A HOME-MADE HI-FI OUTPUT TRANSFORMER

BY W. GROOME

THE USE OF A TERTIARY FEEDBACK WINDING ARRANGEMENT SIMPLIFIES THE CONSTRUCTION OF THIS TRANSFORMER AND REDUCES THE COST.

(Continued from page 400 of the September issue)

IN last month's article the author began an explanation of his home-made transformer which included descriptions of some interesting circuits for its use. In Fig. 4, for example, a triode "see-saw" phase-splitter amplifier stage feeds the output pentodes. The tertiary winding, earthed one end, supplies feedback to V1 via R2 and provides a path for the cathode current.

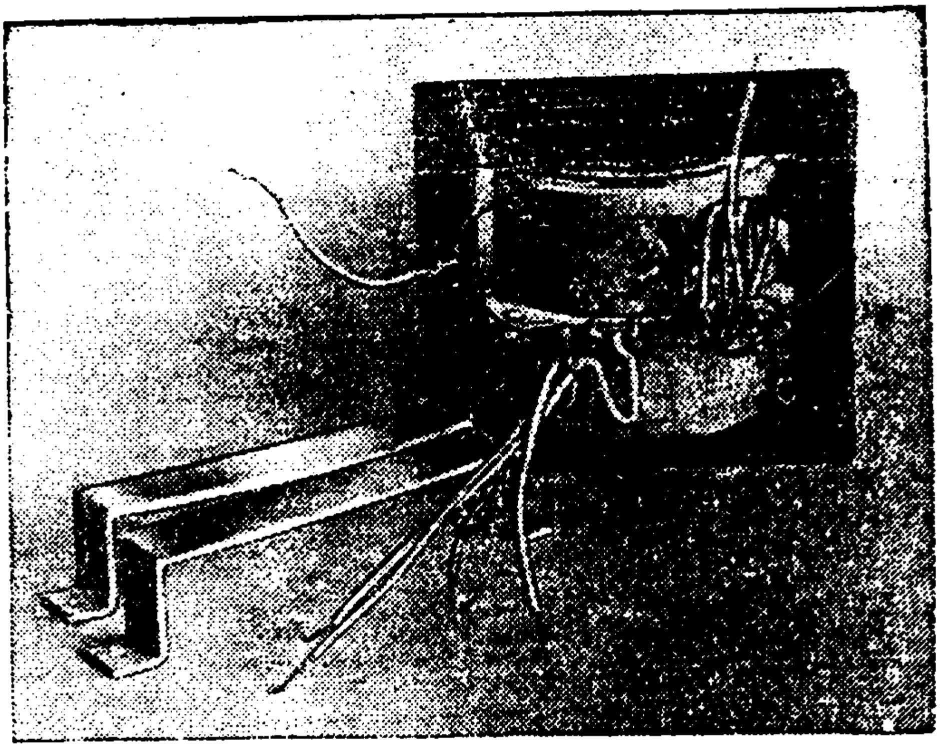
If pentodes were used for the phase-splitter stage the sensitivity, held by the feedback ratio, would remain the same. The feedback ratio, and with it the amplifier sensitivity, can be made variable by shunting the tertiary winding with a 100Ω potentiometer and taking the feedback voltage from the tap, as shown in Fig. 5 (last month). This refinement may be of interest to some experimenters, but the triode circuit will be found suitable for most domestic purposes. The ECL82 valve, comprising an amplifier triode and an output pentode enables a two-stage push-pull amplifier to be built around only two valves—and stereo using only four valves becomes a practical proposition.

Cathode Follower Output

The improvement achieved by the use of feed-back over the output stage (apart from easing the application of overall feedback) is a 'natural sound' that is not likely to show up on instrument tests. It is real enough, however, and the once-popular cathode-follower circuit with its virtually complete cancellation of its own distortion and immunity from the errors that can arise in a complex loop, gives a realism that is still hard to better. Its limitation to triode efficiency and the large grid voltage swing needed for full loading have caused it to decline in popularity and designs more suitable for pentodes have become more popular.

