In the true tradition of our search for new technology, ETI's John Dix presents a novel way of enhancing the low frequency response of small speaker units.

'The enclosure has been designed to make construction as simple as possible'

QUARTER WAVE LOADING

Utilising the space within and under your speaker stands

In these enlightened days of CD, DAT and all that is silent at the source, there is proportionately less in the music budget to be spent on the loudspeakers. The loudspeaker systems manufacturers have concentrated on smaller enclosure designs to achieve a cost reduction with the minimum possible sacrifice in performance.

Although it is more difficult to maintain the low frequency response with a small enclosure, reducing the dimensions has a number of advantages. A significant increase in structural stiffness reduces unwanted radiation from the cabinet walls. The narrow frontal area also improves the sound distribution.

Larger loudspeaker systems have to be complex because a mid-range unit is needed, with careful integration of responses to cover the whole frequency range. In a smaller unit, a single bass/mid-range unit provides seamless coverage beyond the critical mid-frequency range, easing crossover design and producing a radiation pattern conducive to a natural spread of sound and a useful wide stereo sound stage.

However, if a small enclosure results in an abrupt roll off of bass level below 100 Hz, the bass lightness becomes readily apparent and there is, therefore, a limit to the economy feasible if a unit is to provide the reasonably long throw cone excursions necessary for adequately low frequency radiation.

Close proximity to a wall can give rise

to interfering standing wave patterns which deteriorate the stereo image. Having the speakers away from the wall, stably in space at a height such that the high frequencies are not absorbed by the sofa, gives an obvious improvement in depth and image precision.

Bearing all these points in mind it seems logical to consider whether the space within and under the speaker stands could not be used to enhance the low frequency response while maintaining a low cost, freestanding unit.

Design

A freestanding loudspeaker enclosure with similar dimensions to that of a small speaker on a stand, if of conventional design and construction, presents a difficult acoustic problem to the designer because of the long narrow parallel walls. These will tend to vibrate and resonate giving a resonant pipe-like colouration to the low frequency sound which is difficult to control and eliminate.

Another approach (satisfying from an acoustic engineering point of view) is to deliberately exploit the characteristics of a resonant pipe in such a way that the loudspeaker unit is correctly loaded and terminated at the low frequencies, while adequately suppressing unwanted pipe resonant modes.

The low frequency efficiency of such an arrangement is somewhat between that of a horn and a bass reflex enclosure and, therefore, reduces the demands made on the low frequency excursions of the small diaphragm bass speaker unit.

The principle involved utilises the properties of a closed at one end quarter wavelength pipe as originally proposed by Voight in his patent No 447749 and subsequently adapted and described by R. West and R. Baldock in their designs. The design produced by R. West was intended for a corner position with the speaker unit firing into the corner to spread the high frequency sound by reflection from the walls, and R. Baldock's designs were intended to either a semi-omnidirectional sound distribution or a wall reflected distribution.

Present day practice favours loudspeaker operation away from corners and walls, firing directly at the listeners.

The enclosure

The construction of the design is depicted at left. The bass enclosure consists of a quarter wavelength rectangular section pipe with a linear taper, resonant at about 50 Hz.

The bass loudspeaker unit is situated at approximately halfway along the acoustic axis in the best position to suppress higher order resonant modes. At resonance the acoustic pressure is high at the tapered end and still reasonably high at the loudspeaker unit. This ensures that effective acoustic loading is presented to the loudspeaker cone and small excursions of the cone at high pressure are manifested as much larger low pressure movements of air out of the port at the bottom of the enclosure.

Such a process, similar to horn loading, contributes to efficient bass frequency operation with low distortion up to a frequency of 200 Hz, where direct radiation from the cone takes over. The enhanced bass response produced by this method of loading compared with that from the same unit in a 10 litre sealed enclosure is shown in Figure 2, where the curves were obtained under identical measurement conditions.

This enclosure not only satisfies the requirements of being free-standing with the drive units at a convenient height but also provides an enhanced bass response, using the space that would otherwise have been taken up by a stand. Furthermore, only small cone excursions are required in the bass loaded region and this places the minimum of demands on linearity of the cone suspension and the magnetic field in the voice coil gap, allowing reasonably low priced drive units to be employed.

Continuing the quest for a low price design, it is tempting to consider a wide range twin cone unit for use in this enclosure. Figure 3 shows the high frequency response of a 165 mm diameter paper cone bass unit used in this position with considerable ripple in the response due to cone "break-up" modes. Unfortunately, when a small tweeter cone is added to the main cone to widen the frequency range, any improvement in frequency response is accompanied by main cone "break-up" ripple as shown in Figure 4.

A much smoother performer is the 165 mm polypropylene cone bass unit with a frequency response as shown in Figure 5 and this type is recommended for use in the quarter wave enclosure.

Because of the unsatisfactory response of twin cone units, space is provided in the top of the quarter wave enclosure to house a suitable tweeter.

Construction

The enclosure has been designed to make the construction as simple as possible and if the various pieces (see Figure 6) are cut accurately square than there should no difficulties in assembly.

