Crack Manual

A guide to constructing the
Crack Output Transformer-Less tube headphone amplifier kit
Revised December 17, 2013

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HEY! You gotta read this first!

This kit contains parts which operate at high, ***potentially deadly***, voltages. In constructing, operating, and modifying this kit you agree to assume liability for any damage or injury resulting from exposing yourself or others to this high voltage, high temperature hazard. This kit contains only a partial enclosure and thus has not been designed to be shockproof or thermally isolated. The builder must have, or must acquire the knowledge to construct an enclosure which properly isolates this high voltage and high temperature from anyone coming in contact with the kit if deemed necessary.
PLEASE NOTE! If you do not feel that you possess the skills, knowledge, or common sense necessary to safely construct and operate this electronic kit, ***do not attempt its construction!*** You may return the unused kit within 14 days of receipt for a refund of the purchase price, less shipping and handling, if you decide that you cannot safely execute its construction.

DO NOT:

- ***leave the kit operating in the presence of unattended children. Along with the shock hazard, there is also a potential for serious burns from touching hot vacuum tubes.***
- ***leave out the fuses, power switches or power supply bleeder resistors***
- ***Never assume that the shock or high temperature hazards are neutralized, even when the unit is unplugged!***

Safety and the Bottlehead

As more and more audiophiles come to the long forgotten conclusion that building your own tube gear is the best way to sonic heaven, the issue of safety around high voltages becomes terribly important. With the near demise of commercial tube audio gear in the late 60's, and the similar decline of kit building in the late 70's, safe test and construction techniques have been well nigh forgotten by most audiophiles who were there 'way back when' and information on the topic of dealing safely with the kind of high voltages present in the current crop of kit and DIY tube designs seems to be covered lightly if at all.

The basics

Tube audio gear tends to operate a much higher voltages than the current day solid state audio equipment. While a high power solid state amp might draw amps like an arc welder, it usually runs at 75V DC or less. Not to say that these kinds of voltages and currents can't hurt you, but a typical tube circuit may operate at anywhere from 120VDC to as high as an 'electrifying' 1500VDC or even higher! While these voltages are intimidating (in fact many experienced tube DIYers limit their construction to circuits running at 500V or less), that high voltage is only half of the safety issue.

Is high voltage dangerous in and of itself?

Spend some time around a small town TV repairman and eventually you will see him check the HV supply of a picture tube by touching the high voltage lead from the voltage tripler with his bare finger. A small snap will ensue,his hand will fly back, and he'll say, "Yup, it's working". Is there a destructive streak in TV repairmen? That supply is probably at a potential of 5kV to 10 kV!

Nope, the repairman knows that there is virtually no current available from the supply, so while the high voltage may give him a slight 'zap', the supply can't push enough electrons through our intrepid TV guy to really do any short term damage.

NOTE: we are not condoning this practice, in fact there are studies that show repeated microshocks may indeed be detrimental to the nervous system - we're just trying to explain by example!

Current kills

But- let's consider a single ended 300B amp. Now we have a power supply that can supply far less potential than that TV high voltage supply, maybe only 450 volts, but it may be able to push out 160 mA of current (if it's a stereo amp). Before you grab a bare terminal in that supply while in your bare feet on the basement floor, you might want to make sure your life insurance policy covers acts of incredible stupidity.

It is interesting to note that in the days of tube powered test gear Tektronix corporation use to put a warning inside its oscilloscopes reminding the technician that the lowly 400 volt supply, which supplied as many as thirty or forty current hogging tubes, was far more dangerous than the intimidating looking tube rectified voltage tripler circuit.

So yes, those 900V+ 211 and 845 and circuits demand a lot of respect from the builder, but watch those 250V 2A3 amps too!

OK, so how to stay safe?

First some basics. Always wear shoes when working with electronic gear, preferably rubber soled, and particularly when standing on concrete floors. This is because the high potential source will want to find it's way to ground potential. If your body supplies a path to ground, that's where the juice will go, homes. Right through you! The rubber soles will insulate you from ground.

Another classic path to electrocution is from one hand to the other. If you grab the chassis of an amp or preamp with one hand, and touch a live terminal with the other, guess where the current will flow. Right through you! The oldtimers figured out a good way to avoid absent mindedly performing this shocking display - train yourself to always keep one hand in your pocket when reaching into live gear.

A heartstopper

The reason these paths are two of the most critical is because they cross through one of the more electrically sensitive organs in your body - the heart. Because the heart is slighly to the left side of the chest cavity, it is actually slightly safer to use your right hand than your left hand when reaching into or touching a probe to live circuits, as the path to ground through your feet does not pass quite so directly through your heart as current passing through the left hand would.

I'm safe, you're safe, now what?

Make sure you stay away from mains wiring! Remember that the power cord is live even if the equipment is switched off. And don't forget those mains usually supply 15-20A before the circuit breaker will trip. If you don't need a piece of gear plugged into the wall to test it (say you need to check a resistance), don't leave it plugged in! If it must be plugged in, consider use of an isolation transformer between the wall socket and the equipment to be tested, which will create a current limit on what the AC mains can supply.

GFIs

A ground fault interruptor is a must have in garage and basement shops with concrete floors, and anywhere else where the floor could get wet. Install them in your work area if they are not already installed.

A few tips

I use test leads on my meters that have optional alligator clips that can be slipped over the pointed probe tip. If I can avoid holding a probe in my hand when checking a live circuit I do, and the clips make this possible. The alligator clip is particularly useful for the grounded probe. Even if you must measure several points, attaching the negative probe to the ground plane or buss lets you concentrate on the hot test points, which can save not only your precious hide, but help you to keep from shorting the test point to ground from an errant slip, which is the number one way to blow underchassis components.

Never, I repeat, NEVER lean over live equipment or put probes in where you can't see them!

I won't go into the details of a story our friend Scott Grammer told us about an inexperienced tech who didn't heed this warning when working on a microwave oven. Suffice it to say they cut his body away from the still smoldering equipment an hour later.

Also it is a very good practice to only work on high voltage equipment when someone else is present, in case you are accidentally hurt. This can be tough for some of us - all the more reason to practice meticulous safety habits.

Wear safety glasses. I always wore safety glasses when using power tools, but never when soldering. A hot blob of solder in the eye, from an uncooperative desoldered joint, cured me of that right quick.

Don't forget that capacitors can still pack a wallop, even if the equipment is switched off. Practice the habit of bleeding the charge from power supply filter capacitors using a 10Kohm or so resistor with a clip lead attached to each end. Attach one lead to the + terminal of the cap, the other to the - terminal, and leave it on for a few seconds. Better yet, permanently install 270Kohm or so bleeder resistors from + to - across each filter capacitor like we have in our kits. They won't affect peformance, but will save you the hassle of manually bleeding the filter caps.

Well, there's some very basic safety techniques. Tube gear is fabulous, but like all great things, it commands a high level of respect.

Doc B.

ACKNOWLEDGEMENTS

Thanks to Paul “PB” Birkeland for working up the circuit design and layout scheme used in this kit. Thanks to Paul Joppa for the design of the Bottlehead PT-3 power transformer used in this kit. Thanks to John “Buddha” Camille for all his mentoring in proper grounding techniques thru the years. We miss you, boss. Thanks also to Queen Eileen Schmalle for putting up with yet another of Dr. Bottlehead's cockamamie schemes.

What the Crack kit is about

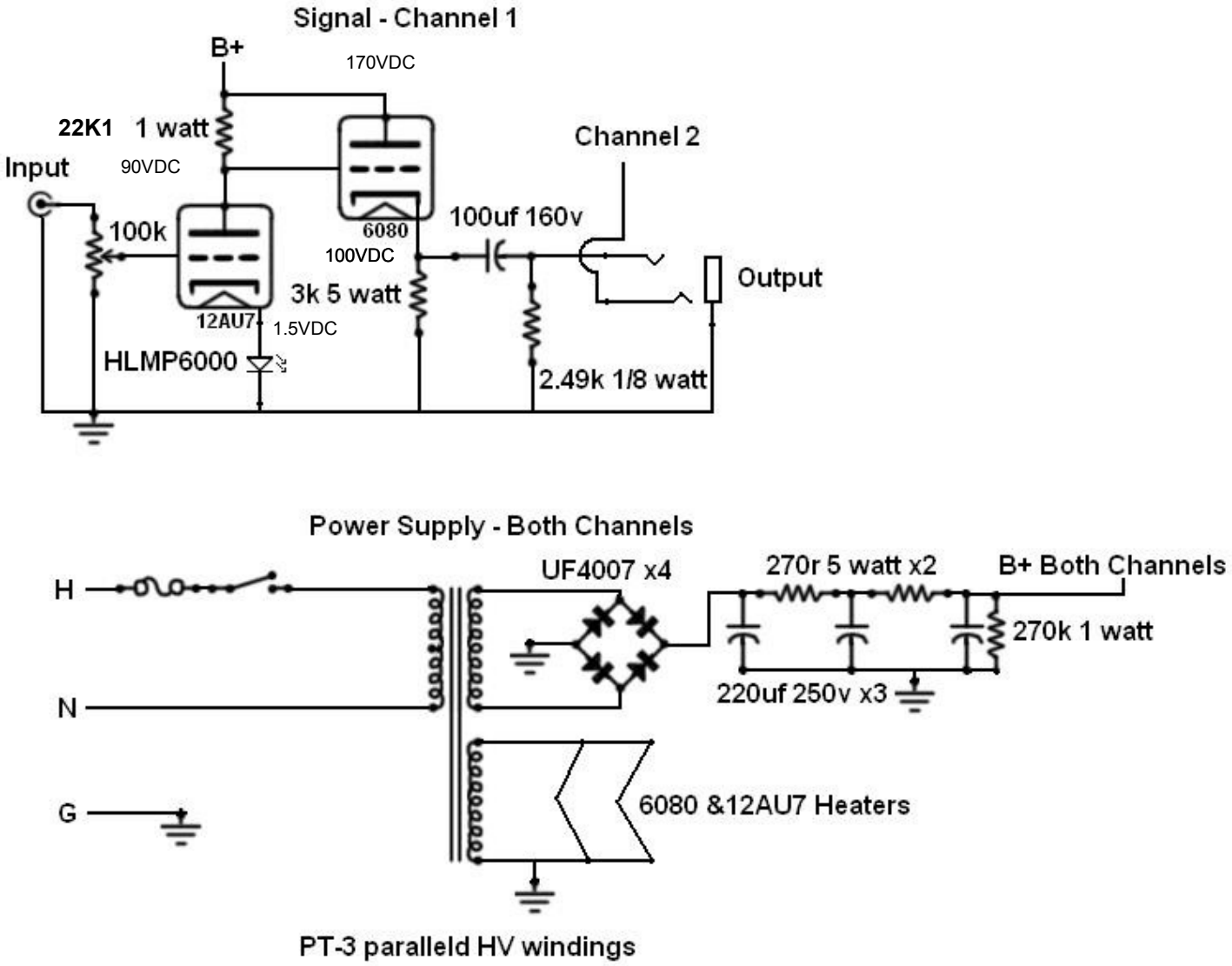
As headphone listening becomes more and more a dominant form of high fidelity listening Bottlehead has wanted to offer a product to that group of listeners that offers the same bang for the buck as our speaker-oriented kits. The Crack Output Transformer-Less (OTL) headphone amplifier has been designed as a relatively simple, highly cost effective, great sounding headphone amp kit for higher impedance headphones (100 ohms or higher) .

Brief circuit theory

The amplifier circuit consists of two channels, each using 1/2 of a 12AU7 tube voltage amplifier direct coupled to 1/2 of a 6080 tube as a cathode follower output. Only one output coupling capacitor is in the signal path of each channel. The high voltage power supply is an efficient solid state ultrafast soft recovery full wave bridge feeding a C-R-C-R-C filter.

Maximum output is about 10V rms (28V pk-pk) before clipping into a 300 ohm load. Gain is about 15 dB into a 300 ohm load. Output impedance is about 120 ohms - recommended headphone load is 100 ohms or greater. Frequency response is +/- 0.5 dB from 10Hz to 50kHz into a 300 ohm load. Phase is not inverted.

Bottlehead Crack Output Transfomer-Less Headphone Amplifier



Tools and additional materials you will need:

- eye protection
- slotted tip screwdriver
- needlenose pliers
- wire cutters
- wire stripper for 12ga. and smaller wire
- soldering iron, 40W is fine. An inexpensive solder station is much, much better
- volt-ohm meter - we suggest a 'pocket DMM' - use this for sorting out hard to read resistors
- a good light source
- Sharpie or other marking pen for terminal ID
- a soft towel or placemat to rest the amps on while working on the underside—the sticky bubble wrap supplied with your kit can also work well as a cushion for your project.

other tools that are nice to have:

- magnifying glass for parts identification
- desoldering tool or desoldering braid
- A set of small sockets and a socket wrench for tightening the mounting hardware
- A “third hand” tool can be useful for situations where you need support the parts you are working on while keeping both hands free to solder

Solder - we recommend standard 60/40 or 63/37 tin/lead solder as the easiest to work with. 2% silver solder is OK, but stay away from 4% silver solder. It does not flow well. If you are using an adjustable solder station you will want to set the temperature to about 650-700 degrees.

Paint—you may wish to paint the power transformer bell end. We suggest a light scuff sanding with 220 grit sandpaper and cleaning of the surfaces with a good degreaser like formula 409 or Fantastik before spraying.

Materials for finishing the wood bases - 220 grit sandpaper, wood glue, masking tape, stain, and a finish. Analine dyes are a great way to get a clear finish that really shows off the wood grain. The newer polymer finishes such as Varathane Diamond are easy to use and easy to clean up with water. Spar varnish gives a nice glossy finish.

