Project 496

Series 4000 four-way loudspeaker

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This project is the first in a series of loudspeaker projects designed to complement our Series 4000 range of quality hi-fi projects.

LOUDSPEAKERS still remain the weakest link in the hi-fi chain and the total sound of any system will depend more on the loudspeakers than any other single hi-fi component. So it is important to get the best loudspeakers, even if this means accepting a slightly lower performance amplifier or turntable. In most systems the performance of the cartridge, turntable and amplifier greatly exceeds that of the loudspeakers so an improvement in the loudspeaker department will often yield a radically improved system.

Unfortunately, there are very few really good kit loudspeakers. This project is an attempt to rectify that situation by providing a loudspeaker suitable for home construction that rates amongst the best available. This is not an inexpensive project – the driver and crossover cost being around $400 – but the finished project will rival commercial units at three times the price.

Choosing the drivers

In order to build a good loudspeaker it is obviously important to use good drivers, but availability is just as important a criterion as performance. For this reason we had a close look at the drivers commonly available in Australia and finally decided to use drivers from the huge range of Philips loudspeakers, some of which were not available in this country at that time. Philips agreed to stock the drivers we decided on and these form the basis of the 4000 series of loudspeakers.

The 4000/1 is a four-way sealed enclosure loudspeaker using 12 dB/octave crossover slopes. The original design for our prototype used an 18 dB/octave M-derived crossover (see 'Principles and problems in loudspeaker design' in last month's and this month's issues) but it was enormously expensive and complex and would have contributed little to the overall sound finally achieved with the 12 dB/octave crossover. The four-way approach allows closer control over the final frequency response than does a three-way. More importantly a major part of the mid-range normally handled by the woofer can be dedicated to a separate mid-range driver. The basic design idea was to use the woofer only up to 150 Hz. A separate mid-range driver would then take over up to 750 Hz where a second mid-range would come in. The lower mid-range driver, crossing in at 150 Hz needs a usable response down to around 60 Hz (i.e. one octave) so that the crossover region will have a reasonably flat response. Similarly, the woofer crossing out at 150 Hz needs to have a usable response to at least 300 Hz.

After a great deal of testing it was finally decided to use the Philips AD12250/W8 unit for the woofer. This is a 100 watt driver with a free air resonance of 26 Hz. When mounted in the enclosure the fundamental resonance rises to around 31 Hz, an excellent figure. This driver seems to have a bad hole in its response at 350 Hz but this is unimportant in this loudspeaker.

The AD70601/W8 unit was chosen as the lower mid-range as it has a free air resonant frequency at 45 Hz. This driver is actually a woofer and does not have the integral sealed enclosure common to many mid-range drivers. The enclosure must be provided by the cabinet construction and the volume chosen in the 4000/1 increases the 45 Hz fundamental resonance of this driver to around 55 Hz, which is ample.

The response between 750 Hz and 3 kHz, where the tweeter takes over, is handled by the latest Philips dome (AD02161/SQ8) mid-range. This driver has a 50 mm textile dome giving a good frequency response and wide dispersion at higher mid-range frequencies.

Above 3 kHz the AD01610/T8 tweeter is used. We tested a large range of Philips tweeters and this was the best, followed closely by the AD01605/T8, which suffered a little from roll-off of the frequencies above 10 kHz.