Referring to Figure 7 it can be seen that there are only two angle cuts to be made, those at the top of both the long front and back panels. All the rest are simple 90° butt joints, and it is left to the individual constructor to decide whether to attempt the angle joints or simply butt the joints and fill the wedge shape gaps with whatever technique and material is convenient.

The dimensions quoted are not critical provided everything is checked to fit as shown in the diagrams so that airtight joints are obtained, particularly in the high acoustic pressure areas in the tapered wedge and around the speaker unit.

The front, back, bottom, top and internal partition members are all made of nominally 12 mm thick chipboard and should all be matched to the same width of 175 mm. The two side panels are made of nominally 6 mm thick plywood and it is recommended that one of the panels is marked out indicating where the 12 mm thick panels are located.

As the assembly progresses check it for squareness and, if necessary, secure

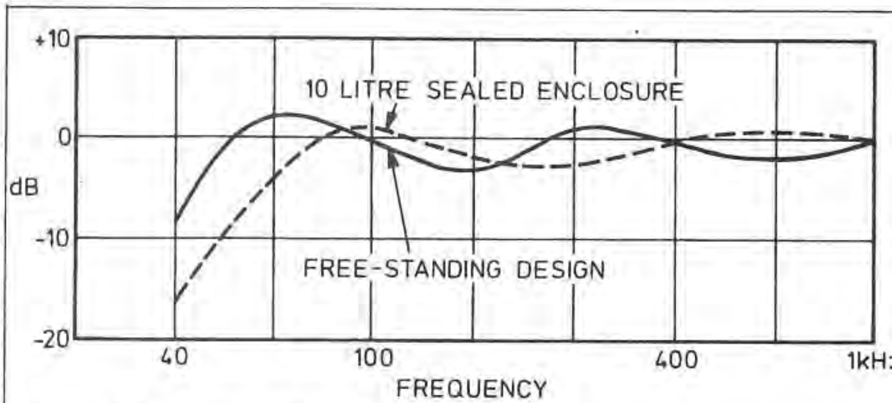

Figure 2: Comparison of bass performance.

one or two cross pieces of plywood with pins driven a little way in to hold the assembly square while the glue sets.

Being reasonably liberal with the glue should ensure airtight joints but pay particular attention to the pointed end of the wedge section and, if necessary, run a fillet of glue along this particular joint.

Finally complete the assembly by glueing and pinning the second 6 mm thick plywood panel into place. It will be noted that the enclosure is reasonably light and stiff and this minimises the energy storage in the enclosure walls. Tapping the sides of the enclosure produces different notes at different positions indicating that the internal bracing and asymmetry is working to minimise undesirable reflections and panel resonances.

Finishing tasks involve punching the pins home, filling and sanding prior to painting or covering with material or an iron-on veneer.

After several years experimenting with various drive units, the best solution — both in terms of cost and performance — seems to be the simplest of crossover arrangements with a direct connection to the bass unit and a capacitor feed to the tweeter.

The need for attentuation is avoided by choosing a sensitivity for the high frequency unit just below the bass unit. The speaker baffle is as small as possible for rigidity and minimum frontal area. The sloping of the baffle time-aligns the outputs from the two units, improves the coupling of the bass unit to the air column in the enclosure. It also exploits an improved smoothness in frequency response of the bass/mid frequency unit observed at this angle off its central axis rather than complicating the crossover.

The response

Figure 8 shows the combined anechoic response of the two units as derived from the manufacturer's quoted responses as a dotted line, with the in-room frequency response as a solid line (in-room measured using third octave noise with a calibrated mic at 0.9 m height). The responses show good integration and smoothness. A bonus of the simple crossover and small sloping baffle is an excellent off-axis response.

The modulus of the installed bass unit's impedance against frequency as shown in Figure 9. A resonance was detected at about 250 Hz but became inaudible with the insertion of damping material into the open end of the closed tapered section as indicated in Figure 1.

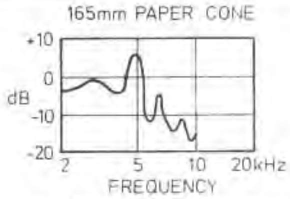

Figure 3: Frequency response of paper cone unit.

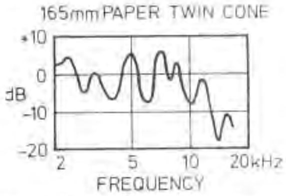

Figure 4: Frequency response of twin cone unit.

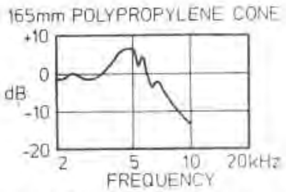

Figure 5: Frequency response of polypropylene cone unit.

The effect of the damping is also shown in Figure 9.

The damping material is a square metre of terylene wadding (from a dressmaker). It should weigh about 100 grams and is cut in two — a piece for each enclosure. Each piece is folded lengthwise in two and the resulting strip is folded again twice to form a 25 cm square, ready for insertion.