Crack Headphone Amplifier Kit Parts List

use your DMM on the "ohms" setting as an easy way to verify the resistor values

( ) 1 wood base kit
( ) 1 — power transformer PT-3
( ) 1 — power transformer bell end
( ) 1 — IEC power Cord

( ) 8 feet red wire
( ) 3 feet white wire
( ) 9 feet black wire
( ) 6" buss wire

( ) 1 — octal tube socket
( ) 1 — octal tube socket clamp
( ) 1 — 9 pin socket
( ) 1 — 9 pin socket clamp
( ) 2 — 5 lug terminal strips
( ) 2 — 6 lug terminal strips
( ) 2 — gold RCA jacks:
one red, one black
( ) 1 — rocker switch
( ) 1 — 0.5A fuse
( ) 1 — IEC power entry/fuse holder
( ) 1 — fuse cover
( ) 1 — knob
( ) 1 — headphone jack
( ) 4 — rubber feet

( ) 4 — #8-32x1-3/4" screws
( ) 4 — nylon shoulder washers
( ) 4 — #8 fiber shoulder washers
( ) 4 — #8 star lockwashers
( ) 1 — #8 solder tab
( ) 1 — 8-32x3/8" screw
( ) 2 — 4-40x1/4" screws
( ) 2 — 4-40x3/8" screws
( ) 3 — #8 round lockwasher (large)
( ) 2 — #6 round lockwasher (small)
( ) 5 — #8 nut (large)
( ) 4 — #4 nuts (small)
( ) 1 — #8-32x3/8" Philips self-tapping screw

( ) 4 — fast/soft recovery silicon rectifiers (UF4007)
( ) 2 — HLMP-6000 red LED's
( ) 2 — 270Ω 5W wirewound resistors
( ) 2 — 3KΩ 10W wirewound resistors
( ) 2 — 22.1KΩ 3/4W metal film resistors
( ) 2 — 2.49KΩ 1/4W metal film resistors
( ) 1 — 270KΩ 1W metal film resistor (rd,pr,yl,go)

( ) 3 — 220µF 250V electrolytic capacitors
( ) 2 — 100µF 160V electrolytic capacitors
( ) 1 — dual 100KΩ potentiometer

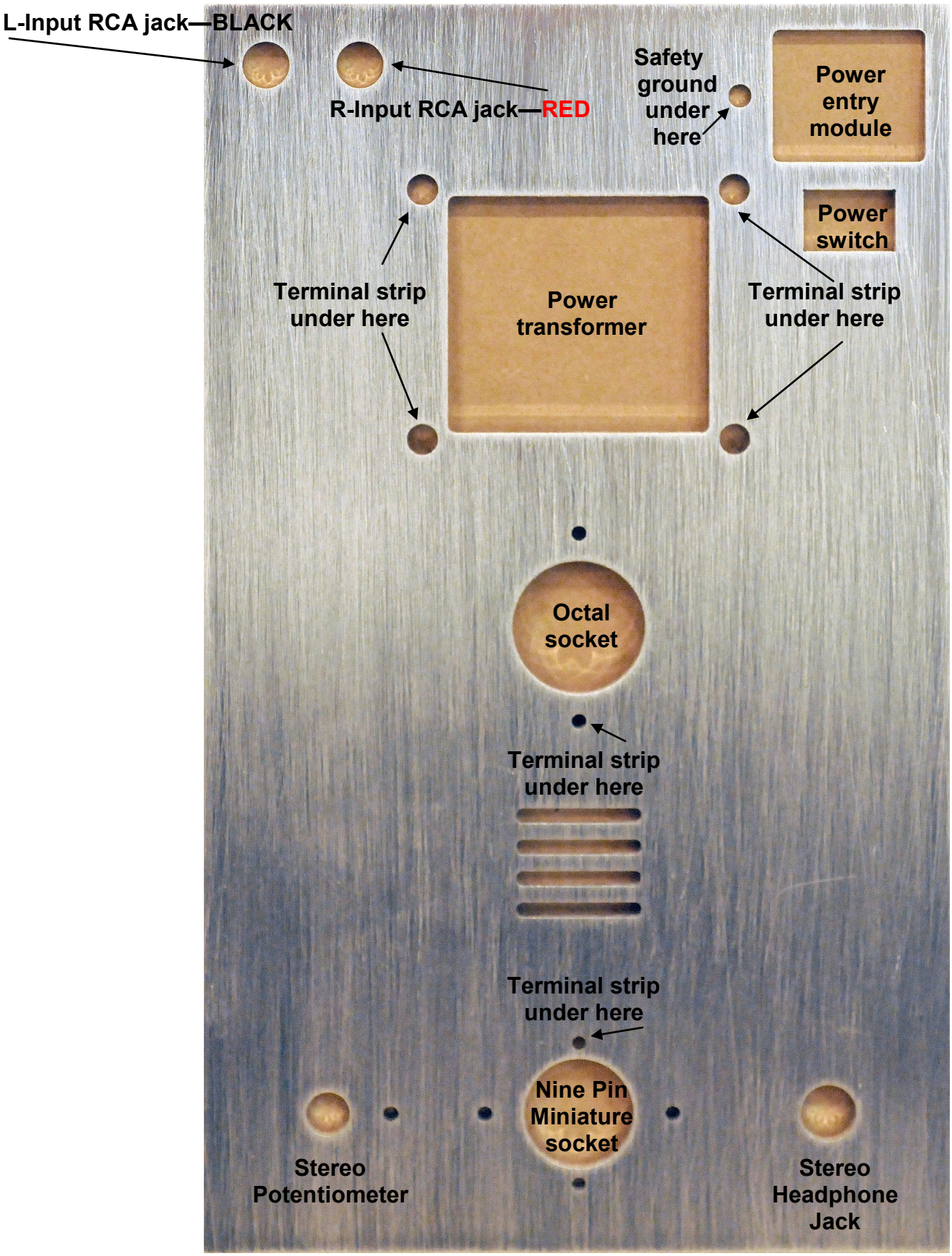
( ) 1 — 6080/6AS7 tube
( ) 1 —12AU7 Tube

( ) 1 — 10"x6" aluminum chassis top plate
( ) 1 — Crack manual CDROM

***Some of the parts included in your kit my vary slightly from the descriptions here. Occasionally parts can be mis-packed, so call us at 206-451-4275 if you have problems finding all the correct parts in your kit.**

Crack chassis plate—top side

(prototype chassis shown, the graining on your chassis plate will be the proper horizontal pattern)



Assembly, Part One -
Building up the chassis

Check each step off as you complete it

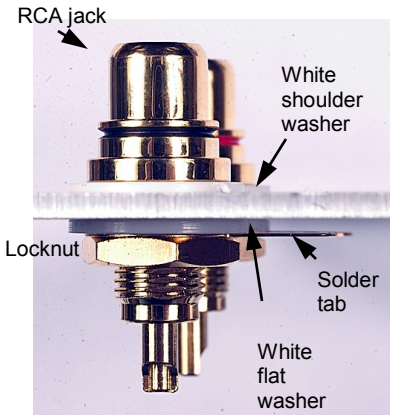
( )First, check the parts supplied in your kit against the check list on the preceding page. Call us at 360-697-1936, M-F 9-5 PT, if you are missing any components listed on the checklist.

Power Entry and Power Switch

( )Now pick up a chassis plate and set it so that the round holes for the tube sockets are toward you, the big rectangular hole for the power transformer toward the rear, and the next smaller rectangular hole for the power entry module is to the right at the rear. You are now looking at the top of the chassis. It should look like the picture on page 10.

( ) First install the power entry socket/fuse holder by snapping it into the large rectangular hole at the rear of the chassis. Be sure to get the power cord pins oriented to the inside of the chassis and the fuse holder to the outside, as shown.

( ) Next snap the power switch into the rectangular hole in front of the power entry socket. Be sure that the white dot sits to the outside edge of the chassis.

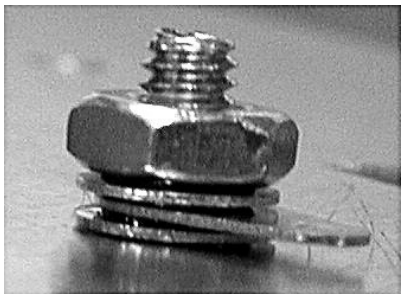


RCA jacks

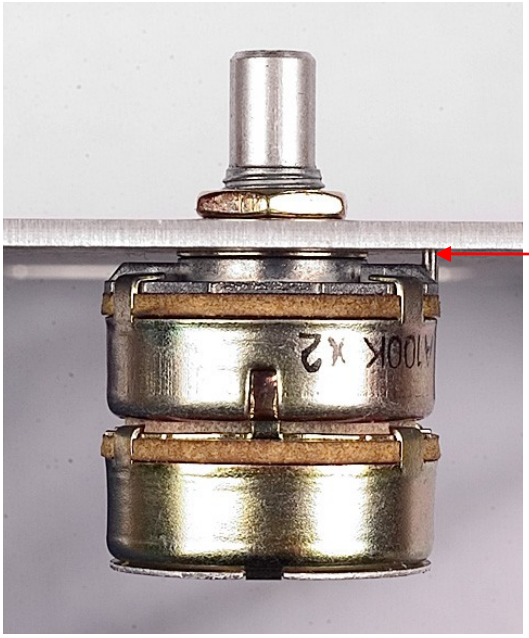
( ) Now install the input RCA jacks in the holes shown in the photo on page 10 (left rear corner of chassis). The black RCA jack goes in the left hole, and the red RCA jack goes in the right hole as you look at them from the front of the chassis. First install the white shouldered washer in the hole from the top, then insert the RCA jack. Flip the chassis over and install the other white washer, the gold solder tab and one lock nut. Tighten the nuts securely. Make sure that the solder tabs point toward the front of the chassis

Safety ground

The safety ground connects the chassis to the ground wire of the power cord. This connection is to safely shunt off any high voltage that might accidentally come in contact with the chassis.



( ) Insert a #8 screw through the hole nearest the power entry module. Stack a lock washer, a #8 solder tab (pointing to the rear of the chassis), and another lock washer, and secure with a #8 nut.

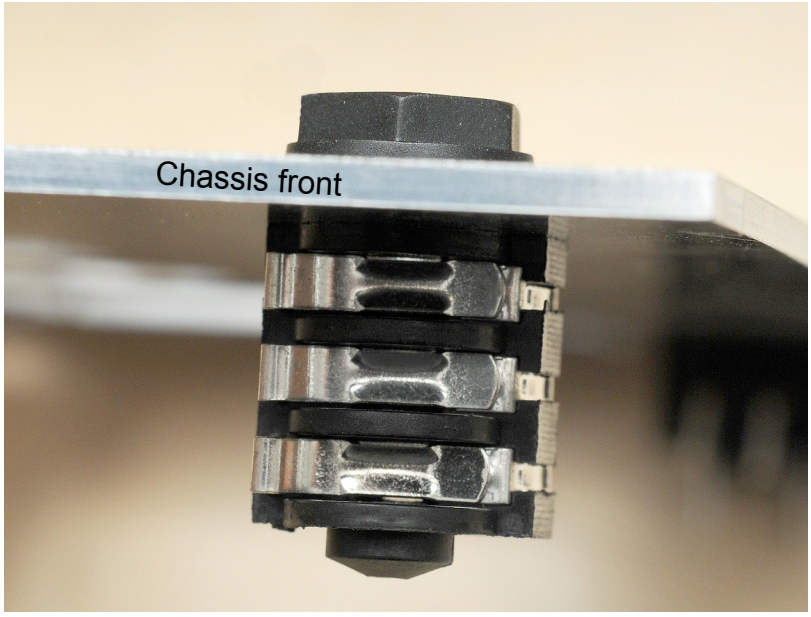


Volume Potentiometer

( ) Remove the nut and one washer from the dual 100K ohm volume potentiometer. Install the potentiometer shaft from the underside, into the hole in the front left of the chassis. Locate the indexing pin on the pot in the small indexing hole to the right of the shaft hole. This keeps the potentiometer from spinning when the knob is turned. Then slip the washer over the shaft, followed by the nut. Tighten the nut down over the threaded portion of the shaft to secure the pot to the chassis.

Headphone jack

( ) Remove the nut and washer from the headphone jack and install the headphone jack in the round hole in the front right corner of the chassis, from the underside. Orient the terminals so that they point to the rear of the chassis. Install the washer and nut from the top and tighten.



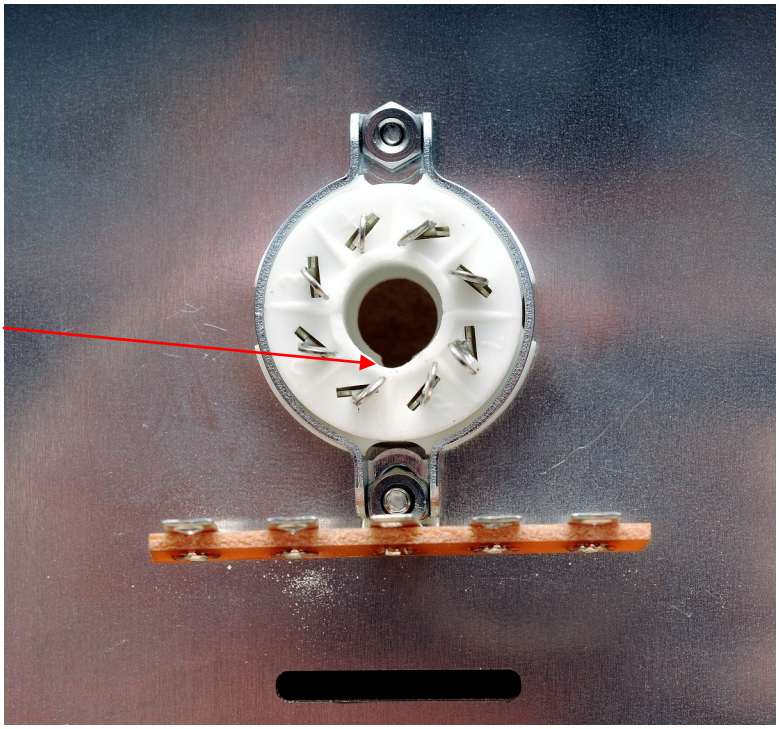
Octal Socket

( ) Start by putting a #4-40 x 3/8” screw into the forward octal socket screw mounting hole from the top side, Slip a terminal strip over the screw from underneath, and secure *lightly* with a #4 nut. Do not use a lockwasher.

