These compact three-way speakers are easy to build and provide a wide-range response

Since we published a number of economical hi-fi amplifiers over the past few years, we have had increasing requests for speakers to suit. With the cooperation of Dick Smith Electronics, here is a three-way design that is compact and gives good performance at an economical price.

Roger Harrison

NOT EVERYONE likes the loudspeakers of a stereo hi-fi system to dominate the loungeroom furniture. Indeed, 'bookshelf' and 'compact' loudspeakers have long been popular, particularly amongst those who live in units or townhouses. While these speakers are certainly compact, they aren't quite as small as many bookshelf models on the market. They stand two-thirds of a metre tall and measure a little over 300 mm wide by 230 mm deep overall.

Tiny bookshelf loudspeakers may have a significant drawback. It is extremely difficult to achieve reasonable bass response in a small cabinet. Since much popular music, and certainly much classical music, has a great deal of bass content, a bass response extending below 100 Hz is important.

Design aspects

This loudspeaker employs a 'pressure box' or 'infinite baffle' design. That is, the box is completely sealed. It is sometimes called an 'acoustic suspension' system, too. Such an enclosure prevents sound radiated from the front of the drivers being coupled to the sound radiated from the rear of the drivers and causing constructive and destructive interference which produces big peaks and dips in the frequency response.

Why use three drivers? Well, a loudspeaker of the type used here — that is, the moving coil type — will only operate over a limited frequency range where the cone acts as a 'piston'. Below a certain frequency, the area of the cone will not move enough air to create audible sound waves. At the other end of the range, the sound commences to travel out *along* the cone, which no longer acts as a piston and the sound output drops off because compression and rarefraction waves are generated which tend to cancel each other.

Ideally, in designing a loudspeaker, any driver should be used only over its 'piston operating range'. The problem is, all but the most expensive and/or specially constructed drivers only have a piston operating range of three to four octaves (an octave is a 2:1 frequency range). You can use a driver over a greater range if some compromises are accepted — otherwise you'd end up with a speaker having five drivers to cover the 10 octaves of the audio spectrum! Expensive.

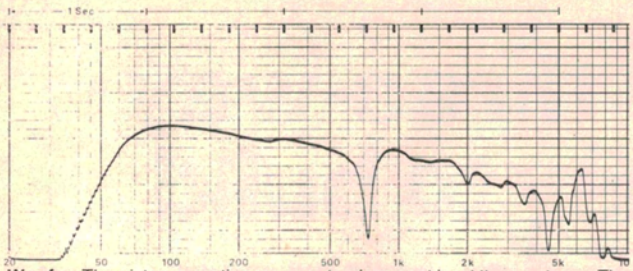
A popular technique is to use three drivers (hence 'three-way'); one to cover the bass end (the 'woofer') below 1 kHz, one to cover the mid-range from 1 kHz to 4 kHz or 5 kHz and one (usually called the 'tweeter') to cover the top end above that. Acknowledging that the most sensitive portion of the ear's frequency response is in the mid-range, three-way designs generally concentrate on using the mid-range driver over its piston operating range and accepting compromise operation with the other two drivers. That's what has been done with this project — and it achieves quite an acceptable result.

The bass response in a pressure box design is very dependant on the internal volume of the box. The bass driver, the air contained within the box, and the box's volume and shape all interact in a very complex way and it's a bit of a juggling act to make the best of things.

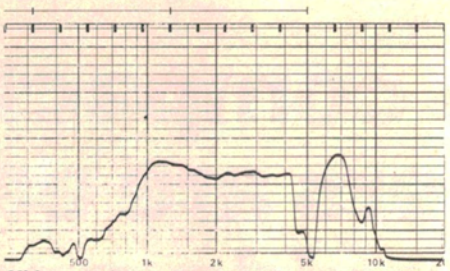
Basically, a sealed box with a driver in it acts like a high-pass filter. That is, the frequency response drops off rapidly below a certain frequency — the 'rolloff' or the 'corner' frequency. The greater the internal volume of the box, the lower the corner

NOMINAL SPECIFICATIONS ETI-421 3-WAY SPEAKERS

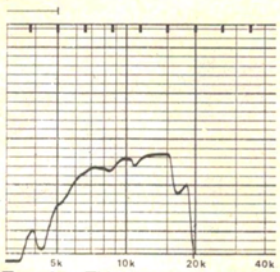
Nominal impedance	8 ohms
Frequency response	45 Hz to 17 kHz (−6 dB) 45 Hz to 19 kHz (−10 dB)
Nominal power handling	40 watts
Box volume	30 litres



Woofer. The piston operating range extends over at least three octaves. The 'dip' near 700 Hz does not show up in the overall response. Vertical scale: 1 dB/increment.



