Portable P.A. Amplifier

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An inexpensive 10 watt design incorporating readily available components

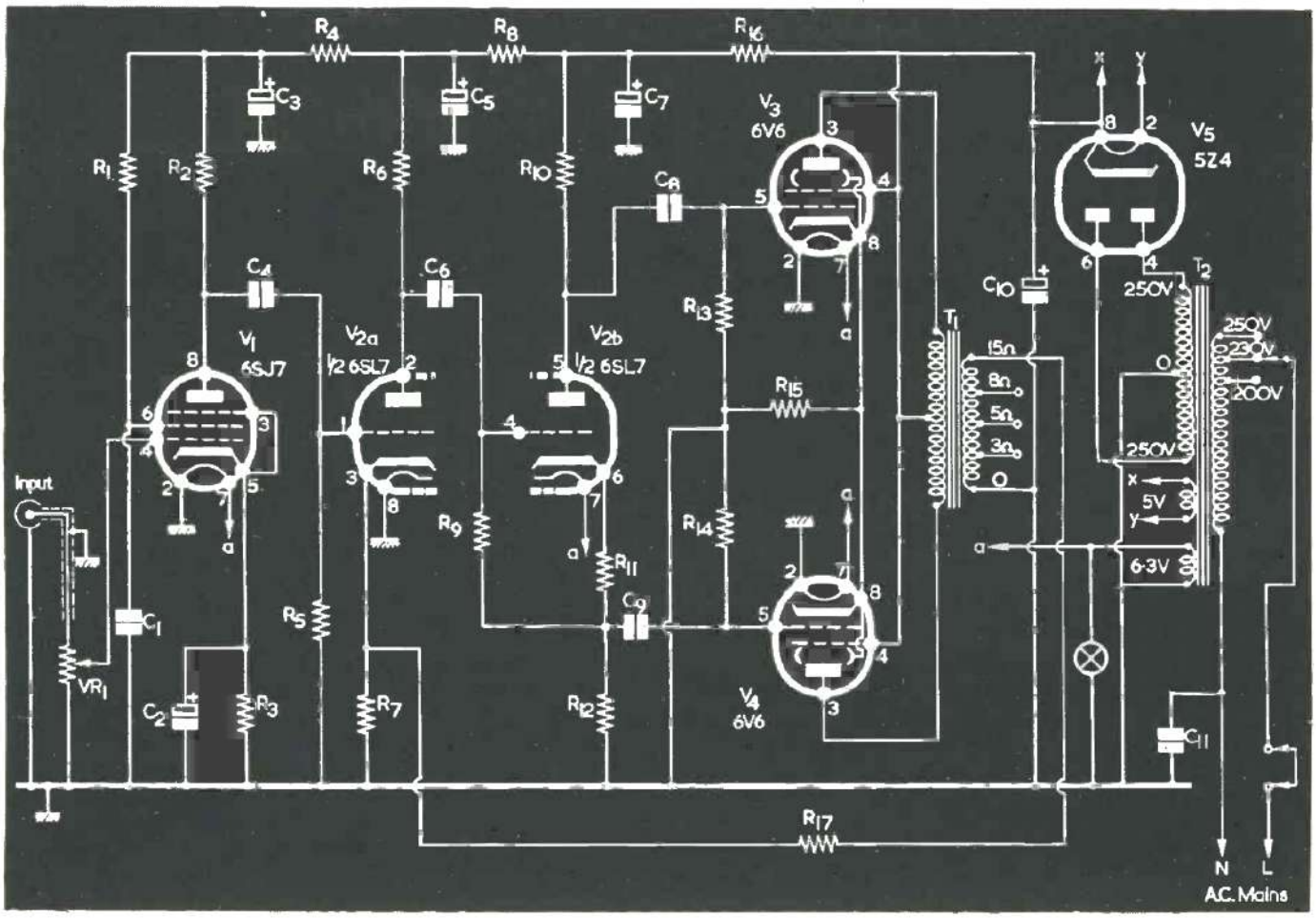

Fig. 1. The circuit of the 10 watt amplifier

THIS EQUIPMENT WAS DESIGNED AND BUILT FOR the use of a travelling lecturer who had, on occasion, to address large audiences. Though small in size and weight, it has an output of 10 watts and will give a good account of itself. The circuit is simple and the components few and inexpensive.

