Winding a toroid transformer

I've completed winding a "Bob Boyce" toroid and thought I'd share my experiences. Please note that I haven't tested it yet but some of my observations may be useful. I didn't find the process difficult, but have been a tradesman for many years (in refrigeration) so have picked up a few skills along the way. If you are concerned about the process, I'd suggest don't be. It is time consuming (maybe three days total) but if you buy the specified high quality materials they are forgiving and can be dismantled and re-used if you don't quite get it right. As an example I reverse wound my primary. It was much harder to unwind and rewind it than it was to wind in the first place but still quite "doable".

Purchasing

I ordered a core from Micro-metals who referred the request to a local Australian dealer, Magcore. I paid over they phone (about $130 Aus) and it turned up a few days later.

The silver plated Teflon wire came priority overseas freight from Steve at www.Apexjr.com . I got two x 100ft rolls of black 16# AWG and 100ft of three different colours 20# AWG for the primaries - hopefully this is enough for two transformers but I haven't really checked how much 20# I have left. Cost was about $175 Aus including $35 priority freight.

Hint Don't get (yellow) wire the same colour as your PE tape or nylon spacers – it's too hard to adjust the gaps well.

Yellow tape came from RS components part # 408-9495 66m x 16mm Class B Polyester tape at about $ 8 / roll. I used just over one roll but wasted a lot.

Beeswax came from a beekeeper on Ebay for about $20 delivered for a 1 kg block which is enough for at least 10 transformers and maybe more. Give the rest to the missus as there are lots of natural cosmetic recipes on the web that use it.

The secondary spacers were 2mm green whipper snipper line and the primary spacers 1.6mm blue.

Process

1. Start by winding the first layer of tape on the metal core. Wind so that it only covers about 3mm new each time through the toroid hole ie about 13mm overlap. This gives a thick layer of tape inside the hole and a lesser coverage on the outside of the core.

Hint Stand the core on its side so you don't have to hold it up.

Hint You need to squash the tape roll a few times so the cardboard core gets "squishy". The roll can then be forced through the hole as required.

2. The tape is very tough and will just unwind as you force the roll through the toroid hole each time with the sticky side against the core. Try to keep it smooth. When the roll's nearly full the tape may not always unwind smoothly, so just pull the tape tight and away from the core once the roll is through and reapply flat. If it gets tangled just unstick that bit, cut off neatly and restart with a fresh end. I found that even partly taped you can spin the toroid standing up so the tape you are applying is always facing you. I think that a roll of tape with damaged edges or a bit old would be very difficult to work with – I had one section that kept tearing when stretched.

Initial taping

3. Mark the top face of the toroid with a biro or felt marker and also the start of the larger secondary winding wire with some doubled PE tape and a marker.

4. Squash the roll of secondary wire in to an oval so it fits through the toroid. Make sure that it is correctly layered so it can unroll correctly and not end up in a knot halfway through winding your coil.

5. Start winding wire on the top of the tape layer taking note of the direction as per D9. Pull each winding tight each time you push the roll through the toroid hole. Always watch the roll of wire itself to make sure it doesn't kink as this will weaken the wire. Stand the core on its side and spin it if it seems easier but always wind and watch the far side of the core hole so you can see and adjust the wires on the inside. This is the critical location to get the turns straight and lying flat next to one another, the outside can be fixed after it is wound as long as the wires are laid at a reasonably correct angle so they don't get "longer" when adjusted. Use bits of tape as required to hold the wire tightly in place but try not to get any ends under the wire itself or it will be stuck there. To get bends out push a flat plastic ruler against the side of the wire or use a finger nail each side of the wire. I found it easy to pick unevenness with the black wire and yellow tape. Be careful of course but this wire is very flexible and pretty tough.

Hint Don't try to leave a flying lead when starting as it will be wrecked by the time you are finished. Tape the end of the wire flat against the toroid and then unroll 600mm or so when you have come back to the beginning..

6. Tape the ends of the wire to prevent movement and tape the flying leads together to give at least minimal protection. Mark the finish of the winding in case the start label comes off. Mark the top of the toroid with some marked tape. I brought the two ends out together in the middle of the outside face – you can't tell the direction or the two wires apart once they are taped and the primary is wound.

