SYSTEM 7

The BSC3 design by C. Rogers, *(Reprinted from HiFi and Audio, December 1977)*

The current popularity of loudspeakers such as the LS3/5a JR149, and other high quality compact loudspeakers, shows that there is a great demand for bookshelf loudspeakers. With this in mind, the BSC (Bookshelf Compact, of course!) 3 became a reality.

No one is going to try to kid themselves that a loudspeaker of this size can achieve the same performance in the lower register, as that of a larger system. However, there is no reason why a small speaker cannot achieve a standard of performance in the mid-band and treble regions that is on a par with, or *better* than, a larger system.

However, a bass performance which is quite reasonable can be achieved; in fact a bass performance similar to that of a large loudspeaker could, in some ways, be achieved, but the sacrifice involved would not be practical. It is, I feel, useful to look at the trade-offs involved in obtaining low frequency extension, and this should give some idea of the compromises which have got to be made.

It is possible to obtain *any* amount of bass extension by the simple expedient of sacrificing efficiency. In isolation, this is fine, but it is quite obvious that as efficiency falls, more power will be required in order to obtain the same listening level. Taken to extremes, this could mean that the speaker would require 100 W in order to achieve a suitable listening level, but be destroyed by levels in excess of 25 W, through lack of power handling, so a compromise has to be made here.

The next problem really has a double edge, and this is the one of cone excursion. There is obviously a limit as to how far the cone can move, but the region in which the cone has *linear* excursion is usually much less than this. When this excursion is exceeded, the drive unit output becomes non linear compared with input, and nasty distortion begins! Allied to this, the voice coil moves out of its gap and power handling is reduced with the result that it is much easier for the drivers to be destroyed.

Compromise

To summarise the foregoing – a compromise has to be made between: bass extension, efficiency, sound pressure level, dynamic range, available power handling and distortion. This then shows that there is a practical limitation to any size of drive unit; the smaller, however, the greater the limitation. Before the compromises are complete, the enclosure size and type naturally have to be considered. The object here is to construct a small compact speaker, so this defines the objective, if not the exact size.

It was decided to use a 12.5 cm (5") bass unit, the D30/110 from Dalesford being the final choice. In order to end up with a compact speaker, a compromise had to be made on enclosure volume, and it was felt that 7.5 litres was as small an enclosure as could be used, without too great a sacrifice of bass performance.

The next question is the type of loading to be used. In a small speaker there is a great temptation to use reflex leading in order to achieve an extension in low frequency performance, but for a variety of reasons this is fraught with trouble. The main problem and the one which concerns us most, is that at low frequencies there is nothing to prevent large cone excursions. In the size of speaker in question, such large excursions are disastrous. At worst, there would be damage to the drive unit, but even at best, the drive unit would spend a lot of the time working outside its linear range, with the result of greatly increased distortion.

There is but one answer to all of this, and that is that a sealed box must be employed in order to give the drive unit a loading which will not allow it to, quote, "hammer against the end stops".

Given the limitations imposed by such loading, it is not difficult to achieve an extended frequency response, as the response curve, Fig. 10 shows. The limiting factor is the amount of low-frequency energy which the speaker can produce, and this is really left up to the designer to compromise on.

This then brings me on to the rather bold statement which I made earlier, along the lines of it being possible to obtain better mid-band and treble performance from a small speaker than a big one. The reason for this is quite simple. Given that you are not driving the low-frequency unit into non-linearity, then this unit should, in theory, be capable of good performance up to around 3 kHz.

This in turn should provide good performance over the mid-band and allow transition to a suitable hf unit. Moving up the scale to a 20.3 cm (8") bass unit, the laws of physics depict that as a pure piston it will only give of its best up to around 2.3 kHz.

Going up yet again to drive units of 25 cm (10") and above, we now come into the realms of three-way systems. While it has got to be said that it is only possible to cover the whole frequency range with three or more drive units, there are an enormous number of disadvantages to this approach, not least of which is the interaction between drive units, and this alone can give poor mid-band sound. So, the fact remains that a good small system can equal or better the mid-band of its larger brother.