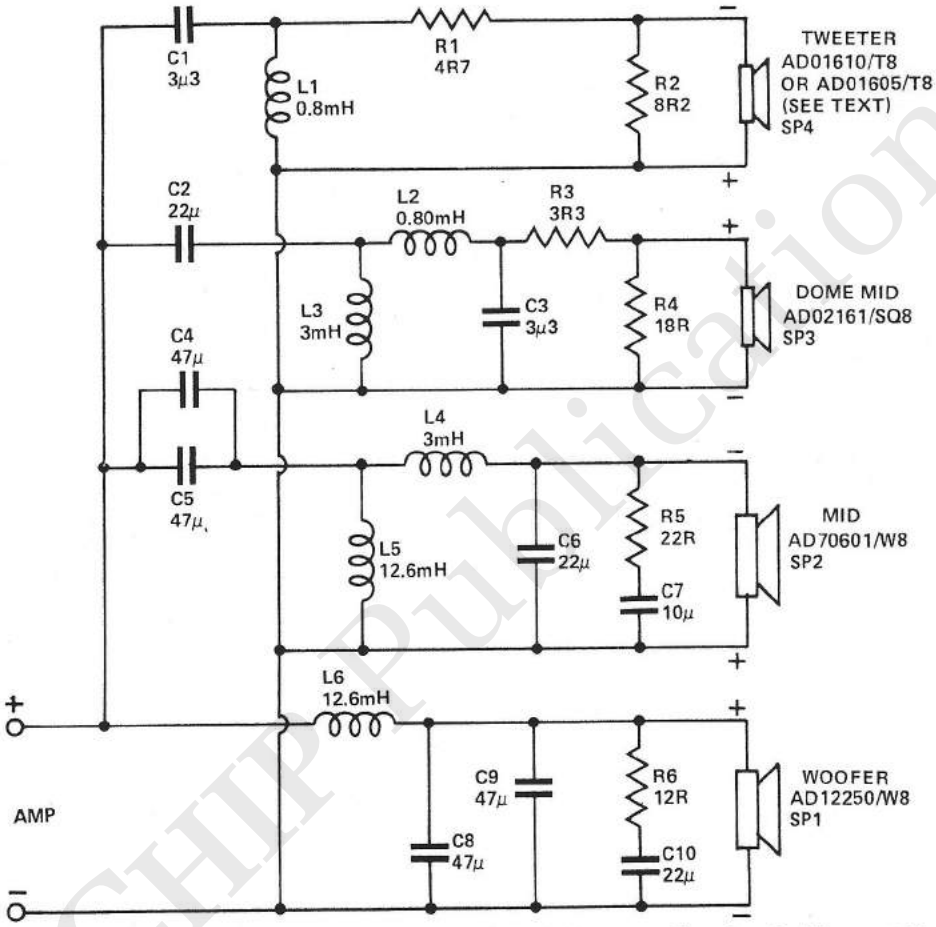
The 4000/1 loudspeaker, without the front grille, showing the drivers. It stands about one metre tall.

Construction

If you are constructing the boxes yourself start by assembling the sides, top, bottom and back of the cabinet. The bottom panel is placed 100 mm above the bottom of the box and the cavity formed under the box can be used to mount the crossover instead of putting it inside the box as is the usual practice. Now insert the two pieces of timber that form the mid-range enclosure. It is essential that there is a perfect seal between the bass and mid-range chambers, as well as between these two chambers and the outside air. Line every joint carefully with caulking compound

HOW IT WORKS.

The input signal from the output of the amplifier is fed to the 4 way crossover that divides the signal into the different frequency bands covered by each of the drivers. The loudspeaker cabinet is divided into two sections, the larger one forming the bass chamber for the woofer and the smaller one forming the midrange chamber. These two chambers are sealed from each other so that interactions cannot occur between the back radiations of the woofer and lower midrange. The other two drivers have their own enclosures as an integral part of the driver. For a detailed account of the design approach and the problems that occur in loudspeaker design read 'Principles and problems in loudspeaker design' in this month's and last month's issues.



Circuit diagram for the four-way system. Driver polarity is important. Note that the "dome mid" driver, AD02161/SQ8, is available in two models, the other being AD02160/SQ8, which is different in appearance but electrically equivalent.

or glue so that no possibility of an air leak exists. This is probably the best stage of the construction to drill the holes for the wiring to the loudspeakers. I used two cores of 240 volt three-core mains cable for this purpose, mainly because a round hole could be drilled and the cable squeezed through it to make a reasonable seal. Three holes need to be drilled in the bottom of the midrange chamber to allow for cables for the two midrange drivers and the tweeter. Cut suitable lengths of 240 V mains cable and insert these through the holes. Seal between the cables and the holes with sealing compound or a glue like Silastic. If the crossover is to be mounted under the loudspeaker, drill four holes through the bottom of the box and run the cables exactly as with the mid-range enclosure. Drill the holes so that they are closer to the rear of the box to allow ample room for mounting of the crossover. The input terminals should be mounted on the back of the enclosure, below the bottom panel if the crossover is mounted under the loudspeaker.

It is not necessary to have the front baffle removable since the drivers are external mounting types. It is probably easier to cut the holes for the drivers before mounting the baffle onto the front of the cabinet. The base panel and midrange enclosure panel should have been cut so that 38 mm remains between these and the front edge of the side and top panels. When the front panel is fitted, 19 mm should remain between the front of the baffle and the front edge of the sides and top. This space will be taken up by the grill cloth frame. Seal the remaining joints between the front baffle and the rest of the box. The only remaining part of the box construction is to attach the small 100 mm high wooden panel to the bottom of the box. The front grill is made by constructing a rectangular frame that fits into the remaining cavity on the front of the baffle. Stretch the grill cloth (use proper speaker grill material to avoid absorption of the treble) tightly over the frame.

