Rewinding the Power Transformer for an Eico ST-84 Preamp   Rev-2
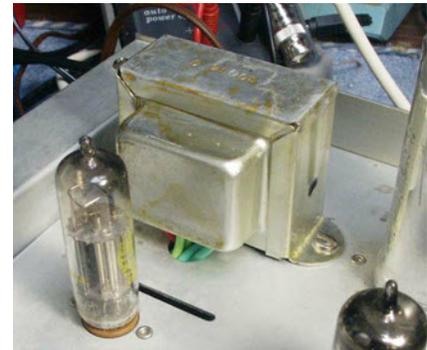
A few months ago, a friend and I were doing some listening with the vintage stereo system, when suddenly we noticed a burning smell. Sniffing around, it became apparent that it was coming from my circa-1962 Eico ST-84 preamplifier. I quickly shut it down. Later troubleshooting revealed that the power transformer (seen **at right**) seemed to have developed shorted windings and had become internally fried.

I searched for replacements, with little hope of finding a close match. Actually, I did find something usable made by Hammond but it was a larger size. I try to keep my vintage equipment as authentic as possible. Though it would fit, I just knew that every time I looked into the cage it would be clearly visible and would remind me that it is a replacement.

Looking around the Web, I came upon a website (unfortunately now gone) which described how the author wound his own secondary coils for power transformers. That encouraged me to think about rewinding the transformer for the ST-84. This is the story about how I did just that and how you can do it too.

I should mention though, that the process is rather difficult (though doable) and buying the stocks of wire and other materials required, wasn't cheap. Since that project, I have been told that there are vendors who will make custom transformers at reasonable prices, though I have not heard what they charge. A custom transformer would probably look quite different from an original, though. Another option is a transformer rewinding service such as this one:
http://members.tripod.com/tubes_tubes_tubes/transformerrewindingservice/index.html
If I were faced with this again, I would seriously consider those alternatives. On the other hand, my ST-84 stands proudly today, looking as it always did (**seen above**), with the transformer which I rewound.

Disassembly

We need to remove the case of the transformer and disassemble the laminations. The case of mine is removed by prying-up the tabs underneath the unit as seen **at left**. The case slides off and the end-bells then fall off. Next, as shown **at right**, use a utility knife to pry the first lamination loose. The cheap knives with the blades which break-off to leave a

new tip seem to work well. You can see the knife I used, **at right**. The first lamination will be the most difficult. You will notice that there are two types of laminations (**hereafter "lams"**). The E-shaped pieces butt against I-shaped pieces. The technique is to work the blade under the corner of an E-lam. They are cemented together by a varnish.

Rock the blade back and forth to work it between the top lam and the next one. Then work it all around, under the top lam. Get the blade as far under the tongue (going into the coil) as possible. Sooner or later, the E-lam will pop free. Then do the I-lam. Don't worry if the first one takes awhile. The others are easier and you will quickly get much better at popping them apart.

Try not to bend them so much that they are no longer flat, though. There is a tradeoff between speed and how much you end up bending them. In the end, we will want them to be as compact a bundle as possible, to optimize the quality of the transformer. It took me about an hour to disassemble the ST-84 transformer–removing about 36-lams.

About the Coil

When you are finished with the lams, you will have the bare transformer coil, as seen **at left**. Let's digress for a moment to take a look at that. You can see the blackened edges of the windings, indicating that my unit had burned. The windings are separated by and covered by layers of paper, impregnated with varnish.

At right, we scrape away some of the paper, exposing a winding. Notice the large diameter wire, indicating that it is a filament winding. The heavier gauge, lower-voltage secondary windings are usually on the outside of the coil. The lacquer insulation on these windings seems charred. Scratching at the wrap further reveals the external connections **at left**. Notice how the leads seem secured by an underlying adhesive. The two black leads on the left are the 117V primary. The next lead has faded from the original red/yellow and is the HV center-tap. The lead on the right is the shield between primary and

2

secondary. **At right**, we zoom-in on the center two leads (primary and HV CT). Notice that there are two HV wires because that is the center of the two halves of the HV secondary. The HV secondary wire looks thin compared to the already-thin primary wire. Varnish pervades the transformer.

In the view **at left**, you can see the green filament leads going to thick winding wires. The light green leads are another 6.3V filament winding going to somewhat thinner winding wire. The HV leads at the upper left were once red but have faded to yellowish orange. If you look carefully at the winding wires going to the 117V primary leads on the lower right, you can see that the primary winding is the innermost, which is typical.

An important piece of information which we need from the original transformer is the number of volts per turn, for which it was designed. To get that, we must count the number of turns of one of the windings. We can use the outermost filament winding, because it is readily accessible and because its wire is thick enough to be pulled-off without breaking. I counted 45-turns for the 6.3V filament windings, yielding 0.14V/turn. (**Hereafter "turn" is abbreviated as "T"**)

When I began this project, I had some hope of salvaging the primary winding, reasoning that the HV secondary was most likely the one which broke-down and shorted. It quickly became apparent though, that the super-thin HV secondary wire was too weak to be pulled-off, with the varnish securing it. There also would be the major pain of trying to scrape-off all the varnish-coated layers of paper interspersed in the windings. So I decided to wind a new coil from scratch. However, before getting into that, we need to clean and recoat the laminations (lams).

