Vintage Radio

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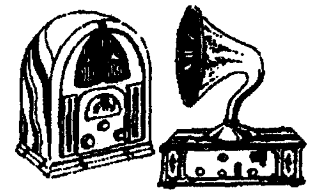


Rewinding audio coupling transformers

Interstage audio transformers are the most unreliable component encountered in the repair and restoration of early radio equipment. Used in practically every pre-1930 radio, their mortality rate from corroded windings was extremely high, and few receivers will be found with their original transformers intact. But like output transformers, they can be rewound.

Professional rewinders are often neither interested in, nor able to handle such small transformers as were used to provide interstage coupling in the audio section of early receivers. Sometimes it is possible to dig into a winding to bypass the open-circuited section, but this is an unsatisfactory method. Desperate restorers have even been known to resort to installing hidden transistorised coupling stages and in the United States, it is possible to purchase miniature transformers to conceal inside original cases.

By using the simple equipment for winding output transformers described in the March 1991 column, rewinding of audio coupling transformers is a practical proposition, and with care and a bit of patience, not difficult. First though, we should look at some background to the history and basic theory of audio transformers.

A long history

The first audio transformers, known as 'induction coils', were produced more than a century ago to match the low impedance of carbon microphones to telephone lines, and are still used today in vast numbers. Their construction was in turn based on the even earlier medical and spark coils, made with primary and secondary windings wound on 'open' cores consisting of bundles of straight iron wires. Automotive ignition coils are, of course, their direct descendants.

As the first valve audio amplifiers were used as telephone 'repeaters', it is not surprising that many early valve coupling transformers were similar to telephone induction coils. However, open cores are not very efficient, and were soon improved by making the core wires several times longer than the winding and folding the ends around so as to enclose the completed transformer.

These were known as 'shell' transformers or 'hedgehogs' (there is no record of Australian versions being called 'echidnas'!). Examples can be found in some of the early Atwater Kent sets.

Miniature versions of the silicon steel laminated cores used for mains transformers were found to be superior to iron wires, and before long were being used in a great variety of shapes and sizes. As anode currents were only a few milliamperes, laminations were usually interleaved, rather than butt jointed.

Performance limitations

Three parameters — inductance, leakage inductance, and distributed capacitance — are of major importance in audio transformer design. Inductance, which governs low frequency response, is dependent on number of turns of wire, core area, and core permeability.

General purpose triodes have an anode impedance of the order of 10,000 - 15,000 ohms, and suitable primary windings must have sufficient inductance to have an impedance at least equal to this at the lowest frequency of interest. In practical terms, this means that the primary inductance must be at least 50 henries for an adequate response.

Leakage inductance results from incomplete coupling between windings, and is related to their physical size and separation, being greatest with large

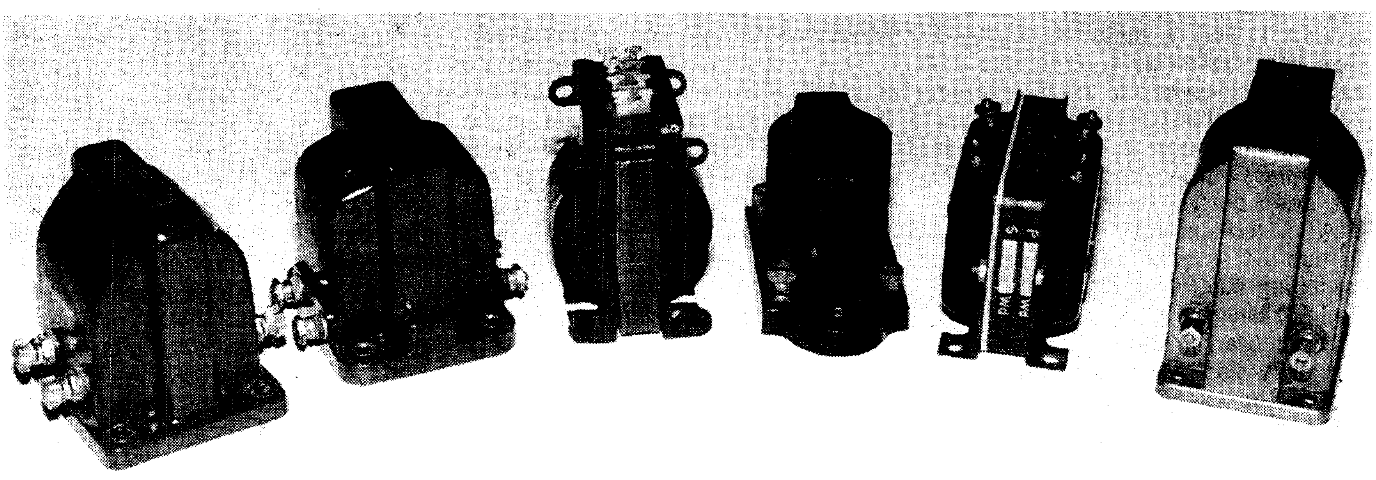


Fig.1: Typical interstage transformers. From the left are an Emmco, a Telsen, an RCA, a Philips, a Primo and an AWA.