These are the "distributed load" circuits, of which the quaintly named ultra-linear version is best known. As the author's transformer has both secondary sections split into two well-insulated sections with free leads, it can be connected in the ultra-linear mode as shown in Fig. 7. It is true that the tap at 50% is higher than is customary but this closer approach to triode conditions has not been found to be the slightest drawback.

Ultra-linear connections are not the only, or even the first, form of distributed load circuit, for a more elegant circuit was developed in this country several years before the 'ultra-linear' circuit appeared. However, the version shown in (Fig. 7) embodies cathode loading which, as stated in an earlier paragraph, is a highly desirable method of obtaining output stage feedback. Despite the strangeness, on paper, of a load distributed between anode and cathode, the relationship to the ultra-linear arrangement can be appreciated when the screen is considered, this being tapped into the transformer load in both cases. This is obvious in the ultra-linear circuit; in Fig. 7, it is still loaded by the transformer because its current and signal are compelled to flow in the cathode winding.



One of the author's prototype experimental output transformers.

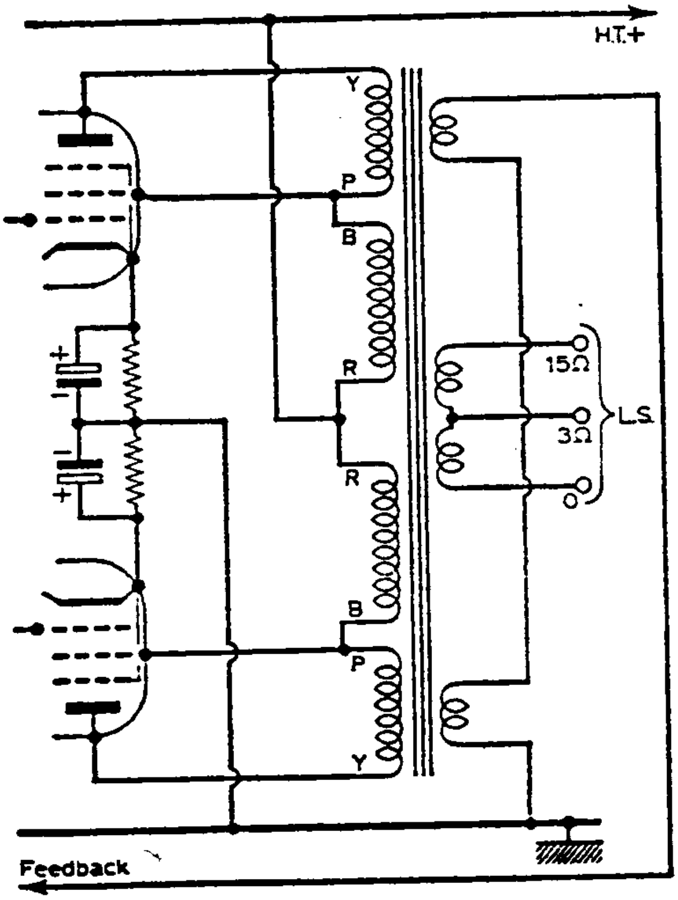
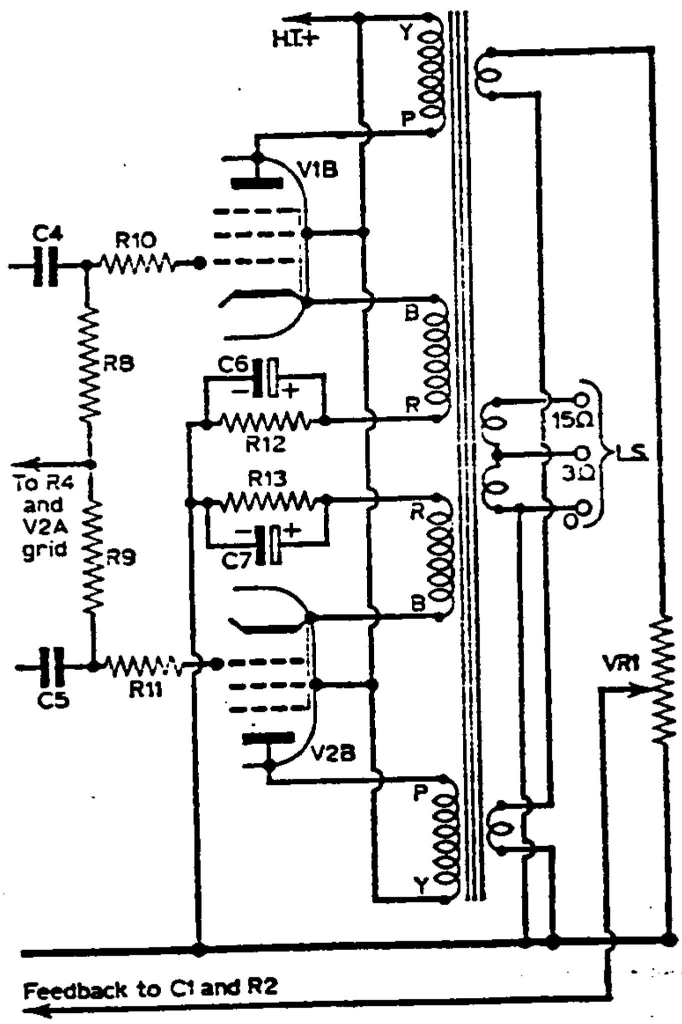