Cleaning and Coating the Lams

The lams are coated with a thin varnish to prevent them from shorting together. Without the coating, eddy currents, generated in the lams would cause losses and heating. Unfortunately, the coating has now been compromised by the high temperatures from the shorted windings and by having to pry the lams apart. To clean them (**at right**), I used a
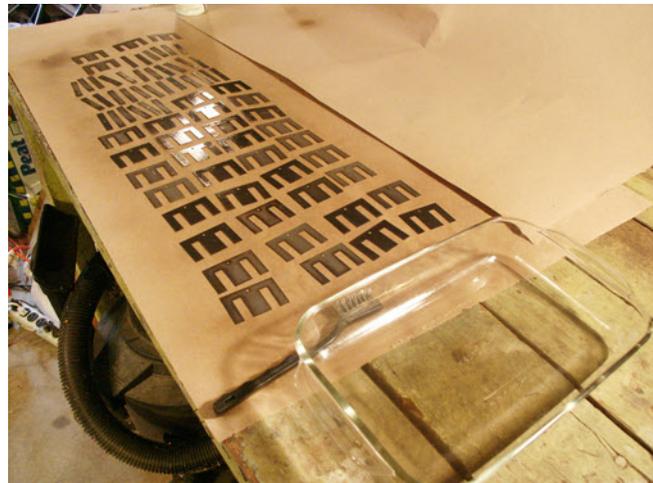
wire brush and a tray of lacquer thinner. Before scrubbing, I let the lams soak overnight. Protective gloves are essential.

After the lams were completely dry, I painted them with three coats of clear acrylic spray on one side. You have to be careful after that, not to flip any of the pieces over, as that would allow them to short, if stacked that way in the transformer.

Wire Size and Selection

Since we will need to order the special, ultra-fine wire needed for the higher voltage windings, we need to know what wire size will be required. Also, as you will see, the wire size affects the calculations of the number of turns required. The first step is to try to measure the size of the existing windings. While it is difficult to get to the actual inner windings, the stubs which are led out to the external connections let us make measurements.

Winding	Thickness	AWG
HV	3.5mil, 0.09mm	40
Primary	7.1, 0.18	34
Filament-1	17, 0.43	26
Filament-2	32, 0.81	20

The best tool I have to measure wire size is a regular, digital caliper. In inch mode, it has a resolution of 0.5mil or about 0.013mm. In millimeter mode, the resolution is a bit better, at 0.01mm, so I used it that way. The measurements and the nearest wire sizes I came up with are listed in the table **at left**.
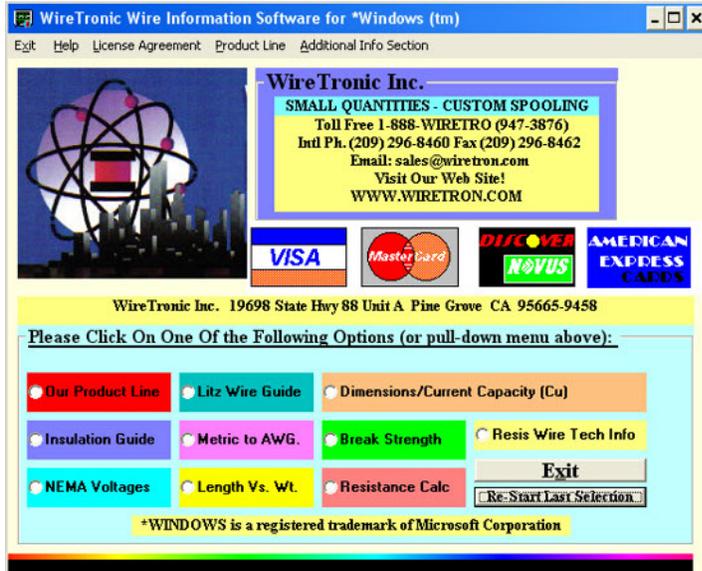
There is a free software application (**at left**), which provides info on wire sizes and insulation breakdown voltages (**"BV"**), available here: http://www.wiretron.com/

It indicates that the BV of the AWG-40 magnet wire will be at least 700V, which should be sufficient for this application if the ends of the HV wires are kept apart. We will also be careful to avoid getting the HV near wires having strongly differing potentials. Adjacent layers of HV winding will have low relative potential. I did not use extra insulation between winding layers within a single winding, as the original transformer had. The insulating coatings for magnet wire these days, can be much better than the plain enamel used in the vintage original. However, I did use a layer of electrical tape between complete windings.

I purchased the magnet wire needed from: http://www.oemwire.com/
They offer magnet wire sizes from 18-40AWG in spools as small as 1/4-pound. At 40AWG, that is a length of 8000-feet! They also sell special tape for transformer coils, but it is expensive and sold in 10-roll packs. I found that regular vinyl electrical tape worked fine.

