New design uses near ideal 250mm woofer

100W sub-woofer speaker enclosure

This compact sub-woofer system will augment the bass response of stereo sound systems down to below 30Hz. The enclosure shape is not critical and could be built into a coffee table or end table to be unobtrusive.

by LEO SIMPSON

Last year in August and September we published articles on "Vented Speaker Systems" by Brian Davies. These articles elucidated the principles of loudspeaker design evolved by A. N. Thiele and R. H. Small. As such, the articles have created a great deal of interest amongst audio enthusiasts, particularly those who are interested in building their own loudspeaker enclosures, using locally available drivers.

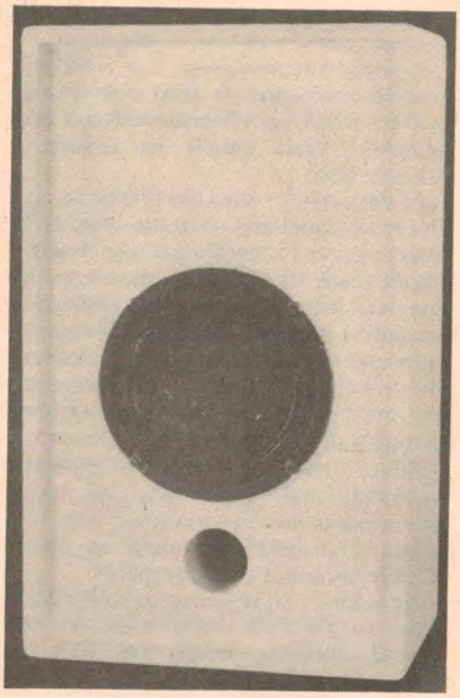
One message is made abundantly clear in the above two articles and that is that the traditional much-regarded large vented system using a 30cm woofer is not an optimum design, particularly as the enclosure volume is made smaller. If you want to guarantee a good bass response down to 40Hz or below, it is extremely difficult to obtain it with a modest enclosure using a 30cm woofer.

For a more reasonably-sized enclosure giving reasonable bass response, a woofer diameter of 20 or 25cm is far more suitable. But until recently there has been a dearth of locally available woofers of this size which had suitable figures for Q_t and V_{AS}. Recognising this, major kitset supplier Jaycar Pty Ltd has arranged for the local manufacture of a 25cm woofer with near ideal characteristics.

The new woofer is designated the SW-250, although the staff at Jaycar are prone to call it by more picturesque names such as the "gut-rumbler" or the "wall-wobbler". Anyway, the SW-250, to call it by its more prosaic appellation, is a really rugged design with a power handling capacity of 100 watts.

It has a substantial cast aluminium chassis and a total mass of almost four kilograms of which three kilograms is the mass of the large ceramic magnet. The heavy curvilinear cone is treated with a viscous damping material and has a large multiple corregation surround and large spider assembly to ensure linear cone excursions at high power levels.

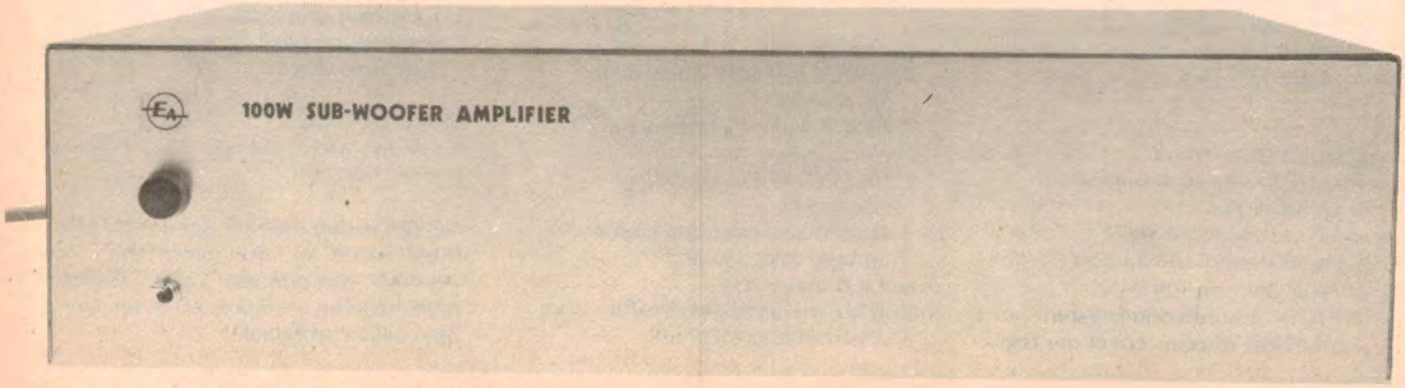
The SW-250 also has a ridiculously large dustcap which may suggest an equally large and massive magnet pole-piece. In reality though, the magnet pole-piece is still quite large at about 50mm in diameter and is in proportion with the overall magnet diameter of 133mm.