Rough wound secondary

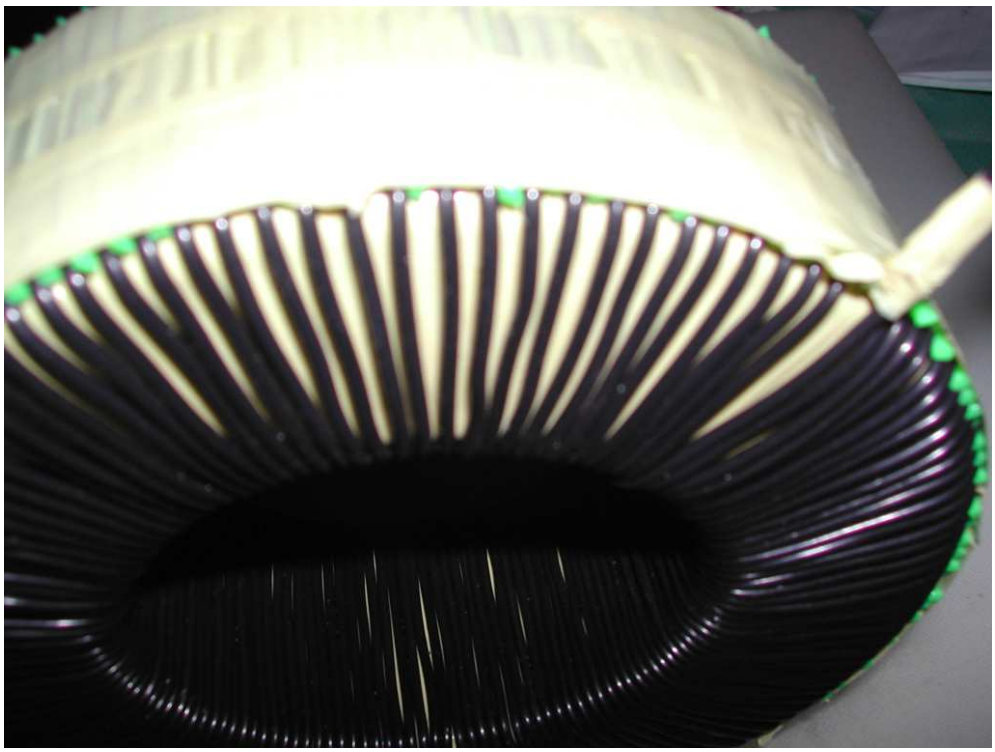
7. Count the windings (that pass through the hole) and record it somewhere- I got 129 and marked this on tape on one end of the winding itself. I counted by making marks on the yellow tape on the outside of the toroid every 5 turns with a black felt pen. It did make it a little harder to judge the spacing later and I wish I hadn't….

8. Adjust the wire spacing outside of the core hole. Start roughly and keep working around until they get neater and neater. All of the top and bottom spaces should be triangle shaped and the outside spaces parallel. When it looks reasonably neat cut the 2mm whipper snipper line to length. You don't want these to stick out past the wires or the tape won't hold properly but nearly that long is best. I made two marks on a newspaper the required length and cut the spacers off three at a time with sidecutters. Stretch three or four heavy rubber bands around the windings and slide the spacers under the rubber bands making final adjustments to the wire spacing as you go.

Hint Whipper Snipper line comes on a roll and tends to stay tightly coiled. Cut into 1m lengths and roll up in a bowl. Pour boiling water on it, fish it out with a stick and hold straight until cold to get most of the curves out.

Rubber bands holding spacers in place (actually the primary winding spacers)

