning points of the two ports.

Higher power sub-woofer design

MDF), with each joint both screwed *and* glued together for an air-tight and sturdy result. We would recommend that you use coarse-threaded particle board screws that are at least 50mm long, and liberal amounts of woodworking glue for each joint.

Note that the ease with which cabinet can be put together and the quality of the result will depend upon the accuracy of the original saw-cuts, which should have clean, straight edges, and be at 90° to the main surface. Some kind of bench or drop-saw is really needed to achieve this sort of accuracy, so your best bet would be to arrange for the box panels to be cut using professional equipment — a timber yard or joinery should be able to provide this service.

On the other hand, unlike yours truly, some constructors may be sufficiently skilled with a hand-held circular saw to produce acceptable results. Remember though, that all joints should be fully air-tight, and mistakes will be expensive if you need to buy replacement timber.

You will also need to consider how you plan to access the driver, wiring and damping material once the enclosure has been completed. With our previous bandpass enclosure design, the 'bottom' panel was screwed (but not glued) in place and a rubber gasket used to maintain the air seal. In the case of our new sub-woofer however, you really need to have access to both the top *and* bottom compartments, which means that the top panel should also be attached with the screw and gasket method.

The only real problem with this arrangement is that the final cabinet may not look as neat as some would like, since both the joint where the panels meet and the screw heads themselves will be visible. Nevertheless, if you paint the screw heads the same colour as the box (say black), they shouldn't be too noticeable.

As an alternative, you could simply install all of the parts inside the enclosure during the construction process, and make the top and bottom panels permanent fixtures. Of course, this means that you'll need to start cutting holes in the cabinet if you decide to check the driver and its wiring, or alter either the vent dimensions or amount of fill material.

Whichever construction method you elect to use, it's important to note that since the driver can deliver large amounts of acoustic energy, the cabinet must be very solidly constructed and free from panel resonances. To this end, the internal