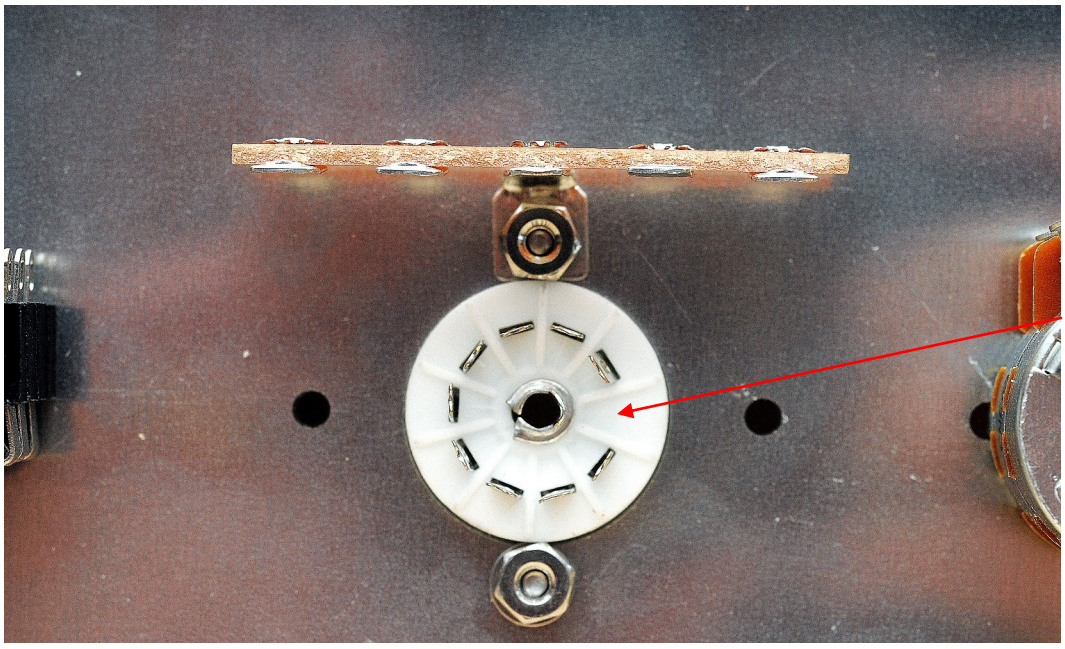
( ) Set the socket into the octal socket hole from the chassis underside, with the slot of the socket’s center hole facing the front of the chassis.

( )Slip the socket hold-down bracket over the socket and slide the front prongs under the nut in the front hole. Tighten the screw snugly, but not enough to make the bracket pull away at the rear hole.

( ) Hold a #4 nut in the rear prong and insert another #4-40 x 1/4” screw in the rear octal socket mounting screw hole from the top side.



( ) Tighten the rear screw down into the nut in the bracket flange, then finish tightening the front screw.



Nine Pin Socket

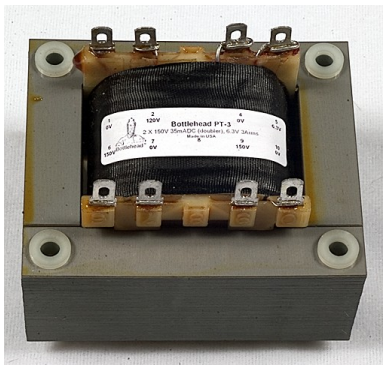
( ) Set the nine pin socket into the nine pin socket hole of the chassis, through the top. Be sure to orient the gap in the circle of pins so that it faces the volume potentiometer. Place the nine pin socket retaining ring over the socket and insert a 4-40 x 3/8” screw through the **rear** mounting hole.

( ) Hold the screw in the hole while you flip the chassis plate over, and slide a five lug terminal strip over the screw, oriented as shown in the photo. Secure with a #4 nut. Slip another #4-40 x 1/4” screw through the front hole. Slip a #6 locknut on the screw from the underside and secure with a #4 nut.

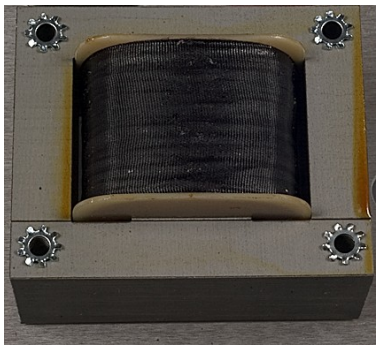
Power transformer

The power transformer comes partially assembled, with the bell end and mountings out. This is to ease installation and to allow the builder to paint the bell end before installation if they so choose.

( ) First grasp the mounting tabs of each 6 lug terminal strip firmly in some pliers and slowly thread the #8-32 x 1/2" self tapping screw into each mounting tab to cut a thread. Remove the screw and set the terminal strip aside. You will not need to use the self tapping screw during the rest of the assembly.



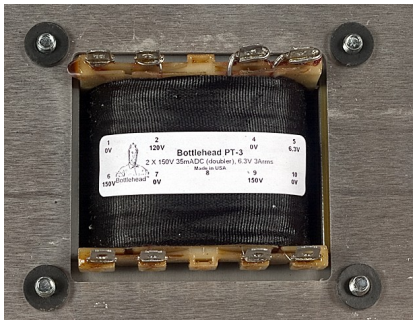
( ) slip a nylon shoulder washer into the hole on each bottom corner of the power transformer, and set the transformer into its hole, taking care to align the mounting holes. The terminals numbered 1-5 should be to the rear of the chassis and the terminals numbered 6-10 should be to the front.



( ) Set a star lock washer on each hole on top of the transformer and carefully set the bell end over them.

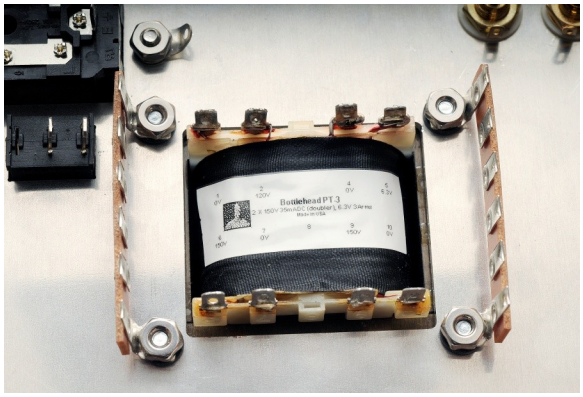
( ) Slip a round #8 lockwasher over one 1-3/4" screw and place that screw in the hole nearest the safety ground. Place three more #8 by 1-3/4" screws into the other holes on each corner of the transformer.

( ) Temporarily tape the screws down over the corners of the bell end and the lamination stack and flip the chassis over, being careful to keep the transformer from coming out of the hole.

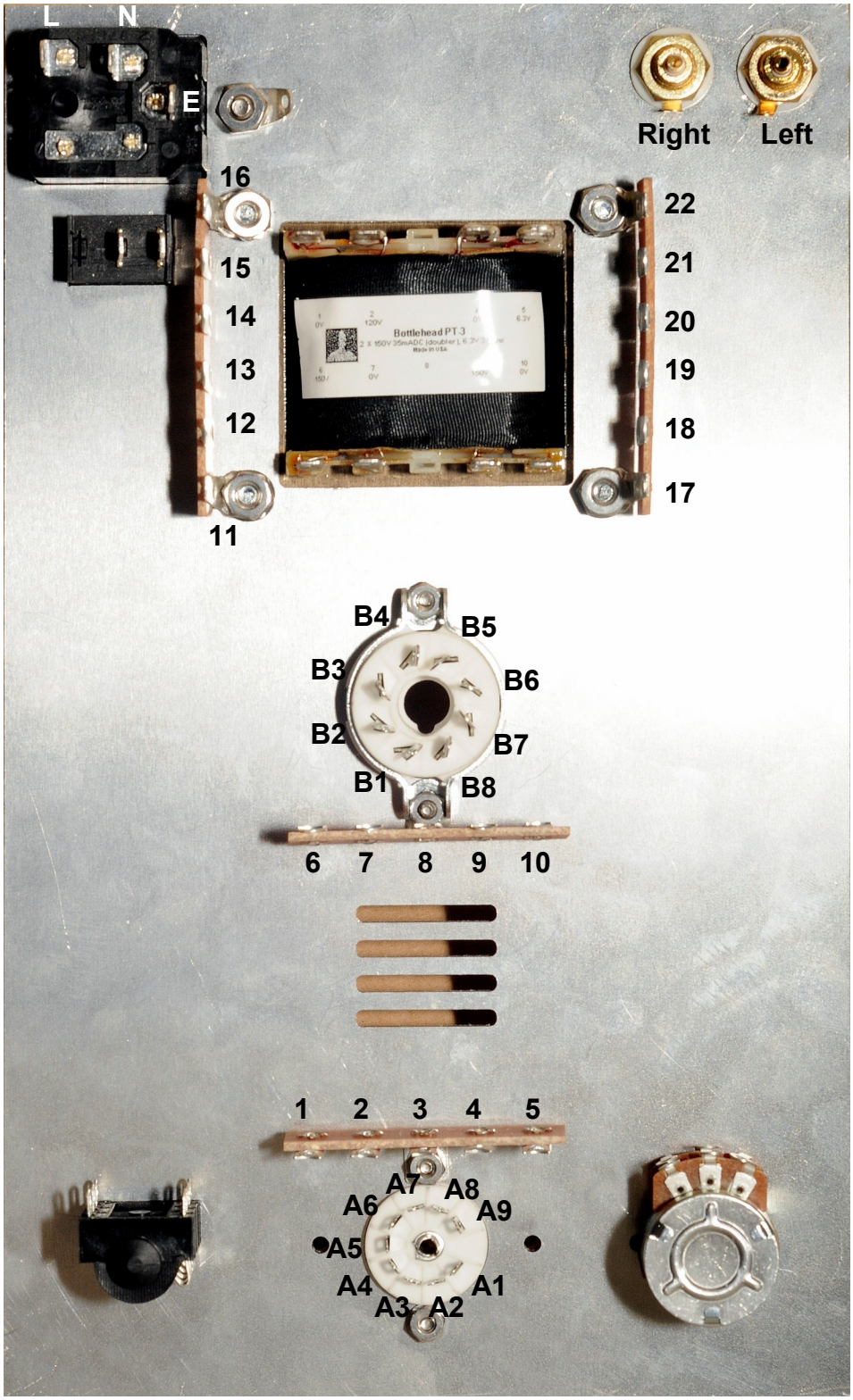


( ) Slip a #8 fiber shoulder washer over each of the screws on the underside of the chassis.

( ) Screw the screws into the threaded terminal strips and secure them each with a #8 nut. The terminal strip can be bent back slightly to aid in starting the nut, then bend it back to perpendicular.



Crack kit chassis hardware assembly —completed underside



( ) **Terminal Identification**—You will use the numbering scheme shown above to identify connection points. It is recommended that you transcribe the terminal numbering scheme shown here onto the chassis plate with a fine tipped marker to ease assembly

Assembly, Part Two– chassis wiring

OK, time to fire up your soldering iron!

WHOA! Soldering lesson!

When you read the word "attach" in this manual, it means to insert a wire lead through a terminal strip hole, and wrap it around the outside of the terminal. Needlenose pliers are the trick here. The idea is to create a mechanically sound connection. If you can't wrap the wire completely around the solder point, at least bend it so that it will hold its position while being soldered. **Don't solder the connection until instructed to in the manual, as other leads may attach to the terminal later.**

Most of all, remember that the soldering iron is a hot item! The tip temperature can approach 800 degrees, and won't feel too good if you absent mindedly touch it! (Think of a steak hitting the hot grill of your BBQ...)
When the instruction is given to solder the terminal use the following procedure:

- Apply the tip of the iron to contact *both* the terminal and the lead(s) attached, and let it rest against the joint long enough to heat the terminal thoroughly.

- Flow enough solder onto the joint to fill the joint between the terminal and every lead attached to it. Look for a concave fillet of solder at each junction rather than a convex blob of solder.

- Be sure to touch the solder to the hot joint, not the tip of the iron.

- Remove the iron and let the joint cool unassisted (don't blow on it!). A joint which cools too quickly or moves will become "cold", it will crystallize and cool to a dull finish. A cold joint will not function structurally, nor will it conduct properly. Reheat any cold joints, applying a small additional amount of solder, and make sure that it cools to the proper shiny finish.

- Keep the tip of the soldering iron clean. A slightly damp sponge is the tip cleaning tool of choice.