Outside evenly spaced – radial wires still to be final straightened



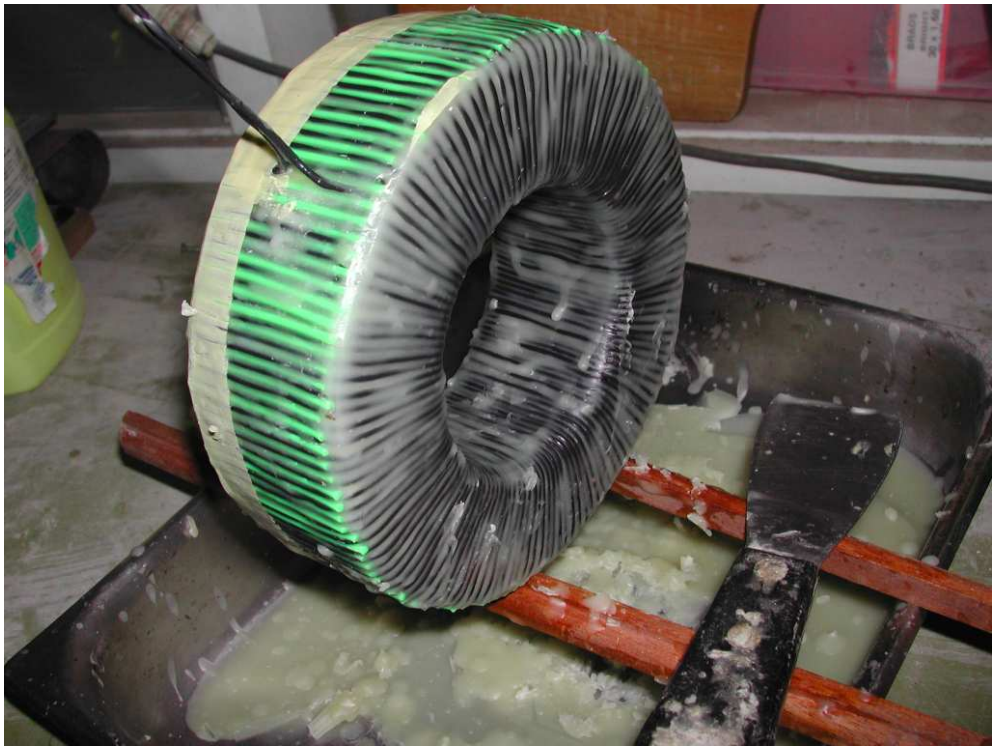
9. When it's nicely spaced slide the rubber bands sideways and replace them with PE tape as the rubber bands aren't heat proof. Check the spacing as you apply the PE tape because you won't remove it without pulling all of the spacers out. The hot wax won't affect the PE tape I used but when you pour the wax the natural curve of the nylon line may curl it up and out from between the windings. I suggest tape it in place then pour wax each end of the spacers to hold them in place. Remove the tape then finish off being careful not to melt the existing wax again or else protect it with tape.

10. I sat the transformer on two small pieces of timber over a stainless or aluminium baking dish (to catch the drips) and sat the whole lot on newspaper as the wax process is a messy one. When finished, heat the dish with a heat gun and pour it back in the tin.

11. Melt some beeswax in a double boiler. I chiselled some off the block with a wood chisel and hammer and melted it in a soup tin sat in a saucepan of boiling water. You'll get some wax on the saucepan if you repeat the process but its easily removed later with soap and hot water (tablecloths, carpets and clothes will be a little less forgiving. Wear leather gloves for safety.

12. Pour the wax onto the windings – it's clear when applied and very quickly sets to a white opaque finish as it hits the cooler core. The idea is not to build it up much, just smooth out the gaps between the individual winding turns. I waxed the top, then the bottom, stood the toroid on its side and just melted what had run down inside the hole into the windings located there. If you heat the wax too much it runs away like water so just warm thick sections until soft and scrape off or smooth out with a blunt scraper. To fill holes, pickup some of the "drippings" on a scraper and heat the scraper itself to drip wax where required. After the top, bottom and inside are complete fill the outside, removing and reapplying tape to keep the spacers in place. If it all goes bad, just melt the wax out gently with the paint stripper and pour some more on. You can melt lumpy wax under the tape if required as it's fairly heatproof.

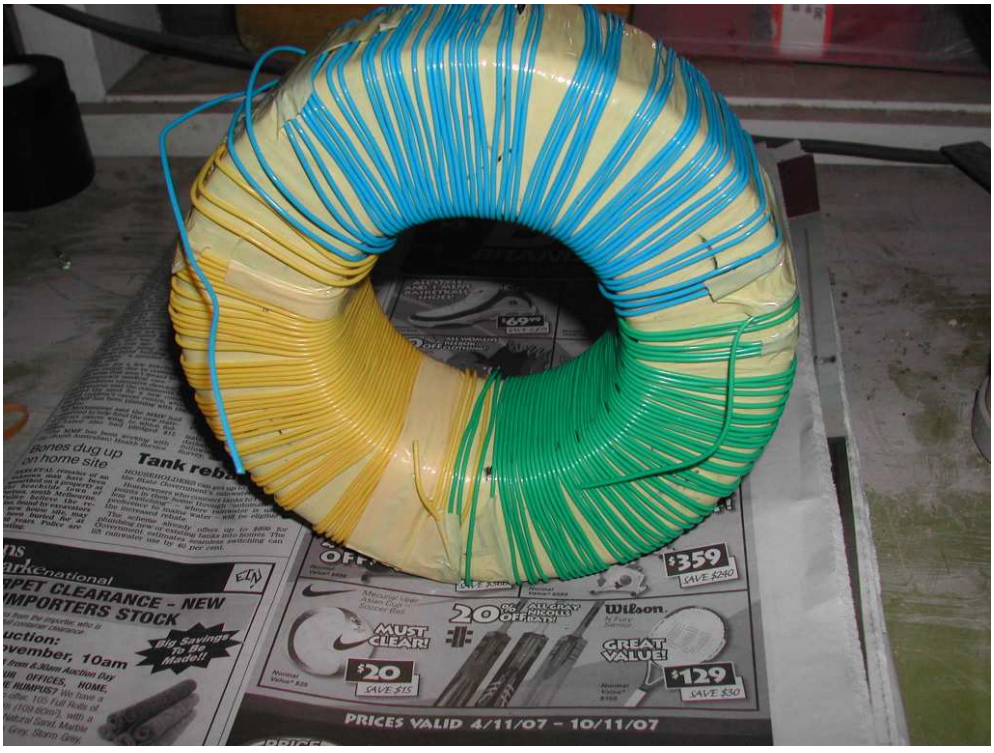
This needs a few more "lumps" taken off yet