Transformer Calculations

Now we need to calculate the number of turns for each winding. For that we will use the model shown **at right**. Vp and Ip are the external AC voltage and current applied to the primary winding. Vp' is the effective voltage on the primary, taking into account the drop across Rp. Each half of the HV winding is represented by the number of turns, Nhv, and the resistance in that half, Rhv. The filament load currents were taken from the tube specifications. Fortunately, I had data on the DC supply from notes on restoring the unit, years earlier. The measured DC output voltage, Vdc, was 349V and the load was 8.5mA. The complete list of variables follows:
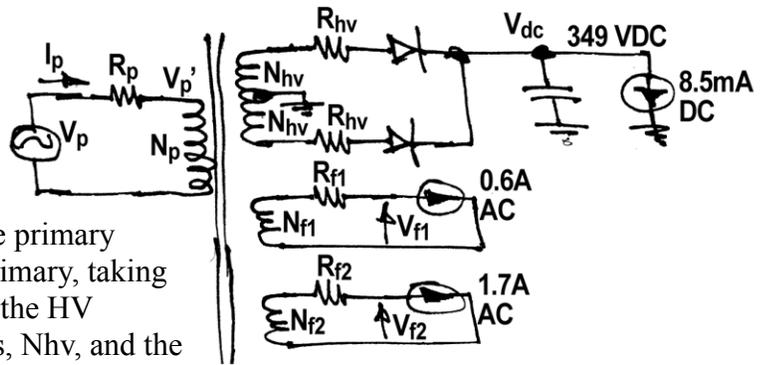
Variable List

- Vp   voltage applied to primary (120VAC)
- Pp   power drawn from mains (Vp)
- Ip   current in the primary
- Im   magnetization current–inductive primary current
- Rp   winding resistance of the primary
- Vp'   primary voltage, less Rp drop
- Np   number of turns in the primary
- Vhvo open circuit HVAC to drive one rectifier plate
- Nhv   number of turns in half of the HV winding
- Rhv   winding resistance of half the HV winding
- Phv   power induced in both HV windings
- Vdc   DC voltage of the HV supply under load
- Idc   DC current delivered by the HV supply
- Vf1   AC voltage delivered by fil-1 under load
- If1   AC load current on filament-1 winding
- Nf1   number of turns in filament-1 winding
- Rf1   winding resistance of filament-1 winding
- Δf1   voltage drop across Rf1
- Pf1   power induced in filament-1 winding
- Vf2   AC voltage delivered by fil-2 under load
- If2   AC load current on filament-2 winding
- Nf2   number of turns in filament-2 winding
- Rf2   winding resistance of filament-2 winding
- Δf2   voltage drop across Rf2
- Pf2   power induced in filament-2 winding
- Δf   average of Δf1 and Δf2
- Vf   average OC voltage of filament windings
- Rsrc   HV source resistor for 6X4 lab test
- Ps   power induced in all secondary windings
- Pxfmr power dissipated in the transformer
- Pcore power dissipated in core losses

- Prp   power dissipated in Rp
- Prhv   power dissipated in Rhv
- Prf1   power dissipated in Rf1
- Prf2   power dissipated in Rf2

Design Procedure

Given certain information about the original transformer and circuit, we want to calculate the number of turns to use in the primary and each secondary of the rewound unit. The strategy is to take into account the resistive losses in the windings so that the voltages are correct at the actual load. Since the resistance of each winding is affected by the number of turns and the resistances affect the calculations, the procedure is iterative. Moreover, the tube rectifier's output depends in part, on the source resistance of the transformer, requiring that we include a lab test in the procedure. Finally, I found that the magnetizing current is a significant contribution to primary current, so I wound the primary first, measured that, and took it into account in the effect of the primary winding resistance.

While it might be possible to derive closed-form equations to avoid some of the iterations in the calculation procedure, there would still be iterations involving the nonlinear rectifier characteristic. One might also try to model the rectifier tube and treat that mathematically and develop a closed-form solution. Those approaches might be valid, but given the ease with which a few iterations could solve the problem, I found the simple, iterative approach to be the most effective. It also provides visibility into what is being estimated and what assumptions are being made.

The following procedure is a distillation and refinement of the circuitous path taken in the original project. Hence, the calculations given do not exactly match those of the project. Where lab tests needed to be incorporated though, the numbers were close enough that it did not make a significant difference. After all, the values of the winding resistances come from rough estimates of the actual length. At the end, we present a summary table of the results, comparing the refined procedure to the original.

### Given Information
Let's list what we know about the transformer:
- Wire sizes: Pri: #34, HV: #40, Fil-1: #26, Fil-2: #20
- Vp=120VAC
- Vdc=349VDC
- Idc= 8.5mA
- Vf1=Vf2=6.3VAC
- If1=0.6A AC
- If2=1.7A AC (includes 0.2A for the pilot light)
- Nf1=45T

Summary of ST-84 transformer design procedure:

- Pull off filament windings, counting turns.
    45T => 6.3VAC

- Measure wire sizes where they attach to external wires. Get ohms/ft.
    Primary   #34, 0.2613ohms/ft.   Fil-1 #26, 0.041ohms/ft.
    HV #40, 1.079ohms/ft.   Fil-2 #20, 0.01013ohms/ft.

- Design a bobbin for the new coil (**below right**). Fit the core to the transformer tongue close-ly. The sides are sized to handle the original coil but still fit the opening. Round the corners of the sides. From the bobbin size, estimate the length of a turn for the (innermost) primary, HV secondary, filament-1 and (outermost) filament-2.

Inner 4″	Primary 4.7 in/T	Fil-1 5 in/T
Mid 4.6″	HV 4.7 in/T	Fil-2 5.4 in/T
Outer 5.4″		
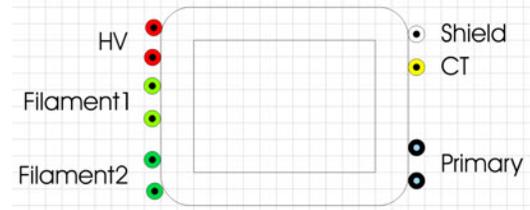
- Calc Rf1, Rf2 from above. Adjust Np to compensate for average filament loss.

