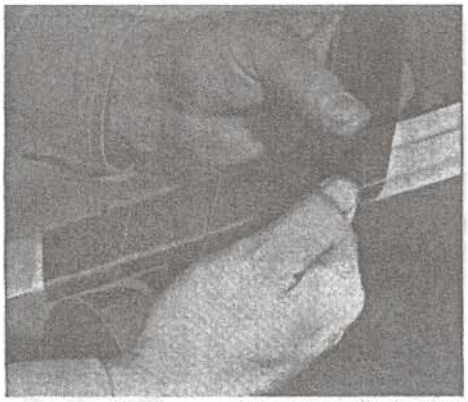
Classic Reprints

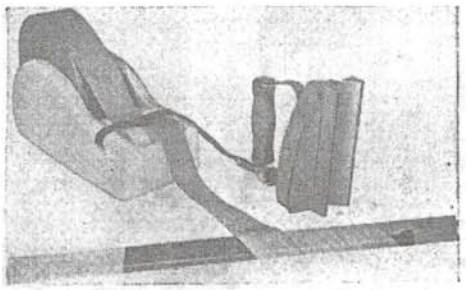
"Roll Your Own Output Transformer"

by J.R. Langham



All photos courtesy U.S. Navy

This is one of several ways to make the form



Finishing the form. Forms may also be made of electrical fiber scored and folded square

Good old J.R. definitely gets our vote for Homebrewer of the Month, December 1948

The first time I ever wound an output transformer was way back when. I was just getting interested in radio, and the XYL was just a YL. I wasn't even in the radio business. I was just an amateur. Money being very scarce those days, I could not afford to buy a decent output transformer for my amplifier. I had a little open-frame 39 cent special and blamed it for the distortion and the short frequency range. I ached to be able to spend ten or twelve bucks for a hi-fi job, but I just didn't have the long green stuff.

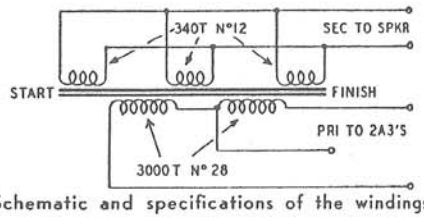
It was the YL who put this particular bug into my head. "Why don't you make your own?" she suggested.

"Me? Wind a transformer myself?" It was absurd. Transformer winding was an esoteric art reserved for the mysterious high-priests of electronics. It was unthinkable,but I thought of it just the same. I heard of a guy who wound transformers, and I made a pilgrimage to see him. He talked, I listened. I bought some beer and was respectful, and he gave me an old burned-out 300-ma power transformer and some insulating paper.

"Here," he said. "This'll make you a honey of an output transformer."

I gulped. "How do I go about it?"

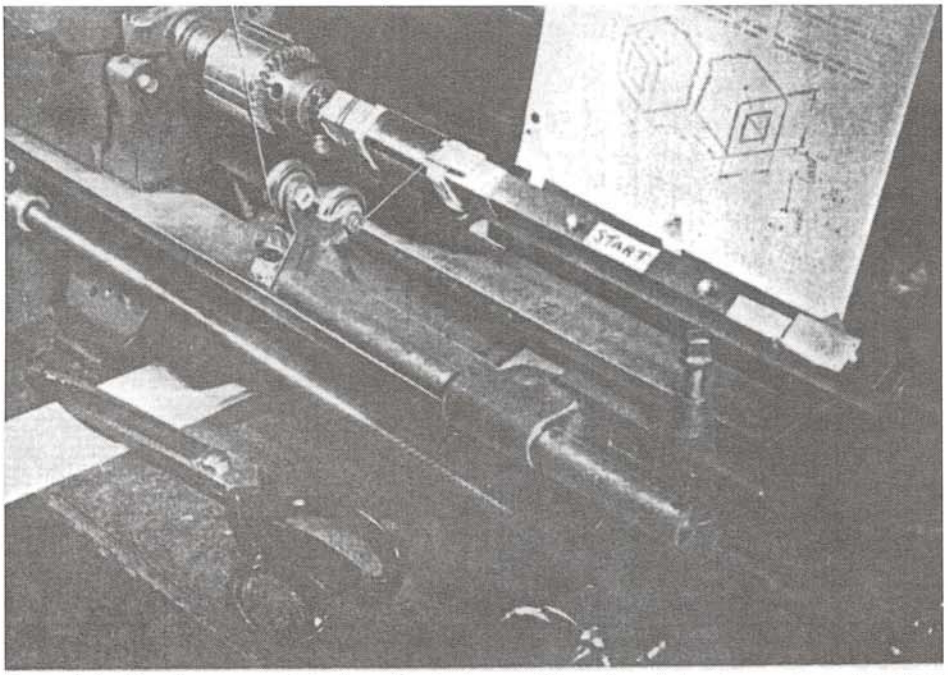
"First un-pot it and knock the laminations apart. Heat them up and then let them cool slowly so they'll get soft. Measure your window carefully and decide how many turns you want of what size wire. You know your impedance ratio, so you know the turns ratio. Get a wire table. Make the primary about half the space available. Put in at least three secondaries and parallel 'em. That's to give good highs. Design it."