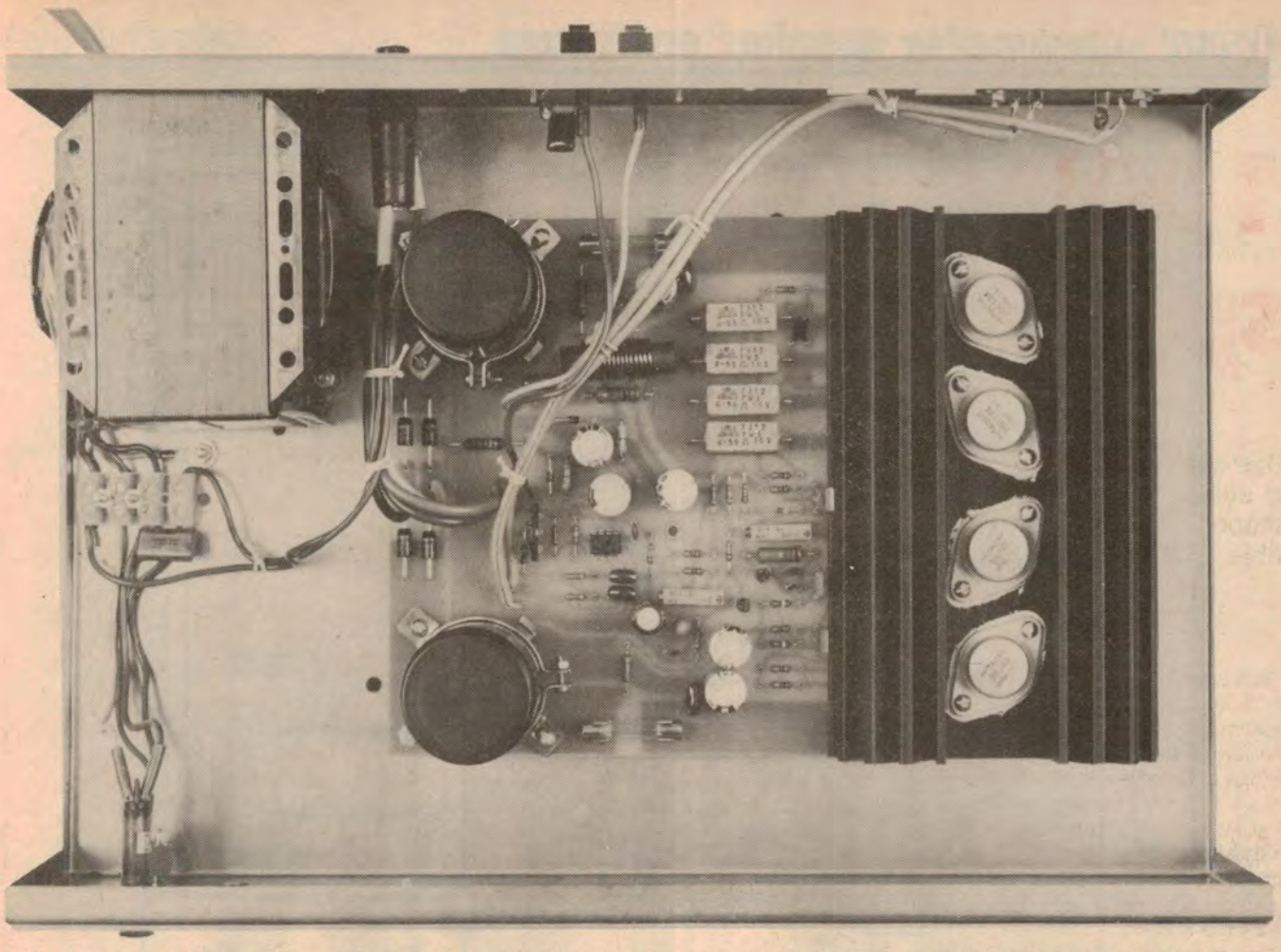


The prototype is ugly. Kit versions will be finished in black vinyl.

Free-air resonance of the new woofer is quoted at 32Hz while the Q_t figure is an almost ideal value of 0.39. The "equivalent volume" or V_{AS} is 63 litres. For the full background to this ter-

The sub-woofer amplifier uses the 100W power module described last month.





Inside the sub-woofer amplifier. Make sure that there is no connection between the board pattern and chassis (see text).

minology, readers should refer to the above-mentioned articles (File Nos: 1/SE/57, 58 and 59).

Efficiency of the SW-250 woofer is in line with what can be expected, given the above parameters. This means that it is about average at 88dB for an input of 