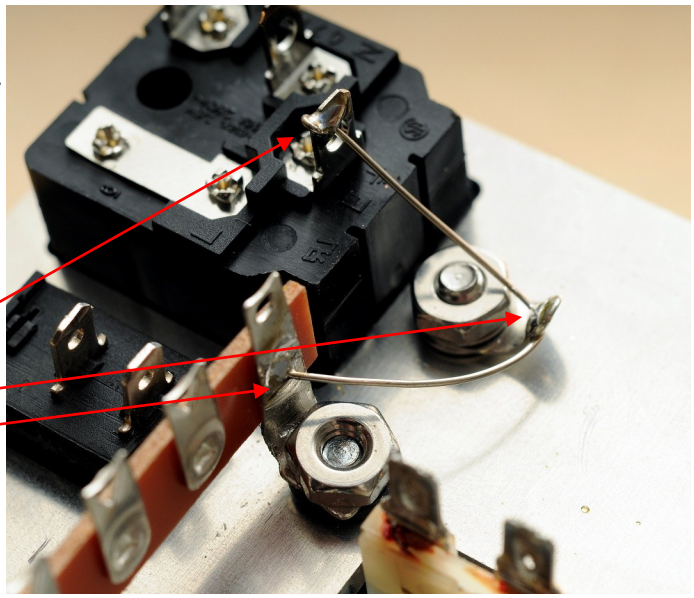
Terminal convention

There are several types of solder terminals in this kit. The terminals on the tube sockets are grouped by a letter designation. The nine pin socket terminals are labeled A1 through A9. The octal socket is labeled B1 through B8. Note—the terminal designations (numerals only) are also molded into the ceramic bottom of each socket. The power transformer terminals are noted on the label, and the terminal numbers are also molded into the plastic next to each terminal. The "L"(live), "N" (neutral) and "E" (earth or safety ground) designations of the IEC power entry socket are also molded into the plastic next to each terminal.

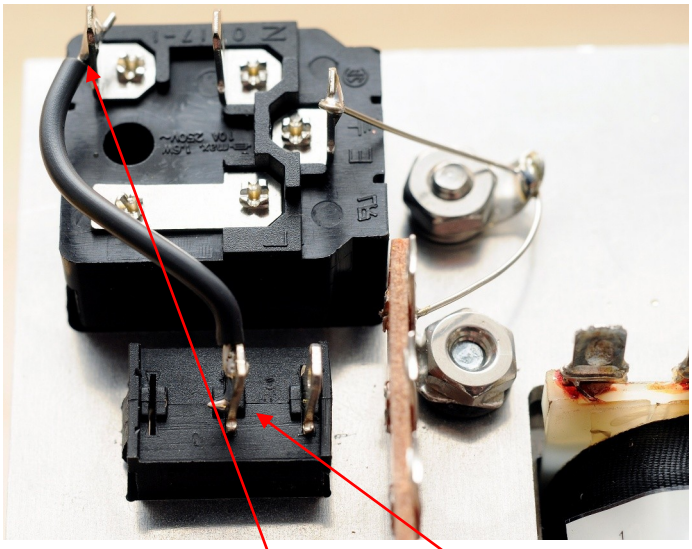
The phenolic terminal strips have terminals assigned 1 through 22. We strongly suggest marking these designations on the chassis plate with a fine tipped Sharpie, referring to the photo on page 15. **IMPORTANT**: each of the terminals on the terminal strips and the octal tube socket has an upper hole and a lower hole. We will use both sets of holes to reduce the number of wires attached to each hole. In the following wiring instructions we will use a U or an L to designate whether the wire is attached the upper or lower hole. For example terminal 1U would mean attach the wire to the upper hole of terminal strip terminal 1, B7L would mean attach the wire to the lower hole of octal socket terminal B7.

AC Ground Buss

This bare ground wire serves to connect the chassis plate and the power transformer to the safety ground wire in your IEC power cord. In the event of an electrical short to the chassis or power transformer case the current will be diverted to the safety ground of your AC mains wiring.



( ) Begin by cutting a 2-1/2” (63mm) piece of bare buss wire. Attach one end to terminal E of the IEC power entry socket. Then lace the wire through the safety ground lug, taking one turn through the lug. Finally, attach the free end of the wire to terminal 16L. Solder all three connections and trim any excess wire ends from terminal 16 and terminal E. Be careful not to melt the plastic body of the power entry module.

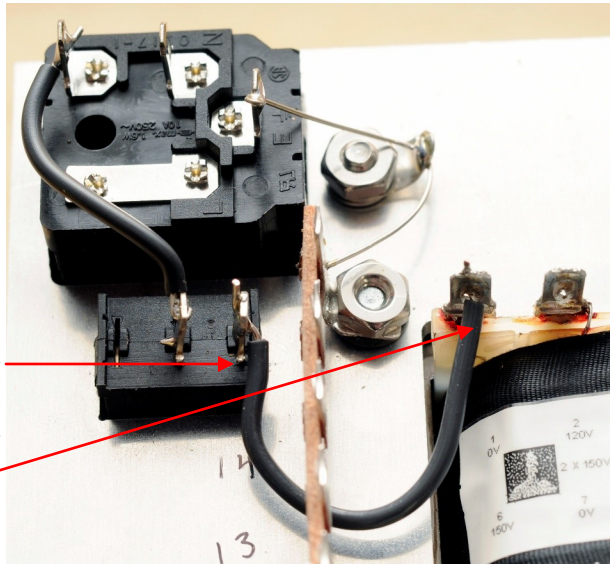


AC Mains and power switch wiring

The standard procedure for AC mains wiring in the US is to connect the neutral wire to one end of the power transformer primary, and to connect the live wire to a fuse, which is then connected to a power switch, which then connects to the other end of the power transformer primary.

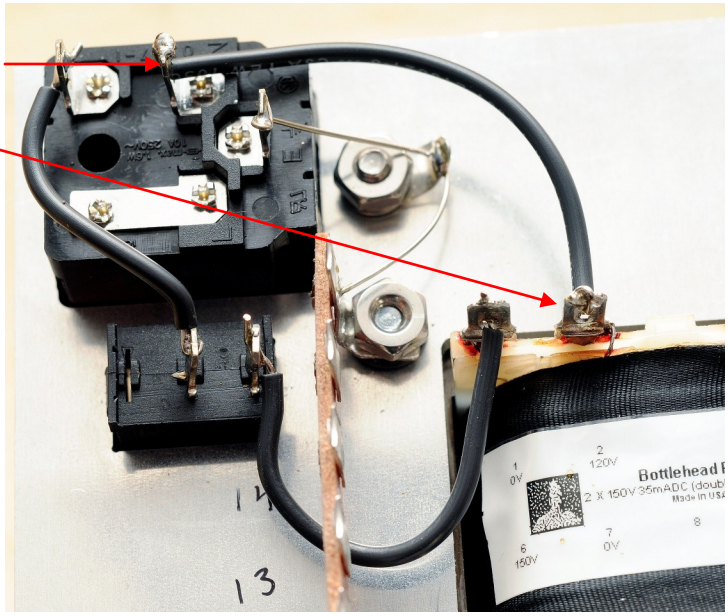
( ) Before you begin take a bit of fine sandpaper, steel wool, or an X-acto knife and gently scrub or scrape the terminals on the power switch. This will allow the solder to flow more easily.

( ) Cut a piece of black wire 2” (50mm) long and strip both ends back 1/4” (6mm). Attach and solder one end of the black wire to the “center” terminal of the power switch. Attach and solder the other end to terminal L of the power entry socket. Carefully solder each terminal, being careful not to melt the plastic body of the switch. If you do melt the switch, contact us at 360-697-1936 for a free replacement switch.



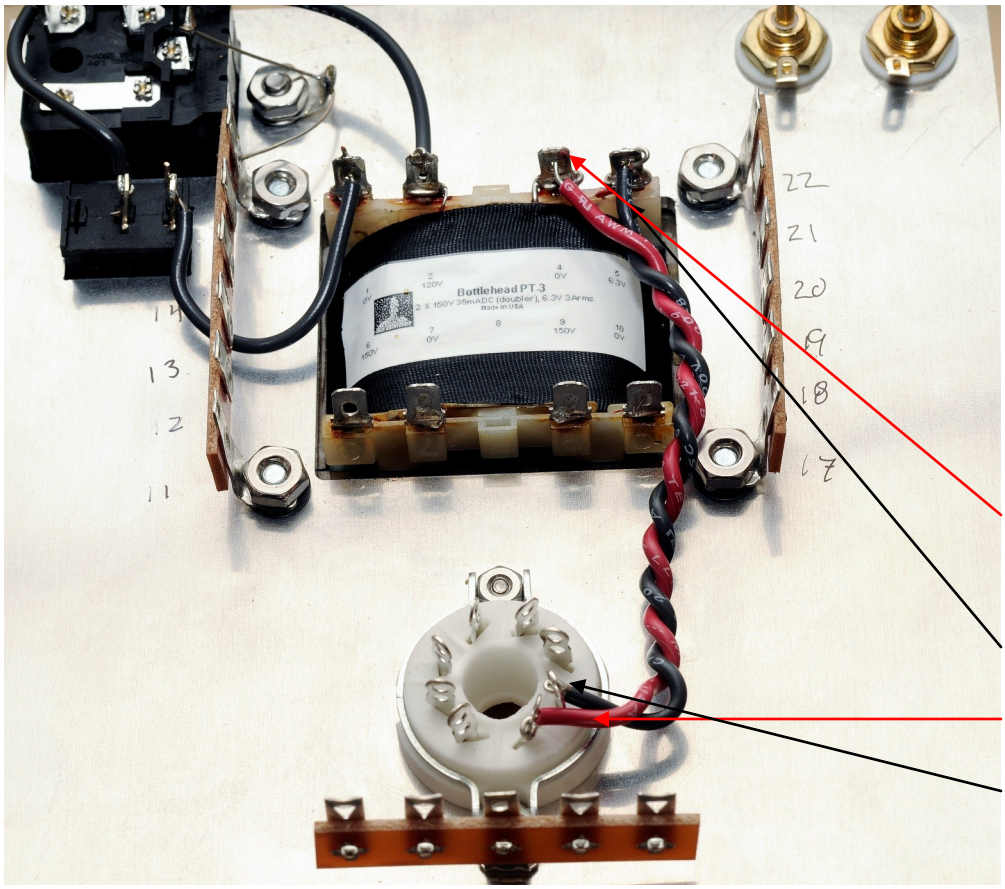
( ) Cut a 3” (75mm) piece of black wire, strip both ends 1/4” (6mm). Attach and solder one end to the other power switch terminal. Route the wire under the adjacent terminal strip and attach and solder the free end to power transformer terminal1.

( ) Cut a 3-1/2” (88mm) piece of black wire and strip both ends 1/4”. Attach and solder one end to terminal N of the power entry jack. Attach and solder the other end to terminal 2 of the power transformer.



Twisted pair wire

( ) Begin by cutting two 30” (75cm) lengths of wire, one red, one black, and twisting them together. This can be done by hand, but it is most easily accomplished by clamping one end of the pair of wires to the workbench (or having an assistant hold the ends in a pair of pliers), and securing the other end of the pair in a drill chuck. Running the drill will spin the wires into a very even twisted pair. The theoretical optimum is three turns per inch. The wire will shorten as it is twisted. Make sure that the finished length of the twisted pair is at least 24” (60cm).



Heater wiring

The tube heaters are powered from the 6.3VAC secondary winding of the power transformer. The octal and nine pin heater pins are wired in parallel.

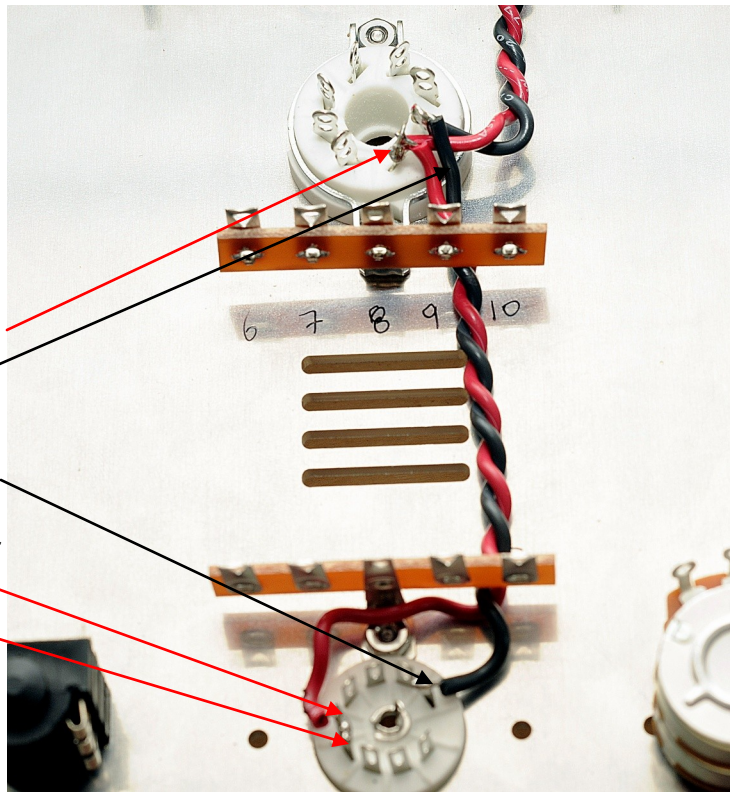
( ) Cut a 5” (125mm) piece of the twisted pair, strip all ends back 1/4” (6mm). Attach but do not solder one red wire end to power transformer terminal 4. Attach and solder the matching black wire end to power transformer terminal 5. At the other end of the twisted pair attach but do not solder the red wire to B8L and attach but do not solder the black wire to B7L.