  Rf1 = 45*(5/12)*0.041 = 0.769ohms Δf = (Δf1+Δf2)/2 = 0.405V

  Δf1 = Rf1*If1 = 0.769*0.6 = 0.4614V   Vf = 6.3 + .405 = 6.705V

  Rf2 = 45*(5.4/12)*0.01013 = 0.2051ohms   Np = 45*120/Vf = 805T

  Δf2 = Rf2*If2 = 0.2051*1.7 = 0.3487V

- Calculate Rp from Np. Estimate Ip from Ps. Calculate Ps from filament loads and Vdc*Idc.

  $Ip = \left(Vac - \sqrt{Vac^2 - 4RpPs}\right)/(2Rp)$ Color shows iterations, with Final value in **bold.**

  Np

  Rp = 805*(4.7/12)*0.2613ohms/ft = 82.4ohms, 72.6, **73.9**

  Ps = Pf1 + Pf2 + Phv = 6.705*0.6+6.705*1.7+349*8.5mA = 18.39W

  Ip = (120 - (120² - 4*82.4*18.39).5)/(2*82.4) = 0.1741A, .1709, **.1713**

- Adjust Np to compensate for Rp.

  Vp' = Vp - Ip*Rp = 120 - 0.1741*82.4 = 105.7V, 107.6, **107.3**

  Np = 45*(105.7/6.705) = 709T, 722, **720**

- Do trial HV secondary turns calculation to estimate Rhv.

  From the RCA 6X4 datasheet, we estimate needing Vhv=275VAC to get 350VDC at 8.5mA.

  Nhv = Vhv*(Np/Vp') = 275*(720/107.3) = 1845T

  Rhv = Nhv*(4.7/12)*1.079ohms/ft = 780ohms
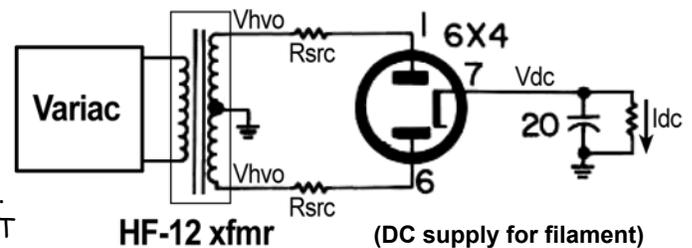
- Do a lab test with an external transformer and variac, **as shown above**. Use source resistors: Rsrc = Rhv+Rp*(Nhv/Np)². Adjust the variac to deliver the known DC voltage (Vdc) to the first cap, with a resistive load to pull nominal circuit current (Idc). Measure the AC voltage, Vhvo, before Rsrc. This is the open circuit voltage needed for half of the HV winding.

  Rsrc = 780 + 73.9*(1845/720)² = 1265ohms

  -- This is close to the tested value of 1302, so we go with the tested result, Vhvo=303VAC.

- From the filament loads, calc filament-Ip then Vp', using the equation above.

  For open circuit HV, Ps = 6.705*(.6+1.7) = 15.4W

  Ip = (120 - (120² - 4*73.9*15.4).5)/(2*73.9) = 0.1405A

  Vp' = Vp - Ip*Rp = 120 - .1405*73.9 = 109.6V   ...Note that these are all for no HV load

- Calculate Nhv to deliver Vhvo. Recalculate Rhv and redo lab test and calcs, if needed.

  Nhv = Vhvo*(Np/Vp') = 303*720/109.6 = 1991T

  Rhv = 1991*(4.7/12)*1.079ohms/ft = 841ohms   Rsrc = 841 + 73.9*(1991/720)² = 1406ohms

  -- Rsrc is 8% higher than the previous 1302ohm lab test. Will stay with the lab test as-is.

- In the lab, measure the RMS drop across Rsrc and calculate Irms = Vrms/Rsrc.
  The test was done at Rsrc=1351ohms. Vrms=15.9V, so Irms = 15.9/1351 = 11.77mA.

- Estimate $Phv = 2*Rhv*Irms^2 + Vdc*Idc$.
  Phv = 2*841*(11.77mA)^2 + 349*8.5mA = 0.233 + 2.97 = 3.2W

- Recalculate Ip and Vp' using Ps = Phv + Pf1 + Pf2.
  Ps = 3.2 + 6.705*(.6+1.7) = 18.6W
  Ip = (120 - (120^2 - 4*73.9*18.6)$^{.5}$)/(2*73.9) = 0.1735A
  Vp' = 120 - .1735*73.9 = 107.2V (was 107.3 above)

- Check filament voltage, Vf. Calculate new Nf and Rf, if needed.
  Ideally open circuit Vf= 6.705V, from above.
  Vf = Nf*Vp'/Np = 45*107.2/720 = 6.7V -- Very close. Okay, as-is.
  Calculate expected Vf's using Δf's above: Vf1 = 6.7 - 0.4614 = 6.239 (-0.061V or -1%), Vf2 = 6.7 - 0.3487 = 6.351 (+0.051V or +0.8%)

Adjustments for Measured Magnetization Current (Im):

Note that, while there was significant Im, it doesn't have very much effect on the number of windings needed. That stems from the fact that Im is inductive, so its current lags 90-deg relative to the other currents. While the adjustments are included here to represent the project as executed, I would probably leave them out of a future effort. Of course, the last step here, of calculating final parameters, would still be relevant.