1 watt and at a distance of one metre, on the axis of the woofer. Combined with the above-mentioned power rating of 100 watts, the maximum practical sound pressure available from the woofer will be 108dBA.

Thus, the efficiency and maximum power handling of the new woofer mean that, when it is teamed with the 100 watt module described last month, it will be able to match with most compact loudspeaker systems.

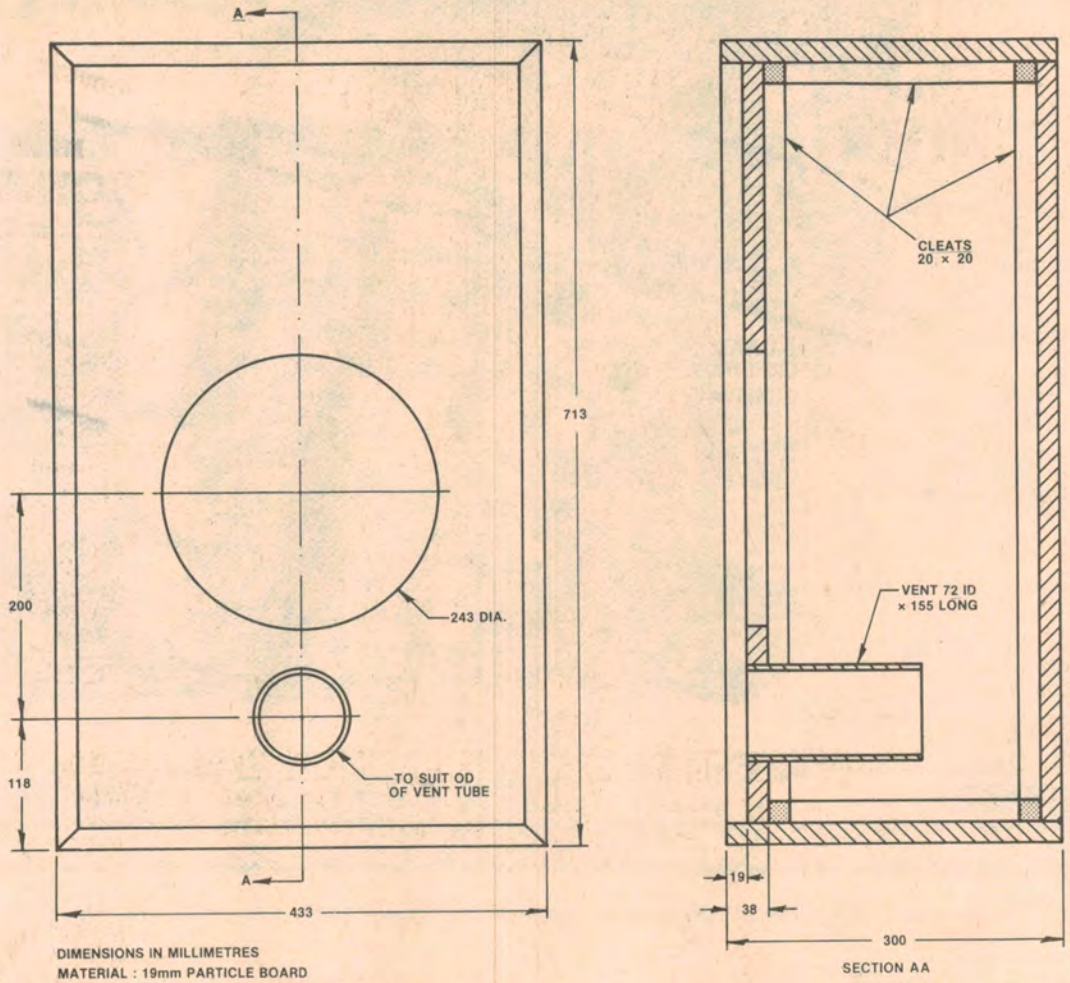
As well as arranging for the manufacture of the SW-250 woofer, Jaycar has also commissioned a design for a suitable enclosure according to the principles of Small and Thiele, as mentioned above. This design is a vented enclosure with a total volume of 63 litres, ie, equal to the V_{AS} figure for the woofer.