When finished, tape with glass tape and PE tape being careful not to damage the flying leads.

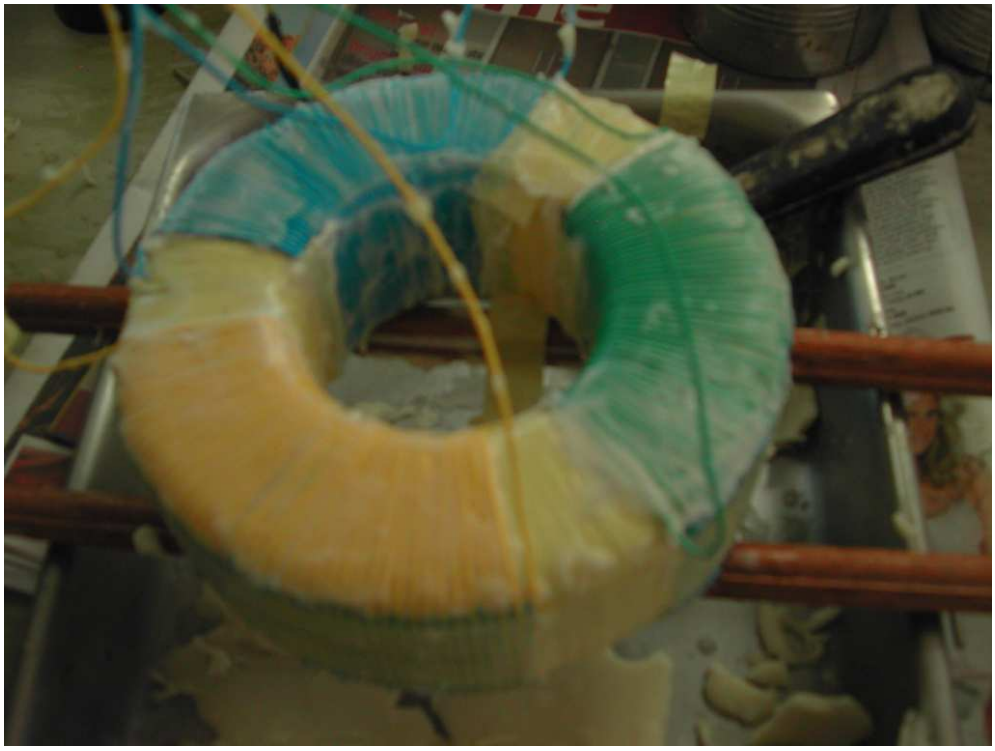
13. Now it's time for the secondaries. I made a layout drawing in Autocad and PDF showing the 120° separated "centre" lines of the primary coils and also the angle that the coils that I wound took up. Print this out, lay it on the top face of the toroid with the centre point of one winding centred on the secondary flying leads and mark the end points of the windings.

14. Leaving the winding that straddles the secondary wires until last, wind the primaries in the same direction as the secondary and adjust so that they are centred on the 120° angle lines. You've got a lot more wire ends to keep undamaged this time – I taped them up into a bundle with the secondary leads as they were wound. There's spare space on the core so again I'd start with the flying leads wound and unwind them when nearly completed.



15. Then check locations, tape firmly in place and fit spacers.

16. Apply wax



17. Final tape. If you want a low voltage sensor loop wind between two primaries before taping.