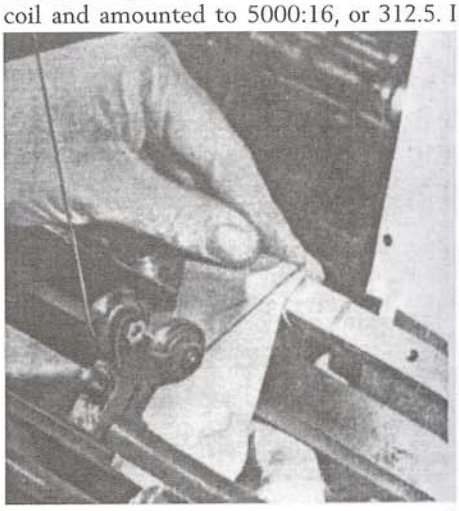


Schematic and specifications of the windings.

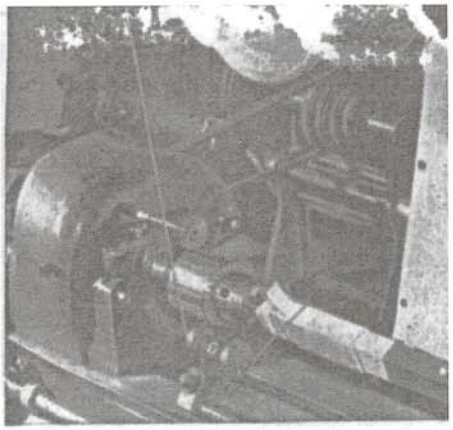
I gulped and went home with my booty. I melted the tar out and pulled the ugly thing out of the case. I hammered the laminations apart and cooked them in an electric oven over at the technical school. That was to anneal the iron and soften it. It had to cool slowly to do it. I spend a morning easing the temperature up slowly, and then I just shut the oven off and left the laminations in there with the door closed. That was on a Saturday, and I came back on Monday to take them out.

Well, the textbooks gave me most of the dope: the efficiency varies with the amount of copper in the window; bass response is determined by the primary inductance; treble response depends on the leakage inductance (mostly). I knew I wouldn't have to worry about capacitance because it was to be used from tube to speaker and therefore was a low-impedance affair. My impedance ratio was from a pair of 2A3's to a 16-ohm voice coil and amounted to 5000:16, or 312.5. I