- Measure the magnetization current, Im.
  After winding just the primary, we measure Ip at Vp=120VAC. Im = 0.14A

- Redo the open circuit HV calculations, this time including Im, along with the filament loading. Will affect Vp' and hence Nhv.
  Ip due to filament loading was 0.1405A. The filament loading is resistive and the Im is inductive.
  In-phase drop across Rp: 73.9*0.1405 = 10.38. In-phase remainder: 120-10.38 = 109.62.
  90-deg drop across Rp: 73.9*0.14 = 10.35. 90deg remainder: 10.35.
  Vp' = (109.62^2 + 10.35^2)$^{.5}$ = 110.1 Strange but true: The addition of Im actually <u>increases</u> Vp'.
  ---Confirmed with Spice.
  Nhv = Vhvo*(Np/Vp') = 303*720/110.1 = 1981T -- A 0.5% effect. Will not need to iterate.
  Rhv = 1981*(4.7/12)*1.079ohms/ft = 837ohms

- Calculate final parameters:
  ▪ Check Rsrc, since Rhv, Nhv changed.
  Rsrc = 837 + 73.9*(1981/720)^2 = 1396ohms
  -- This is close to the tested value of 1302, so the previous result, Vhvo=303VAC is still good.

  ▪ Vp' with Im and HV loads:
  Ps = 18.6W from above (Rhv changed little)
  In-phase Ip = (120 - (120^2 - 4*73.9*18.6)$^{.5}$)/(2*73.9) = 0.1735A
  In-phase drop across Rp: 73.9*0.1735 = 12.83. In-phase remainder: 120-12.83 = 107.2V

90deg remainder from above: 10.35V
$Vp' = (107.2^2 + 10.35^2)^{.5} = 107.7V$

- ▪ Calculate Ip, expected Vf1, Vf2, Pxfmr, Pp

Magnitude of Ip: $Ip = (.1735^2 + .14^2)^{.5} = 0.223A$

$Vf1 = Vp'*(Nf/Np) - \Delta f1 = 107.7*45/720 - 0.4614 = 6.27$ (-.03V or -0.5%)

$Vf2 = Vp'*(Nf/Np) - \Delta f2 = 107.7*45/720 - 0.3487 = 6.38$ (+.08V or +1.3%)

$Pxfmr = Prp + Prhv + Prf1 + Prf2 + Pcore$

$= 73.9*(.223)^2 + 2*837*(11.77mA)^2 + .77(.6)^2 + .21(1.7)^2 + Pcore$

$= 3.675 + .232 + .277 + .607 + Pcore$

$= 4.79W + Pcore$

$Pp = Vp* Re(Ip) = 120*.1735 = 20.8W$

Summary of transformer parameters:

Parameter	Value	Orig Project Value	Actual (in ST-84)
Np	720T, #34	733T, #34	
Vp'	107.7	106.5V	
Ip	0.223A	0.22A	
Nhv	1981T+1981T, #40	2060T+2060T, #40	
Nf1	45T, #26	47T, #26	
Nf2	45T, #20	46T, #20	
Rp	73.9Ω	75Ω	61.4Ω
Rhv	837Ω each side	871Ω each side	827, 875Ω
Vhv	303V OC per side	303V OC per side	
Rf1	0.77Ω	0.8Ω	
Rf2	0.21Ω	0.21Ω	
Vf1	6.27V at 0.6A	6.35V at 0.6A	6.31V
Vf2	6.38V at 1.7A	6.33V at 1.7A	6.33V
Pp	20.8W	21.0W	
Pxfmr	4.79W + Pcore	4.11W + Pcore	
Vdc	349V	349V	370V (6% high – note p.14)
Idc	8.5mA	8.5mA	

What we have from all these calculations, are the numbers of turns for each winding; just four numbers: 720, 1981 (twice), 45 and 45. Notice that we are talking about winding roughly 5000 turns, altogether.

Making a Bobbin

The design for the bobbin is shown and discussed on p.7. It's made from the chipboard of a mailer, as shown **at right**. I fitted the core tightly around the tongue of the transformer, with a carefully measured and cut butt joint. Used electrical tape to secure it. Next, I traced the ends of

 the core onto chipboard, drew rectangles around them and cut out the end pieces. That insured that the core ends would fit the end pieces well. The core measures 1.1 x 0.8 inches, and the sides are 1.5 x 1.2 inches. To get the smooth, rounded corners, use a corner punch like the Marvy Uchida item **at left**. Why is this important? When you are winding at high speed and get close to the edge, occasionally the wire will brush against the sides. If there is a sharp or rough spot on the side, it might snag the wire. The ultra-thin HV wire might actually break, forcing you to start that winding over.

I don't recall the glue I used to secure the sides to the core but it was probably white glue. After the glue dried, I dipped the bobbin in spar varnish and baked it at 175F for several hours. This made a fairly sturdy core for the windings.