Mid-range. Its piston operating range extends from about 1 kHz to about 4.5 kHz.



Tweeter. This shows reasonable response from about 5-15 kHz.

frequency — and vice versa. But there's a limit to the size of the speaker enclosure that "... s/he who must be obeyed" will accept in the loungeroom. Another compromise — but this one's easy to satisfy and still get good bass response.

The enclosure dimensions settled on for this project result in quite a compact box having an internal volume of near as damn to 30 litres which, together with the 200 mm bass driver selected, delivers a bass end which extends to 60 Hz. Not a bad result. Many compact and bookshelf speakers barely make it to 100 Hz.

The mid-range and tweeter both have a sealed rear so that sound pressure inside the box, from the bass driver, does not interfere with their operation.

The piston operating range of the mid-range driver chosen appears to extend from about 1 kHz to 4.5 kHz or thereabouts. Hence, this determines where the operation of the other two drivers has to 'cross-over', from bass to mid-range and mid-range to tweeter. A filter system is used to effect this, rather than just connecting all the drivers in parallel. This filter is called the 'crossover network'.

The response of the bass driver is 'roled off' at the frequency where you want it to cross-over into the mid-range. Thus, a low pass filter is employed. In this case, a simple inductor (L2) has been used connected in series with the bass driver. A series capacitor (C2) 'rolls in' the mid-range in the same region. A simple inductor-capacitor high pass filter (L1-C1) rolls in the tweeter at around 4.5 kHz.

A fairly simple crossover network like this avoids difficulties with phase response and driver-network interactions, resulting in no 'little surprises' in the general response of the loudspeaker.

The resistors connected to the mid-range and tweeter are there to attenuate their output levels so that the three drivers have generally equal output. The mid-range and tweeter are more sensitive than the bass driver employed.

The capacitors used are 'bipolar' electrolytic types. That is, they are manufactured so that they are not polarised — no positive or negative terminal. This allows them to be used in purely ac applications.

Construction

The box supplied by Dick Smith Electronics is generally constructed of 15 mm chipboard with a base made from 18 mm chipboard — the base is likely to take more punishment during handling! The outside faces are covered in plastic wood veneer. The front panel, with the three cutouts for mounting the drivers, is set flush with the front of the cabinet and the front surface is covered in black vinyl, for appearance's sake.

Four 'sockets' are set into the front panel near the corners. The grille cloth is stretched over a polycarbonate moulding which has four pins projecting from the rear that set into the sockets on the front panel, providing a simple, yet effective, method of securing the front grille.

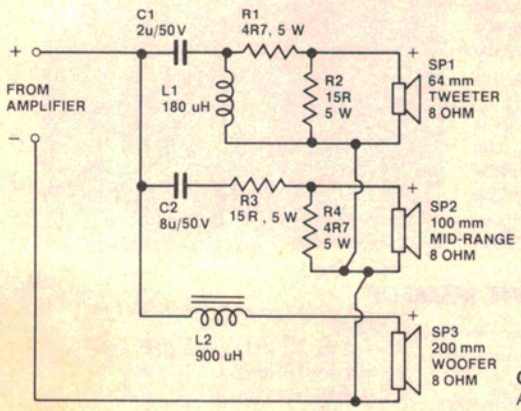
The rear panel is recessed slightly. The crossover network pc board is screwed on the inside to this and speaker connecting terminals pass through from the outer rear.

As Dick Smith Electronics will be providing precut box panels, construction is quite simple. Fold the top-bottom-side panels around the rear panel, running generous quantities of PVA glue (Aquadhere, or similar) in the folds as you go. Position the rear panel so that it's recessed about 10 mm (not critical) from the rear of the box and run a bead of glue around the joint on the *inside* of the cabinet. Small 'chocks' are used to strengthen the rear panel and these should be positioned around the joint on all four sides and thoroughly glued in place. Lay the box on its back to do this and leave it there while the glue cures.