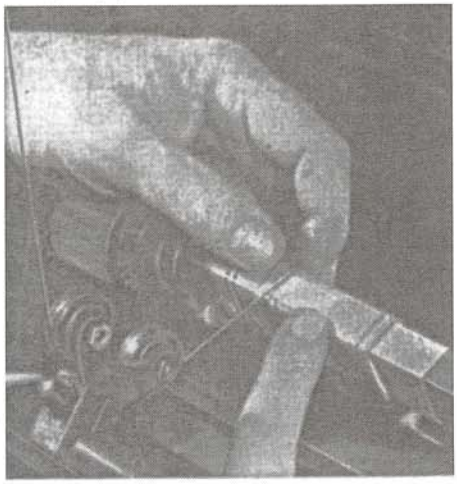




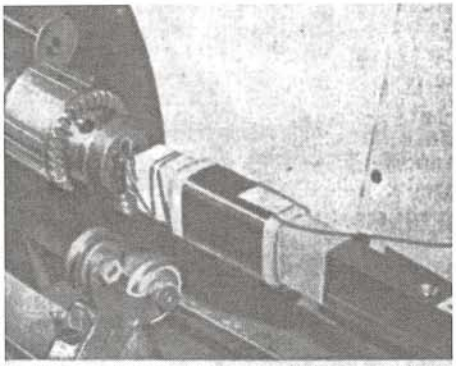
Above, left– First layer wound in place. To start second layer, insert glassine paper under wire so that wire is at least one-eighth inch from paper's edge, and roll it on with the next turn of wire (photo right). Paper secures and stiffens ends of windings.



If an end turn cuts through the glassine, lay a strip of paper under it as shown above



and loop it back, winding other turns over it. Pull the loop up snug after a few turns.



Finishing winding. Place paper loop as shown, wind a few turns over it, pull up loop ends and continue. On last layer pull end turn through and pull loop ends tight. If winding ends midway, use loop as above, wind a few turns over it and slip the end turn through.

knew the turns ratio had to be the square root of that: 17.7 approximately. Plain arithmetic gave that and it meant there had to be 17.7 primary turns for each secondary turn.

I forget now just what the dimensions of my window were, but I remember deciding that 6,000 turns of No. 28 wire would come very close to filling the bill for the primary. The figure of 6000/17.7 meant 340 on my secondary would get the needed impedance ratio.

My friend had told me to make at least three secondaries. That didn't really mean much so I called him on the phone. "Why, its simple," he answered. "To get good high-note response you have to have good coupling. So make three secondaries: one next to the core, another between the two halves of the primary, and the third on the outside. That way you get better coupling between the primary and the secondary. Just tie all three of the secondaries in parallel."

"But I figured 340 turns for my secondary and ..."

"That's fine," he said. "Make three of them and tie 'em together. Just use a smaller-size wire so you can accommodate three 340-turn windings."

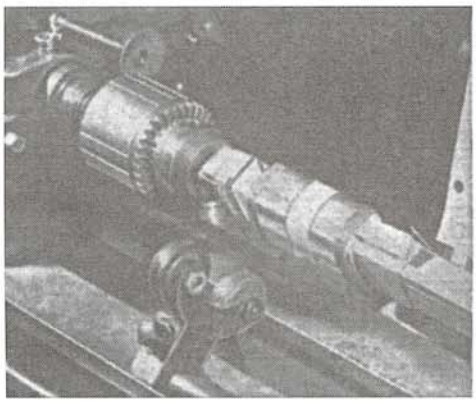
"But about this high response business," I said. "The books say it's a matter of leakage inductance and ..."

"That's just a measure of the coupling. With low-impedance stuff the coupling is all that limits your high notes. Forget the capacitance."

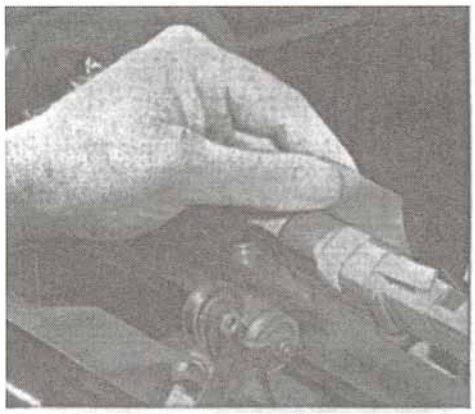
I sat down again with my wire tables and figured. 3 X 340 meant 1,020 turns had to go into that space and, what with the thickness of the insulation–hmmmm. No. 12 wire ought to be about right. A trifle light, but No. 11 would be too big. I drew up my winding sketch. (See diagram.)

Now came the big problem: how to do the actual winding. There were several lathes over at the technical school, and the management said I was welcome to use them if I'd clean up after myself. I provided a counter that could be attached to the end of the spindle to keep track of the number of turns. I still had the old cardboard winding form and I stripped all the old wire off it. Then I sawed a piece of wood that fitted nicely into the form and bought my wire.