Fig. 6 (left)—Connections for ultra-linear loading.

Fig. 8 (below)—Rearrangement of a two-stage amplifier for anode/cathode loading.



50 : 50 Distribution

This form of loading can be tried by connecting the transformer as indicated in Fig. 8. Bear in mind, however, that the output circuit is patented. The transformer and its associated circuits must not be compared with a well-known make of amplifiers to which this form of loading is exclusive. As 50:50 load distribution must be used, the output stage feedback is already nearly enough to give the required reduction in distortion and output impedance and the amount needed in the overall loop is therefore small. For this reason, a potentiometer is shown across the feedback winding in Fig. 8, which shows the ECL82 circuit modified for this form of loading.

As the grid resistors are returned to earth (via the grid resistor of V2A) the D.C. resistance of the cathode loads contributes towards the bias voltage of the output valves. The resistance of these portions of the windings should therefore be checked and the value of the bias resistors reduced correspondingly. A variation of this form of distributed loading has the grid resistors connected to the cathode ends of the load and no adjustment of the bias resistors is needed. It is not really suitable for use with a see-saw phase-splitter, but can be driven by a "concertina" circuit either in the straight form or in the high-gain versions, one of which employs the input resistance of the phase-splitter to load an amplifier pentode, and another using the pentode in starvation anode conditions. This phase-splitter can also be used in a positive feedback circuit for high gain but it is preferred to keep the signal "clean" at every stage rather than have to clean up an accumulation of distortions with the main feedback loop.

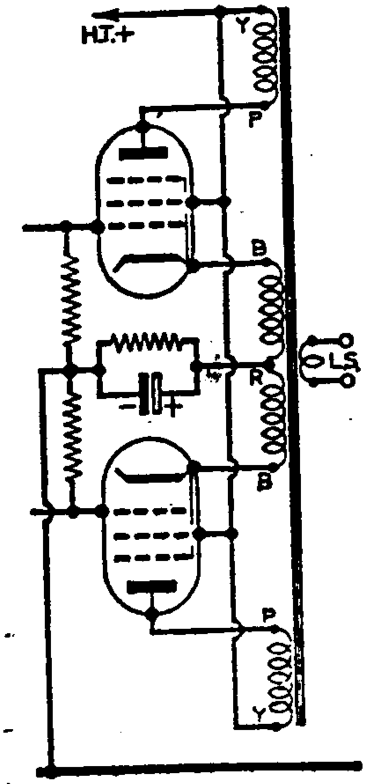


Fig. 7 (right)—Here the load is distributed between the anodes and cathodes.

