# SATELLITE LOUDSPEAKERS

*This article deals with the satellite loudspeakers that complement the subwoofer featured elsewhere in this issue, to give complete coverage of the audio spectrum. These satellite are, however, also perfectly suitable for independent use.*

Satellite loudspeakers are not a separate category of sound reproducing equipment; any loudspeaker whose bass performance should be improved could be classified as a satellite. So-called bookcase speakers are invariably satellites, because their modest dimensions prohibit proper reproduction of frequencies below about 100 Hz.

If you are planning a new loudspeaker system, you could do worse than to opt for a subwoofer-satellites system. It is then, of course, best right from the start to design the satellites for optimum performance with the subwoofer and vice versa. It is on this basis that the present article has come about: the results are very satisfactory, indeed.

Even those who are not terribly interested in the subwoofer will find that the bass performance of the satellite speakers (−3 dB point at 65 Hz) is perfectly adequate for their requirements.

Although the design of a loudspeaker enclosure is never an easy task, the one proposed here presents the constructor with relatively few difficulties. This is, of course, largely due to there being no need of paying much attention to the bass reproduction. A response down to 100 Hz would be perfectly adequate; true, an octave further down would be very nice, but is, in this case, not necessary.

This immediately removes the problem of choosing the right shape and size of enclosure and deciding how many "ways" the system should have. The enclosure decided on is a normal closed box, while it was felt that a two-way system would be perfectly acceptable, provided that the chosen drive units would allow this. The latter aspect also requires less arithmetic and fewer measurements than, e.g., a three-way system.

These considerations have resulted in a very satisfactory practical realization, both as regards the enclosure and the number of drive units. As a bonus, the bass performance measured is considerable better than that aimed at. In short, the proposed design is compact, easy to build, not expensive, and, even without a subwoofer, gives an excellent overall performance.

## The drive units

As said, the design is based on two drive units. Since the majority of

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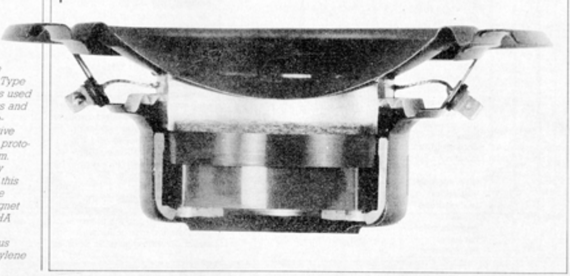

*Fig. 1. The Dynaudio Type 17W75 was used as the bass and middle frequency drive unit in the prototype system. Noteworthy aspects of this unit are the centre magnet and the PHA (phase homogenous area) propylene cone.*

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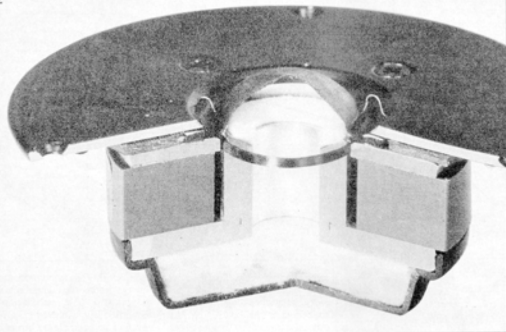

*Fig. 2. The tweeter is a Dynaudio Type D-28 AF, which was specially designed for use with 6 dB/octave cross-over filters.*

middle-frequency units are not really satisfactory above about 2000 to 2500 Hz, which causes problems in the choice of tweeter. Dynaudio units were used for the prototypes. These units did not only meet the requirements for the present design better than most; they also offer the advantage of an excellent match with the subwoofer (which also uses a Dynaudio drive unit). The units are the Type 17W75, a 170 mm bass and middle-frequency unit, and the Type D-28 AF tweeter.

The 17W75, shown in Fig. 1, is a drive unit with a relatively large voice coil (75 mm) in hexacoil technique, which, in conjunction with the unusual shape of the one-piece cone, gives an ideal transfer of the acceleration force from the coil to the PHA (phase homogeneous area) cone. Another advantage of the big voice coil is the short rise time (fast transient response) of 50 μs. Very low distortion and excellent phase characteristics are a result of the total concave shape of the cone.

The D-28 AF, shown in Fig. 2, is a 28 mm soft dome tweeter. The voice coil is coupled with the aid of ferro fluid. The unit has a noteworthy fast transient response (short rise time) of 12 μs. It offers the great advantage of having been designed specifically for use with 6 dB/octave filters: not many dome tweeters have!