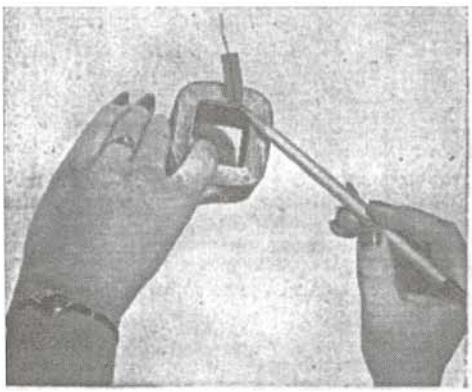
One more visit to my transformer friend showed me how to tape the ends of each winding layer, and then I started. It went much easier than I had expected. Actually it wasn't hard at all. Tedious, but not at all difficult. It took the better part of the day, what with attaching the counter and setting up a roller for the spool of wire to feed from. I wore heavy gloves and fed it by hand.



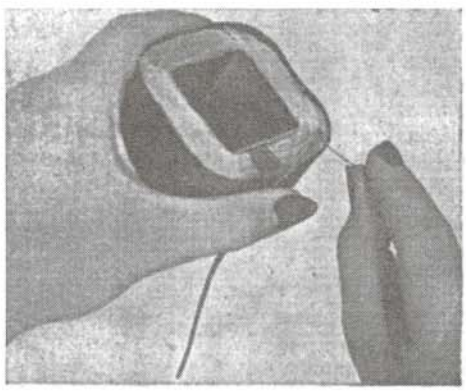
Winding finished with final paper wrapping and a strip of adhesive to hold it secure



Putting insulating fiber between windings evens up the surface and provides insulation



Finished job, showing method of attaching lead wires. These connections are usually



made in the interior, between windings, and are held securely by the windings over them

Cutting the insulation carefully with a pair of shears, I taped it as neatly as possible.

The YL and I had a date that night, and we spent it fitting the laminations into and around the winding and then re-potting the transformer. Her mother still resents the fact that we used a saucepan to heat the tar and pour it into the case. We cleaned it, but I guess we didn't get it as clean as she thought we should have. Tar wouldn't hurt her anyhow. We used to chew it when we were kids.

The transformer was still warm when we bolted it onto the chassis and soldered the leads in. We hadn't checked it for shorts or opens or anything, just hitched it up and tried it out. It worked fine. I swore I could hear lows and highs that hadn't been there before. The old 39 cent open-frame job was given to the YL's kid brother who was building a set at that time.

But that transformer had faults. Several of them. The two halves of the primary weren't balanced properly, and the whole unit was too big and clumsy. My finances improved, and the YL became my XYL, and before long I could buy a big, fancy output transformer and build a new audio amplifier. That old wreck was kicked around the house for a couple of years before it was given, traded really, to a chap I knew. I had never run a test on it at all while I had it.

The new owner did run a test. I was amazed when he gave me the results. He used it in a class-B 6L6 PA amplifier and ran loads of current out one time, and he put an audio oscillator into the circuit as a sort of signal-tracer deal. He found the trouble and then idly twisted the dial on the thing. It went right down to 20 cycles on the bottom and (he said) up to 16 kc on the top.

I frowned when he told me, so he unshipped the big brute from the chassis and made a bench test. The half-power points on the curve were 11 cycles and 23 kc. Those were where the level dropped 3 db. The efficiency was 87% and there was no sign of distortion at 30 watts, which was as much as he had available. All this too, was without feedback, mind you.

It sounded as though it were better than the transformer I had bought. The curve on that was supposed to be 1 db from 20 cycles to 20 kc but it conked out at 12 kc on the top.

I got a new job around then in a laboratory and was put to running bench tests on a whole series of standard transformers. I found an amazing thing: None of the "high-fidelity" transformers tested would meet their published curves. In fact, most of them didn't come near them. There were only two brands among all those I tested whose transformers all came up to their own specifications. Since our work involved Sonar listening gear we had to have the highest possible fidelity in transformers for faithful transmission of submarine sounds. We soon found we could not get enough really good transformers from the busy companies and so we had to wind a lot of our own.

The winding was done much as I had done it. I managed to get those photographs from the U.S. Navy. They show the work done in that laboratory in making up a transformer– and we made a great many of them.