Input Signal

Now that crystal pick-ups have reached high fidelity standard, with outputs so much greater than the magnetic types that were once essential for the discriminating listener, and radio tuners also deliver large signals, there is no longer an urgent need for great sensitivity in the domestic amplifier. Indeed, amplifiers requiring as much as 4V input can be fully loaded, for the signa

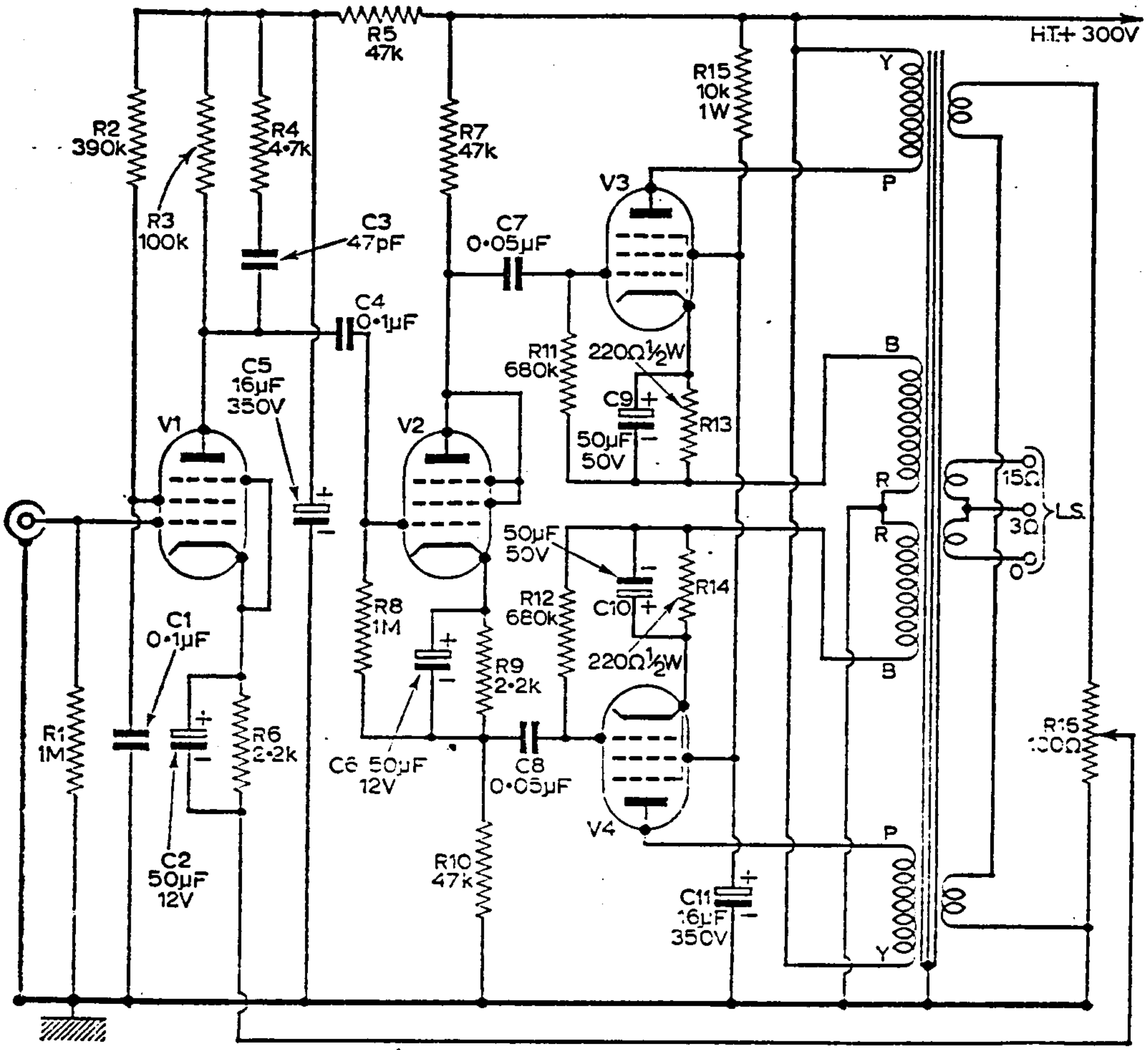


Fig. 9—A three-stage amplifier with another version of anode/cathode loading.

is almost always passed through a pre-amplifier control unit first, and a highly sensitive amplifier could be hopelessly overloaded.