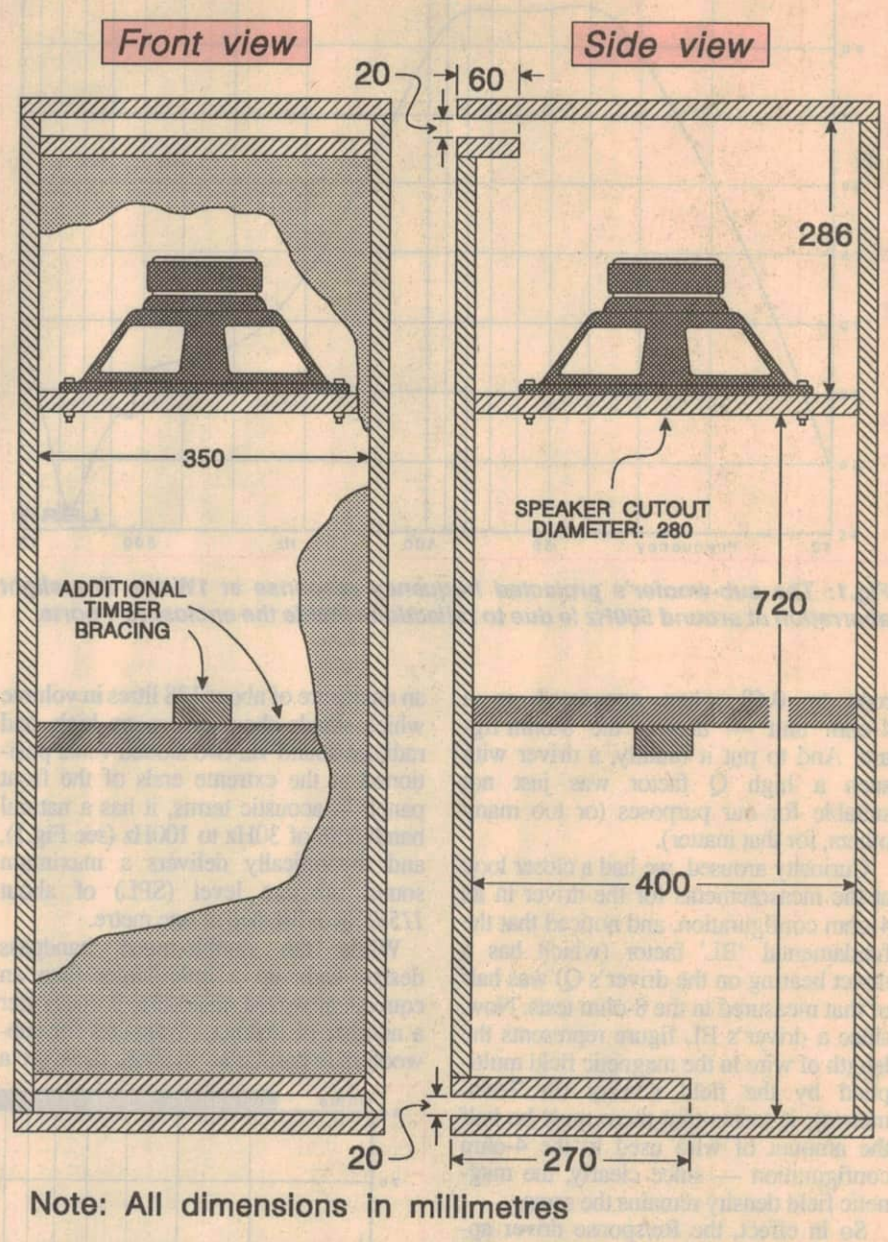

Fig.3: Make sure that the cabinet's internal dimensions are as shown in this construction guide. The final external dimensions will depend upon the thickness of the timber used.

braces should be made from 25mm x 50mm timber and be a firm fit between the cabinet's side panels, and the baffle board (where the driver is mounted) must be solidly fixed in place with at least four screws per side.

When mounting the speaker onto the baffle, use a thin rubber sealing gasket between the two, and attach the driver with nuts and bolts rather than self-tapping or particle board screws. The nuts and bolts should also be fitted to each of the eight available mounting points. Also, make sure that the speaker wire is of a heavy duty type, and is positioned where it cannot come into contact with the driver's cone. And remember, use the *8-ohm* voice coil connections (the two outer terminals).

The sub-woofer's power capability also means that the velocity of the air in the vents can reach very high levels, which can lead to audible turbulence effects as the air rapidly flows past any sharp edges. This can be minimised by slightly rounding the lips of the vent openings, at the outside *and* inside inlets — don't overdo it though, or you might significantly alter the volume of air in the port and effect the cabinet's tuning.

As a last point, we should mention that the enclosure has been designed and tuned with a moderate amount of acoustic damping material in mind. For the upper chamber, drape a square of the material (about the size of the top panel) over the driver and tack or staple the ends in place, so that it cannot come into contact with the speaker's cone.

For the lower chamber, we would suggest using two pieces of acoustic material; one for the section above the braces, and the other for the lower area between the braces and the vent. Referring to the side view of the enclosure as shown in Fig.3, the lower piece can be stapled between the bottom left-hand corner (just above the port) and the right-hand end of the braces, in a diagonal position — this keeps the material well away from the port opening, where it could audibly 'flutter' due to air turbulence.

The other section can be fitted to the top of the chamber in the same diagonal manner, with one end secured at the left-hand end of the braces (the enclosure's front panel, in fact), and the other below the right-hand end of the baffle board (the rear panel). The damping material itself can be formed from fibreglass home insulation 'batts', or a proprietary acoustic wadding such as Innerbond or an equivalent product.

Note that in its 25mm thick form, this latter fill material appears to have about half of the damping effect of the fibreglass batts, so you will need a double layer for each of the three sections. However this material won't irritate your skin or tend to break up like fibreglass batts, so the few extra dollars may be well spent.

Checks

It's an unfortunate fact of life (or manufacturing) that a driver's parameters will tend to change between production runs, and the performance of a number of 'standard' speakers in a given enclosure may not be consistent.

While the more conventional highpass designs (sealed and vented) are reasonably tolerant to these changes, a bandpass enclosure is much more interactive with the driver and can therefore respond quite dramatically to a shift in its specifications.

After performing a number of trials with LEAP, it soon became apparent that a shift in the driver's free air resonance (Fo) seems to have a significant effect on the cabinet's final performance, while changes in the other essential parameters — Vas and Qts — will produce relatively minor aberrations.