Treble and crossover

Having covered the bass end of the system, in theory at least, consideration should now be given to the treble unit used. While it is popular to use a 19 mm (¾") dome tweeter in loudspeakers of this type, I do not consider this to be the most suitable choice, as a unit of this size is not really suitable for use down to 3 kHz. A far better choice is a 2.5 cm (1") dome, as this is capable of working down to 3 kHz and is equally well suited to operate up to 20 kHz. With this in mind, the tweeter selected was the Audax HD12.9D25.

The next item is the crossover. To discuss this now is really putting things in the wrong order, because it is not possible to design the network before the cabinet is complete. As can be seen from the complete circuit, Fig. 2, the section for the bass unit is unavoidably quite complex, in order to achieve the correction necessary for the bass unit. It appears at first sight to be a fourth order 24 dB/oct. network, which I suppose by definition of the configuration it is, but as the values show, its function is far more complex. To save a needless explanation, the uncorrected response curve of the bass unit can be seen in Fig. 3. When this is compared with the electrical response curve of the network, Fig. 4, it can be seen that the network is designed to correct for the bass *system.*

All the inductors used are ferrite-cored components selected for the job that they have to do, while all capacitors are polyester, which enables maximum efficiency to be preserved, along with a reasonable tight tolerance.

Coloration

At this point I think it is worthwhile pointing out that it is easily possible to make the network more complex and remove some obvious coloration within the system. However, while this does remove audible coloration such as there might be, with it quite a large chunk of information along with dynamic range can also be removed.

Reverting back to the enclosure, the volume has already been decided, which in turn has to be developed into a set of dimensions, internal sizes being the important ones. Here again, the basic laws of physics cannot be defied and a few simple rules apply. Firstly none of the internal dimensions should sub-divide, in order to prevent standing wave problems. For example the worst case condition would be something like 25 cm × 25 cm × 50 cm (10″ × 10″ × 20″).

The next factor of importance is that the largest dimension should not be in greatly excess of the next dimension to it, as this can cause an organ pipe effect within the enclosure. In practice, however, this rule can be *bent* a little if steps are taken to prevent such effects, such as baffling shelves within the enclosure (viz. the Mission 730 reviewed elsewhere in this issue). The final inside sizes were chosen as 15.2 cm wide × 28 cm high × 17.9 cm deep (6″ × 11″ × 7″).

The next thing to decide was the material to be used for the cabinet, and what, if any, damping material will be required. As a constructional material, chipboard is most suited, as in general terms it is superior to other wood types and far cheaper.

From a structural and resonance viewpoint, 12 mm (½″) thickness is quite adequate, but as far as acoustic transparency is concerned, it is not. The plain fact is that the sound passing *straight through* the cabinet walls is on average only in the order of 30 dB down on that emanating from the drive unit, while peaks can be only 10 dB or so down. You may think that increasing the thickness of the enclosure may do the trick, but I am afraid that doubling the thickness only gives an improvement of 4 dB.

There is, said to say, no complete solution to the problem, as even solid brick transmits sound, but for our purposes there is an adequate solution. This is achieved with laminated bituminous panels of 12 mm ($\frac{1}{2}$") thickness. While I am not pretending that this will completely solve the problem, it will certainly go a long way towards it. This material is used to totally line the enclosures, with the exception of the front baffle.

With this decided, we now end up with a total panel thickness of 24 mm (1") apart from the front baffle, but to which is added 10 mm ($\frac{3}{8}$") for the grille frame. This then gives an overall size for the speaker of 20 cm wide × 32.8 cm high × 22.5 cm deep (7.9" × 12.9" × 8.9").