The straight pentode and concertina circuit shown in Fig. 9 will give all the gain likely to be needed. The grid resistors of the output valves are connected to the cathode ends of the cathode loads. The front end can be altered if it is wished to try one of the high-gain versions, without drastic alteration of the remainder. The use of two A.C. couplings is not likely to cause instability with tertiary feedback, but direct coupling between V1 and V2 can be used by the constructor interested in the experiment. V1 and V2 could be triodes, i.e., a double triode.

The transformer, of which constructional details will be given in the next issue, has been used in a variety of circuits, not all of which were considered desirable when matters of cost and ease of adjustment were taken into account. All, however, tended to prove the inherent stability of the tertiary feedback system.

(To be continued)

P.W. SIGNAL GENERATOR

(Continued from page 482)

so on, at 200kc/s intervals, until the generator harmonics are too weak to hear.

The fifth harmonic of 200kc/s will be 1,000kc/s, or 1Mc/s, and the generator may be tuned to this. Harmonics of the generator will then be heard at 2Mc/s, 3Mc/s, 4Mc/s and so on, at 1Mc/s intervals, until too weak to be found. It is, of course, necessary to have a receiver with short-wave ranges, for this purpose. By proceeding as described, calibration marks can be obtained at 1Mc/s intervals.

In many parts of the country the National Physical Labaratory signal on 2·5Mc/s can be received. This will furnish a 2·5Mc/s calibration of great accuracy. By proceeding as above, harmonics of this will furnish calibration marks at 5Mc/s, 7·5Mc/s, 10Mc/s and so on, at 2·5Mc/s intervals. ■

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(Continued from page 502 of the October issue)

THE section diagram of one of the author's tertiary-wound transformers is shown in Fig. 12, which may seem, at first glance, to be as complex as the conventional high quality product, but it is really quite a simple job for the enthusiastic home constructor. Sections 1 and 7 are only of 20 turns each spaced to form single layers and the secondary (4) is a simple winding of about a hundred turns. The primary is so arranged that sections 2 and 5, serving one valve,

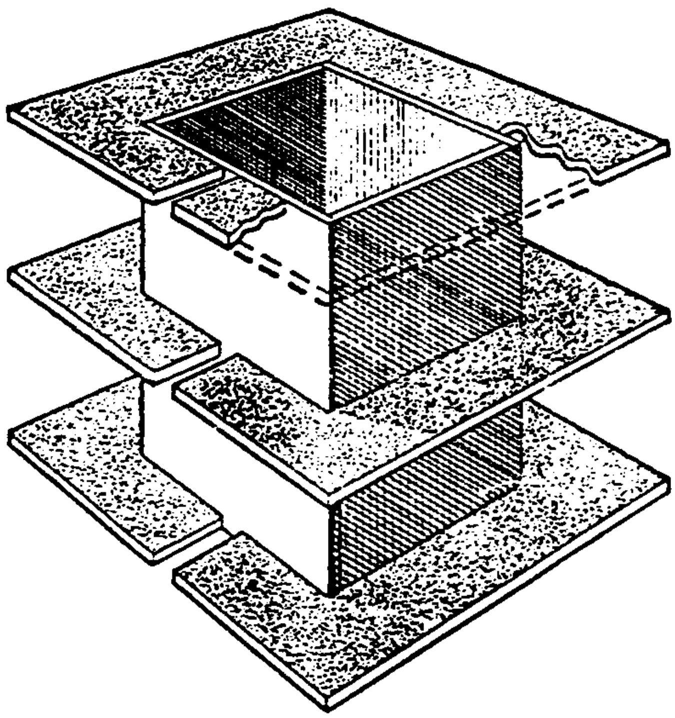

Fig. 10—The construction of the bobbin.

match 3 and 6 for the other much more accurately than the more usual arrangement in which only the number or turns—and nothing else—can be matched.