Design Considerations

Minimum size and weight are the primary considerations and the completed amplifier can be enclosed in a carrying case measuring only 10 x 7 x 5in, with a total weight of 7 lb. The requirement for clean, crisp reproduction of speech is met by introducing some attentuation of the lower audio frequencies, but this is done entirely at the input and output. The amplifier itself is suitable for any service and it will, in fact, reproduce music at a very acceptable standard of fidelity. Space does not permit the introduction of tone controls.

Circuit

The circuit is shown in Fig. 1. Surprise may be felt at the use of octal valves, but these are more robust and less likely to be dislodged from their bases than are the more modern all-glass variety. Such considerations outweigh the disadvantage of size in portable equipment.

Power Supply

To keep the weight down, the power supply is obtained from a double wound mains transformer having a full wave h.t. secondary rated at only 250–0–250V, 80mA. Using a 5Z4 rectifier and a 32μF reservoir capacitor (C_{10}), a d.c. voltage of 300 is available at the reservoir under working conditions. This leaves no margin for voltage drop in smoothing components and so the output stage is fed direct from C_{10}. There is, of course, a large hum voltage at this point but since, with the push-pull connection, current flows through the two halves of the output transformer primary in opposite directions, it is largely cancelled out, leaving a satisfactorily low background level.

The mains transformer must have a 5V 2 amp. winding for the rectifier and a 6.3V winding for

Components List

Resistors

(All fixed resistors 10% ½ watt unless otherwise stated)

R_1	1.2MΩ, high-stability
R_2	270kΩ, high-stability
R_3	1.2kΩ
R_4	47kΩ
R_5	1.2MΩ
R_6	100kΩ
R_7	3.3kΩ
R_8	22kΩ
R_9	1.2MΩ
*R_{10}	100kΩ
R_{11}	3.9kΩ
*R_{12}	100kΩ
*R_{13}	470kΩ
*R_{14}	470kΩ
R_{15}	270Ω, 2 watts
R_{16}	4.7kΩ
R_{17}	15kΩ
VR_1	2MΩ potentiometer, log track

* Matched pairs.

Capacitors

(All capacitors 350V wkg. minimum unless otherwise stated—see text)

C_1	0.01μF
C_2	25μF electrolytic, 12V wkg.
†C_3	8μF electrolytic
C_4	0.01μF
†C_5	8μF electrolytic
C_6	0.01μF
†C_7	16μF electrolytic
C_8	0.01μF
C_9	0.01μF
†C_{10}	32μF electrolytic
C_{11}	0.02μF paper, 250V a.c. wkg.

† C_3 and C_5 are in a single can as are C_7 and C_{10}.

Valves

V_1	6SJ7
V_2	6SL7
V_3	6V6
V_4	6V6
V_5	5Z4

Transformers

T_1	Mains transformer with tapped primary. Secondaries, 250–0–250V, 80mA; 6.3V, 2 amp; 5V, 2 amp. Upright mounting (see text)
T_2	Output transformer. Push-Pull, 10–12 watts, 6V6 to 3, 5, 8 or 15Ω. (R.S.C. (Manchester) Ltd., 54 Wellington Street, Leeds, 1)

Speakers

Re-entrant or cone units, as required

Microphone

Crystal microphone with floor stand

Lamp

M.E.S. indicator lamp, 6.3V, 0.3 amp.

Plugs and Sockets

1 octal plug
1 coaxial input plug
6 octal sockets
1 indicator lamp holder
1 coaxial input socket

Miscellaneous

Chassis, 16 s.w.g. aluminium (see Fig. 2)
1 2-way tagstrip
2 ¼in grommets
Wire, etc.

