surround-sound subwoofer

part 1

Most surround-sound installations use loudspeaker boxes of modest dimensions so as to avoid making them too obtrusive for the usual living room. The consequence of this is a limited bass response, whereas especially the low frequencies can provide impressive effects with a good surround-sound system. To counter this drawback, the bass response can be enhanced with the subwoofer described in this three-part article.

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Surround sound, the popular audio craze of the past few years, can provide an impressive combination of sound and picture when it is used in conjunction with a TV set. Good-quality spatial sound is provided by a number of loudspeakers (usually five) located in front of and behind the listener(s). Five loudspeakers present a problem, of course, in that they take up a lot of space in the average living room. To keep the space occupied by them to a minimum, the loudspeakers are often fairly small. Moreover, in economy-price systems, cost is important, too, and this also tends to keep the boxes small.

Unfortunately, small loudspeaker boxes are detrimental to good bass reproduction. On the surface, this may not seem such a terrible thing in an audio-visual system until it is realized that the low frequencies contain spatial information. Moreover, we perceive low frequencies not only via our ears, but also through our entire body and this causes good low-frequency reproduction to give that added feeling of reality to the sound. All this makes it clear that the importance of low frequencies must not be underestimated.

The reproduction of low frequencies requires the displacement of large volumes of air. This in turn means that a large low-frequency drive unit (woofer) should be used. But such a unit must be contained in a large enclosure to enable it to reproduce low frequencies effectively. And this is where the crux of the matter is: most living rooms just do not have the space for such a large box.

In the subwoofer described in this article an attempt has been made to find a compromise between the contradictory requirements just outlined. It uses a large (300 mm) drive unit

Technical data

Drive unit	*300 mm (8 in), e.g. Monacor (SPH-300TC); KEF; Radio Shack (40-1024); Parts Express (295-240)*
Dimensions of box	*660×406×420 mm (26×16×16 9⁄16 in) incl. legs*
Volume of box	*about 65 l net*
Type of box	*bass reflex*
Nominal impedance	*8 Ω per channel*
Efficiency	*88 dB W^{-1} m^{-1}*
Frequency range	*45–105 Hz*
Loading	*max 250 W per channel*

housed in a modestly-sized enclosure of 65 *l*. The enclosure is designed in the form of a side table with the drive unit fitted between the legs so as to make it (virtually) invisible. The volume of the enclosure is not really large enough for very low frequency reproduction, but a solution for this will be published in next month's instalment. This consists of an active correction network and associated amplifier that bring the –3 dB point down to 20 Hz. This article describes the passive version of the subwoofer which can be used without any difficulties with existing apparatus. Its frequency range extends from about 45 Hz to 105 Hz. The upper frequency and the efficiency of the unit provide a good match with the (smaller) front loudspeakers.

Although so far reference has been made only to a surround-sound system, the subwoofer may, of course, also be used with a standard stereo sound system.

The (passive) design

The design is based on a 300 mm (8 in) Monacor SPH-300TC drive unit, but other makes, such as KEF, Radio Shack (40-1024), or Parts Express (295-240) should give good performance as well. The SPH-300TC is a relatively inexpensive unit with a fairly large magnet that displaces a volume of around 0.2 *l*. Its parameters make it suitable for use in a bass reflex enclosure.

If the loudspeaker is to be used with a stereo system, it should have connections for both channels. This means that either two drive units or a drive unit with dual voice coil should be used. Each voice coil is connected to one of the channels via a suitable filter. The present design uses the latter solution, since the use of two drive units would make the box unnecessarily large.

The alignment of the enclosure is determined with the simulation program Boxcalc, and aims to arrive at a compromise between a (relatively) small volume and a low –3 dB point. This results in a 65 *l* box with the pipe (acoustical resonator) tuned to 23 Hz. The overall frequency response is shown in **Fig. 1**. The –3 dB point is at 45 Hz, which, considering the small box volume, is pretty good. The –3 dB point is low enough to allow the subwoofer to be used as a passive unit with most existing systems.