Makeshift Winder and Counter

With 5000-turns to wind, clearly I needed a machine to help with this. Did some looking on the Net for winding machines and found some on eBay. Among the products of inter-est were these two from China:

- $235 with a motor, LED counter and foot pedal
- $100, hand-cranked, two speed ratios, mechanical counter

The thing was, I might never need this machine again, depending on how this went. After think-ing about it, I decided to try rigging-up a simple winder, using my Dad's old ¼" hand drill, as **shown above right**. I used a standard lab counter, operating in totalize mode, to count the turns.
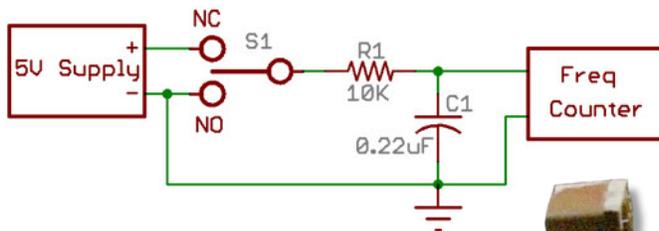
It's triggered by a Velleman magnetic reed switch, purchased from the local Fry's. The only tricky part was rigging a simple RC filter to debounce the switch. A schematic is shown **at left**. I found that the supplied magnet easily operated the switch at a dis-tance sufficient to provide adequate clearance.

The bobbin holder assembly is shown **at right** with the primary winding just completed. The holder consists of a #10 x 2.5" screw, two nuts and two 1.5" fender washers. The magnet assembly is held against the head of the screw by one nut. A washer rests against the nut. The bobbin and a second washer go on,
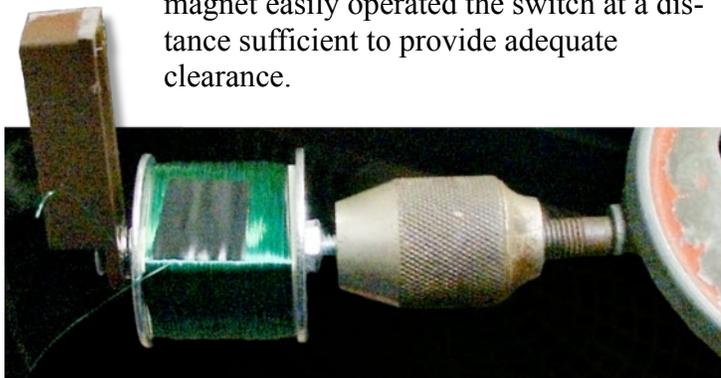
held by the second nut. The end of the screw is held in the drill chuck. Of course, you want to center the bobbin well, but it isn't critical. Don't tighten the last nut so much as to crush the chip-board bobbin. However, the bobbin will take sufficient force to hold it securely.

I was surprised at how well the simple arrangement worked. The wire feed was just a dowel passed-through the spool to serve as an axle. The dowel was taped across the top of a cardboard box. During the winding, I held the wire inside a folded paper towel with my fingers, manually sweeping back and forth across the bobbin to get as even a wind as possible. For the HV #40-wire wind, I had to be very careful not to break the wire during winding. The #40 wire breaks at just 8-ounces.

On the other hand, during the 2000T winds, one wants to move pretty fast. I let the end of the folded paper towel towards the supply spool act as a spring to allow "give" when the spool would balk a little. I would guess that, at peaks, I would be doing about two cranks per second, resulting in 8T per second. That meant that the 2000T wind took at least 5-minutes of cranking. In practice it was probably about 10-15-minutes. Certainly not difficult to last that long.

It is important to get a fairly even wind. Of course, you can't do it nearly as well as a machine would do. If you look carefully at the photos on the previous page, you can see that they were taken with my first attempt, using a bobbin without sides. The lack of sides meant that I had to stay away from the outside edges. That and not realizing that an even wind matters, resulted in a winding which was thicker in the center. I found that it caused the magnetization current to be about 300mA, as opposed to the 140mA achieved on the second try. This could be due to local saturation of the core due to the heavier flux in dense areas.

Winding Details and Lead Dress

The tongue of the transformer is mounted vertically in the finished product and the coil winds around that. I designated one side of the coil to be the top and it is at left in the pictures. The ends of each winding are brought to that side. As seen the the photo of the original at the bottom of p.2, the external leads will be brought up from the bottom end of the coil and will connect to the winding wires coming from the top of the coil. The connections will be secured on the side of the coil as was done in the original.
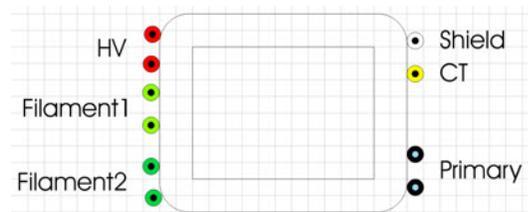
- The lead wire positions are shown **at left**. The positions of the leads match the original.

- Ends of winding wires are brought to the top end at the positions where the leads will be, in the figure.

- Notice the shield connection. That is a strip of copper foil, covering the primary. It is covered with electrical tape to insulate it. The ends of the foil must be insulated from each other, to keep the strip from becoming a shorted turn on the transformer.

- Except for the center tap (CT), windings start/end at same compass position.

- HV/CT: Wind the first half, starting at the HV (red) corner. The turn count is reached at the red corner. Continue to the CT (yellow) corner and bring the end out. Wind the second half, starting at the CT (yellow) corner. The turn count is reached at the CT (yellow) corner. Continue to the HV (red) corner and bring the end out.