If you have purchased a kit of ready made boxes it will still be necessary to drill the holes for the cables and to seal the box thoroughly with some sealing compound. If the slightest leak exists between the bass and mid-range chambers the large pressure increases created in the bass chamber will force the mid-range to vibrate, causing distortion.

The last stage before mounting the drivers is to line the box with 25 mm thick loudspeaker innerbond. Line the back, sides, top and bottom of both the bass and mid-range chambers. Attach the innerbond firmly to the sides of the box using tacks or thin nails and glue.

The tweeter and dome mid-range drivers are supplied with mounting washers so that good seals can be made between the drivers and the baffle. Use adhesive foam tape available from most hardware stores, to make a good seal around the lower mid-range unit and the woofer. Stick the tape to the front of the baffle around the edge of the holes cut for the woofer and mid-range so that when the drivers are mounted a good seal results.

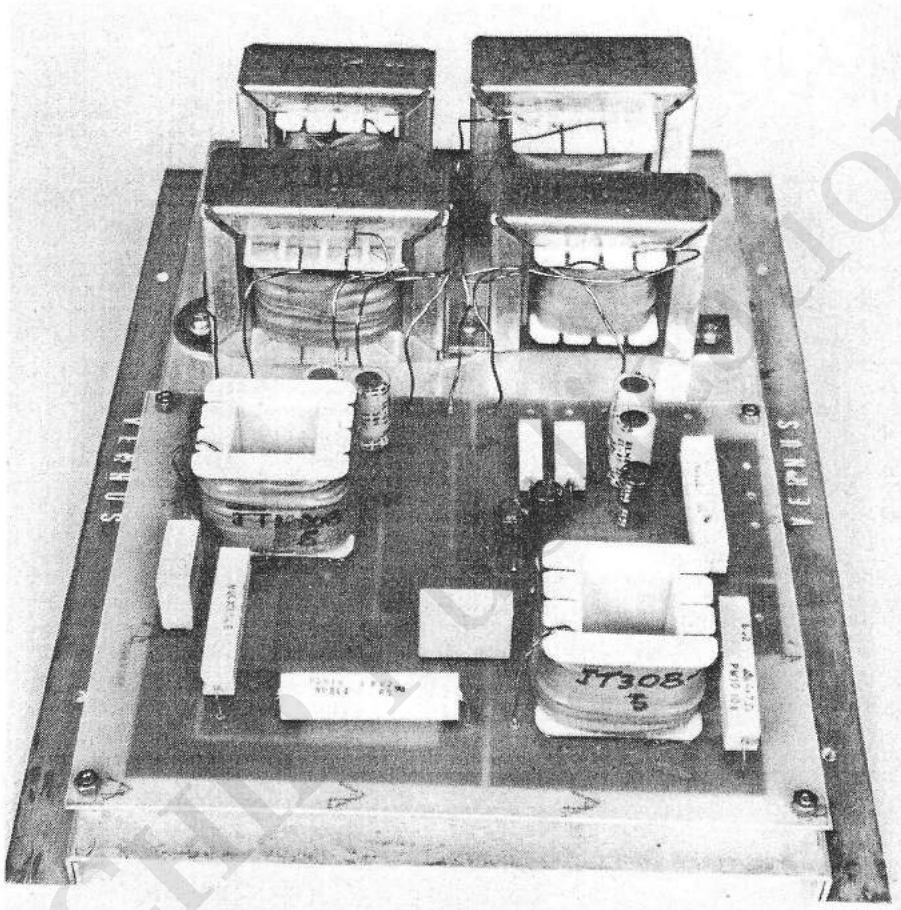
Solder the wires to each of the drivers making sure you know which wire is connected to the positive terminal on the loudspeaker. This terminal is marked on the driver either by a red terminal or a red dot near one of the terminals. Mark the other ends of the cables so that it is clear which cables connect to which drivers. *This is important;* if the outputs of the cross-over are connected to the wrong drivers ▶

this could result in damage to the drivers.

Once all of the drivers are mounted the final stage is the construction and mounting of the crossover. If the crossover is mounted inside, instead of under the box it will be necessary to leave mounting of the woofer until last. After all of the drivers have been mounted connect a 1.5 volt battery to the woofer wires and watch the lower mid-range cone. If it moves, the seal between the bass and mid-range chambers is not complete.