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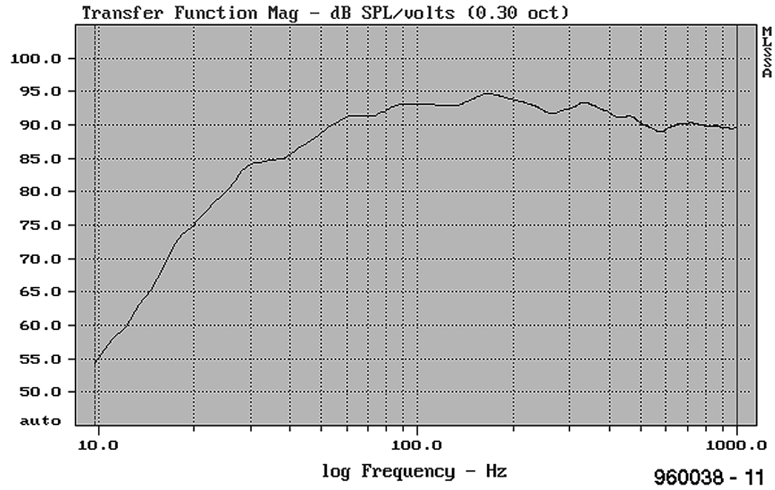

Fig. 1. The frequency response curve of the SPH-300TC in a 65 l bass reflex enclosure tuned to 23 Hz.

The filter

Since the design aims at keeping the costs as low as feasible, the (passive) filter has been kept as simple as possible, which, in the case of a subwoofer, is not as easy as it may seem.

The impedance characteristic of the drive unit is shown in **Fig. 2**. The two voice coils are connected in parallel to obtain a reliable curve (which means that for each coil double the impedance value must be taken). The curve shows two peaks. The lower one at about 10 Hz results from the bass reflex alignment (which, by the way, is exactly in line with the 23 Hz resonator). The second peak, just above 50 Hz, is caused by the resonance frequency of the drive unit in the box.

Normally, filtering of a subwoofer starts at around 100 Hz or slightly lower to ensure good matching with the standard stereo loudspeakers. A passive filter, however, has the drawback that it functions properly only if it is terminated into a pure resistance. If the cut-off point were chosen at 100 Hz, the 52 Hz peak would create a problem: the resulting overall curve of a theoretically computed filter would not be usable. To solve this problem, the impedance curve of the drive unit has to be corrected. This is often effected by connecting parallel across its terminals (for each channel) an *RLC* network with the same resonant frequency. Unfortunately, at such low frequencies, the values of the necessary inductors and capacitors are such that they result in physically large (and expensive) components.

The solution in the present design consists simply of shunting the voice coil with a resistor. This does not totally eradicate the peaks, but

Fig. 2. The impedance curve when the two voice coils are in parallel. The high peak poses a problem for the passive filter.

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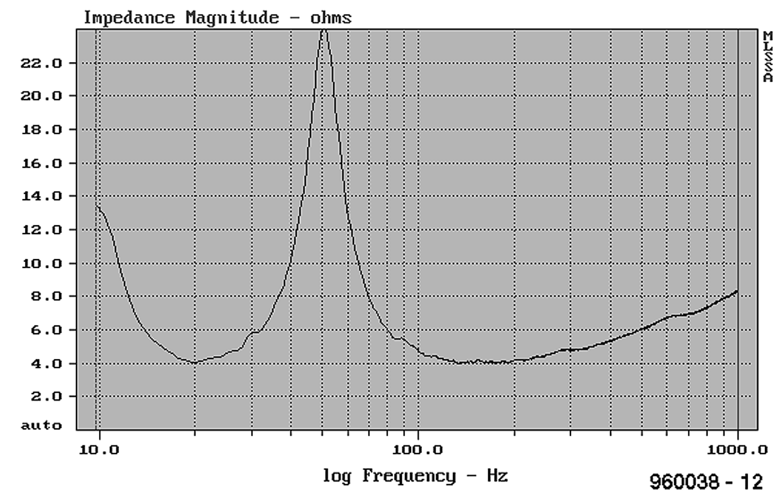