The resulting sub-woofer system has a near ideal bass response over the region from 30Hz to above 400Hz, as shown by the accompanying frequency response plot. In fact, over the region from 50Hz to 400Hz, the response is as flat as any loudspeaker is ever likely to be, using a close-microphone test.

The SW-250 woofer has near ideal characteristics for this application. Free-air resonance is 32Hz, Q_t is 0.39, and V_{AS} is 63 litres.

And as might be expected from such a response curve, the bass is particularly smooth to the ear, with no evidence of frequency doubling at all, even at high power levels.

The impedance curve is also a "copybook" specimen, with peaks at



EA 100 WATT SUB-WOOFER ENCLOSURE

These dimensional details are supplied for those who wish to build their own enclosures. Actual dimensions are not critical, provided the volume remains the same (see text below).

about 15Hz and just below 50Hz, corresponding to the two system resonances (f_H and f_l) while the dip is at just below 30Hz. Since the system does not use a passive crossover network, the minimum impedance of the system is just above the DC resistance of the SW-250 driver, at 6.1 ohms.

Construction

As presented in this article, the prototype (which is as ugly as sin) follows conventional lines and uses a cardboard tube as the tuned port. We understand that Jaycar will have precut enclosure kits (of the "fold around the baffle type") which will be finished in black vinyl. For those who can build their own enclosure from scratch, we have provided a dimensional diagram, with timber cleats as the panel fixing method.