The loudspeaker units are mounted from the outside of the enclosure and the bass unit needs a sealing gasket cut out of a thin sheet of plastic foam or paper, depending on the surface finish of the baffle. Use chipboard screws and do not over tighten.

Electrical connections may be made to a connector block fastened just above the port. The bass speaker lead is simply passed down through the bass enclosure and out through the port while the tweeter lead is secured by clips down the back of the enclosure. The series capacitor supplied with the tweeter is a non-polarised elecrolytic and readers may wish to upgrade the performance by replacing this component by a better quality version. Readers may also wish to experiment with the provision of steel or plastic spikes in the base of the enclosure.

Performance

The present design is the result of many

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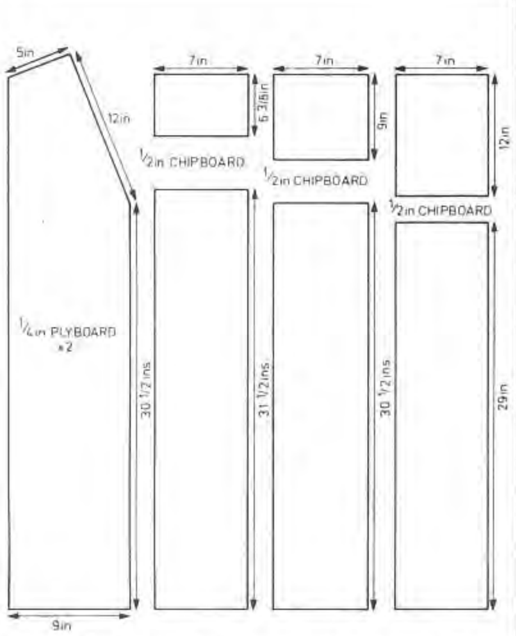

Figure 6: The cutting diagram for a single QWL loudspeaker (the baffle plate is also needed and is shown in Figure 7).

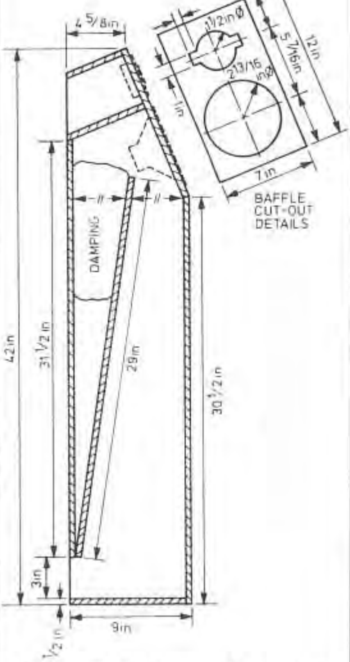

Figure 7: Enclosure dimensions and construction.

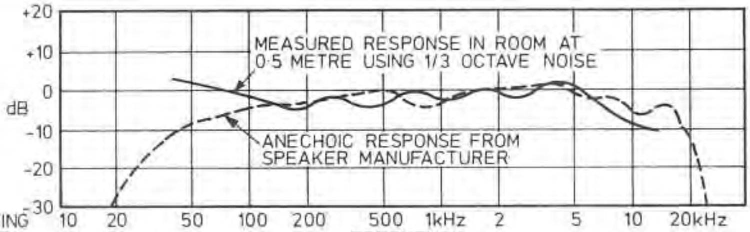

Figure 8: Frequency response of complete loudspeaker systems.

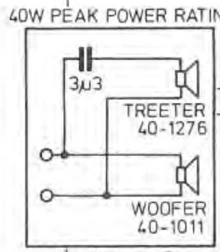

Figure 9: Off-axis response.

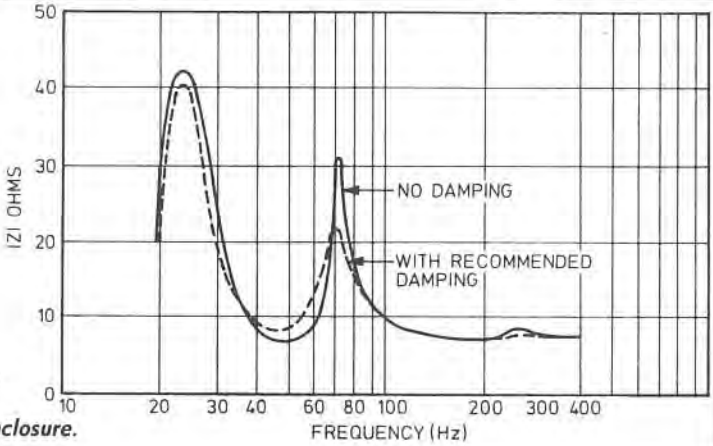

Figure 10: Bass loudspeaker impedance in enclosure.

hours of measurement and listening.

This QWL design is relatively cheap and easy to build but achieves a combination of good measured frequency response, stereo imaging, sound quality and efficiency. They occupy very little floor space, are easily moved and are the correct height to preclude the need for stands.

Happy listening.

The drivers used in this project are the Tandy 40-1011 and 40-1276.