I have since wound up more output transformers for my own outfit and for those of some friends. I use essentially the same techniques as with that first hoary old model. I try to find a big old power transformer that someone has burned out and rip the old windings off it. I anneal the laminations and then design a new winding. This is really very simple and takes just a little figuring. You have to remember these things:

1. Fill up the window with copper. Fill it as full as you can. This governs the efficiency.

2. As a rule of thumb, allot half your space to the primary and half to the secondary. It works fine.

3. Have plenty of turns for the primary to get good low-frequency response. I never use wire larger than No. 30 anymore. Even with 6L6's the transformer still runs plenty cool. For 2A3's you can use even smaller wire if you wish. Lots of turns.

4. Have several secondaries in parallel for your coupling. At least three. Five is even better. Put them here and there and all over and then just tie them together–but watch your polarity.

5. If it's to be for a push-pull amplifier, wind both your primaries at the same time from two spools of wire. That way you can get good balance and keep down the intermodulation distortion. Make them in two sections or three, interleaved with the secondaries, but if you wind both primaries together you'll have a good balance.

6. Lay the turns in closely and don't let any overlaps stay in. Go back and remove them.

7. Don't use transparent sticky tape if you live near water. Get thin cambric tape and regular thin paper insulation from your supply house.

As to what kind of power transformer is best–that's up to you. The bigger it is, the easier it is to get enough primary turns for good bass response. Just get yourself a wire table and study the turns-per-inch of the different sizes. Don't squeeze it. A thousandth of an inch too little means a slight loss in your efficiency, but a thousandth too much means you can't get the laminations back together and you'll have done your work for nothing. Measure your insulation thickness and plan the whole thing carefully.

You might be arguing to yourself now, "Well, if it's so easy, why don't the companies make transformers that are as good?" I'll tell you why. The economics are against it. You're worry is about one transformer –your own. They have to think in terms of a thousand or more. Extra wire, extra insulation, and larger cores run up the cost considerably and then they couldn't compete with the other's prices.

You can have any coil-winding firm make you up a special transformer to your own specifications, and it will cost you plenty. Or, if you're a working stiff without much lettuce, you can look around for an old, burned-out 300 mA power transformer and, with a little work, make yourself a really fine output transformer. It's really easy and, what's more, a lot of fun. Try it!

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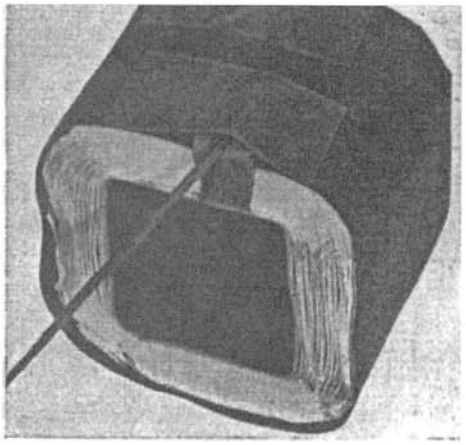
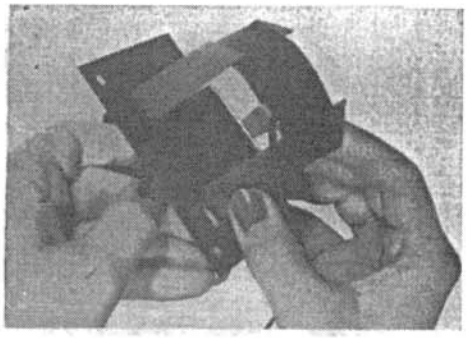
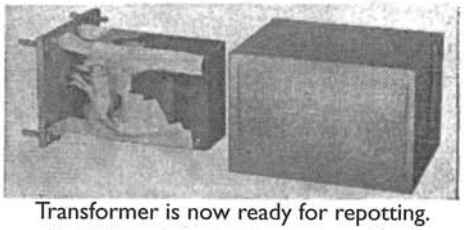


Adhesive strips make external connections stronger. Whole winding may be taped also.



Last job of all is inserting laminations. This is not hard if all the dimensions are correct



Transformer is now ready for repotting. Don't forget to give it a test run first!