It is many years (over forty) since I was directly involved in the production of a three-stage ratio transformer. I do recall, however, that our production manager (Brian Densham) was a resourceful chap. He always found ingenious and practical ways to produce transformers, albeit in small batches – no special machinery.

More recently (over ten years) I produced a single-stage transformer with quite a long secondary rope. I had the good fortune of access to a lab/workshop next to a long corridor which, in the early evening, had very little human traffic. The corridor floor was covered with carpet tiles on which a couple of metal framed stools provided anchor points with reasonable grip. At one stage I relied on a PhD student, working late in the lab, to sit on the stool at one end, to provide extra traction; otherwise it was a one-person job (i.e. I did not need an extra pair of hands – buttocks yes, PhD not essential).

1. Rope spinning

The most important feature of an IVD or RT, apart from ensuring the exact number of turns, is the uniformity of the tightly twisted rope, especially for the first and second decade – no kinks sticking out. This is to ensure that any stray flux (outside the toroid) links each of the strands equally, on average.

Two stools provided anchor points, each with a strip of plywood with a smooth circular peg (typically 1cm diameter, metal or plastic) firmly pressed in a hole at one edge. Each plywood strip was on the floor and held back by the legs of the stool. The pegs were vertical and about 10cm high. Viz: -

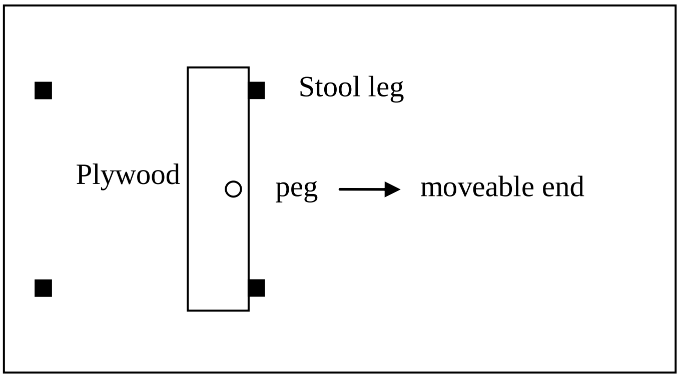

Fig. 1.1 Fixed end anchor point

The start of the first strand was firmly tied to the peg ("fixed" end) and pulled tight until there was no slippage. With the reel of wire on a pen (or pencil) I was then able to lay the strands on the floor, around the peg at the "moveable" end and back again for the required number of strands.

With an odd number of strands (often the case) the last strand ends at the moveable end. Pass the strand around the peg, slide it off and tie a knot, being careful that the last strand is the same length as the others, at least approximately, when it is put back on the peg. The last (single strand) loop/knot should not be able to slip. Move the stool and, by pulling gently on the plywood/peg and manipulating sideways, ensure that the strands slide over the peg to form a "bunch" of more precisely equal length. It may be a good idea, at this stage, to hold the bunch together, at 3 or 4 points along the length (loosely) with string tied in bows (reef knot – like tying a shoelace).

At this point all the strands should be of approximately the same length. It is important, however, that they are precisely parallel, under moderate tension, before spinning. You will also begin to wish you had a very long work bench. Find a cushion or knee pads.

Remove the bunch from the moveable end peg and hold it in place with a heavy book (or similar). Move the stool and plywood/peg back about 0.5m. Attach elastic bands (3 or 4 in series) to the peg and prepare s-shaped hooks (unfolded paper clips?) ready to connect to each pair of strands (and any single strand). The tension should be about 100gramme-force per pair of strands. Before attaching the hooks use a circular plastic tube (pen or pencil) through each pair/loop and apply moderate tension (book still in place) and rotate/manipulate until each strand is precisely the same length. Attach the hooks/elastic and pull firmly.

To be even more precise (especially with thicker gauge wire) return to the fixed end and tie a string bow around the bunch (2 or 3 loops around the bunch followed by a reef knot bow – this time rather more tightly). Slide the knot along the bunch (0.5m to the moveable end) and tie another, then a second and a third. As you slide the knots down the bunch remove the loose ones and continue to the moveable end. Return to the fixed end and keep adding knots, as required, until you have knots every 0.5m (or thereabouts) along the length of the bunch. If necessary remove the first 2 or 3 tight knots and add them to the start end. Manipulate the hooks/strands to take up any slack.