- Secure the winding ends with tape. Tape over the wire as it runs up the side of the bobbin.

- Tape over the primary and each HV secondary winding.

The completed coil is shown **at right**. Please note though, that this was taken of the first try, which did not have sides on the bobbin.
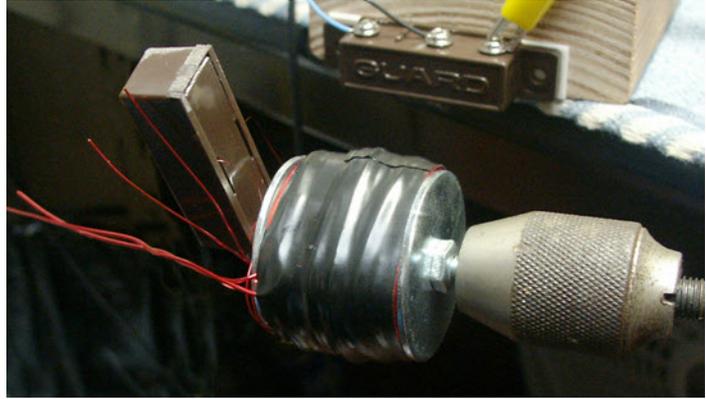
Testing and Finishing

The next step is to temporarily assemble the laminations of the transformer as started **below**, so the coil can be tested. ▶

The loosely assembled transformer is **shown below**, being tested. This pic was taken of the second try, showing the bobbin with sides. Because the laminations are loose, the transformer makes an awful racket during testing, which is normal.
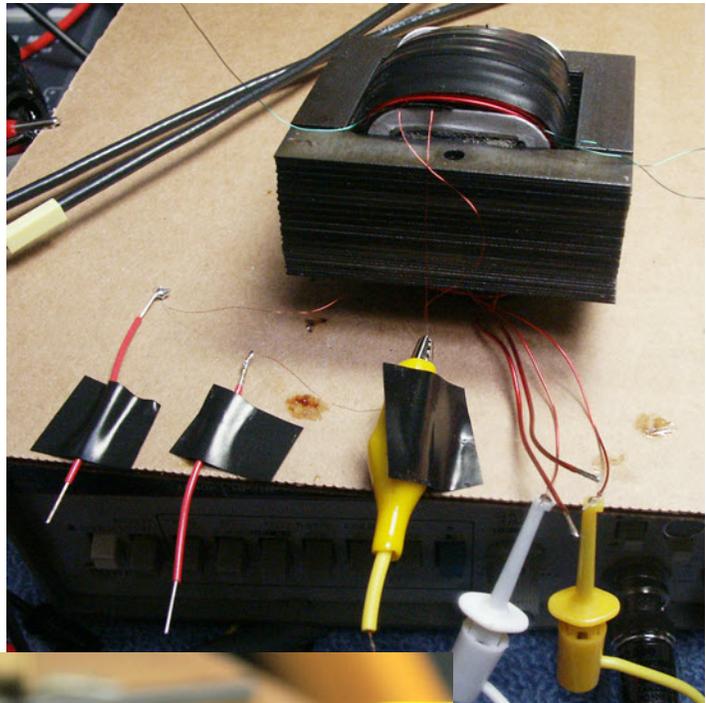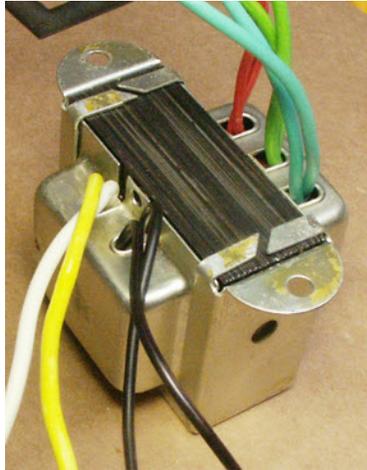
◀ (**Below**) After applying two layers of 3M 9465PC transfer adhesive to the coil, leads are soldered to the winding wires and covered with heatshrink.
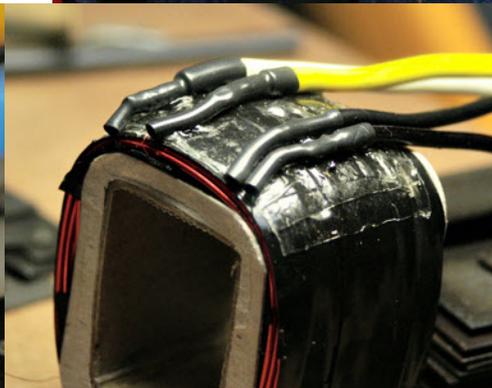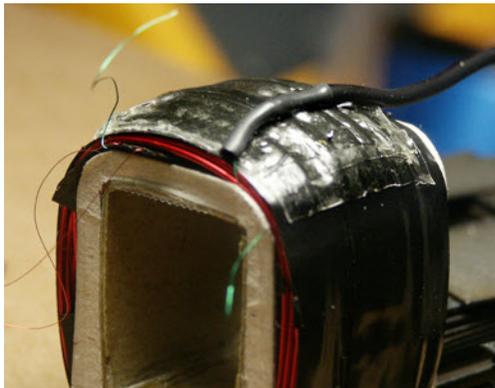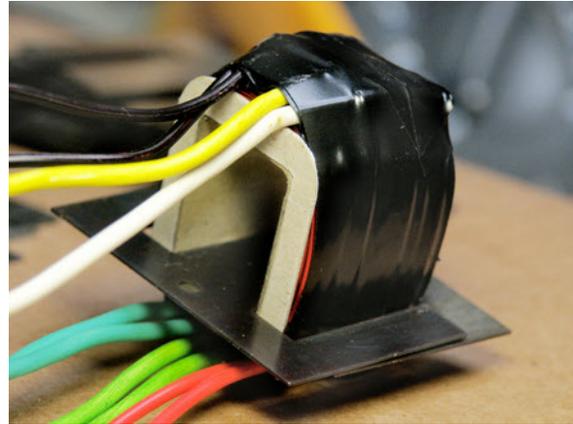
(**Left**) The leads are now firmly affixed to the transformer coil.