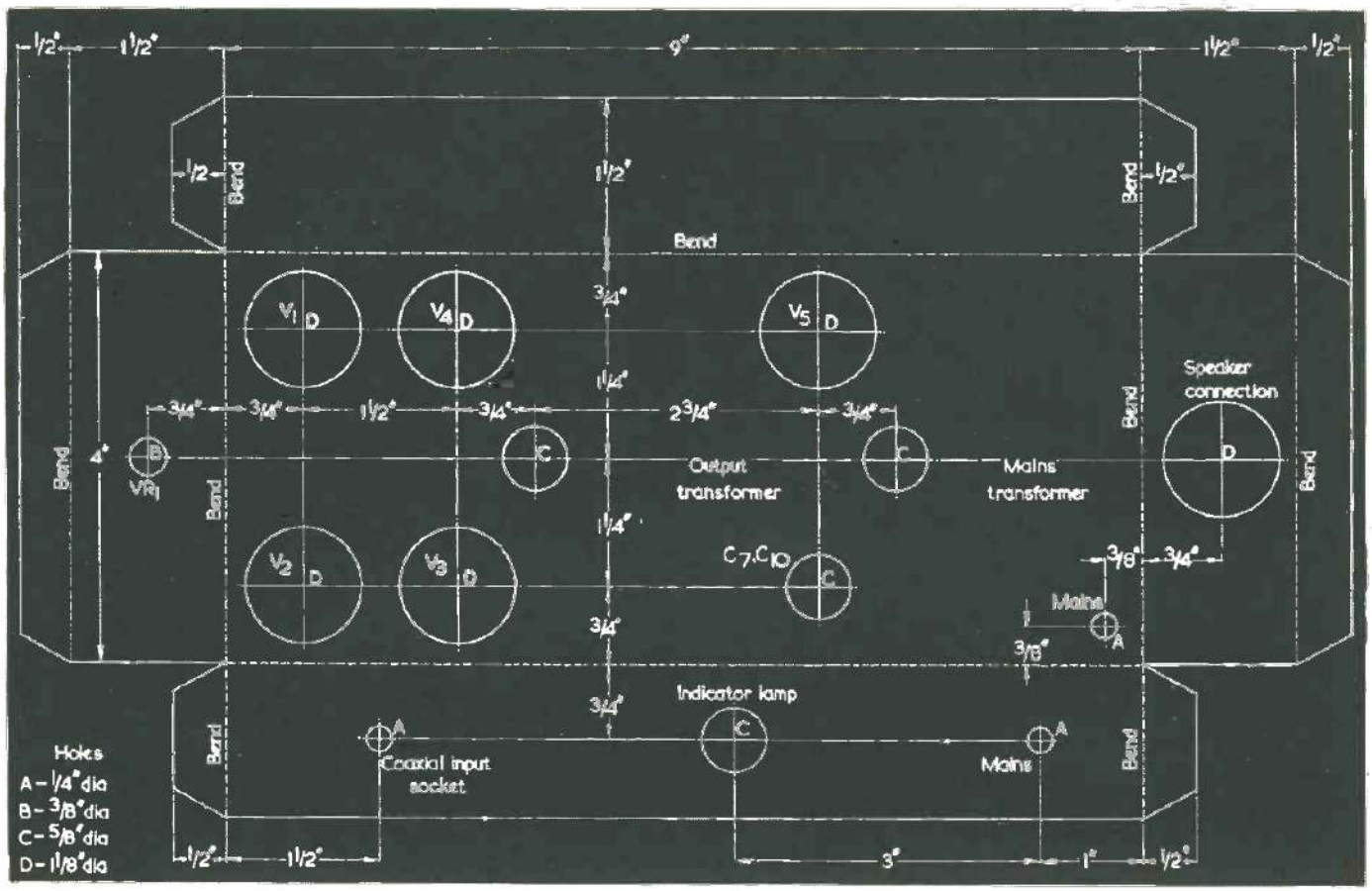

Fig. 2. The dimensions and principal holes in the chassis. The $\frac{5}{8}$in hole for $C_{7,10}$ may need to be larger for some components. Before drilling mounting holes for the valveholders, check against Fig. 3 for orientation

the other valve heaters and indicator lamp, which together need 1.8 amp. No mains switch is provided but in order to avoid damage to the output valves should the amplifier be operated accidentally with no load, it is arranged that the withdrawal of the loudspeaker connecting plug shall interrupt the mains supply. It is convenient if the mains transformer has a mains voltage adjuster but if it has not, one can be fitted separately on the chassis in a position where it will be easily accessible in service.

Capacitor C_{11}, connected between the chassis and the neutral supply line, serves as an effective earth connection, as will be explained later. It may not always be needed.

