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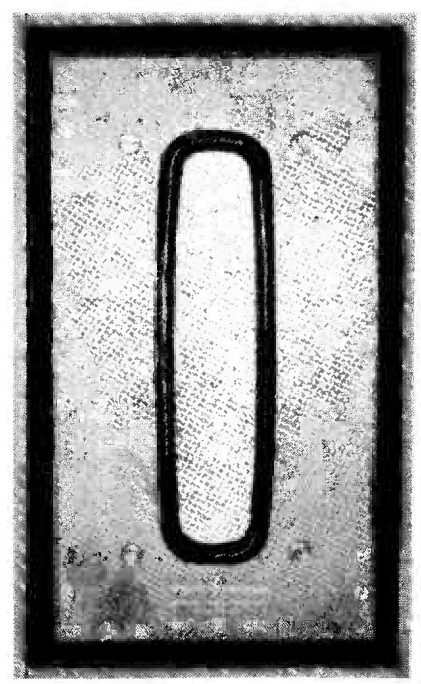
NOVEL LOUDSPEAKER DESIGN

Carl Pinfold has created quite a stir in the hi-fi world with his full-range, flat diaphragm loudspeakers. This article covers the design philosophy of both the drive units and their enclosure, and goes on to describe the construction of similar enclosures for use with these or any other small-cone-area drive units.

The majority of loudspeaker designs currently available use a number of separate drive units fed through a crossover so that each handles only a discrete portion of the audible frequency spectrum. There are a number of advantages with such an arrangement but there are also a number of drawbacks. Where only two drive units are used, the crossover frequency will be between 2.5 and 3.5 kHz, the frequency band in which the ear is at its most sensitive and discriminating. The cone diameter of the drivers can be matched to the wavelength of the frequency bands over which they are operating, but this leaves a tweeter of no more than 5 cm^2 diaphragm area to handle the band of frequencies which often contain the greatest power levels in music, further compounding the problems of crossover design. The use of drive units with conventional cone-shaped diaphragms generates further problems in itself. The frontal volume forms a resonant cavity which introduces megaphone-like colourations, while the limited speed of the sound through the cone material results in a phase lag between the inner and outer areas, causing the cone to 'break-up' and producing an irregular response.

In designing the Musician Loudspeaker drive unit, Carl Pinfold has attempted to overcome the limitations inherent in multiple drive unit systems using conventional cone loudspeakers by employing a single, full-range drive unit using a flat diaphragm. He argues that the use of a single drive unit rather than a multiple system with crossover makes a lot of sense with the present, almost universal, use of direct-coupled amplifiers since it preserves a high electrical damping factor. He goes on to suggest that a valid alternative to present design philosophies is to start with a good mid-range unit and then concentrate on extending its performance in the upper and lower octaves. This will lead to a sharper stereo image since the most crucial musical and spatial information is carried in the middle frequency range, and he believes the effect will be best achieved by making the sound source substantially narrower than the distance between human ears.

The result of his endeavours is a drive unit with a flat, 'lozenge shaped' diaphragm driven by a similarly elongated coil. The long thin shape fulfils the requirement that, when positioned vertically, the diaphragm is considerably narrower than the distance between human ears, and in addition it ensures that the diaphragm is fairly evenly driven since no part of its surface is more than 10 mm from the coil. The flat diaphragm does not have the stiffness of a



A Musician drive unit in an enclosure made of the cement-based inorganic plastic, NIMS 127.

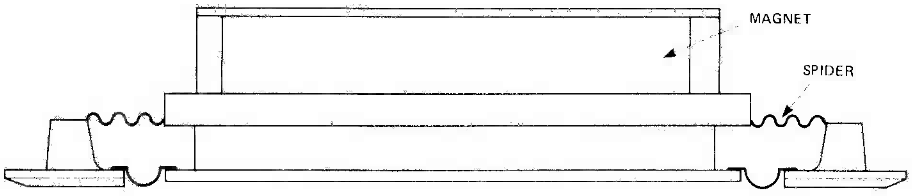


Fig. 1 Vertical cross-section through the Musician drive unit.

cone, but the more evenly-distributed drive overcomes this disadvantage to some extent, and the use of a stiff, lightweight, laminated plastic with a degree of self damping helps ensure that the inevitable flexing is not catastrophic.

The use of a large coil and relatively small diaphragm area does introduce certain limitations. Unless it is to make impossibly large excursions, a small diaphragm cannot produce high acoustic power levels. This prevents the unit delivering the power levels demanded by some heavy rock enthusiasts, but for most other tastes the sound level in a domestic room of average size should be satisfactory. The other limitation is the sensitivity. A low sensitivity is quite normal for small loudspeakers, and even with the substantial magnets used in the prototypes the sensitivity did not exceed 86 dB for 1 watt at 1 metre on axis. This simply means that the loudspeakers sould be driven by an amplifier offering in excess of 40 watts per channel, not an uncommon output level for a modern, high quality amplifier.