The final part of the enclosure to be considered is the drive unit mounting and grille frame. The 110 series has in the past been mounted in a number of different ways, all of which have problems. The main one is due to the construction of the chassis. If the drive unit is mounted from the front, as is now considered normal, the rear openings can be obscured. This causes a constriction, the subsequent coloration from which can be most objectionable, and the drive unit gets the blame for something which is not its fault. One possible solution is to rear mount the unit as is done in the BBC LS3/5a. While this gets over the problem of the constriction at the rear, it introduces an additional problem of creating a cavity at the front, which, too, can cause coloration. There is, however, one solution to the problem – this is to front-mount the drive unit, but then chamfer the baffle at the rear in order to remove the constriction, as is shown in the diagram.

With both drive units mounted directly on the front, there is now the matter of a grille frame. With a small enclosure there is a greater problem of diffraction from its edges. With the enclosures in question, the problems will be a multiple of 1.75 kHz and 2 kHz.

In order to try to minimise these problems, a grille frame has been devised which is, for want of a better word, *sculptured* to provide a smooth transition from the drive unit to the flat front.

The construction

Having covered the philosophy behind the project at some length, let's move on to the construction of the speakers. The tools required are few – tenon saw; keyhole coping or jigsaw; screwdriver suitable for No. 6 screws; 2pt Pozidrive screwdriver; rule; hammer, chisel, two small 'G' clamps; various drills; soldering iron; cutters and pliers.

At the end of the article a list of parts is printed which should first be obtained. As far as the timber is concerned, there should be no problem in taking the cutting plan, Fig. 5, along to your local timber shop and having the chipboard, and plywood for the grille frame cut. This, then, virtually reduces the job to one of assembly. With all the parts of the enclosure laid out they should be numbered in accordance with numbers on the cutting plan, Fig. 5, as future reference will be made to these numbers.

Fig. 6 gives an overall view of how the cabinet is constructed, from which it can be seen that all joints are butted and made with 12 mm ($\frac{1}{2}$") square ramin batten. First, four lengths of batten should be cut which run from front-to-back, these are 16.7 cm ($6\frac{1}{2}$") long. These should be fitted by means of gluing and screwing to the top and bottom edges of the sides 1 and 2 so that they are 24 mm (1") in from the back edge. With this done the top and bottom, 5 and 6, may now be glued and screwed to the sides, 1 and 2. At this stage, the front and back should be dropped into the cabinet temporarily, to hold it square, and the assembly set aside to dry.

Before going any further, I think it pertinent to suggest the best method of drilling screw holes. First, the appropriate batten should be clamped in place, after having first marked out the screw positions. Drilling the screw holes is made simpler if a Stanley Screwmate for 2.5 cm (1") × No. 6 screws can be bought. This small, inexpensive device drills the pilot hole, counter bores for the shank and countersinks for the head all in one operation. If one is not available, you should drill a pilot hole of 2 mm right through both panel and batten, then remove the batten, and open up the hole in the panel to 3.5 mm to clear the screw shank. Finally, this hole should be lightly countersunk.

Once the assembly has been allowed to dry (preferably overnight), the battens for the front and rear to be fitted may now be glued and screwed into place. These should be cut to fit as precisely as possible, but as a guide, the vertical battens should be in the region of 28 cm (11") long, while the horizontal ones should be 17.6 cm (6.9") long. With these fitted, the back may now be glued and screwed into place, after which the assembly can be set aside to dry and attention given to the front baffle 4.

Fig. 7 shows both the front and rear views of the front baffle 4. With the holes drilled and cut. The baffle should, with care, be chamfered away on the rear as shown. With this done, the grille frame, Fig. 8, is marked off carefully from the baffle and the cut-outs made. There should be no gaps around the drive units when the grille frame is placed over them, and assuming this is correct, then the contours should be worked with a chisel, and finished with glass paper.

It will be necessary to reduce the sizes of grille frame in order to give clearance for the grille cloth. This will, of course, vary in accordance with the thickness of the grille cloth chosen and must be done to suit. With this done, a slight radius should be made on the edges of the grille frame in order not to damage the cloth.