Output Stage

The output stage employs a pair of valves type 6V6. The anodes and screen-grids are fed from the 300V h.t. line which, allowing for bias, provides about 280V, between these electrodes and the cathodes. The use of a common bias resistor, R_{15}, has two advantages. Firstly, because the signal currents through the valves cancel out at the cathodes, no bypass capacitor is required and, secondly, it tends to minimise differences between the valves so that exact matching is not necessary. It is well, though to check that the valves are not widely different. The value of R_{15} is a little on the high side in order to keep the h.t. current within the capacity of the 80mA mains transformer secondary. The optimum anode-to-anode load is 8,000 ohms. The prototype uses one or two speakers (in series) of 7.5Ω impedance and the ratios provided by the output transformer are therefore 33:1 and 24:1. If it is desired to use a 3Ω speaker, a ratio of 50:1 will be needed.

Phase Inverter

For full loading, the output stage requires a signal of about 36V grid-to-grid and this is provided by $V_{2(b)}$ arranged as a phase inverter with equal anode and cathode loads of 100kΩ. These resistors, R_{10} and R_{12}, must be matched as closely as possible as also must the grid resistors of the output stage, R_{13} and R_{14}. The grid resistor for the inverter stage, R_9, is returned to the junction of the bias and cathode load resistors, and since R_{11} is very small in relation to R_{12}, there is no point in bypassing it. The signal is applied to the stage between grid and earth so there is heavy negative current feedback and, as might be expected, the gain is low; it is in fact limited to 0.9 times each side or 1.8 times overall, so that an input of $\frac{36}{1.8}$ or 20V peak is needed. There will be no overloading with this large signal since most of it goes to counteract negative feedback in the cathode load. The

power supply to this stage needs some smoothing, which is provided by R_{16} and the associated 16μF capacitor, C_7.

Voltage Amplification

The signal required by the inverter is supplied by $V_{2,(a)}$ arranged as a resistance-capacitance amplifier with both current and voltage negative feedback. It will be noted that the cathode bias resistor consists effectively of R_7 and R_{17} in parallel, and that a negative voltage feedback derived from the secondary of the output transformer is applied by way of R_{17}. This improves the response of the amplifier and removes any hum not eliminated by the push-pull connection in the output stage. If the greatest gain is required, the value of R_{17} may be increased up to 33kΩ without raising the residual hum level unduly whilst, if quality be the aim, it can be reduced to 6.8kΩ, when hum will be almost completely inaudible.

Pre-amplification is needed to raise the microphone signal to a suitable level for injection to the grid of $V_{2(a)}$. This is provided by a high gain pentode, 6SJ7, again resistance-capacitance coupled, and having the volume control, VR_1 in its grid circuit.

The overall gain of the amplifier is fairly high, especially if a high value is assigned to R_{17}, and care is necessary in the selection of the resistors R_1 and R_2 which should be of the high stability noise-free type. The valve V_1 must be free from any tendency to microphony and its h.t. supply must be free from ripple. The latter point is taken care of by resistor R_4 and capacitor C_3.

Frequency Response

The desired frequency response for speech is achieved by using re-entrant speakers which have only a limited low frequency range and by employing at the input a crystal microphone, for which the recommended load is 5MΩ or more. Such an instrument may be regarded as an a.c. generator having in series with its output a small capacitance and it follows that, if the load resistance be reduced, so will be the output at the lower frequencies. VR_1 is therefore given a value of 2MΩ only.

Components

All the resistors can be ½ watt except R_{15}, which must be 2 watts, and all the capacitors except the electrolytics and C_{11} should be ceramic so that they can be accommodated easily in the rather restricted space available below chassis around the valveholders. Capacitors connected to the h.t. circuits must be at least 350V wkg., and it is a good idea to use 500V wkg. components so that if the amplifier should by mistake be connected to 240V mains with the voltage adjuster set for say, 200V, the overload will not be likely to cause a breakdown. Capacitor C_{11} should be rated for 250V a.c.

There is little room to spare on the deck of the chassis and unless the mains and output transformers are of the type shown in the illustration, it may be necessary to increase the size to accommodate them. The transformers should therefore be obtained before commencing construction.