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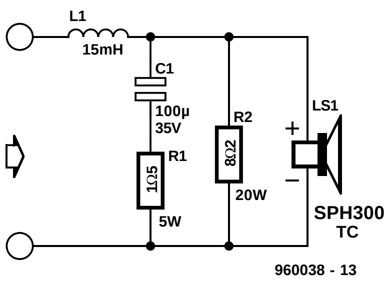

Fig. 3. The filter has been kept simple. Resistor R2 corrects the impedance curve. Inductor L1 and capacitor C1 provide a slope of 12 dB per octave and a high cut-off point at about 105 Hz.

flattens them sufficiently to enable a simulation program—Calsod—correcting the filter such that its frequency response is close to requirements.

To keep the number of components small, the filter is a second-order type consisting of conductor L_1 and capacitor C_1 (see **Fig. 3**). The resistor in series with the capacitor damps the *LC* circuit to some extent. The effect of the filter is shown in **Fig. 4**. Although the high cut-off point is about 105 Hz, the response will ensure a good match to most small loudspeakers.

Building the box

The prototype box is made from 28 mm thick medium-density chipboard (MDF), but, as in some cases it may not be possible to obtain this, 22 mm thick chipboard may be used (note that the dimensions in **Fig. 5** must then be adapted as appropriate). The box consists of six rectangular sheets and a stiffening crosspiece which are firmly fixed together with a suitable heavy-duty glue.

At one side are the apertures for the drive unit and acoustical resonator. The resonator consists of a 365 mm long piece of 80 mm dia. PVC pipe available from a builders merchant.

The four banana sockets for connecting the cables from the amplifier are fitted at the bottom of the one of the side panels.

The box is designed to rest on four 50 mm high legs with the drive unit fitted at the bottom facing the floor of the living room.

After the glue has dried thoroughly and the material has been sand-papered, the box can be given a final coat to individual taste.

The box is half filled (up to the cross piece) with suitable loudspeaker wadding, but take care that the opening of the pipe remains reasonably free of it.

The filter components are available from a specialist audio/hi-fi retailer or a good electronics shop. The inductor is a 15 mH type with a 56 mm ferrite core, preferably an HQ56 from IT. The capacitor is a bipolar type with smooth terminals.

The filter components may be glued to a small sheet of wood,chipboard, or prototyping board and then wired together. Note that some retailers stock general-purpose filter boards.

Screw the completed filter into the box and wire it up as shown. Take care not to interchange the plus and minus connections to the two channels. The cables to the drive unit must be terminated into cable clips to avoid the necessity of having to solder to the drive unit terminals.

Place the resonator in position, make the connections to the drive unit (make sure that the connections to the + terminals match, otherwise the drive unit does not work). Finally, place a strip of draught-excluding tape under the rim of the drive unit and screw the unit to the box.

Some constructors (or their wives) may find it aesthetically pleasing to place a sheet of glass, marble or similar material on top of the box to give it the look of a side table.

The passive subwoofer is then ready for use. It may be connected in parallel with the existing stereo speakers. It will work most satisfactorily when its efficiency of about 88 dB W^{-1} m^{-1} corresponds roughly to that of the existing loudspeakers and it is placed in close proximity to these. Note that if you want the active version, which will be described next month, you do not need the passive filter; the box remains the same.

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Fig. 4. The frequency response of the loudspeaker and filter combination. It ensures correct matching to most smaller stereo loudspeakers.

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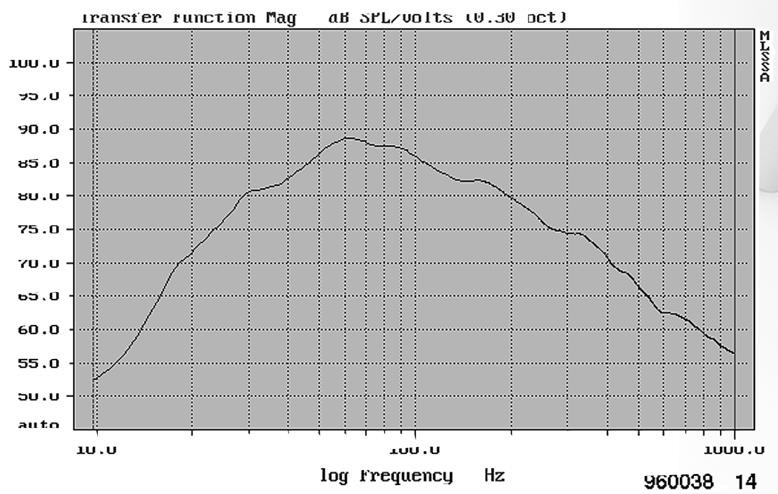