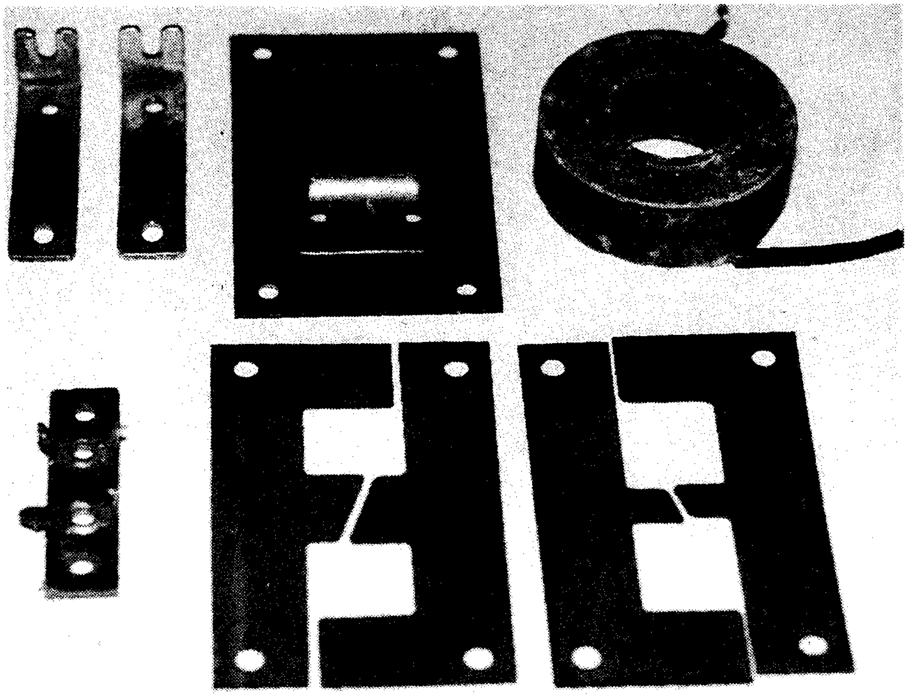


Fig.2: One reason why commercial bobbins are not suitable for audio transformers. Round windings were easy to make, but needed odd-shaped laminations with two or more sizes of centre leg.

windings. One effect of leakage inductance is to restrict high frequency performance, by acting as a choke in series with the transformer.

Winding capacitance bypasses high frequencies and resonates with leakage inductance to produce a peak in the frequency response of the transformer.

Compromises

Audio transformer design involves serious compromises. To have adequate inductance, the windings must be of large physical size with many turns of wire — the very factors which increase capacitance and leakage inductance.

For a reasonable amount of leakage inductance and winding capacitance, using simple winding configurations, the transformer must be physically small, and therefore have a limited winding space. Obviously, to maximise the number of turns, the wire must be as fine as possible. Fortunately, resistance is not a problem, but fine wire is fragile and very vulnerable to corrosion. The finest diameter that can be handled easily is about 0.08mm (44 SWG), and many transformers were wound with this gauge.

Interstage transformers provide a voltage gain, governed by the ratio of turns on the primary and secondary windings. Primaries require a large number of turns to provide a good low frequency performance, and the size of the associated secondary winding is severely restricted if leakage inductance and winding capacitance are to be kept at reasonable levels.