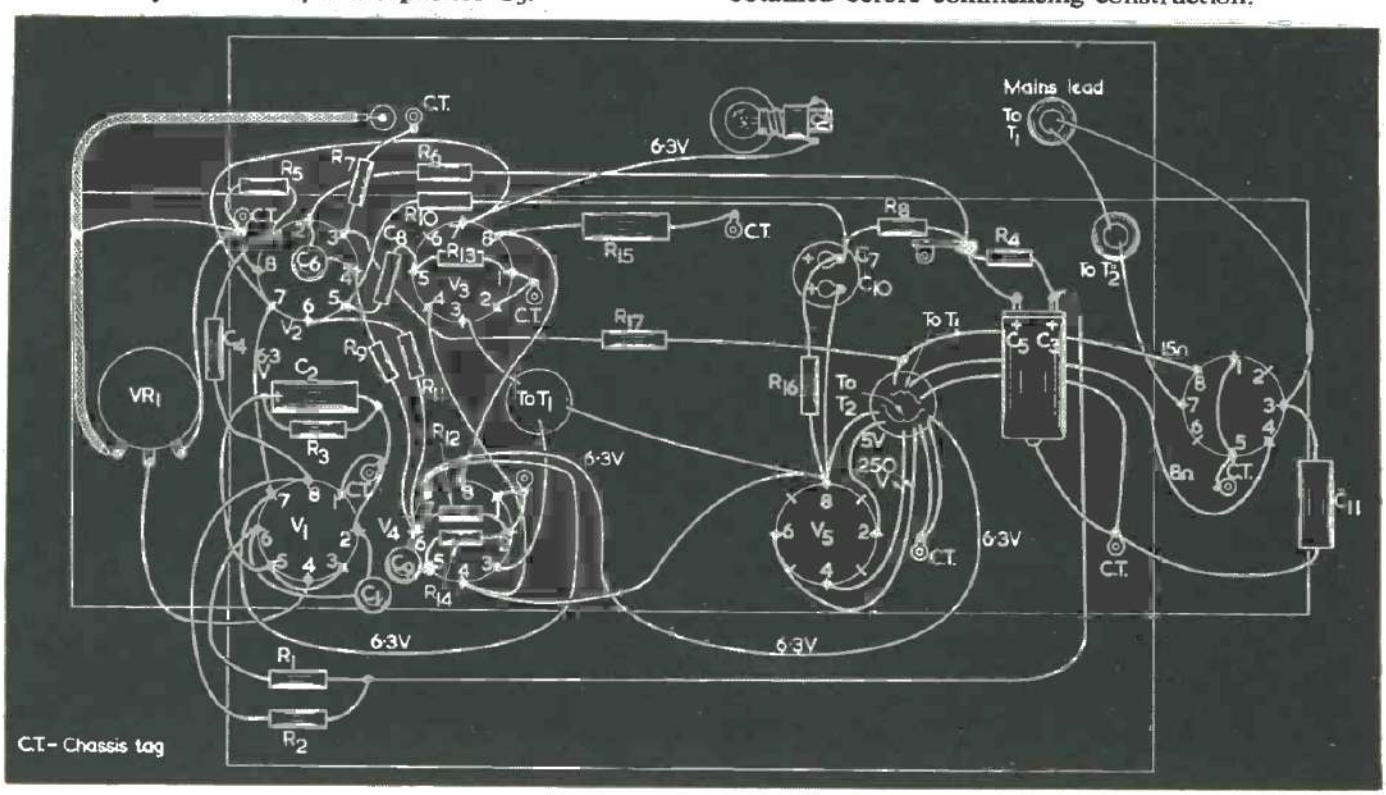

Fig. 3. The components and wiring below the chassis. Pin 6 of V_4 valveholder is employed as an anchor tag

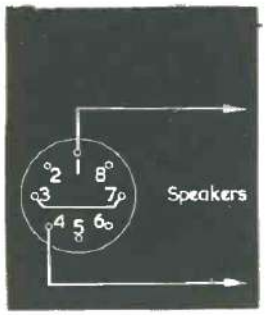

Fig. 4. Connections to the octal speaker plug. These enable one of two impedances to be selected