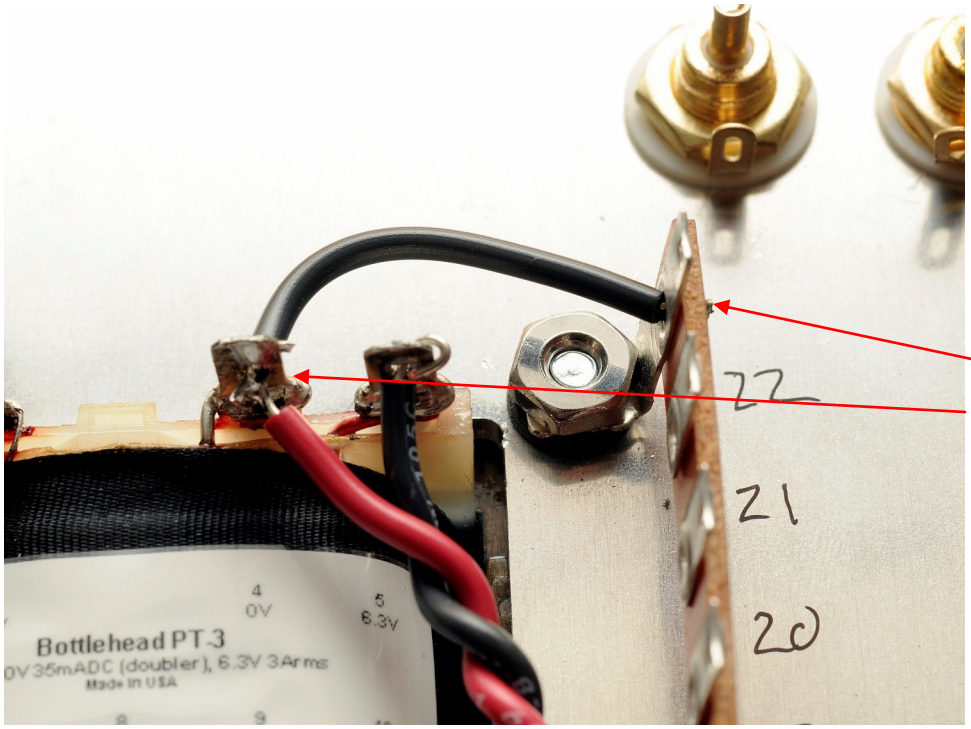
( ) Cut a 6” (150mm) piece of twisted pair. Strip both wires back 1/4” (6mm) at one end.

At the other end unwind 2” (50mm) of the twist. Trim off 1-1/2” (37mm) of the black wire. Strip the black wire back 1/4” (6mm). Strip the red wire back 3/4” (19mm).

( ) At the first end attach and solder the red wire to B8U, attach and solder the black wire to B7U.

At the uneven end route the wires under the terminal strip behind the nine pin socket. Attach and solder the black wire to A9. Insert the red wire end through A5 and then A4, and solder both A4 and A5.





( ) Cut a 2” (50mm) piece of black wire, strip both ends back 1/4” (6mm). Attach and solder one end to power transformer terminal 4. Attach and solder the other end to terminal 22L.

REVISION 5/6/10:

Making this wire 3” long and connecting it to Terminal 14U instead of terminal 22L may yield more quiet operation.

Input wiring

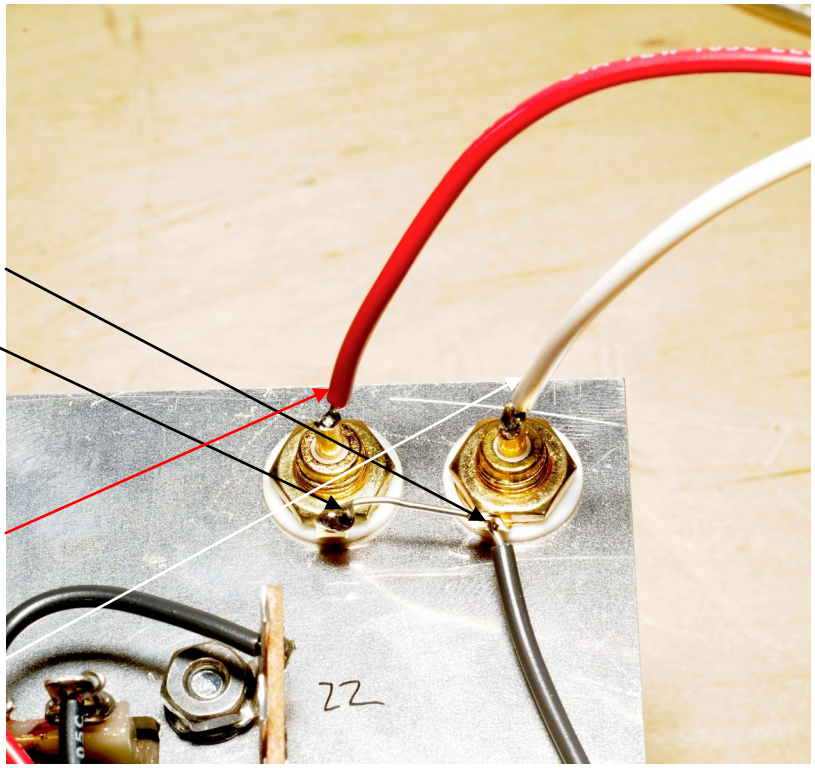
The next step is a bit tedious, but a methodical approach will yield a nice looking, functional job. The braiding will help to reject noise pickup.

( ) Cut a 10” (250mm) piece each of red, black and white wire.

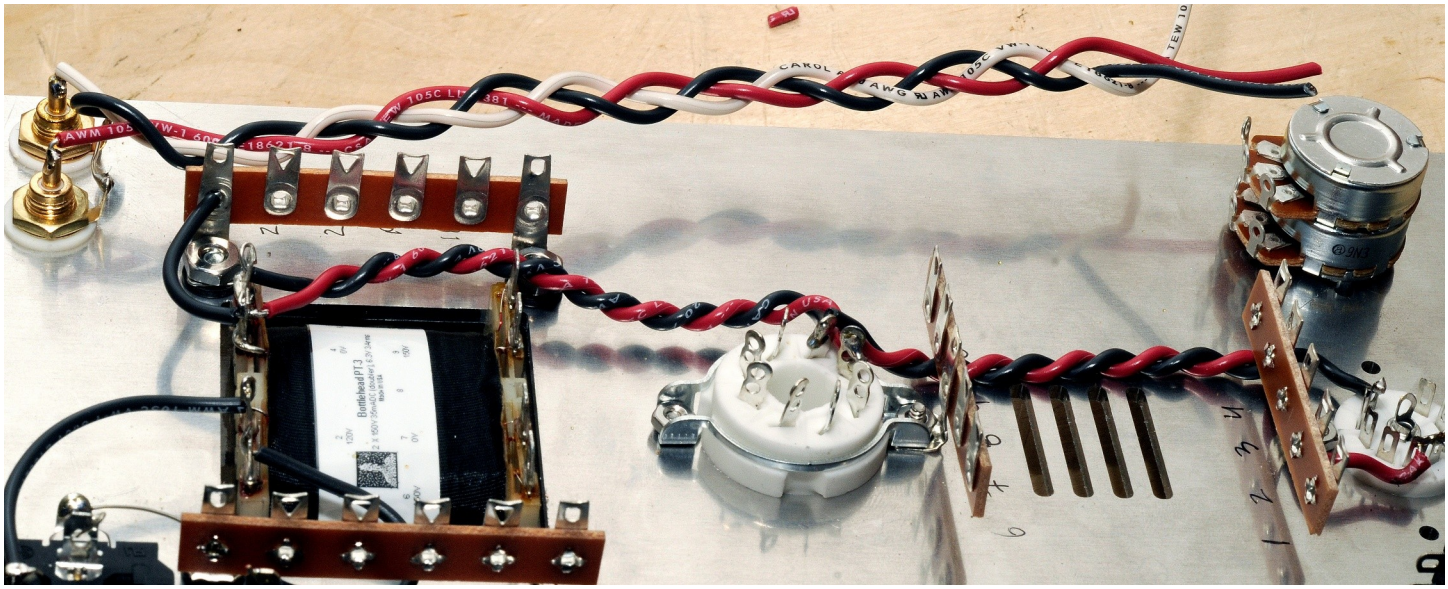
( ) Strip one end of the black wire back 1” (25mm) and insert it through the left RCA jack ground tab and then attach it to the right RCA ground tab. Solder the wire to each ground tab.

( ) Strip one end of the red wire back 1/4” (6mm) and solder it into the center pin solder cup of the right (red) RCA jack.

( ) Strip one end of the white wire back 1/4” (6mm) and solder it into the center pin solder cup of the left (black) RCA jack.



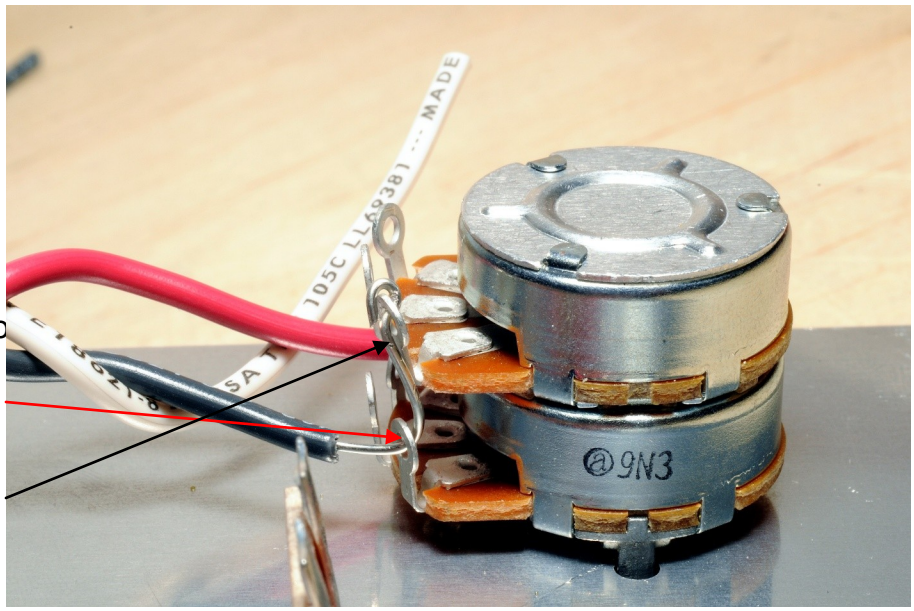
( ) Braid the three wires together as shown, leaving about 2” (50mm) unbraided at the free end.

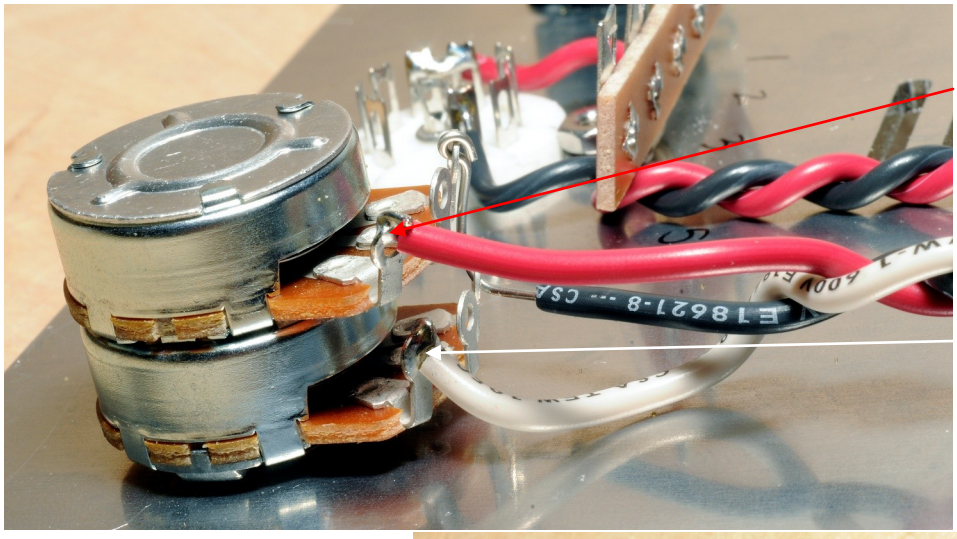


Attenuator Wiring

The braided wire you have installed connects the left and right audio signals coming from the input jacks to the potentiometer attenuator, a.k.a the volume control.

( ) Strip 1/2" (12mm) of insulatio from the free end of the black wire. Thread the bare end through the inboard potentiometer terminal closest to the chassis plate, then through the terminal directly above that (that is, “above” with the chassis inverted). Don’t solder yet.