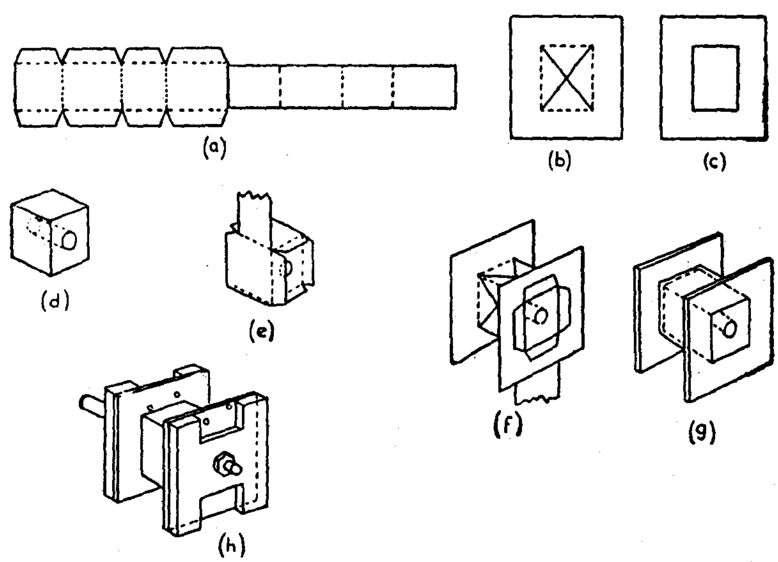
As a general rule, the maximum step up ratio for acceptable audio quality was 5:1, and for reasonable quality was limited to a 3:1 turns ratio.

The reality is that many audio transformers were not engineered, but made empirically and with economy a prime factor. Some early constructional articles specified the weight of wire rather than an exact number of turns!

Various techniques, most of them too expensive for competitively priced transformers, can be used to minimise the design problems. A late development was high permeability core steel, requiring fewer turns for a given inductance. Most potent in minimising winding capacitance and leakage inductance is splitting windings into 'pies', or by sandwiching them in sections. However, transformers encountered in restoration projects are not likely to have many refinements, most just having the secondary wound on top of the primary.

With all the problems and expense, it is not surprising that after 1930, with improved valves and resistors becoming available, and with better understanding of R-C coupling, interstage transformers were generally avoided.

Fig.3: Making a bobbin. First cut heavy paper or thin card to form the centre strip (a), allowing about 0.5mm clearance around the core. The two inner cheeks (b) have diagonal cuts to form flaps, while the outer cheeks (c) have core clearance holes. The wooden mandrel (d) should be 'square', an accurate fit within the bobbin and about 0.5mm shorter than the centre leg of the core. Make sure that the hole is parallel to the sides, or the bobbin will wobble. Wrap the centre strip around the mandrel (e), gluing with polystyrene cement. Then glue the inner cheeks in position (f), being careful not to get glue on the mandrel. Wrap a single layer of paper around the centre. Then fasten the outer cheeks (g), coating with varnish when the glue sets. Finally make up two end support washers from heavy aluminium sheet or hardboard, with slots to provide clearance for the winding leads as in (h).



There were several different terminal identification codes used for interstage coupling transformers. Anode connections are most commonly labelled 'A' or 'P' (for 'plate'). High tension terminals are usually 'B+', 'B' or 'HT+'. 'G' is of course the grid terminal, but the grid bias return can be 'F', 'C-', 'C' or 'GB' (for 'grid bias').

Some transformers were marked 'IP' (inside primary), 'OP' (outside primary), 'IS' (inside secondary) and 'OS' (outside secondary). Reference books disagree completely as to the preferred sequence of connection for transformers marked in this way, although most consider that 'OS' should be the grid connection.

Rewinding

Audio coupling transformers can be rewound without complex equipment. The method to be described is basically that for output transformers in the April 1991 column, using a hand drill.

As with output transformers, random winding without any destructive interleaving paper will result in a more reliable transformer than the original. Be warned, though: more patience is required, as the wire is finer and there can be as many as 10 times the total number of turns used for output transformers.

There was no standardisation of interstage transformer cores, and suitable commercially made bobbins are unlikely to be available. Fig.3 shows an easy way to make them from thin card or heavy paper. The laminated construction results in surprisingly tough bobbins, which should be thoroughly coated with polyurethane varnish before winding.

To count the turns on the original winding would be very difficult. If, as is often the case, both windings are wound with the same gauge of wire, all that is necessary is to fill the available space in the proportions of the original turns ratio, as randomly wound fine wire occupies much the same space as paper and layer winding.

For example, allowing for insulation, a standard 3:1 transformer primary should occupy about 25% of the window space and the secondary 75%. As a guide, a typical primary winding will have 5000 turns.

First dismantle the original winding, noting any unusual details and the sequence of connections. Now pull the winding apart to ascertain the wire gauge. Chances are it will be in the region of 0.08mm. A micrometer is a considerable help here. Otherwise the diameter of the wire can be calculated by neatly winding a layer of the wire one centimetre wide on a pencil, and counting the number of turns (n). The formula 10/n will then give the diameter in millimetres.