Laminations

The amateur's main difficulty is obtaining core material, for very few dealers carry laminations in stock and the delivery for small orders of one or two stacks seems somewhat lengthy. Fortunately, the tertiary-wound transformer is so stable, so free of trouble in the use of heavy negative feedback, that quite generous tolerance is permissible in the choice of laminations before any audibly detectable loss of quality occurs. Because of this, a departure has been made from the usual rigid specification that limits the amateur's choice of material (and reduces expenses because core material is far from cheap) and constructional details will be given which can be adapted to material that is available or easily obtainable.

Stripping down an old component is one way of obtaining laminations, and wire too. It can bring a slight simplification in the job of re-winding, because, as stripping proceeds, the turns per layer, and the number of layers can be counted and so the number of primary turns to put on for power-handling at least equal to, and probably better than, the original component can be discovered. It will be a useful guide, but not quite all of the wire will go back on because two single-layer tertiary windings, some extra insulation and a possible loss of compactness owing to hand-winding, will use up some space. The sacrifice need not be too great, and the turns-ratio (if it must be the same) can be maintained.

Former

The constructor who does not resort to using old components will have to make decisions on wire gauge and number of turns, but some guidance will be given. The transformer needs a special cheeked and partitioned bobbin in place of the simple former most often used, and this, shown in Fig. 10, can be made at home from paxolin, Perspex or even cardboard. Cardboard bobbins look rather the worse for wear on completion of the winding but can be made to serve the purpose.

Set the dimensions by measurement of the stack of laminations. The end cheeks and the central partition are identical, and can be slotted to enable the leads to be brought out if rigid material is used. Alternatively, with cardboard, they can be brought out through holes pierced with a needle as winding proceeds. A bobbin made for a core of square section will wind more smoothly than one made for a rectangular stack. A geared hand-brace makes a useful winder when clamped in a vice. Check the gear ratio by counting the chuck revolutions for one turn of the handle. Fig. 11 shows one simple way of fitting the bobbin to the chuck. It comprises a woodscrew driven into a piece of wood of the same size and section as the core; the head is then removed.

The gadget must be made accurately, otherwise it will revolve with a wobble that will cause overlapping turns and snapped wires. Try cutting the wood oversize and paring it to exact size after fitting the screw.

Ratio

Almost the only simple aspect of transformer design is the turns ratio, which is given by (Zp/Zs) where Zp and Zs are respectively the valve output impedance and the nominal loudspeaker impedance. All others are so complex that no single specification can be offered when the object is to enable the constructor to use available materials. Nor would it be helpful to present a page of formulae with an invitation to the constructor to sort it out himself. Because of these difficulties, and because the tertiary-wound transformer is tolerant to a reasonable range of variation, a procedure that seems rough and ready is given but which will prove satisfactory. A general description of the method will be given first, followed by step-to-step winding instructions.

Refer to Fig. 12, which gives a cross-section of the windings with the core on the left and the partition seen horizontally. The cheeks, which would be horizontal at top and bottom, have been omitted to avoid confusing the leads in the diagram. All sections are balanced equally each side of the secondary winding (section 4), and therefore this section must be positioned accurately half-way through the depth of the winding space. Allowing for four layers (at the most) of 20 or 22 s.w.g. enamelled wire plus paper interleaving and Empire cloth insulation, the secondary will occupy 0·20in. of winding space, of which 0·10in. will lie either side of the true mid-point.

Mark these boundaries on the outsides of the cheeks near the slots, or on the insides if they are not slotted. The inner marks indicate the limits of sections 1, 2 and 3. There, with all insulation layers, they must stop, regardless of the number of turns wound on because an equal space is needed for sections 5, 6 and 7. As all four primary sections are equal, the number of turns on section 2 can be multiplied by 4 and the product divided by the required turns ratio to give the number of turns that must be wound on for the secondary (section 4).