The Musician Loudspeaker, at the expense of introducing these minor limitations, has been designed to offer a sound which is largely free of colouration. There is little point, therefore, in mounting such a drive unit in a conventional resonant enclosure. There are two major sources of resonance in a loudspeaker enclosure, cavity resonance generated within the space and resonances set up within the panels of which the enclosure is constructed. Both of these sources have been considered and dealt with in arriving at a design which complements the low colouration of the drive units.

Considering first the question of cavity resonance, standing waves always occur in an enclosure which has flat, parallel

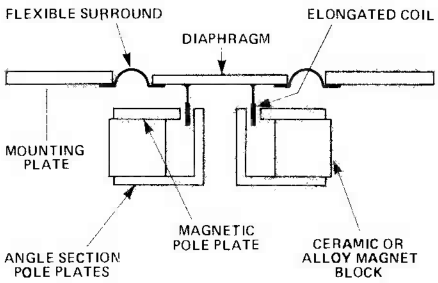


Fig. 2 Horizontal cross-section through the Musician drive unit.

interfacing surfaces. The wavelengths of the resulting resonances will be comparable to the distance between the faces.

Thus in a rectangular box 300 x 250 x 200 mm there will be resonances at approximately 1125, 1350 and 1700 Hz. Absorbent filling in the cavity will reduce these resonances but will not kill them altogether. The designers of musical instruments avoid the formation of standing waves by making their sound boxes in irregular shapes eg, the violin, the 'cello, the lute and the guitar. Reflections inside these soundboxes are so diffuse that standing waves cannot occur. An instrument with a rectangular sound box would produce some notes much more loudly than others.

It is inconvenient and impractical to house loudspeaker drive units in irregularly shaped enclosures but the same effect can be obtained by inserting an irregularly shaped object inside the cavity which similarly diffuses reflections between the inner surfaces. The 'sound splasher' used for this purpose is shown in Fig. 6 and simply consists of a number of lengths of square section timber glued together to form a spiral. BAF wadding is used in the normal way to fill the remainder of the cavity.

In a conventional box with mitred or butt jointed corners, each panel is rigidly held at all its edges and is readily excited into resonances, the frequencies of which will depend upon its mass, its stiffness and its dimensions. Again taking a lesson from the designers of musical instruments and noting that a piano string is damped by a resilient pad at one of its ends, the panels of the boxes are separated by a 1mm gap and fixed together with cork fillets, giving them a degree of acoustic independence and providing a small but useful amount of damping.

The enclosure material must also be carefully chosen if excessive resonance is to be avoided. The best materials are heavy and stiff, and concrete and sand filled panels are among those which have been tried. Glass, ceramics and heavy metal plate are all better than timber or common chipboard, and very good results have been obtained using large (300 x 200 x 8 mm) Italian ceramic floor tiles. The constructional techniques outlined above can be used with all these materials.

The material most favoured by Carl Pinfold is a cement-based inorganic plastic called NIMS 127 which has been developed by Professor Birchall working for ICI. Cement mortar normally has no tensile or compressive strength and is prone to crumbling, the result of having large spaces between its molecules. By mixing a polymer additive with simple cement, Professor Birchall has produced a material which has the strength of aluminium plate, can be readily machined, cast and extruded, and which can be produced in any colour simply by adding pigments into the mix. It is fireproof, waterproof and requires a minimum of energy in its manufacture, but its most attractive features from the loudspeaker designer's point of view are that it is both dense and stiff and hence acoustically very non-resonant. Unfortunately, this material is not yet available to the general public, so the enclosure design presented here is that of Carl Pinfold's 'Basic' enclosure which is constructed from Medium Density Fibre board. Ordinary particle board could also be used, but will not give quite such good results and will need to be at least 18mm thick.

The enclosure to be described is of the fully-sealed or 'infinite baffle' variety. It has been designed principally for use with the Musician drive units which have a free-air resonance at 42 Hz rising to a modest peak at 70 Hz when so enclosed. The peak is not pro-

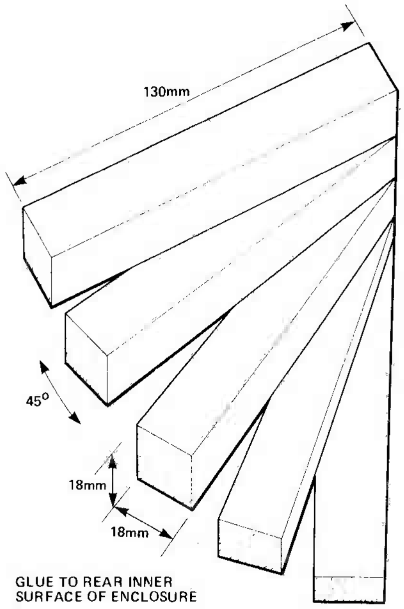
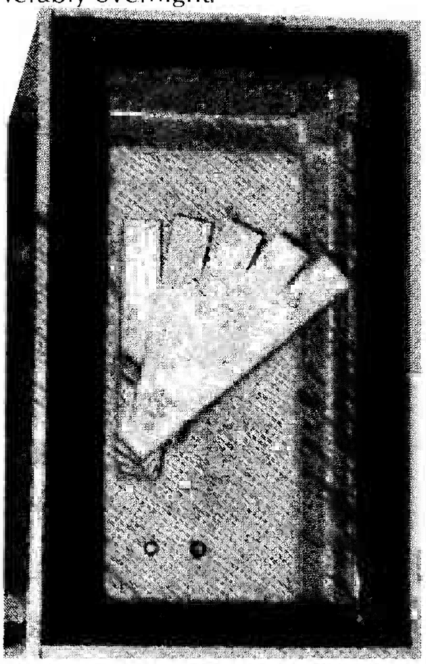


Fig. 6 The 'spasher'.