The inductors used in the crossover are too big to be mounted on the pc board. All the other crossover components are on the pc board. Start construction of the crossover by mounting and soldering the capacitors to the pc board. Next solder the resistors into place spacing them approximately 10 mm off the board. This is necessary to prevent charring the pc board should these resistors get hot when the speaker is used with high power amplifiers. The remaining two inductors should be glued onto the pc board and then the leads soldered.

The prototype crossover was mounted on a sheet of aluminium 200 mm by 330 mm, but this is optional. If you elect to use this method of construction screw the remaining four inductors onto the aluminium sheet and solder the leads from these onto the pc board. Solder the leads from the drivers and input terminals onto the pc board and mount the pc board onto the aluminium base using 6 mm spacers. Finally, the whole crossover can be screwed to the bottom of the loudspeaker box. If you are not using the aluminium base the pc board and inductors are mounted directly to the bottom of the loudspeaker box. The advantage of using the aluminium base is so that the crossover can be handled as one complete unit.



We mounted the crossover network assembly on an aluminium plate, bent as shown. The whole assembly was then screwed to the bottom of the loudspeaker and each driver connected as per the overlay.

PARTS LIST - ETI 496

The following is a parts list for one only loudspeaker so two of every component will be needed for a stereo pair.

Drivers

SP1	Philips AD12250/W8
SP2	Philips AD70601/W8
SP3	Philips AD02161/SQ8 Philips AD02161/SQ8 or AD02160/SQ8
SP4	Philips AD01610/T8 or AD01605/T8, see text.

Inductors

L1, L2	0.8 mH max dc resistance 0.5 R
L3, L4	3.0 mH max dc resistance 0.5 R
L5, L6	12.6 mH max dc resistance 0.7 R

Capacitors

C1	3μ3 polycarbonate
C2	22μ bipolar electrolytic 50 V
C3	3μ3 polycarbonate
C4, C5	47μ bipolar electrolytic 50 V
C6	22μ bipolar electrolytic 50 V
C7	10μ bipolar electrolytic 50 V
C8, C9	47μ bipolar electrolytic 50 V
C10	22μ bipolar electrolytic 50 V

Resistors

R1	4R7 10 W 5%
R2	8R2 10 W 5%
R3	3R3 10 W 5%
R4	18R 10 W 5%
R5	22R 5 W 5%
R6	12R 5 W 5%

Miscellaneous

pc board . . . . ETI 496

Wire, one pair of spring terminals, particle board, screws, glue, etc. Speaker grill cloth, innerbond.