Turns

Reference to standard wire tables will give advance guidance as to the likely number of primary turns that can be accommodated. The width between one cheek and the partition divided by the wire diameter gives the number of close-wound turns per layer. The section depth less 0·05in. for insulation gives the actual winding space. Add 0·003in. to the wire diameter for interleaving paper and the layer thickness is obtained. The total number of turns is then given by

$$\frac{\text{Winding space} \times \text{turns-per-layer}}{\text{Layer thickness}}$$

From 3000 to 3500 turns is a fair total for a primary winding and the gauge can be chosen from the range 32 to 38s.w.g. to suit the available space. If the original gauge of wire is used with an old component, it will be found that the number of turns is less than the number removed.

Use laminations of reasonably good quality and aim for a core section of about ¾in. square for 5W and up to 1¼in. thickness for 10W. Make the bobbin to suit and mark the secondary boundaries on the cheeks. Wind section 1 (Fig. 12) straight on to the bobbin, 20 turns only, spaced to occupy the full width, passing the partition so that 10 turns lie each side of it. Gauge (25 to 30s.w.g.)

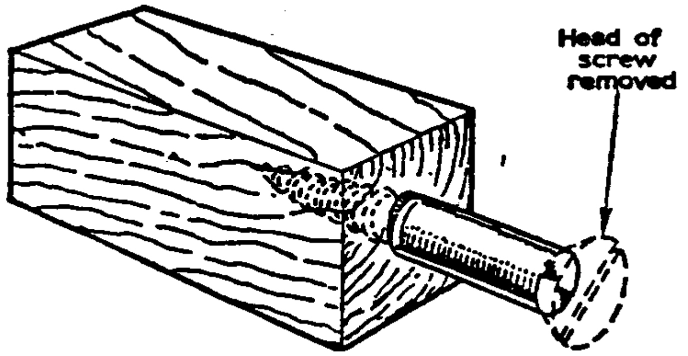

Fig. 11—A suitable bobbin holder for use with a geared brace for winding.

is not very important because the feedback network draws virtually zero current and only a few milliamps of V1 cathode current passes through the winding.

Insulation

Fasten the wire ends to the cheeks with adhesive tape to prevent them becoming tangled as winding proceeds. This section will operate near to earth potential, but the next will have a wide A.C. swing; therefore, three layers of 0·005in. Empire cloth should be wound on for insulation. It also provides an even surface on which to commence the next winding.

The first primary layer for section 2 should be close-wound to fill the width between one cheek and the partition. Note the number of turns, add a layer of 0·003in. paper and continue to add similar paper-interleaved layers until it is obvious that the addition of three layers of Empire cloth will fill the allotted space up to the boundary mark. Calculate the total number of turns.

Section 3 is identical to section 2 but, as it serves the other valve of a push-pull pair, it must be wound in the reverse direction. Simply take the bobbin off its temporary wood core and put it on the other way round; then, rotation of the winder need not be reversed. This section, complete with insulation, should

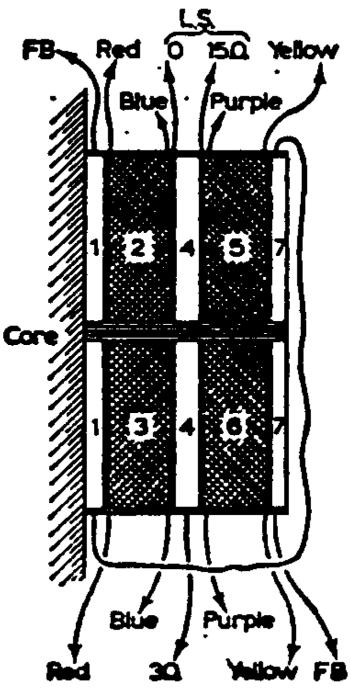

Fig. 12 (right)—The arrangement of the sections.

end up level with section 2 on the other side of the partition.