Reassembly

The completed coil is seen **at right**, as the laminations are being re-stacked for final assembly.

At left, the end bells and frame have been slipped-on and the bottom tabs crimped.

Impregnation

The next step is to impregnate the transformer with resin, to fill air spaces and dampen buzzing made by the lams. The resin cannot be air-cured type, because it would be very slow to cure in the tiny voids which must be filled. That leaves heat-cured and two-part resins. Heat-cured resins are a specialty item and I could not readily find them in small quantities.

The product I used is EnviroTex Lite Pour-On epoxy-based clear resin. While it is thicker than I would have liked, it did the job well. I found it at the Dick Blick art store but it is also available here: http://www.amazon.com/Environmental-EnviroTex-Finish-Ounces-ETI02008/dp/B001CEMU3I/ref=pd_sim_dbs_k_1. It's about $1/ounce and I used 16-ounces.

However, to do this right, you really need to pull a vacuum to remove trapped air in the transformer, after it is submersed in the resin. For that, I improvised a vacuum chamber using a hand pump and a pickle jar. I used an Actron CP7830 Hand Vacuum Pump ordered through Amazon: http://www.amazon.com/Actron-CP7830-Hand-Vacuum-Pump/dp/B0009XQUK2/ref=sr_1_1?ie=UTF8&s=automotive&qid=1263421183&sr=8-1

The current price is about $39. I only had to drill a hole in the lid of the jar. The vacuum seals the tapered rubber end-piece, provided with the pump. You can see the process in the **photo above right:**
- Transformer leads are bound-up and covered to protect them from resin.
- Two-part resin is mixed in the jar.
- Transformer is inserted in the jar and the lid closed.
- Pump the max vacuum possible–requires perhaps 5-10-minutes of pumping.
- Watch for bubbles egressing from the transformer. After that is complete (maybe 5-10-minutes or so), open the lid and remove the transformer.
- Hang it up to dry. I used a small heater to keep it warm (**shown at right**).
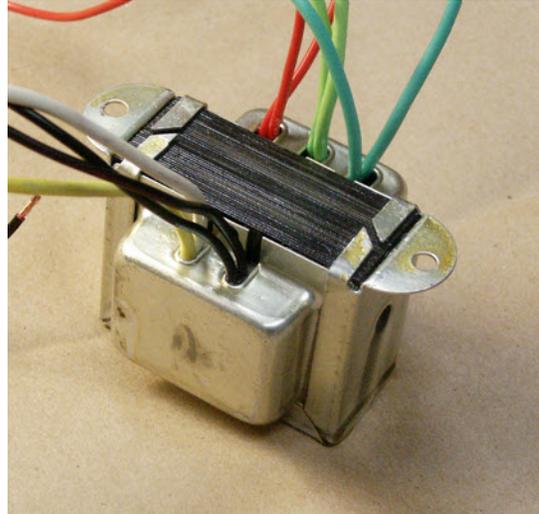- Transformer was ready to use in 24-hours.

Installation and Final Results

The completed transformer is shown **at right**. Note that the yellow varnish residue is from the original manufacture, not the rebuild. The new coating is clear.
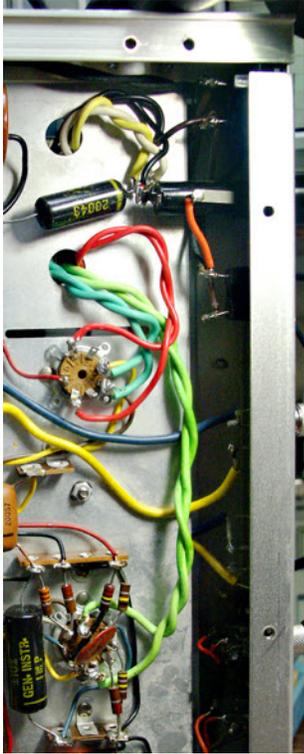
The photo **at left** shows the installation into the Eico ST-84 preamp.

I am pleased to report that there was no audible buzz from the unit, so the impregnation step was successful. Actual measured performance results are given in the table on p.9, with the transformer operating in the ST-84. As you can see, it came out quite close to the design targets. **Note:** As explained on p.6, the procedure given here is a refinement of the one actually used. With the refinement, Vdc would only have been 4% high, rather than 6%. The preamp performs as well as ever. It was a very satisfying end to a challenging but educational project.

Comparing the final **photo below** to the original unit shown on p.1, you can see that it appears virtually identical. So the ST-84 retains its look and authenticity. Ah, life is good again. :)