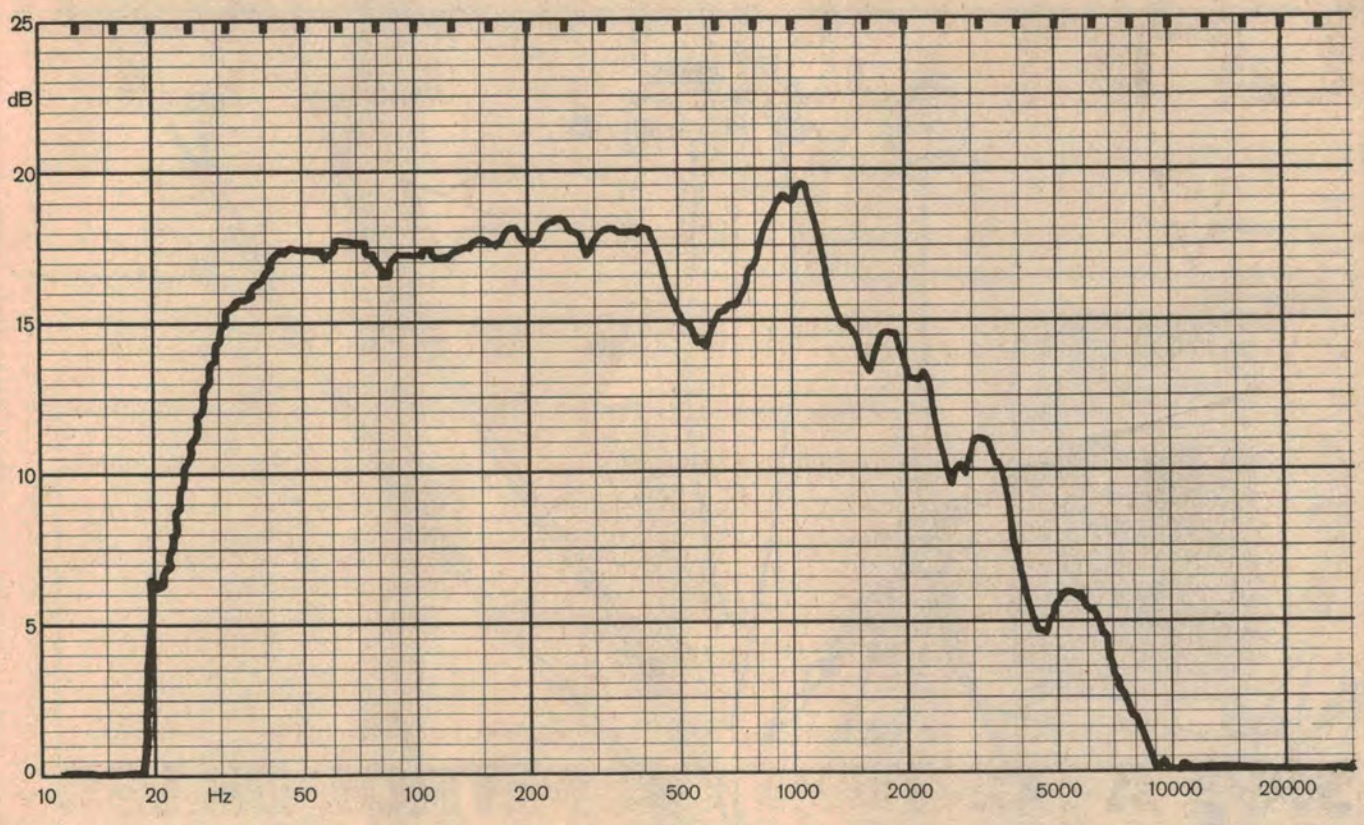
But the important point to note about this enclosure is that the actual dimensions are not at all critical. As long as the enclosure volume is close to the design figure of 63 litres (give or take a few litres) and the distance from the end of the tuning port to the rear panel is not less than in our diagram, the box can be almost any shape at all. And the port can be cut into any of the six panels (it does not have to be on the woofer panel).

This means that the sub-woofer enclosure can be built into a piece of furniture such as an end table, or even built into a sofa to make it as unobtrusive as possible. As a further advantage, this means that the main stereo speakers can be really compact and also unobtrusive, as they only require a bass response down to around 100Hz or so. In fact, for an absolute minimum enclosure for the main stereo speakers, the response need only extend down to about 200Hz and embody only tweeter and midrange drivers.

No special constructional procedure is required in building the sub-woofer enclosure apart from normal provisos such as ensuring that the panels are thick enough to avoid undue resonances which would add harmonic distortion to the reproduction. Naturally, the system must be thoroughly sealed to avoid any leaks around the woofer itself, at the panel joins and at the connection terminals. A curtain of bonded acetate fibre (BAF) should be placed loosely over the rear of the woofer and tacked to the baffle, but apart from that, no enclosure filling is required.