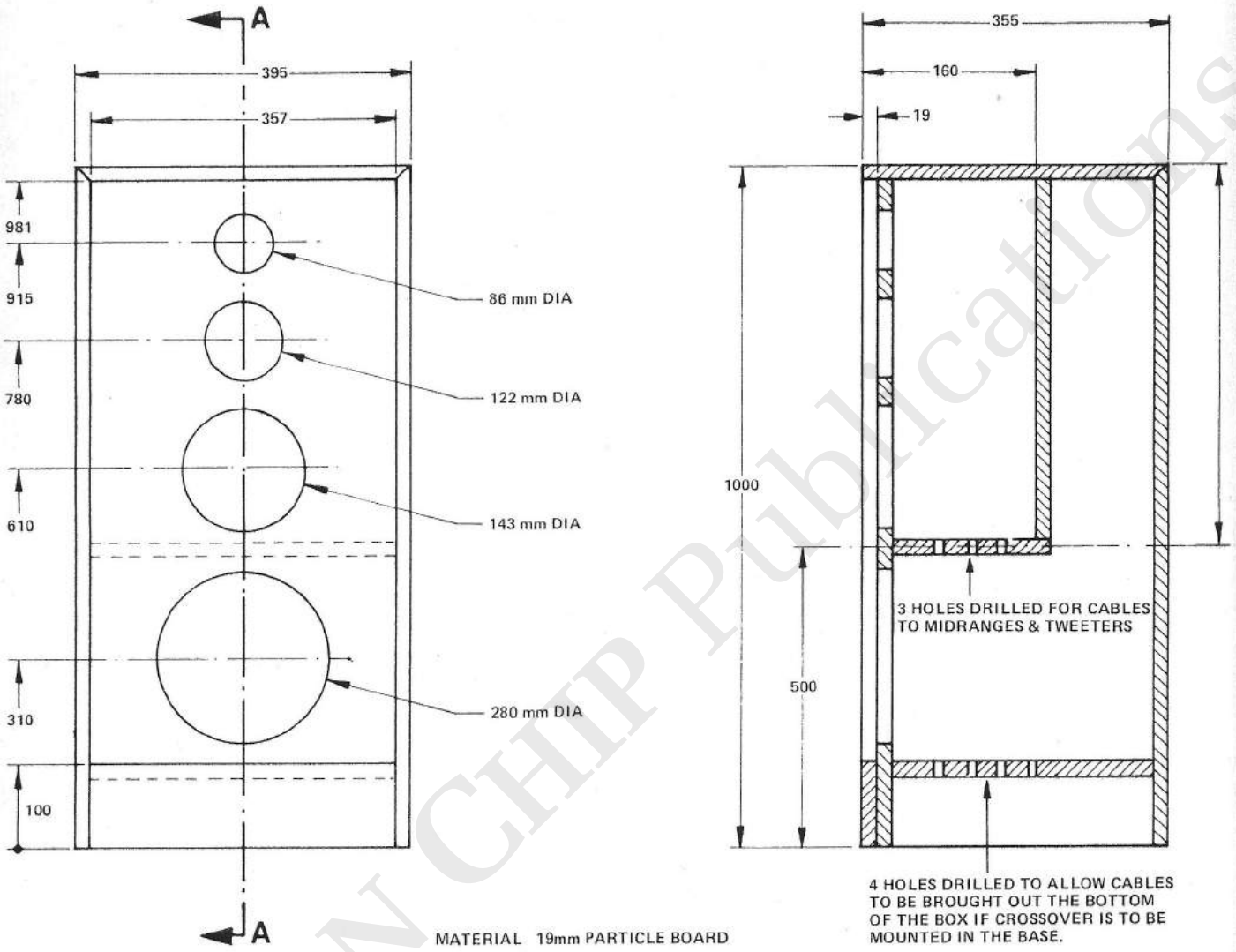
Powering up

Before connecting the loudspeaker to an amplifier touch the input of the loudspeaker to a *single 1½ volt* penlight battery. With the positive of the battery connected to the positive input (red terminal) of the loudspeaker the woofer cone should move forward and the loudspeaker should make a loud thump. Listen to all the drivers separately while connecting and disconnecting the battery to check that all of the drivers are operating. Don't use a battery any bigger than 1½ volts for this test or you could damage the woofer.

If all is well, connect the speakers to an amplifier and turn the volume up slowly.

Performance

Power handling figures for loudspeakers ▶



MATERIAL 19mm PARTICLE BOARD

ALL DIMENSIONS ARE IN MILLIMETRES

NOT TO SCALE

Complete cutting and assembly details for the four-way loudspeaker box. It is important that all joints be well sealed.

are a very dubious quantity. Some manufacturers (not many) quote continuous sine wave power handling at a particular frequency, but it is doubtful that this is a really neaningful figure. Probably the best way of measuring power handling is with pink noise. This is a type of noise which contains equal energy per octave over the entire audio range. Using this technique, these loudspeakers are rated at 100 watt power handling. The bipolar electrolytic capacitors used in the crossover are rated at 50 volts. This corresponds to 156 watts into an 8 ohm load so this should be considered the *absolute maximum* power for the loudspeaker. It is sometimes mistakenly thought that the power handling figure represents the power below which the loudspeaker cannot be damaged. The most dangerous condition for any loudspeaker is a heavily clipping amplifier. In this state the output of the amplifier approaches dc and even a 20 watt amplifier can do irreparable damage if operated incorrectly.

Your ears are the best indication that the loudspeakers are operating safely. If the sound becomes distorted or unpleasant at higher power levels, turn down your amplifier. Nine times out of ten it will be the amplifier and not the loudspeaker that is running out of power.

The 4000/1 loudspeaker has been designed in accordance with extensive tests that reveal the "ideal" frequency response characteristics for most listening environments. This response is not flat but has a tapered top end, so that the extreme treble is attenuated slightly with respect to the mid-range and bass.

The subjective test revealed just how good the loudspeakers are. The frequency response is smooth and extended and the bass and treble are present only when they should be!

Above all, the sound is clean and easy to listen to for extended periods, even at very high listening levels. I hope you get as much enjoyment from your 4000/1 speakers as I have. ●