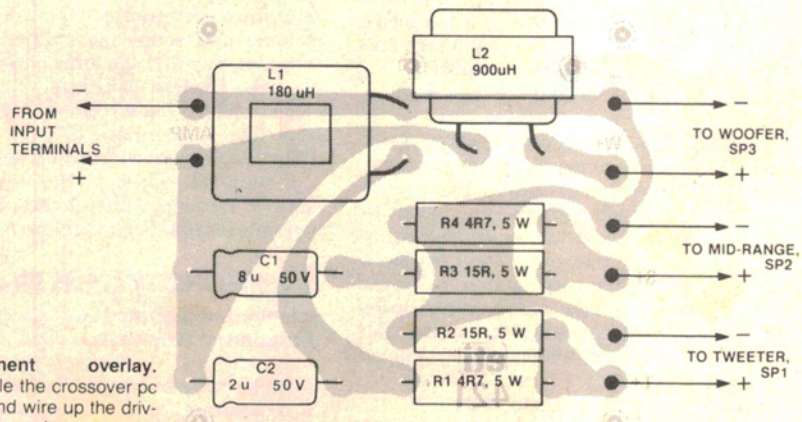
When the box is ready to handle again, take some sealing or caulking compound (Silastic is very good) and run a bead around all the joints. All joints must be

PARTS LIST ETI-421

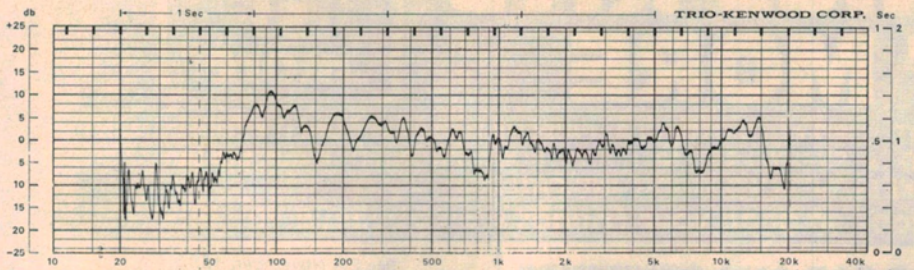
Resistors.....all 5 W, 10%
R1, R4.....4R7
R2, R3.....15R
Capacitors
C1.....2u/50 V non-polarised electro.
C2.....8u/50 V non-polarised electro.
Inductors
L1.....180 uH air-cored
L2.....900 uH iron-cored, open-end
Miscellaneous
SP1.....8 ohm, 64 mm tweeter (parg of D.S.E. C-2046)
SP2.....8 ohm 100 mm mid-range (part of D.S.E. C-2046)
SP3.....8 ohm 200 mm woofer (part of D.S.E. C-2046)
ETI-421 pc board for crossover; box to dimensions in drawings; speaker terminals; wire, speaker box lining, etc.



Circuit. How the drivers and crossover are connected.



Component overlay. Assemble the crossover pc board and wire up the drivers as shown here.



The result. No speaker has a truly 'flat' response and this speaker is no exception! But, the result is very good, achieving a frequency response from 45 Hz to 17 kHz (−6 dB from average).

airtight if the pressure box is to work properly.

Now, run a generous amount of glue around the rabbet at the front of the box, where the front panel will set in. Make sure it's generous as this will have to seal the front panel. Run more glue around the edges of the front panel and then set it in place. Wipe off any excess glue that may be on the outside faces of the box. Allow the glue to cure before proceeding.

Stand the box on its top and assemble the base, carefully gluing it in place. Run the glue on the mating surfaces of the base pieces. Leave the box while the glue cures.

Now for the crossover. This is assembled on a small pc board. The overlay diagram shows the general layout. It can be constructed in any order, but I'd suggest you start by mounting the resistors and capacitors first. Stand the resistors a few millimetres off the board so that heat can escape. The resistors will sure get hot at party time!

Mount the inductors last of all. Both are supplied prewound. The 900 uH inductor has a set of 'E' laminations to obtain the inductance required on the small bobbin. This inductor is secured to the board passing the lugs through two holes drilled in the board for them, and bending over them at the rear. The other inductor is simply wound on a bobbin which can be glued to the board in the place indicated.

Solder pc stakes in place for terminating the input and speaker wires.