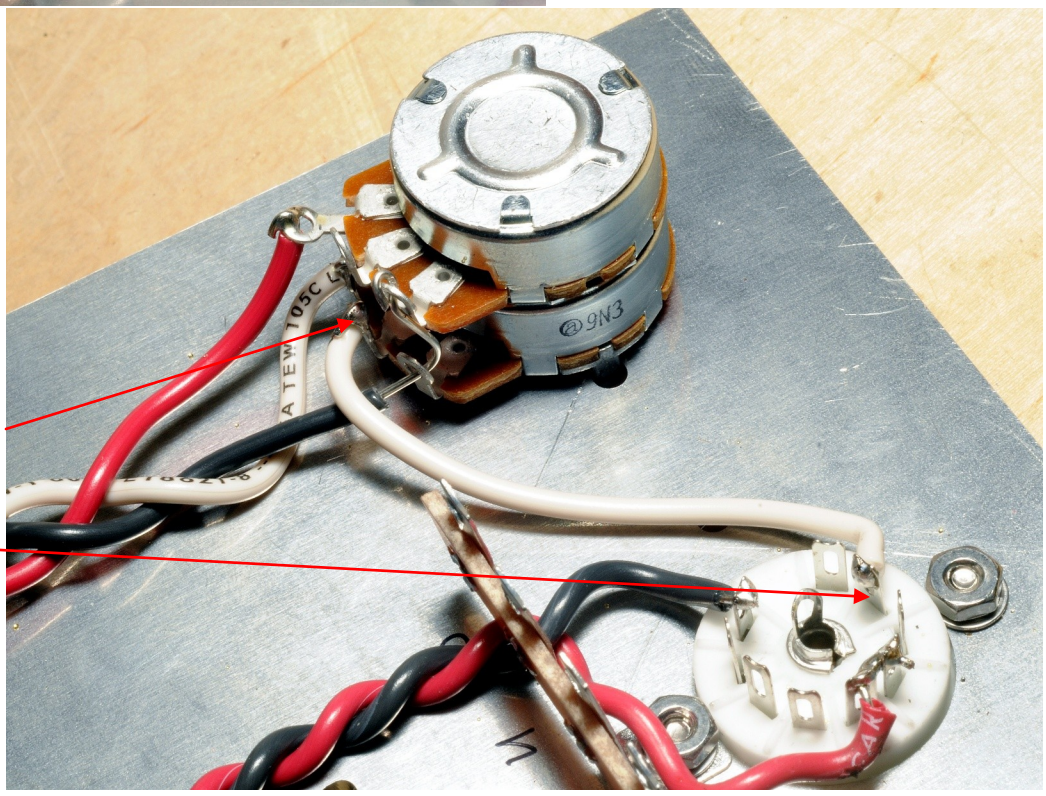




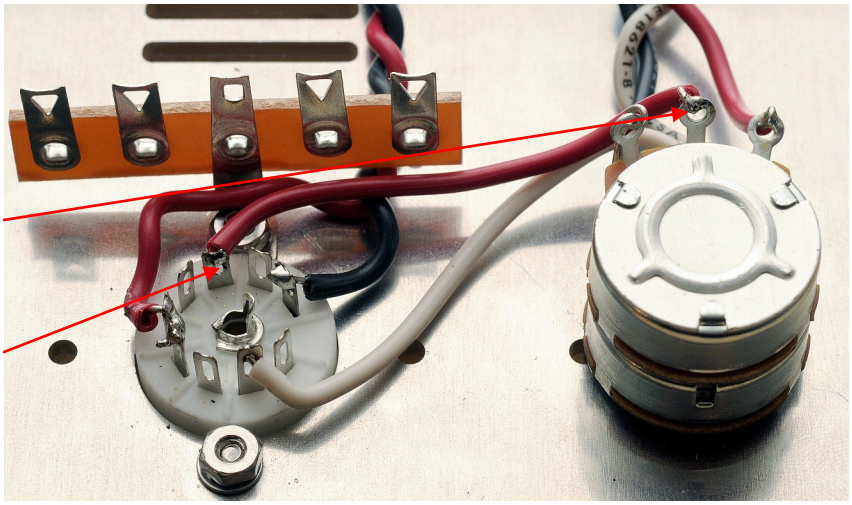
( ) Trim 1” (25mm) from free end of the red wire. Strip 1/4” (6mm) of insulation from end and attach the bare end through the outboard potentiometer terminal farthest from the chassis plate. Solder.
( ) Trim 1/2” (12mm) from free end of the white wire. Strip 1/4” (6mm) of insulation from end and attach the bare end through the outboard terminal closest to the chassis plate. Solder.

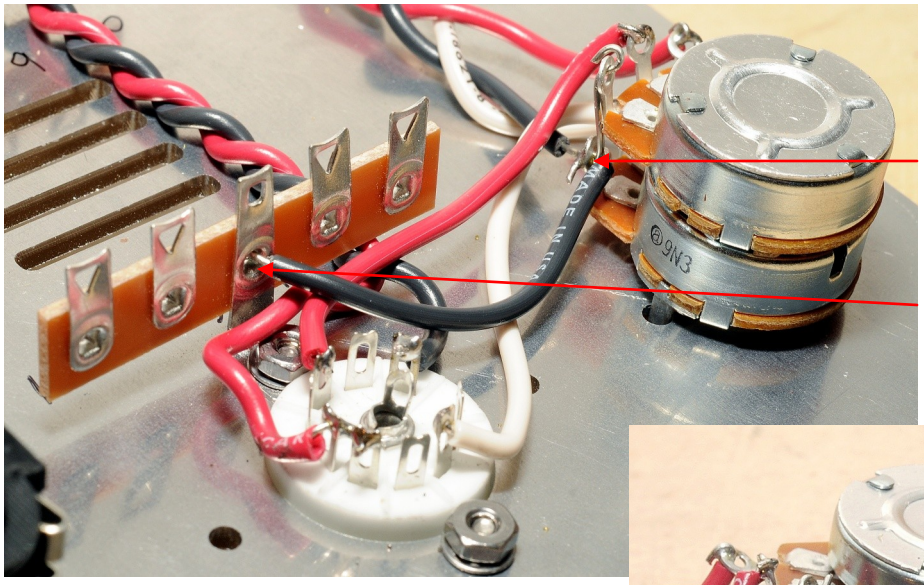
Now you will connect the attenuator to the grids of the input tube.

( ) Cut a 3” (75mm) piece of white wire and strip both ends 1/4” (6mm). Attach and solder one end to the center terminal of the potentiometer that is closest to the chassis plate. Attach and solder the other end to nine pin socket terminal A2.

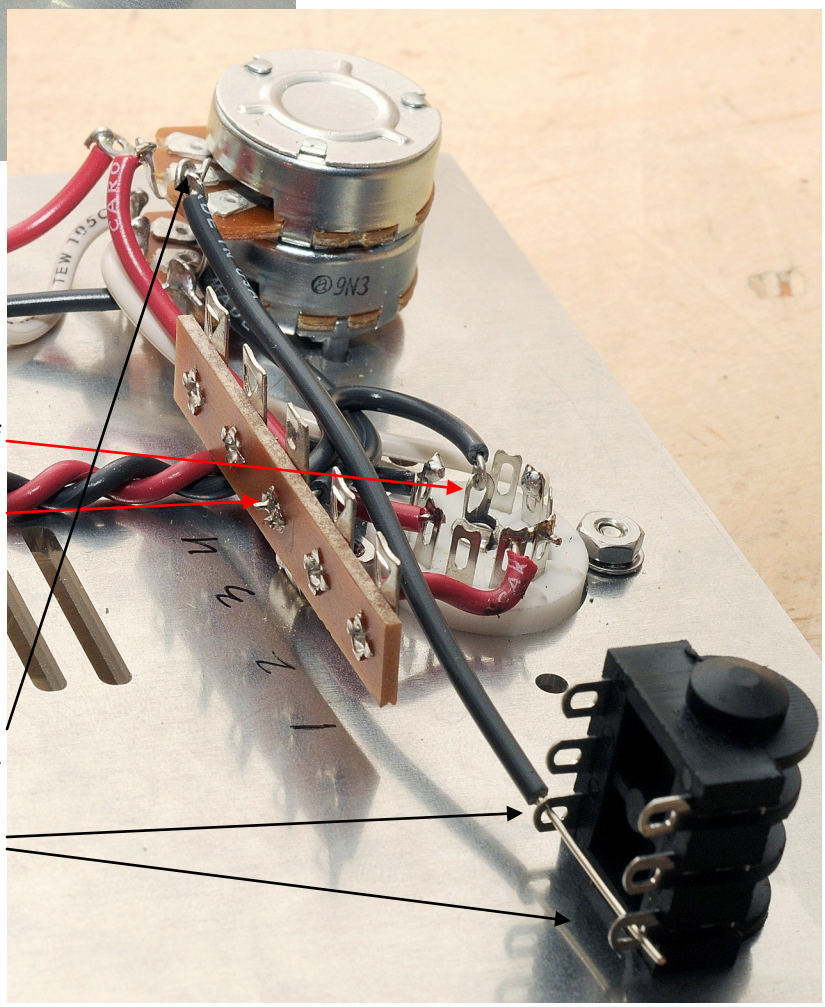


( ) Cut a 2-3/4” (70mm) piece of red wire and strip both ends 1/4” (6mm). Attach and solder one end to the center terminal of the potentiometer that is farthest from the chassis plate. Attach and solder the other end to nine pin socket terminal A7.





( ) Cut a 2-1/2” (62mm) piece of black wire and strip both ends 1/4” (6mm).
Attach and solder one end to the inboard terminal of the potentiometer that is closest the chassis plate. Attach the other end to terminal 3L, but don’t solder.



( ) Cut a 2-1/4” (56mm) piece of black wire and strip both ends 1/4” (6mm). Attach one end to the center terminal of the nine pin tube socket A. Don’t solder. Attach the other end to terminal 3L and solder.

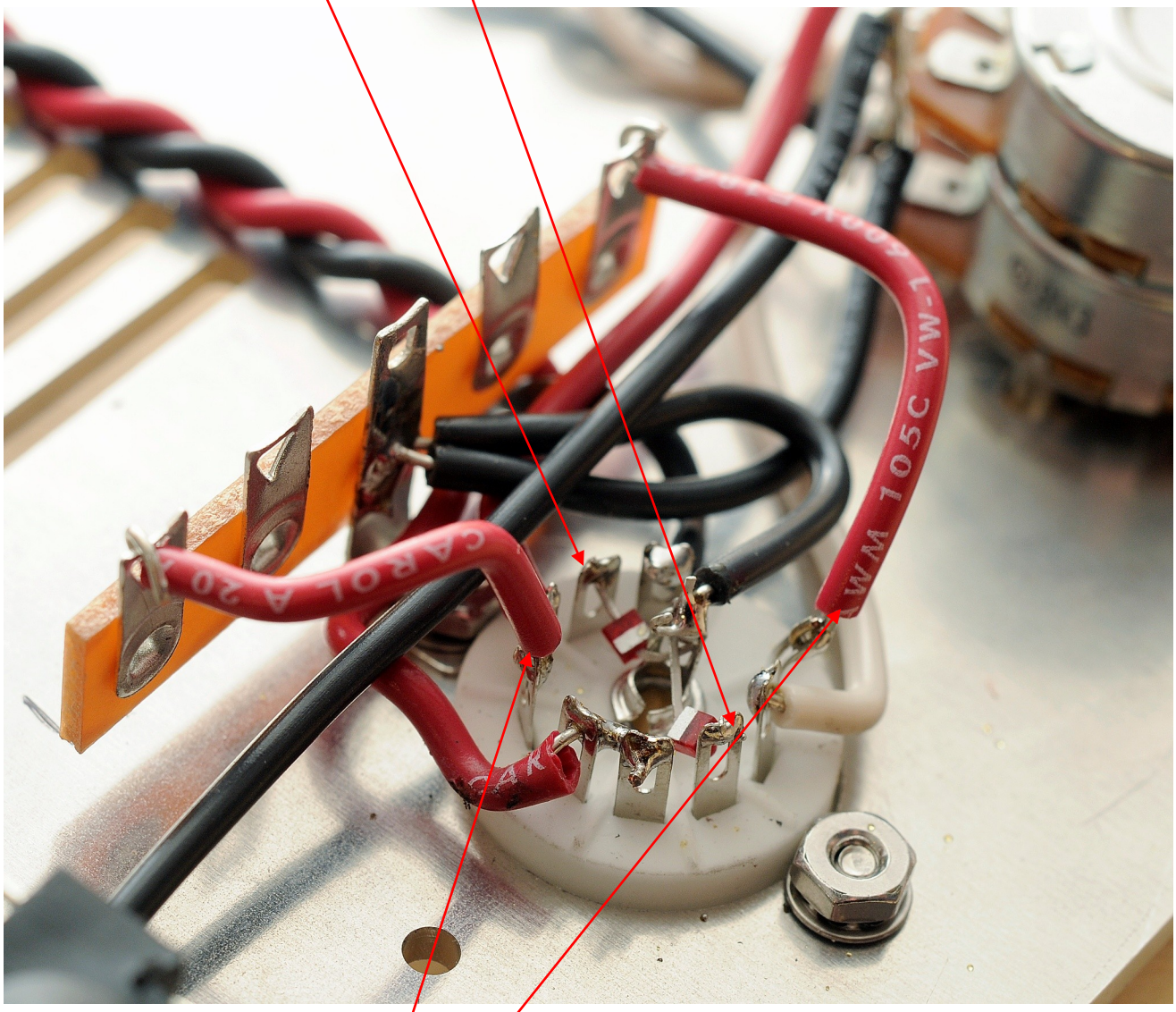
( ) Cut a 4-1/2” (112mm) piece of black wire. Strip one end 1” (25mm) and strip the other 1/4” (6mm).
Attach and solder the 1/4” stripped end to the inboard terminal of the potentiometer that is farthest from the chassis plate. Insert the 1” stripped end through the two TRS phone jack terminals closest to the chassis (the “S” of the TRS), but don’t solder.

Nine pin socket A wiring

You will now install the two LEDs that set the bias voltage of the input tube. These LEDs have a silver band at one end of the red body. It is absolutely critical that they are installed with this silver band connected to the proper terminal.

( ) Attach the silver band end lead of one LED to the center terminal of the nine pin socket A. Don't solder. Attach the other end to A3 and solder.