## Cross-over filter

Cross-over filters (or networks) are, unfortunately, necessary, because there is not a drive unit that can reproduce the entire audio range satisfactorily. As long as these filters are not to steep-skirted, they do not cause too much harm, but with increasing skirt steepness the flaws they introduce become more and more serious. Steep-skirted filters have particularly bad transient response characteristics.

The design of a cross-over network should therefore be based on 6 dB/octave slopes, provided the drive units used allow this. This is so in the present design as can be seen from the diagram in Fig. 3. Strictly speaking, this circuit contains only two true filter components: $L_1$ and C2. The remainder of the components perform the correcting functions that are always necessary for good filter operation. Network $R_1$-$C_1$ serves to counteract the impedance of the 17W75, which increases with rising frequency. This carefully designed network ensures that the overall impedance of the drive unit remains constant above its resonance frequency. Only because of this can the filter perform as required.

Resistive divider $R_2$-$R_3$ serves a twofold function. In the first place, it ensures level matching of the tweeter, whose efficiency is somewhat higher than that of the 17W75. Then, the value of $R_2$ may be varied between zero ohms and 2.2 ohms without the necessity of changing the value of C. A value of 0 ohms corresponds to a 0.5 dB correction for the tweeter, while 2.2 ohms gives a −1.5 dB correction. Moreover, $R_3$ smoothes out a small uneveness in the tweeter characteristic: its value must, therefore, not be changed under any circumstances.

The characteristic in Fig. 4 represents the output voltage of the filter, measured across the two drive units. Note that the cross-over point only appears to be at −5 dB; it is actually at the customary −3 dB. The characteristic of the 17W75 has a slight peak at the cross-over frequency, and this has been corrected by a slightly earlier action of the filter. Acoustically, everything is, therefore, as it should be.

Construction of the filter should not give any difficulties if the PCB (Type 86016) shown in Fig. 5 is used. Note, however, that $L_1$ should be fastened with glue or a brass/nylon bolt: a

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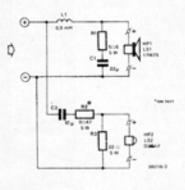


*Fig. 3. The 6 dB/octave cross-over network is typified by its simplicity.*

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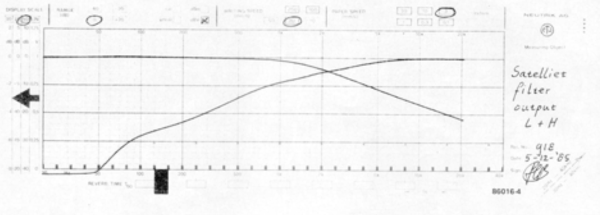


*Fig. 4. Characteristic curve of the output voltage of the cross-over filter measured with the drive units connected.*

*Fig. 5. The printed-circuit board for the cross-over network (Type 86016 — available through our Readers' Services).*

**Parts list**

$L_1$ = 0.5 mH air-cored inductor; wire diameter 1 mm
$C_1$ = 22 μ bipolar electrolytic or polyester
$C_2$ = 10 μ polyester
$R_1$ = 5 Ω5 W
$R_2$ = 0.47 Ω5 W
$R_3$ = 22 Ω5 W
Dynaudio Type 17W75 drive unit
Dynaudio Type D-28 AF drive unit
chip board or plywood, 18 mm thick, as required (see Fig. 6)
about 0.25 m² rubber-backed floor covering
about 0.25 m² rock-wool
1 variovent; 110 mm; (Dynaudio)
connector terminals as required
wood glue, screws, and nails as required

steel fastening would affect the value of the inductor. Also, observe correct polarity when the drive units are connected to the board. The PCB may be conveniently mounted —on spacers— on the bottom lid or against the back panel of the enclosure.

## The enclosure

According to the manufacturer's data, the 17W75 is best housed in a 10 to 15 litre closed box, which has been provided with a so-called variovent (acoustic resistance). Although theoretical considerations point to a somewhat larger volume, in practice the manufacturer's recommendations proved to be correct. In a damped closed box of exactly 10 litres volume, the bass performance of the 17W75 was surprisingly good. The difference between a box with, and one without, a variovent is slight. The variovent only serves to attenuate the resonance peak, and this results in a somewhat more rigid performance at low frequencies.

Although some photographs accompanying this article show a beautifully styled pentagonal, pyramid-shaped prototype enclosure (courtesy Dynaudio), the proposed enclosure has been kept rather simpler. Note, however, that the pentagonal enclosure is available from Dynaudio as a kit: it is acoustically excellent, but quite difficult to build. Our own proposal, shown in Fig. 6, offers similar advantages as the Dynaudio design: no parallel side panels; leaning backwards; upward tapering front panel; but does not demand the craft of a furniture maker.