We also found that a change in these latter parameters tends to be accompanied by a substantial shift in Fo, so the resonance figure turns out to be a reasonable yardstick for detecting a variation in the driver's specifications — and as a bonus, it's also the easiest figure to test. In fact we would recommend that you determine the driver's free air resonance *before* you build the enclosure, so that the cabinet can be re-tuned to minimise the negative effects of any change.

The simplest way to test the driver's Fo is to measure its impedance over the 10Hz to 100Hz range, and note where the response peaks due to its natural resonance. To do this, suspend the driver above the floor by placing it between two flat surfaces (a couple of tables are ideal) so that it's only held at two points around the perimeter. Then connect an audio oscillator as a signal source, and monitor its output voltage with a multimeter or oscilloscope.

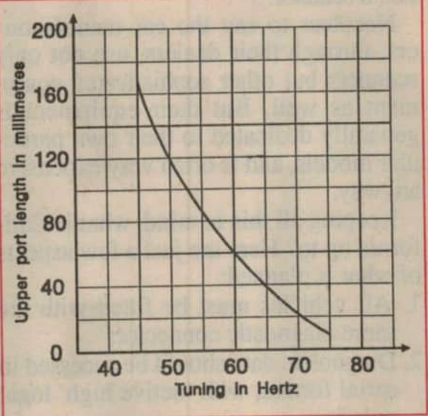

Fig.4: If necessary, use this 'tuning' graph to alter the length of the enclosure's upper port (see text).

Providing the oscillator has a relatively high output impedance (greater than 100 ohms, which is usually the case), you should see a dramatic increase in its output level as you sweep the frequency past the driver's resonant point. In the case of the 12" Re/sponse driver, the peak should occur at about 29Hz.

If the figure from your test differs by more than about 2Hz, you will need to retune the enclosure's *upper* vent by around the same figure to bring things back into line. For example, if the driver's Fo is 5Hz too high (34Hz), you need to tune the top enclosure to about 65Hz rather than 60Hz.

To help you with this process, we've included a vent length versus tuning frequency graph for the upper port, as shown in Fig.4 — so in the above example, the length will need to be reduced to about 38mm. Conversely, if the driver has an Fo of 24Hz (5Hz low), you will need an 85mm upper vent (55Hz).

While on the subject of impedance tests, some constructors may wish to check that the final enclosure is indeed tuned to the correct frequencies, indicating that it will perform as specified. In this case the same impedance testing method can be used to determine the tuning points of the two chambers, by noting the frequency of the two *dips* in the impedance curve, as shown in Fig.2.

As you would expect, the dip at around 23Hz corresponds to the tuning of the lower vent, while the 60Hz dip is due to the action of the upper vent. If these are more than a few Hertz out from what is expected, double check that the enclosure and vents are indeed the correct dimensions, and the specified amount of fill material has been installed. Also, remember that if you have retuned the top vent to compensate for the driver's parameters, the final impedance curve will reflect this change.

Setting up

Once you are happy with the sub-woofer's construction and tuning, you will need to decide how it will be connected to your existing hifi system and where it might be placed in the listening room. As you would expect, both of these decisions will play a large part in determining the quality of the final sound, and should be given as much attention as the construction project itself.

In short, we would recommend using *EA* Sub-woofer Adaptor (published in the May 1989 issue) for deriving an appropriate signal from the existing system, driving an amplifier with a power capability of at least 100W. We also suggest placing the sub-woofer enclosure against the wall, but away from the corners of the room.

There are a number of other variables to consider, such as the acoustic balance between the two speaker systems, their phase relationship, and the most appropriate crossover frequency.

We'd suggest that you refer back to the June 1992 sub-woofer article for further information on these points, which were discussed in some detail in the 'Setting up' section.

Above all, it's really just a matter of experimenting with all of these factors, within the constraints of the existing system's capabilities and the layout of your listening room.

There will no doubt be some clear (possibly spouse-induced) restrictions on where the sub-woofer can be be positioned, for example. Once you have the system up and running however, you should find that your new sub-woofer has an extremely clean and extended output, and can effortlessly deliver very large amounts of low-frequency energy. ❖