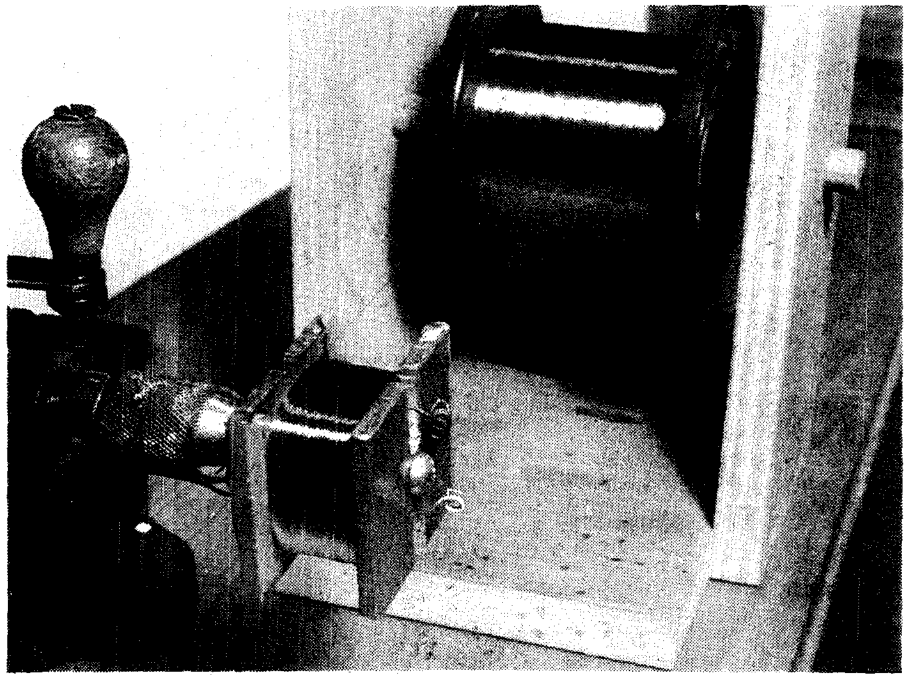


Fig.4: Rewinding of an AWA 'Ideal' transformer in progress. Narrow strips of cellulose tape have been used to hold the cheeks of the paper bobbin against the end washers. Otherwise, the fine wire used is likely to slip between the cheeks and the end washers, during the winding operation.

Set up the winding equipment, and solder a fine stranded leadout wire to the winding wire. With a hot iron it is possible to solder many modern winding wires directly, without first removing the enamel, and it is worth trying. If this does not work, gently remove the enamel with 400 grit abrasive paper.

With a darning needle, make a hole in the bobbin and thread the lead through. Position the lead so that it occupies the full width of the bobbin, and insulate the join with a slip of plastic tape; then proceed with the winding, keeping it as level as possible.

The fine wire requires very careful handling. If a break occurs, twist the ends of the wire together, and after soldering, insulate with a fold of cellulose tape.

Varnish winding

As winding proceeds, keep a tally of your turns of the drill handle. Regularly apply coats of polyurethane varnish, to lock the windings rigidly and prevent damage and distortion during reassembly. Be careful not to get any varnish between the bobbin and the end plates.

For a 3:1 ratio transformer, fill about 1/5 the winding space with the primary winding and terminate with another stranded lead, again allowing it to cross the full width of the winding. Apply two or three layers of varnished, waxed or plastic coated paper before winding on the secondary, making sure of a neat fit with no gaps at the edges.

Now wind on the secondary, terminating the leadout wire in the same manner as the primary. With the full number of turns completed, connect a flexible lead, this time taking a full turn round the winding before passing it through a suitable hole in the side of the bobbin. Allow the varnish to harden, finish off with a layer of tape or varnished paper and trim the sides of the bobbin to the contour of the winding.

All that remains is to check continuity of the windings with an ohm meter, and reassemble. The result should be a transformer with a performance comparable to the original, and a much greater life expectancy.

In trying it out, be very careful not to short circuit the anode terminal to ground. Modern 'B-battery eliminator' power supplies are often capable of providing enough current to burn out the fine wire used in audio transformers.

Driver transformers

Although classed as interstage transformers, the pushpull driver transformers for class AB and B amplifiers popular in battery and some mains equipment during the 1930's were different from conventional audio transformers. They were in fact specialised output transformers, required to deliver power to the grids of the output valves.

Instead of a step up, they had a step down ratio, and could be wound with heavier gauge wire than found on interstage transformers. Turns ratios varied considerably, valve manuals quoting primary to secondary ratios of between 1.5:1+1 and 5:1+1.

If exact details are not available, a reasonable compromise would be to have a primary winding of 4500 turns of 0.1mm wire, with secondary windings of 1500 turns each. ■