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Drive unit revisited

During the design of the loudspeaker, a thorough search was made for a 300 mm drive unit at a reasonable price (to keep total costs down to not more than £ 80–90). Of course, such an economy-price unit cannot be expected to be perfect. And, indeed, in the testing of the SPH-300TC unit, it appeared that the parameters stated by the manufacturer did not agree with our own measurements. Fortunately, the deviations were beneficial to the box dimensions. Also, there was a kind of rustling noise at large cone movements. This was suspected in the first instance to be caused by a loose cone or air leak, but a second example exhibited exactly the same noise. A detailed investigation showed that the dust hood in the cone (the convex cap that closes the upper side of the cone) was the culprit. Its material is fairly soft, so that at large cone movements it begins to vibrate at its own (higher) frequency and thus causes the rustling noise. This deficiency is easily negated by spraying the dust hood a couple of times with a suitable plastic spray or applying a few layers of a suitable cone impregnator. This makes the cap more rigid so that it is not set into vibration at large cone movements.
The Parts Express unit appears to be rather more rugged than the Radio Shack and is rather cheaper.

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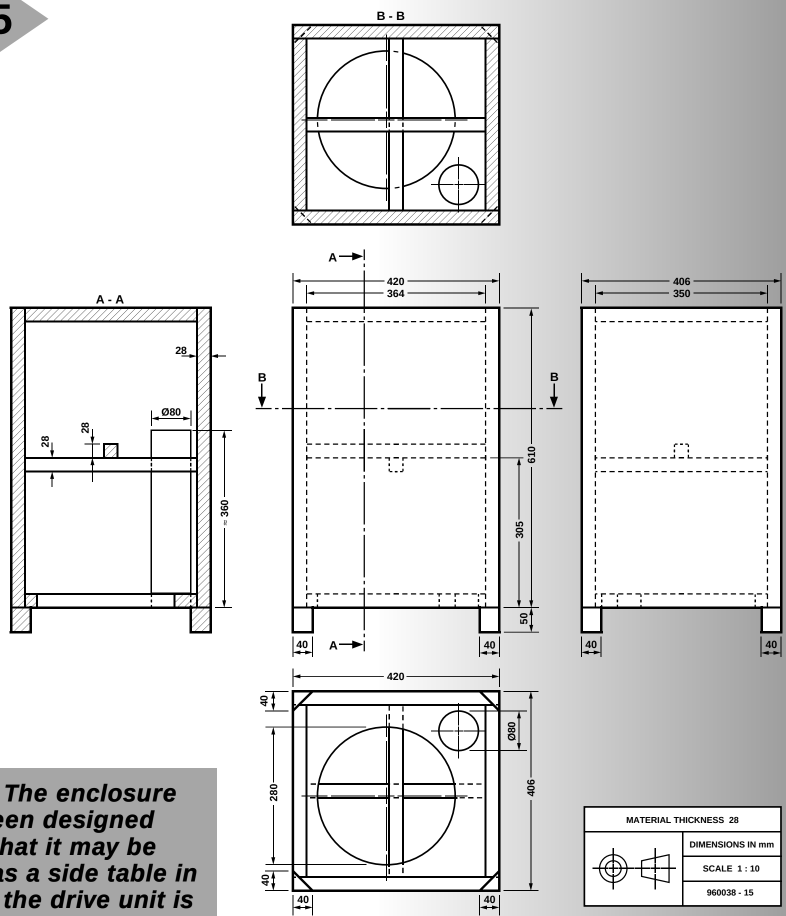

Fig. 5. The enclosure has been designed such that it may be used as a side table in which the drive unit is not (or hardly) visible.