Construction

The amplifier is built on a chassis of 16 s.w.g. sheet aluminium measuring 9 x 4 x 1½in., a plan of which is given in Fig. 2. The work is quite straightforward and after the transformers and valveholders have been fitted, the wiring can proceed in any desired order. A wiring diagram is given in Fig. 3. The connections between the output transformer primary and the anodes of V_3 and V_4 should be sufficiently long to enable the leads to be changed over if, when the testing stage is reached, the feedback circuit is found to be positive. The speaker connection is made by way of an octal socket and this must be modified slightly by filing an additional keyway down the centre 180° opposite the existing one, i.e. between contacts 4 and 5. Check before fitting to the chassis that the modification permits the insertion of an octal plug in either of two positions, thus enabling the appropriate output transformer ratio to be selected according to the number of speakers in use. The wiring for the plug is shown in Fig. 4. The base of an unserviceable octal valve makes a good plug and the impedance can be painted on opposite sides of it so that the correct figure is at the top when in position.

When metal valves are used, pin 1 of V_1, V_3 and V_4 should be earthed, as shown in the wiring diagram.

Testing

When the wiring is complete and has been checked, connect a meter switched to a high resistance range between C_{10} and chassis to verify that there are no short-circuits in the h.t. wiring. If all is well, power can be applied and the operating voltages checked at the valve electrodes. As the valves warm up, there may be instability. If this occurs the mains supply should be switched off at once and the connections to the anodes of V_3 and V_4 interchanged to make the feedback negative. Residual hum should now be very low and, with VR_1 at minimum, should be inaudible at more than several feet from the speaker.

Carrying Case

Fig. 5 shows the construction of a simple carrying case made of ⅜in plywood. No skilled carpentry is needed here, and simple butt joints secured with panel pins and glue are adequate. If the cover is made a good fit round the amplifier chassis, the latter will be secured very firmly in position by its flanges when the cover is screwed to the baseboard. Attention must be paid to ventilation and not less than three 1in holes are required on each side and in the top and bottom of the case. These may be covered on the inside with perforated zinc secured with a reliable impact adhesive. Four rubber buffers should be fitted to the bottom of the baseboard so that it is raised a little from the surface on which it stands, thus permitting some under-chassis ventilation. The carrying handle is fitted at the point of balance.

Operation

The accessories for portable service should include lengths of mains, speaker and microphone cables sufficient to meet any likely contingency and a good assortment of various plugs and adaptors for making connection to the mains. A "neon mains tester" screwdriver is practically indispensable for detecting live outlets. Three-point outlets are by no means universal in many of the older buildings, so there is no point in using 3-core mains cable.

When an amplifier is operated with a high impedance input, it is often necessary to have an earth connection in order to avoid electrostatic hum pick-up. This is difficult with portable equip-

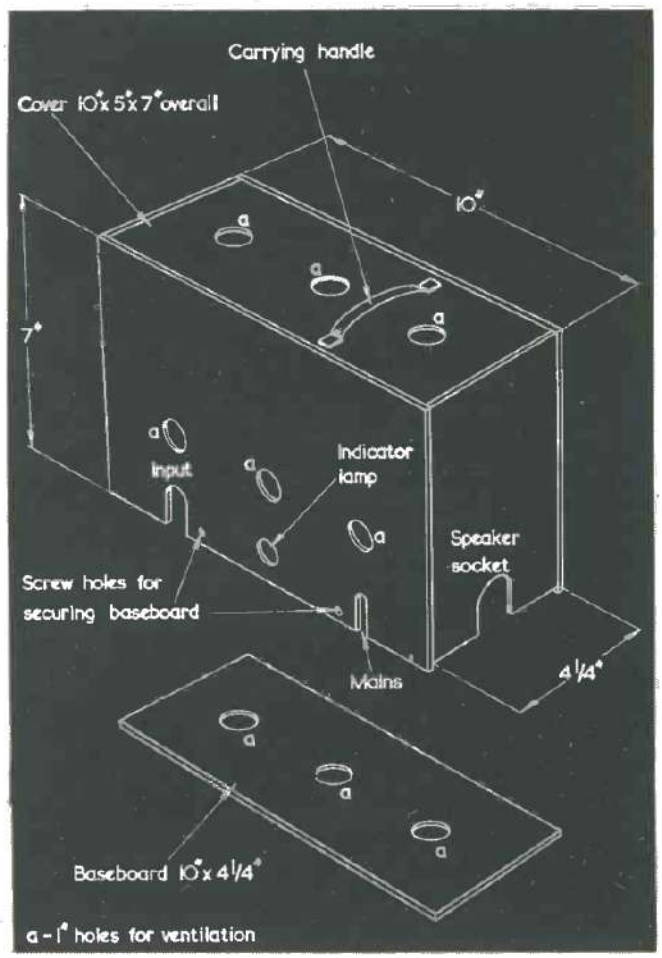

Fig. 5. Dimensions for a suitable carrying case. The handle is mounted at the point of balance. The material is 5in plywood