Calculation

Next is the secondary, section 4, and the number of turns has to be calculated. The number of turns in section 2, multiplied by 4, gives the total primary turns and this figure divided by the turns ratio, gives the number of secondary turns. For example, if section 2 has 750 turns and the ratio required is 30:1 the calculation is

$$\frac{750 \times 4}{30} = 100$$

The secondary must be wound evenly right across the bobbin, passing the partition as it extends from cheek to cheek. If the last layer has insufficient turns to fill its full width the turns must be spaced evenly to distribute them equally each side of the partition. A 3Ω tap can be made at 50% of a 15Ω secondary provided it can be arranged near a cheek. This is impossible with a three-layer secondary and easy with a two-layer one when the wire gauge is chosen to fill the width exactly. In a four-layer winding, the second and fourth can be spaced evenly so that the tap can be at a cheek and the balance maintained.

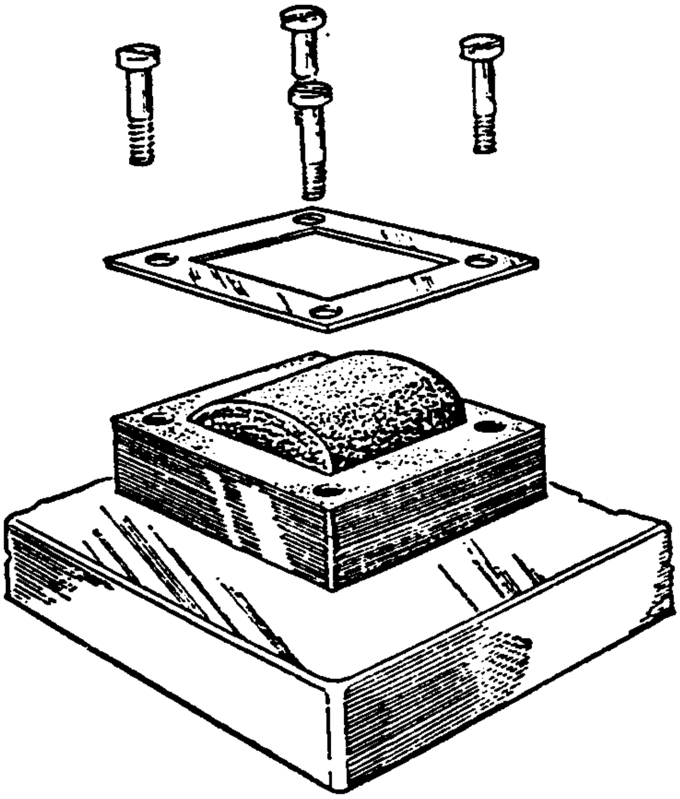

Fig. 13—A method of clamping the finished transformer to the amplifier chassis.

When the secondary has been insulated with three layers of Empire cloth, the remaining winding space should equal that used for sections 1, 2 and 3. Wind section 5 exactly the same as section 2 and in the same direction. Section 6 must be wound in the same direction as section 3. These sections, with three-layer insulation, should leave just enough space for the outer tertiary winding which is identical with section 1 and wound in the same direction. Three more layers of Empire cloth complete the work of winding.

The end of section 1 and the beginning of section 2 should be soldered together, leaving two leads which should be sleeved. The flimsy primary wires should be anchored and colour coded immediately, those from each cheek being a separate one-valve set. Sleeve them, using the colours indicated in Fig. 12, and then bind the sleeves firmly to the insulated windings with adhesive tape, or tape coloured leads to the insulation and solder the wires to these. If the securing is delayed until after assembly of the laminations, tag-strips can be fitted to the transformer mounting.

Assembly

Insert the laminations with the E's and I's in alternate directions, and butted together without gaps. Firm clamping is essential to avoid buzz and chatter. Fig. 13 shows a transformer dropped into a rectangular hole in the chassis and clamped by a plate with a rectangular hole bolted through the laminations.

In all circuits to which this versatile transformer can be applied, sections 2 and 5 together form the load for one valve of a push-pull pair and for straight anode loading they are put in series by joining the blue and purple leads together. Yellow is then taken to the anode and red to H.T. Sections 3 and 6 are used in exactly the same way with the other valve. Ultra-linear loading is obtained by taking the screens to the junctions of the blue and purple leads. ■