Housing the amplifier

Our first thoughts, in solving the problem of driver amplifier accommodation, were to house the amplifier in the plinth of the subwoofer enclosure. However, that course is really only practical if a conventional enclosure is used. Even then it does have drawbacks in that a power cord and two pairs of loudspeaker leads (from the two channels of the main stereo amplifier) would need to be run to the enclosure.



The graph shows the frequency response of the system at 1W, using a microphone at 15cm on-axis.

Add to that the need for adequate ventilation and a pilot light to indicate that power is present and a powered sub-woofer enclosure may not be all that attractive. So we took the alternative approach of housing the sub-woofer amplifier in a conventional chassis which can be positioned in or out of sight, near the main stereo amplifier.

This will mean that power cord and signal connections can be short and unseen, and a single run of heavy-duty figure-8 cable is all that is required to make the connection to the sub-woofer enclosure.

Accordingly, we decided to house the sub-woofer amplifier module described last month in a chassis which measures 370 × 248 × 90mm (W × H × D) and has a wrapover Marviplate cover. Suitable chassis should be available from Jaycar or selected resellers shortly after this article appears. In fact, there is nothing particularly special about the chassis apart from the need to provide a reasonable amount of ventilation for the on-board heatsink. This can be provided by drilling a number of holes in the base and rear panel of the chassis.

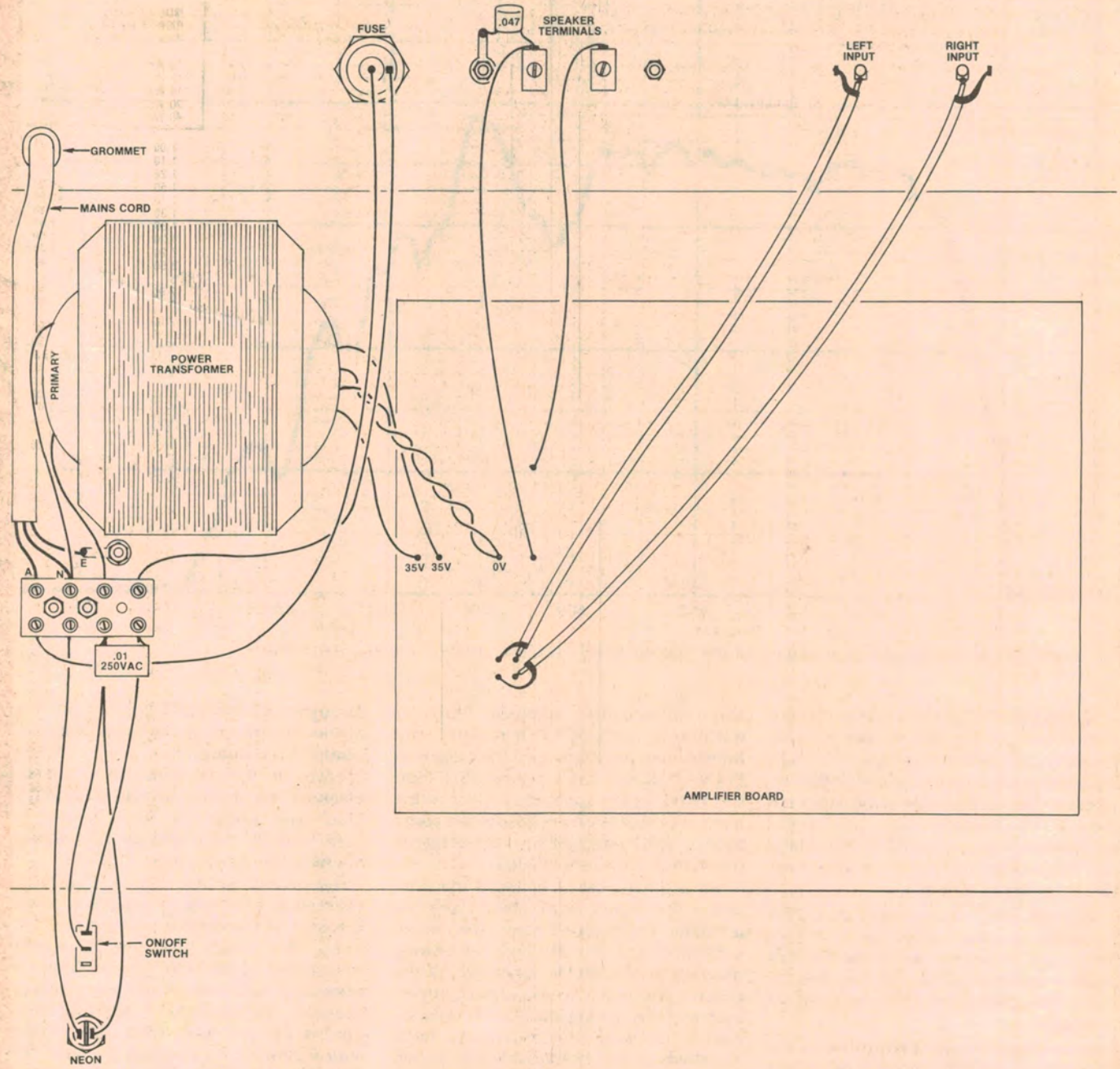
(Our prototype chassis already had a number of cutouts in the rear panel, thus avoiding the need for drilling).