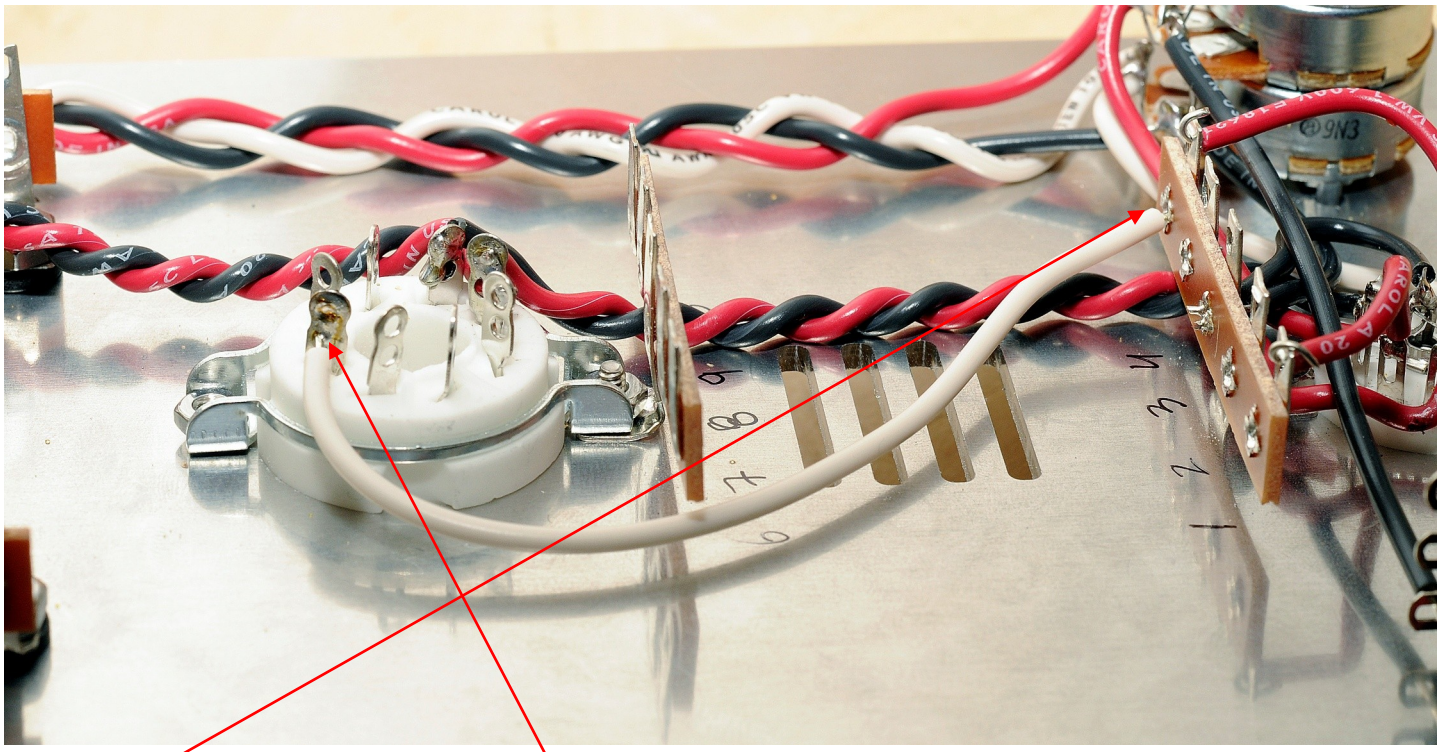
( ) Attach the silver banded end of the second LED to the center terminal of socket A and solder. Attach the other end to A8 and solder.



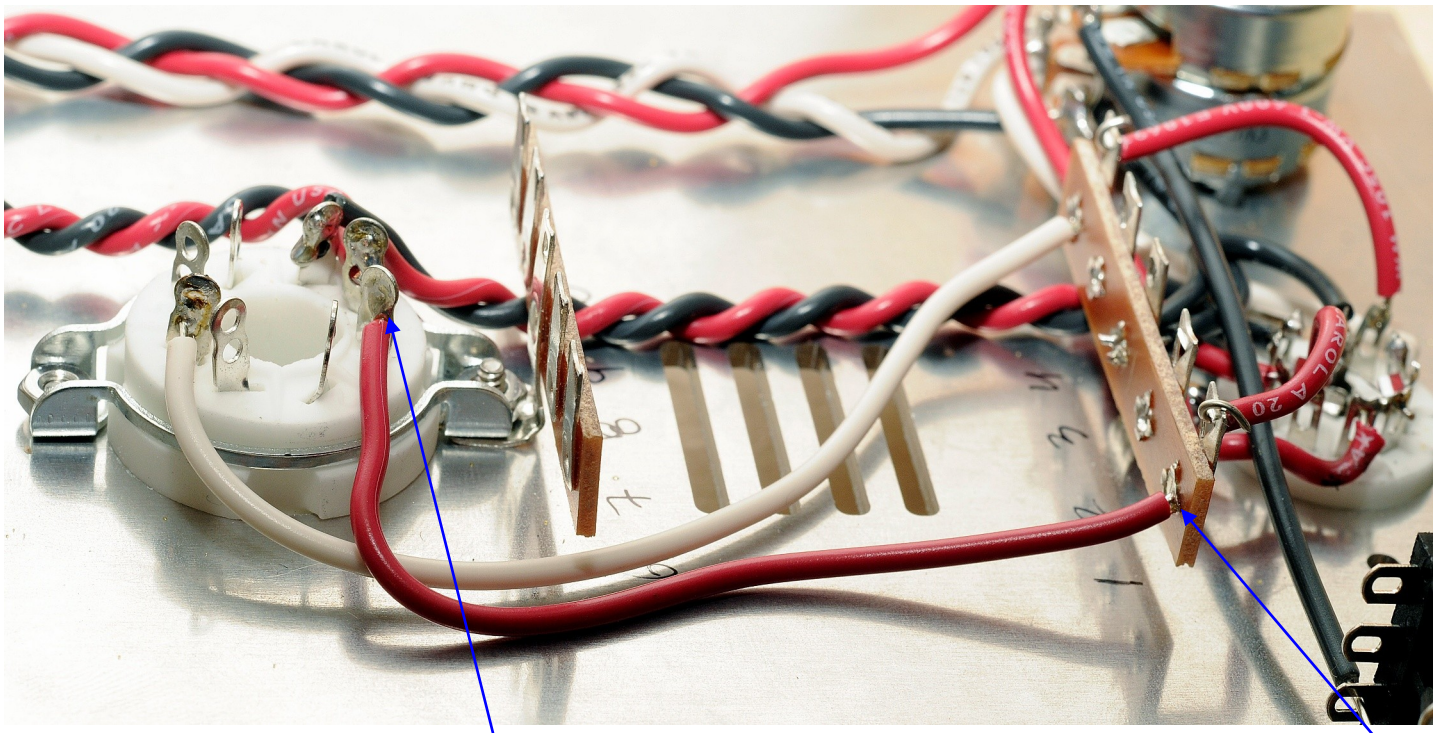
( ) Cut a 1-1/2" (37mm) piece of red wire and strip both ends 1/4" (6mm). Attach and solder one end to A6. Attach the other end to terminal 1U.

( ) Cut a 2" (50mm) piece of red wire and strip both ends 1/4" (6mm). Attach and solder one end to A1. Attach the other end to terminal 5U.

Octal Socket B wiring



( ) Cut a 5” (125mm) piece of white wire. Strip both ends 1/4” (6mm). Attach and solder one end to 5L . Attach and solder the other end to B4.



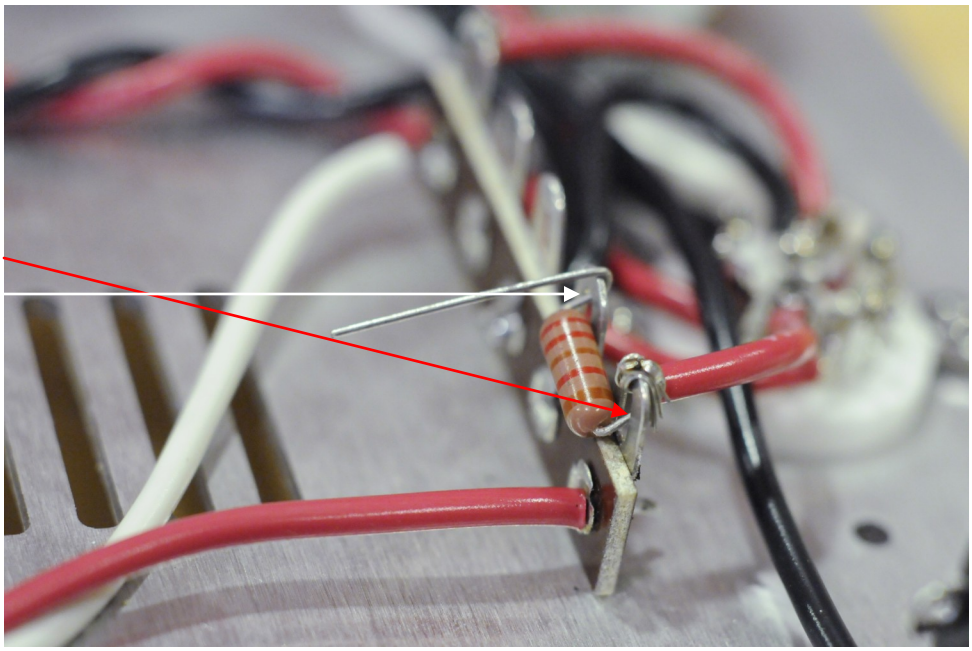
( ) Cut a 4” (100mm) piece of red wire. Strip both ends 1/4” (6mm). Attach and solder one end to 1L Attach and solder the other end to B1.

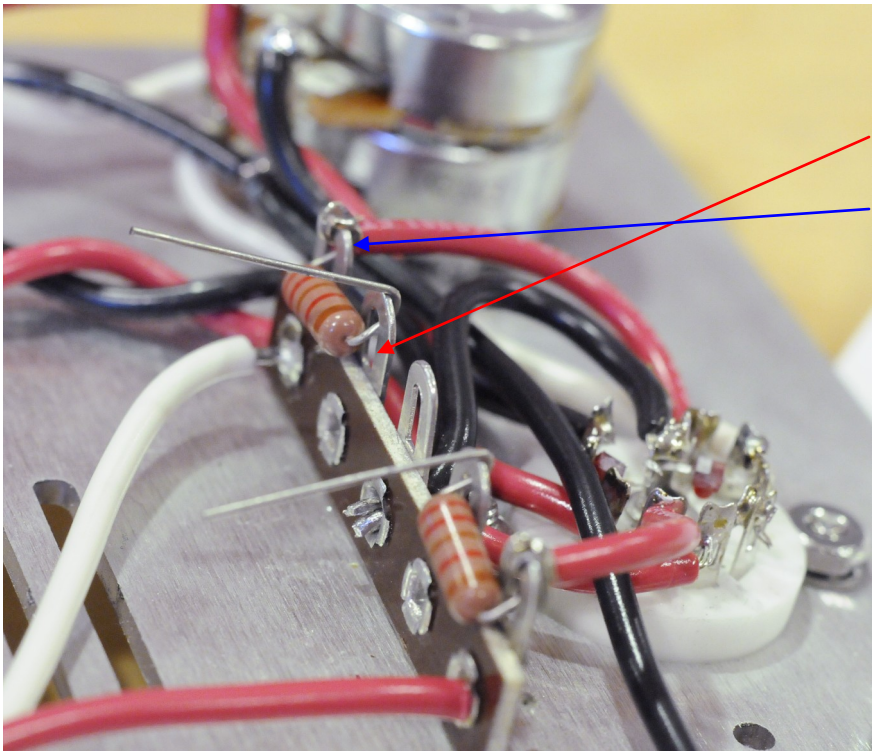
Assembly, Part Three—components and Power Supply

Plate Load Resistors

These resistors create loads for the plates of the driver triodes.

( ) Attach one end of an 22.1K ohm 1W resistor to 1U.
Attach the other end to 2U.
Solder 1U.



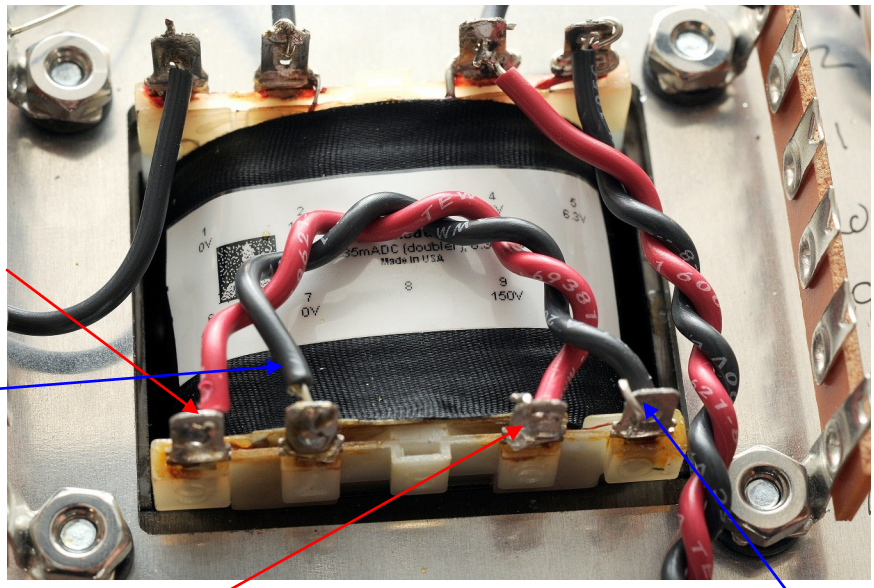


( ) Attach one end of an 22.1K ohm 1W resistor to 4U.
Attach the other end to 5U.
Solder 5U.

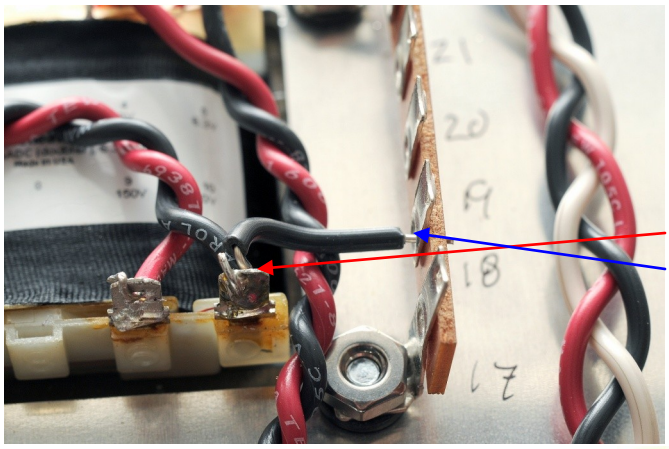
B+ Power Supply

In this next part you will build the high voltage power supply.