The basic idea is to end up with parallel strands, held in a bunch by the string, ready for spinning.

At the moveable end remove the hooks, carefully fold the bunch over to form a loop around a circular tube (pen or pencil) and, while holding the double bunch firmly in one fist pull on the tube and start spinning the rope. Initially this is to twist the bunch pair to form a loop but it will also start to spin the main part of the rope. Once formed and reasonably stable use masking tape to stop the loop unravelling. Low adhesion masking tape is easily removed and leaves no sticky residue.

This is when you are likely to need a friend to anchor the fixed end as you apply considerable tension - sufficient to stretch the strands, permanently, by 1 or 2%. The copper and polyurethane insulation can tolerate this.

Use an electric hand drill, with a hook held firmly in the chuck, to apply the main tension and turns. An old style chuck (with chuck key) is likely to be a best.

The pitch should be as tight as possible – causing the length of the bunch to reduce by 10 to 20%, equivalent to one complete twist per 5 to 10 times the diameter of the rope. Here's the best picture I can find (an ASL F250).

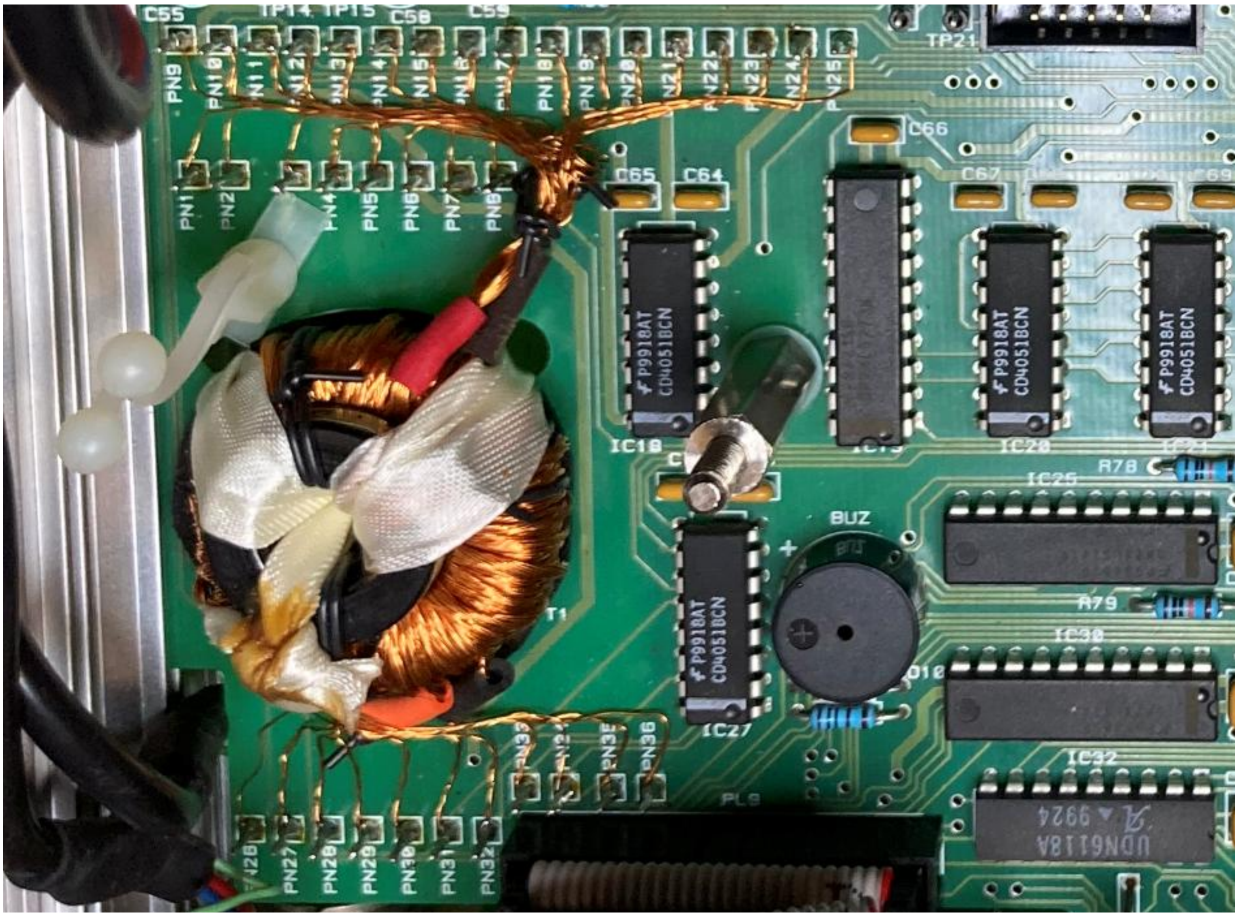

Fig. 1.2 An example single-stage ratio transformer

2. Winding the toroid

Depending on the length of the rope (or single strand) I found it most convenient to first apply the winding to a stick (length of wood or similar) with a slot at each end: -