Now, back to the cabinets. The speaker terminals need to be mounted. Two holes are drilled in the rear of the cabinet somewhere near the middle. The lugs of the speaker terminals will pass through these. But first, solder a 400 mm length of *red* insulated hookup wire (heavy duty, 24 x 0.2 mm, wire is best) to the terminal marked with a *red spot*. This is the "positive" terminal (marked with a plus on the circuit). Solder a 400 mm length of *black* insulated hookup wire to the other terminal.

Pass the wires almost right through the holes in the cabinet rear and then put caulking compound in the holes to seal them. Press the terminal strip in place and screw it down. Go to the inside of the cabinet and caulk the holes again just to be sure.

Wires should now be soldered to each driver. Use heavy duty hookup wire (24 x 0.2 mm, at least). Each driver will have the positive terminal marked in some way — maybe with a '+', with a red spot or with a red-coloured insulating washer. Attach a 400 mm length of *black* insulated hookup wire to each driver's negative terminal. Then, attach a 400 mm length of coloured wire to each driver's positive terminal — using a different colour for each driver (say, white for the tweeter, yellow for the mid-range and blue for the woofer).

Next, place the crossover pc board on the inside of the rear panel, opposite the woofer's hole (it's easier to get at through the large hole). Screw it in place. Solder the input wires to the two input terminals on the board. *Be careful to observe the correct polarity.* Place each driver on the front face, adjacent to its mounting hole. Pass the wires from each driver, through its mounting hole, and solder them to their respective terminations on the crossover board. Be careful, once again, to *observe correct polarity.*

Now, completely stuff the inside of the cabinet with innerbond.

Before screwing each driver in place, attach adhesive foam tape (available from hardware stores, used for sealing cupboards, etc) around the lip of each driver hole so that a good seal is made. Then screw the drivers in place.

Powering up

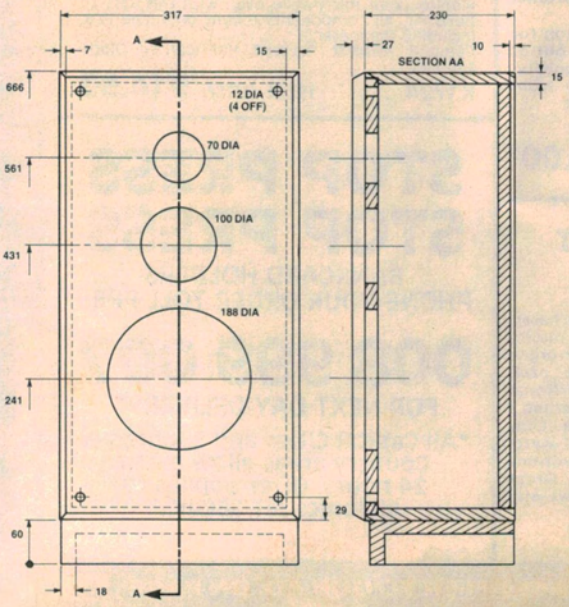
Before connecting the speakers to an amplifier, take a *single* 1.5 V cell and briefly touch its terminals to each speaker's input terminals — positive to the terminal marked with a red spot. The woofer cone should move *forward* as you do this, and the loudspeaker should make a loud thump. *Do not* use a battery any larger than a 1.5 V cell for this test or you could damage the woofer.

If all is well, connected the speakers to an amplifier, select your favourite record or tape, turn the volume up slowly and sit back and enjoy the satisfaction of having built your own speakers!

A word of caution. These speakers should be able to comfortably handle 40 W of power. This is not a peak rating. In fact, transients up to 100 W should cause no ill effects. The most dangerous condition for using any speaker is when the amplifier is clipping heavily. Under these conditions, the amplifier's output approaches dc and even a 20 W amp is capable of doing irreparable damage if clipping operation is prolonged.

For safety's sake (and to save the expense of replacing drivers), you might add our Signal-Powered Loudspeaker Protector, ETI-494, published in the October 1982 issue. This will protect your speakers from both overpower abuse and from amplifier faults that might apply dc to the speakers.

Good listening.



Cabinet details. All the cabinet dimensions are shown on the left and an exploded view of the assembly is shown at right. Dick Smith Electronics supplies precut panels with kits, which makes the assembly job a breeze. The front grille is an open weave black cloth stretched over a polycarbonate frame.

ALL DIMENSIONS IN mm
NB: FRONT GRILLE REMOVED TO SHOW DRIVER POSITIONS
BOX MADE OF 15 mm CHIPBOARD
BASE MADE OF 18 mm CHIPBOARD