The material is 18 mm fine-chip board; plywood may, of course, also be used, but is rather more expensive. The front, back, and side panels have exactly the same dimensions. If these are sawn very carefully, all four can be glued together in one go. The bottom and top lid must be sawn very carefully to ensure a good, tight fit onto the leaning vertical panels. The top lid may be glued in place, but the bottom panel is best fitted with screws and sealing tape so that access is possible at a later stage, if required. Next, the holes for the drive units, the variovent, and the connector terminals should be cut. The variovent should be glued into

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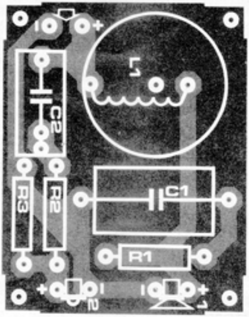

**Technical characteristics**

| | |
|---|---|
| System | passive; two-way |
| Enclosure | closed box |
| Net volume | about 10 litres |
| Cross-over filter | 6 dB/octave; cross-over point at about 2500 Hz |
| Frequency range | −3 dB points at 60 Hz and 20 kHz |
| Amplifier rating | 30-100 watts |
| Sensitivity | 89 dB |

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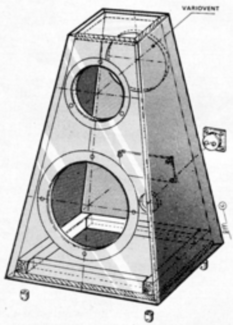


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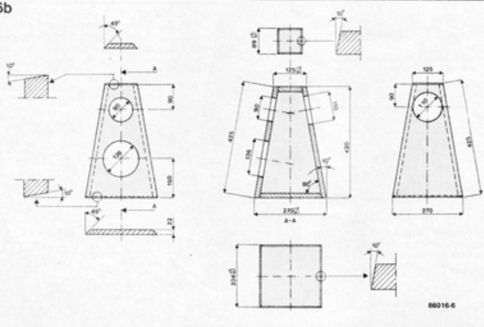


*Fig. 6. Construction details of the proposed enclosure. The material may be 18 mm plywood or good quality chip board.*

place, while the drive units should be screwed on. Afterwards, the gap between the rim of the drive units and the front panel should be sealed with suitable tape.

The beste place to fit the cross-over filter is at the back panel between the variovent and the connector terminals.

Panel resonance is further prevented by gluing strips of rubber-backed floor covering at the inside of all panels and then covering these with 30 mm thick rock-wool. If this material is amply cut, the strips will be push-fitt, obviating the need for gluing them into place.

The finish of the exterior of the enclosure is left to your own taste and preference.

## Performance

It is, of course, easy (and tempting) for a designer to sing his own praises, so the performance of the system can be gauged from the measured impedance and frequency response characteristics illustrated in Figures 7 and 8 respectively. The smooth impedance curve should not present any problems to a good output amplifier. The frequency response curve was measured with $R_2 = 0.47$ ohms. When this is increased to 2.2 ohms, the characteristic shifts down by about 2 dB above 2 kHz. Response at low frequencies was ascertained by close-proximity (20 mm) measure-

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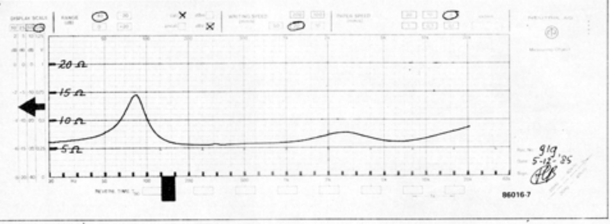


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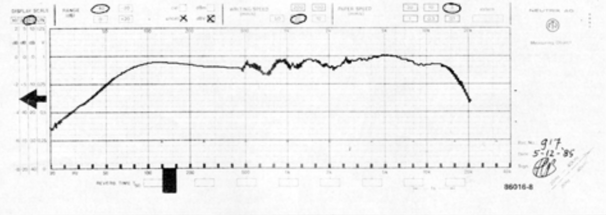


*Fig 7. Characteristic impedance curve of the completed satellite system.*

*Fig. 8. Frequency response curve of the completed satellite system.*

ments. The acoustics of the test room has such an effect that measurements at greater distances give no meaningful information as to the behaviour of the system at low frequencies. For measurements at middle and high frequencies, the test microphone was placed at a distance of about 2 metres at roughly the height of the acoustic centre of the enclosure.