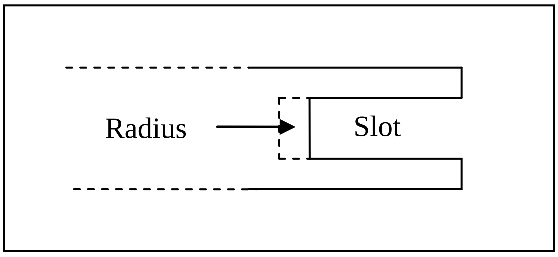

Fig. 2.1 A stick with slots at each end

The length of the stick depends on the length of rope required (typically up to 75cm) and the width depends on the size of the toroid internal diameter (including previous windings). The end of the slot should be filed to a semi-circle (or chamfered at least) to provide a minimum bend radius, especially for thicker ropes or heavier gauge single-strand wire.

To hold the toroid in place I used a plywood plate with a slot and pegs. The plywood was screwed to a bent metal plate and clamped to a shoulder-high shelf with a g-cramp. Viz: -

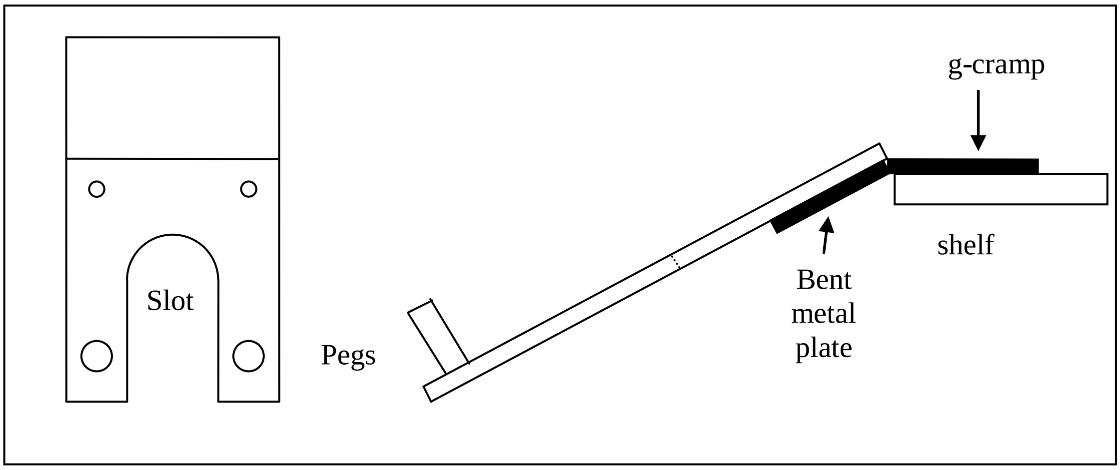

Fig. 2.2 Toroid support plate

As often the case (serendipity) I found a length of aluminium rod, drilled and tapped (M3) at each end, from which I cut the pegs. The diameter was perfect for short lengths of rubber tube to cushion the toroid and windings.

Start the winding by anchoring the "start" end with string/masking tape and a stool (or similar). "Start" and "Finish" are often used to define the polarity of a winding, though it is wise to check electrically, relative to a primary winding, before cutting and soldering.

It is a good idea to cover a winding with one or two layers of tape before overlaying with another: plumber's tape (PTFE) or polyester/nylon ribbon is ideal.

3. Preparation and planning

For the first attempt it is a good idea to produce a detailed plan and be generous in estimating the length of rope required. It will be possible (and sensible) to optimise the design on the second iteration. Record your calculations and label each winding clearly with masking tape. A simple code is, for example W4S for winding 4 "start" (F for "finish").

If you wish send to me a copy of your design/calculations and I will check them for you.
Regards, Chris.