On the subject of fixing the grille frames in the prototypes, they were not fixed but held in place by a *slightly* tight fit around the edge. While I am not claiming that this is perfection, it is quite suitable. If it is found that the grilles will not stay in place, or that a more secure fixing is required, a single strip of Velcro across the centre between units will solve the problem.

To date we should have a completed carcass ready for damping and final assembly. Next stage is drilling the holes in the back to fit the input sockets, Fig. 9. The reason for using simple 4 mm terminals is that when fitted they are air-tight, which may not be the case if input panels are used.

The bitumen panels should now be cut to fit closely in between the battens. The quoted number of pads are adequate for both speakers if the left over pieces are carefully pieced together. With the pads cut to size they should be glued in place with Aquaseal No. 5 *(no other adhesive is suitable)*, and tacked with a few panel pins to provide location while the glue dries. Before the pads are fixed to the rear of the enclosure, two holes should be cut to clear the input sockets and allow the nuts to be tightened; about 2.5 cm (1") square should suit.

Covering the enclosures

The prototypes were finished with cork tiles as visitors to our stands at the Harrogate and Cunard Hotel shows will have observed. There's a vast number of other finishes available, and a little ingenuity will find them. May I make a few suggestions? One of the many Formica-type laminates looks good, woven material such as hessian which is available in quite a few colours, or they may be painted; wallpaper could be used, particularly one of the vinyls; thin carpet can look very effective; or, if you prefer, a simple wood veneer – teak, oak, rosewood, walnut, etc.

A suitable glue must be used to fix the appropriate type of finish, however, and adhesives such as Evo-Stik Impact or Dunlop Thixofix are quite satisfactory for most applications.

With the cabinet out of the way, the remaining item to be finished is the grille frame. This should first be given a coat of black or dark brown stain so that it does not show through the cloth. As far as grille cloths are concerned, there's a wide choice of proprietary grille fabrics available. Lightweight polyester jersey is very good for this application. This is the fabric which is used on a great many commercial speakers, and is available from most department or material stores.

Fitting the grille cloth is quite simple and straightforward, and it should be cut so that it wraps around the frame by about 15 mm ($\frac{5}{8}$"). It may be fixed with either a contact adhesive or, if available, a staple gun. When fitted, it should be pulled reasonably tightly so that it does not sag, but don't over do it!

Final assembly

With all the component parts finished, final assembly can begin. Leads of about 30 cm (12") length should be soldered to the input terminals before fitting, as it is very awkward to do this with them *in situ*. The terminals should then be fitted and the nuts tightened. Leads, again of around 30 cm (12") long should be soldered to the crossover board for the drive units, along with the leads from the input terminals. The crossover board should now be securely screwed to the back of the enclosure.

The next operation is to put the BAF wadding inside the cabinet; one piece on the back, with the drive unit leads brought around it, the other piece wrapped around the sides of the enclosure.

I should, at this stage, emphasise the importance of the loudspeaker being airtight. Assuming that the enclosure has been properly made, with sound joints, there should be no problem in that region, but the fitting of the baffle and drive units can easily be suspect. To ensure that these areas are airtight, I have used Hermetite Instant Gasket to seal them, and this compound certainly does make a good seal.

The front baffle should be fitted to the enclosure using a bead of Instant Gasket, and screwed in place. The leads for the drive units may now be brought out through the holes and soldered in place. Another bead of Instant Gasket is now used around both drive units and these are screwed in place, using 2BA screws and 'T' nuts which must, of course, be fixed to the baffle before it is fitted.

With all this done, the grille frame may be fitted, and the job is complete.

Sweet music

If all is well, the speakers can now be connected up, and sweet music should waft through the air.

In conclusion, I think I should add a few cursory notes on the use of these loudspeakers. In order to achieve the response as shown, they should be placed clear of any reflective surfaces, but if more bass is desired, then they should be placed against a wall. A little experimenting will give the best location in *your* room.

With regard to drive requirements, amplifier power should ideally be around 40 watts, but from 20 watts up to 50 watts is quite suitable – or 15 watts of valve power is adequate!