Preparation of the chassis starts with drilling any necessary mounting holes for the sub-woofer module, power transformer and other hardware. The transformer we used was the Ferguson PF4361/1 which has a copper flux shorting band. In this application the shorting band is probably not necessary so some money could be saved by purchasing the non-banded version, PF4361.

Not a great deal of wiring is involved and a few hours' work should see the amplifier complete. Follow the circuit published last month and the wiring diagram in this article when wiring the chassis. The mains wiring is most important and the wiring diagram should be closely followed. It incorporates a neon bezel which was not included in the circuit published last month.

The mains cord should be passed through a grommetted hole in the rear of the chassis and anchored with a cord clamp. Terminate the mains active (brown or red) and neutral (blue or black) wires to the insulated terminal block and solder the earth (green or green with yellow stripe) wire to a solder lug near the transformer.

The mains switch has a .01μF interference suppression capacitor wired across it, at the insulated terminal block. Keep the leads to this capacitor reasonably short and sleeve them if necessary with Nylex and spaghetti to prevent them from contacting the chassis (or the user). This interference suppression capacitor must be rated for 250VAC operation. This means that it must either be a metallised paper or dual



Wiring details for the 100W sub-woofer amplifier. Not that mains wiring should use 250VAC-rated cable.

dielectric (paper plus polyethylene terephthalate) type rated at 250VAC, a metallised polypropylene type with a rating of 250VAC or 1kV or 1600VDC or a ceramic disc capacitor rated at 2kV or higher.

Do not use polyester or polypropylene capacitors rated at 630VDC or 220VAC. They could be a potential fire hazard.

The mains fuse is wired in series with the active lead, before the power switch. The input to the fuse should be made to the end terminal while the switch is wired to the side terminal. Both terminals should be sleeved after the connections are made, to avoid later accidental contact with the mains potential.

Before the sub-woofer module can be installed, the four heavy-gauge secondary wires from the transformer must be terminated. Thoroughly clean the lead ends of varnish with a razor blade and tin them with solder. Then pass each of the four leads through its appropriate hole on the PC board and solder.