ment but an equivalent result can be achieved by coupling the chassis to the neutral side of the mains through a capacitor (C_{11} in Fig. 1). Whether C_{11} becomes connected to the live or neutral main is a matter of chance at each connection but it can be checked by applying the mains tester to the chassis; if the tester glows, reverse the connection.* The most convenient operational arrangement is to site the amplifier near the foot of the microphone stand so that the mike cable is of no great length. Under these conditions, C_{11} may be found unnecessary and can be deleted. The re-entrant speakers have practically no output to the rear and may, if need be, be placed quite close to the microphone without fear of acoustic feedback.

Input

A cheap crystal microphone will provide a sufficient signal to load the amplifier fully. Alternatively, a moving-coil instrument may be used provided a suitable step-up transformer is interposed before VR_1. For reproducing music almost any high impedance pick-up is suitable and, as there is plenty of gain available, compensation for recording loss and a tone control may be added if desired. In designing such a network the aim should be to make the load on the pick-up at middle frequencies equal to that recommended by the manufacturer; VR_1 will of course be part of this load.

Output

The re-entrant type speakers recommended are very suitable for the reproduction of speech and have the advantage of small physical size but, if good fidelity is required for music, cone speakers should be used instead. Two 10in units will give excellent results. The re-entrants will, however, serve well enough for some purposes, such as background music at open-air functions. Speakers may be connected in series or in parallel according to their impedances, the series connection being preferable if there is a long run of cable. The recommended output transformer provides impedances of 3, 5, 8 and 15Ω, any two of which can be made available at the speaker socket.

When two or more speakers are used, results will be inferior unless they are correctly phased. In other words, all the cones or diaphragms must be moving in the same direction at any instant. The terminals of re-entrant speakers often bear "+" and "—" signs for this reason. With cone units, the proper connections can be determined by connecting a 1.5V dry cell to the speaker line; place a finger lightly upon the cone and note the direction of movement as the circuit is made.

* A capacitor such as C_{11} between one side of the mains and an amplifier chassis is employed with some commercial designs in order to prevent hum pick-up. If the connection to the mains supply is such that the live side connects to C_{11}, it is possible to experience a mild "tingling" type of shock when touching metal at chassis potential if the operator is standing on damp ground, a concrete floor, or a similar relatively low resistance substance. Because of this it is preferable to employ a capacitor in this circuit position only when entirely essential and to make quite certain that it connects to the neutral side of the mains. If the mains transformer has an electrostatic screen between primary and secondaries, this should be connected to chassis, whereupon it will probably be found that C_{11} is not needed. C_{11} should also not be needed if the emplifier chassis can be connected to a reliable earth. When C_{11} is fitted, it is essential that it be a completely reliable component with a minimum a.c. rating of 250V.—EDITOR.

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* * *

PCR2 Receiver.—W. Burke, GM3TQH, c/o 6 Belgrave Terrace, Glasgow, C.2, would like the circuit and any other data.

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R1392.—W. J. Butt, 1 Harcourt Villas, London Road, Teynham, Sittingbourne, Kent, would be grateful for any information on this unit.

Ekco TV Model 155.—W. J. Robins, 7 Cedar Avenue, Birstall, Leicester, requires the circuit or any other information—particularly on the valve line-up.

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CR100 Receiver.—B. Gordon, 72 Coldshott, Holland, Oxted, Surrey, requires loan or purchase of the manual for this receiver.

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BC620F and PSU.—D. W. Viton, 169 Worthing Road, Laindon, Basildon, Essex, would like to obtain any information, service manual or circuits of this ex-U.S. Army transmitter/receiver.