While the glue on the enclosure is drying, you can get on and produce the 'splasher'. As explained, this simply consists of five pieces of wood laid one-on-top-of-the-other at one end and staggered so as to form a spiral. You will need a clamp or a bench vice or some other means of holding the pieces in the correct position while the glue dries, although it should not be too difficult to devise another means of support if neither of these is available. As with the enclosure itself, the 'splasher' should be left to dry for a reasonably long time and preferably overnight.



Internal view of an enclosure made of NIMS 127 showing the cork fillets and the 'spasher'. The same construction is used for the MDF board version.

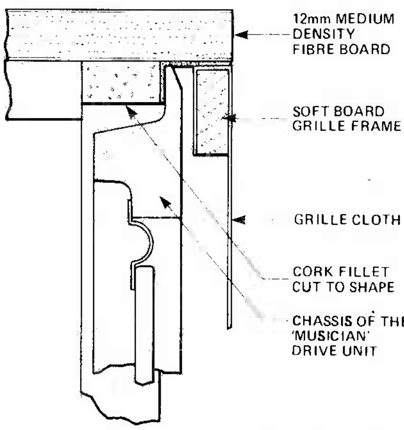


Fig. 7 Vertical cross-section through the enclosure with the Musician drive unit in position.

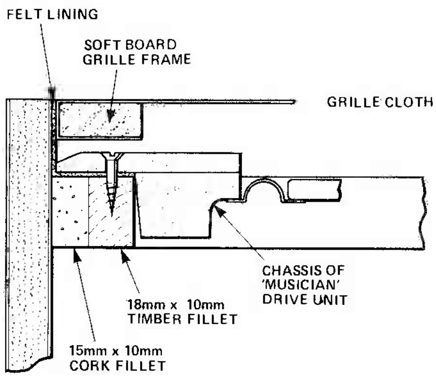


Fig. 8 Horizontal cross-section through the enclosure with the Musician drive unit in position.

When the glue on the enclosure is dry, remove the binding and then seal all of the inside joints with a flexible mastic sealant so as to make the final unit air tight. Depending upon the type of drive unit you are planning to use, identify the spot on the inside back panel directly opposite the driver coil and stick the 'splasher' down. The enclosure can be left on its back whilst the glue dries, but you will still need to tape the 'splasher' in place to stop it tipping over.

If you are using a drive unit other than the Musician loudspeaker, you can now glue the front panel into place. Remember to leave 1 mm gaps around the edges just as you have done with all the other panels. If you are using the Musician drive units, glue the two vertical timber pieces to the cork fillets at the front of the enclosure and support them in place until the glue is dry.

When the final glueing stage is over and the glue is dry, you can finish the exterior surfaces of the enclosure to your taste, either by staining the wood or painting it or by covering it with veneer or fabric. If you do cover the enclosure with something like veneer remember to expose the gaps between the panels and don't just cover over them. Stick a layer of felt to the inside faces of the front of the enclosure, and make up a simple wooden frame to hold the grille cloth. Provided you make the frame the right size, the cloth will bind against the felt and hold it in place and no other means of support will be necessary. The cloth itself should be as acoustically transparent as possible, and open-weave hessian or something similar is recommended.

The only tasks remaining are to install the drive unit and the input connectors and wire them up. Two 4 mm sockets are ideal as input connectors and only require two small (usually 5/16") holes. If you are using the Musician driver unit, position it within the front of the enclosure and line it up so that it is in the centre of the space. Six holes can then be drilled into the two vertical battens and wood screws used to hold the driver in place. If you are using any other drive unit you will have to devise your own mounting system but for obvious reasons you should avoid using a drive unit which can only be mounted from the rear of the panel. Finally, wire up the drive units to the terminals, loosely fill the cabinets with BAF wadding, secure the drive units in place and then sit back and enjoy them.

BUYLINES

Medium Density Fibre (MDF) board is widely available from DIY and timber shops, and if you don't have an old cork bathmat to hand you should have no trouble finding someone to sell you a new one. The BAF wadding and the hessian should both be available locally but if you encounter problems you could try Wilmslow Audio who certainly have the wadding and probably have a suitable grille cloth. The Musician drive units are available from Merseyside Acoustic Developments, Merseyside Innovation Centre, 131 Mount Pleasant, Liverpool L3 5TF, tel 051-709 0427, and cost £140.00 per pair inclusive of VAT, carriage and packing. If you don't feel like doing all the hard work but would still like a pair of Musician loudspeakers, they can be obtained from the same address and cost £240.00 inclusive in the 'Basic', MDF board enclosure and £320.00 inclusive in the NIMS 127 enclosures.

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