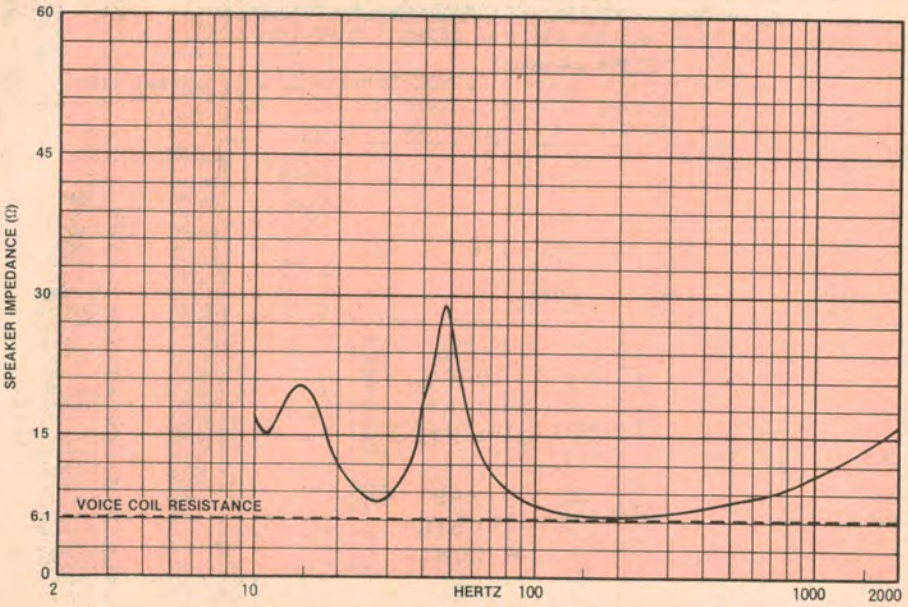
Now install the module using four PC standoffs or screws, nuts and spacers. Make sure that there is no connection between the PC board pattern and the chassis, via the module mounting screws. This can be tested by checking for continuity between the module earth connection and chassis. If there is any continuity, remove the module and rectify the problem before proceeding fur-

ther. It may be necessary to fit insulating washers to the mounting screws to avoid shorts between the supply rails and chassis.

Mains power can now be applied and the voltage checks and setting up procedure, outlined last month, carried out.

Finally, the input and output wiring can be installed. The input shielded cables are run from the dual RCA phono socket to the board. Cut and dress the cables so that they lie together neatly, as shown in the photograph. Use cable ties or lacing to hold them in position. There should be no connection between the mains chassis earth and the input cable shields.

On the loudspeaker terminals, connect a .047μF capacitor from the common or "earth" side to the chassis, via a solder lug. This capacitor is visible in the photograph and should be included as a precaution against instability and possible interference which may be picked up by the speaker leads.



The impedance curve is "copybook", with peaks at 15Hz and just below 50Hz corresponding to the two system resonances. Minimum impedance is 6.1Ω.

Setting up

When the sub-woofer enclosure and power amplifier are both complete, final system set-up must be performed. This involves matching the signal level of the sub-woofer to that produced by the main stereo speakers.

Typically, most loudspeaker systems used in domestic stereo set-ups will have a reasonably flat frequency response to below 100Hz. But ideally, for good matching between the sub-woofer and main stereo speakers, the −3dB point of the sub-woofer system, as determined by the input low-pass filter, should match the −3dB rolloff of the main stereo speakers. If you know that your main stereo speakers are reasonably flat to 100Hz and roll off below that, you have no problem.

Alternatively, if you know that your stereo speakers are flat to say, 70Hz, and roll off below that you could change the corner frequency (−3dB) of the sub-woofer amplifier low-pass filter by suitable scaling of the capacitor values.

An alternative method can be used if your stereo amplifier has separate preamplifier outputs and power amplifier inputs. In this case, the signals for the sub-woofer amplifier should be taken from the preamplifier outputs and the bass control set for cut of 3dB at 100Hz, which would be confirmed by measurement at this frequency.

This is done by feeding a 100Hz signal through the stereo amplifier and measuring the output with an AC millivoltmeter or multimeter switched to a low scale. The tone controls are set flat, the signal measured and noted and then the bass control set to reduce the signal level by 30%. This corresponds to a level reduction of −3dB.

Matching the sub-woofer and the main stereo speakers is then adjusted by feeding a 100Hz tone to all speakers and setting the trimpot for equal loudness from sub-woofer and main speakers. Listening tests may then indicate a further small adjustment to obtain good overall balance.