( ) Cut a 3” (75mm) piece of twisted pair and strip all ends back 1/4” (6mm). At one end of the twisted pair attach and solder the red wire to power transformer terminal 6 and attach and solder the black wire to power transformer terminal 7.

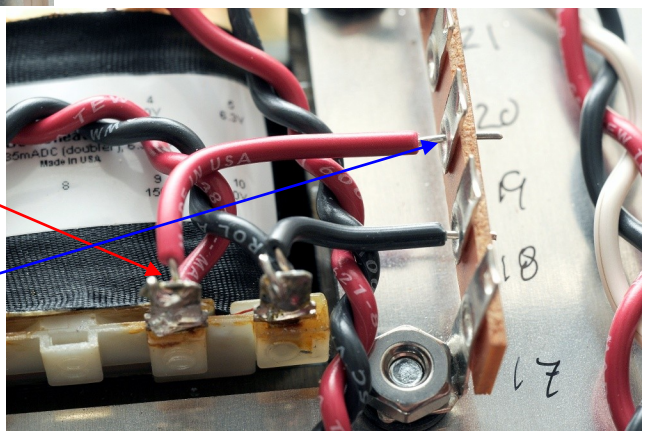


( ) At the other end of the twisted pair attach the red wire to power transformer terminal 9 and the black wire to power transformer terminal 10.



( ) Cut a 1-1/2” (37mm) piece of black wire and strip both ends back 1/4” (6mm). Attach and solder one end to power transformer terminal 10. Attach the other end to terminal 18L.

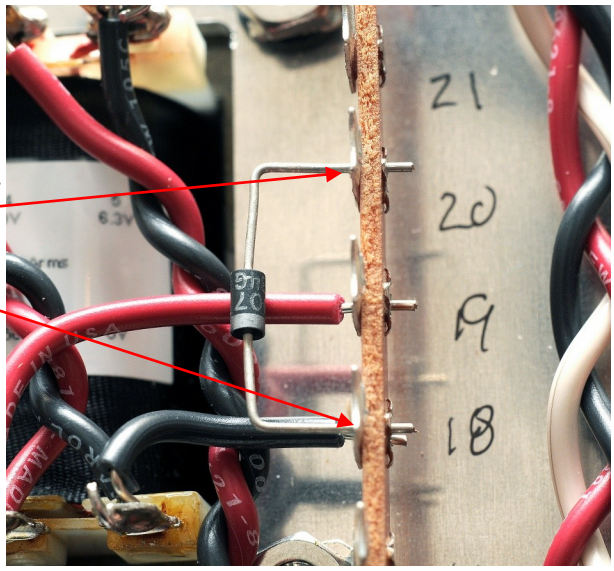
( ) Cut a 2” (50mm) piece of red wire and strip both ends back 1/4” (6mm). Attach and solder one end to power transformer terminal 9. Attach the other end to terminal 19L.



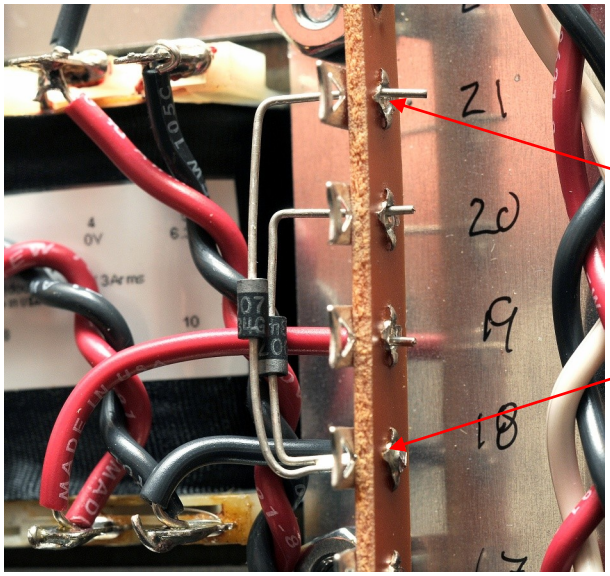
B+ supply component orientation

The B+ or high voltage supply uses a full wave bridge type power supply. **The orientation of the bands and stripes of the rectifier diodes and filter capacitors is absolutely critical.** Refer to the photos for proper orientation of the components.

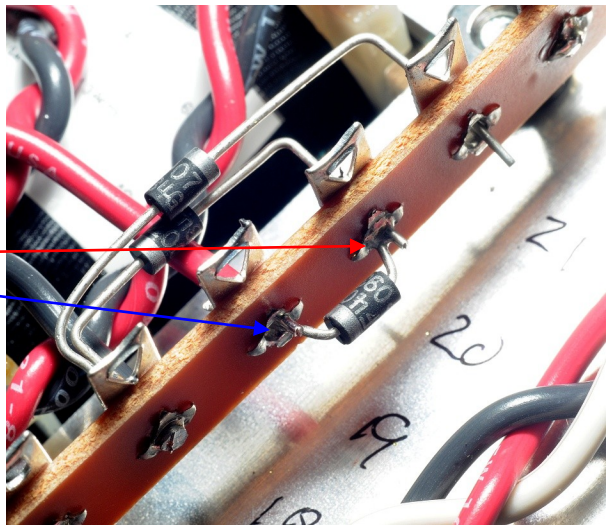
Full Wave Bridge



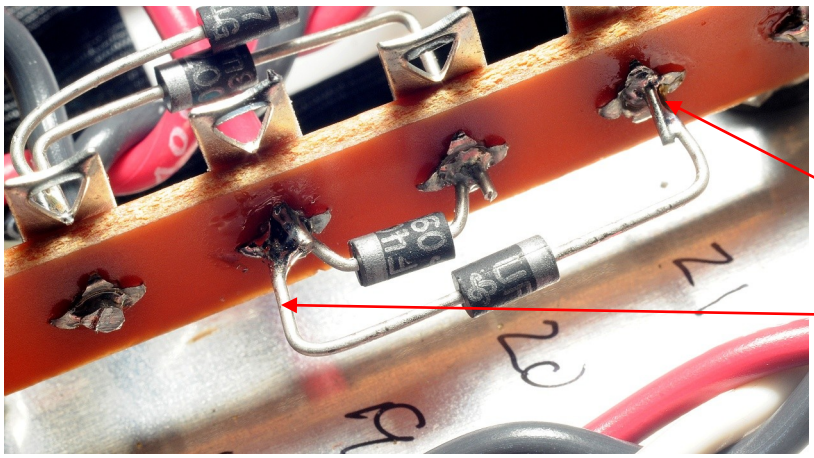
( ) Bend the leads of a UF4007 rectifier 3/8" (9mm) from the rectifier body. With the rectifier located on the side of the terminal strip nearest the power transformer, attach the black end to 20L and attach the banded end to terminal 18L.



( ) Bend the leads of the second UF4007 rectifier with leads 1/2"(12mm) from the rectifier body. Line the rectifier body up over the first one on the same side of terminal strip, with the black end attached and soldered to terminal 18L and the banded end attached to terminal 21L. Trim excess leads from18L.

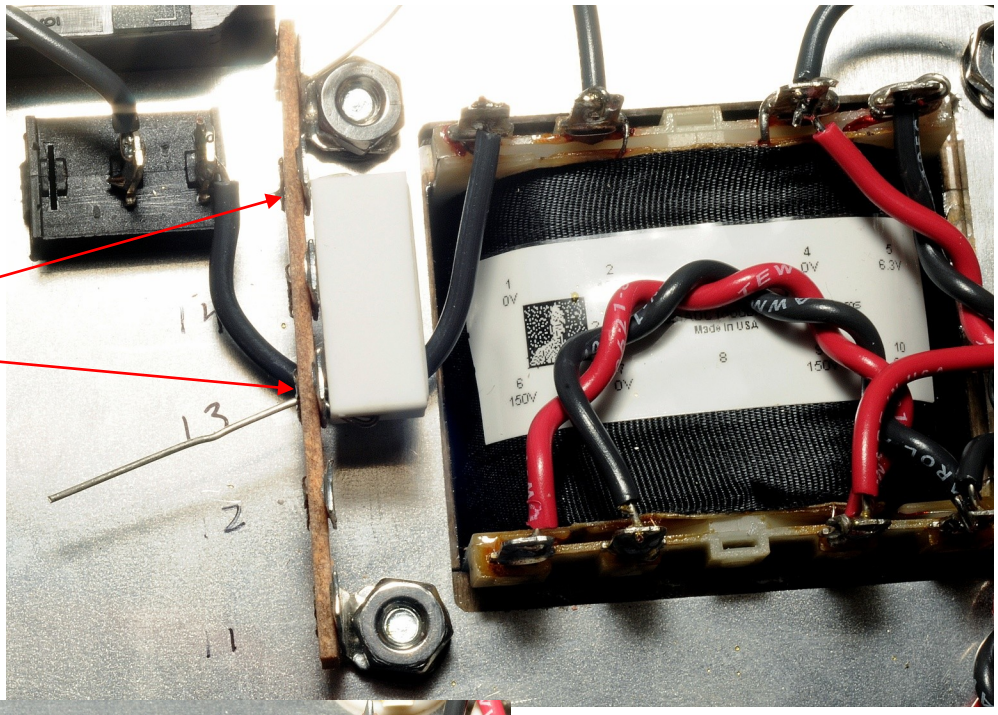


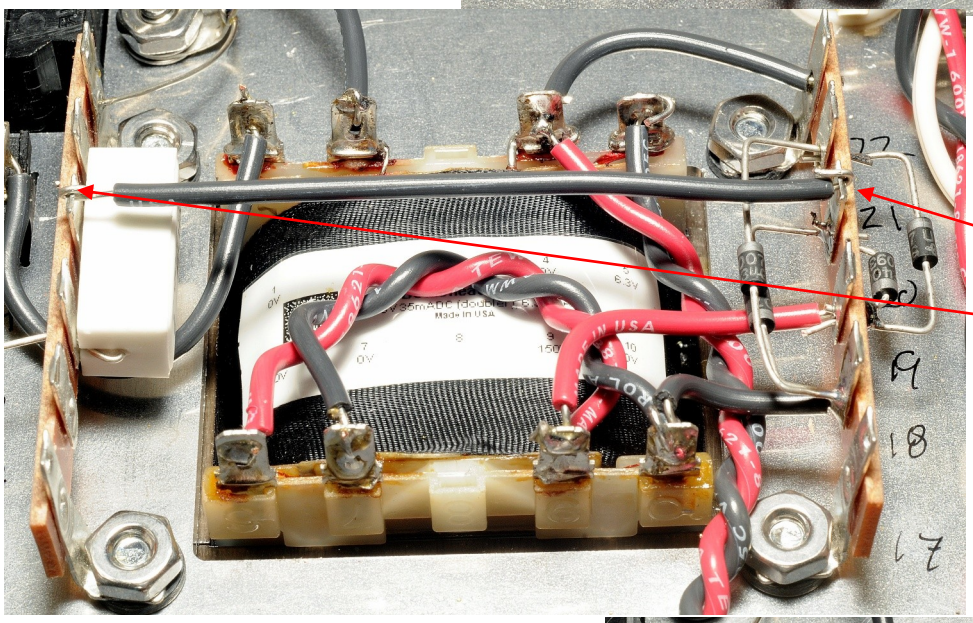
( ) Bend the leads of a third UF4007 rectifier close to the rectifier body. With the rectifier located on the side of the terminal strip away from the power transformer, attach the black end to 20L and attach the banded end to terminal 19L.
Solder and trim excess leads from 20L.



( ) Bend the leads of a fourth UF4007 rectifier 3/8" (9mm) from the rectifier body. With the rectifier located on the side of the terminal strip away from the power transformer, attach the black end to 19L and attach the banded end to terminal 21L. Solder 19L, 21L and trim excess leads.

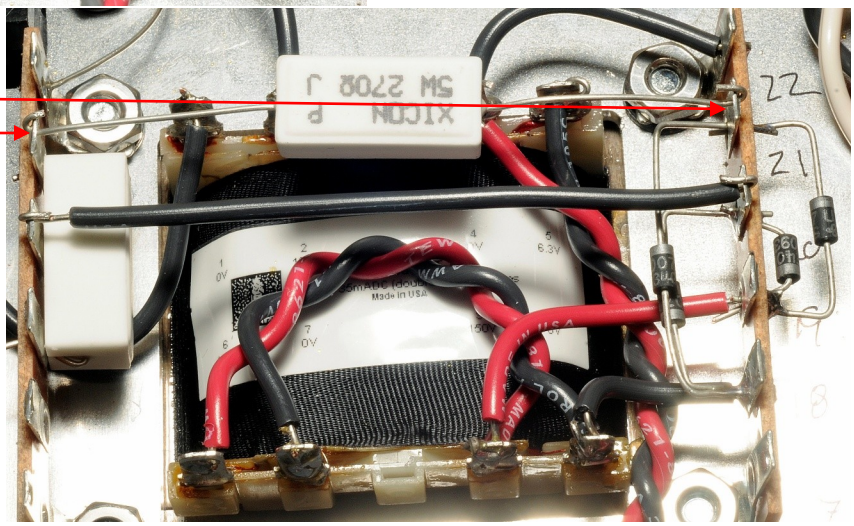
( ) Insert one lead of a 270 ohm 5W resistor into terminal 13L Insert the other lead into 15L. Solder 15L.Trim excess leads.



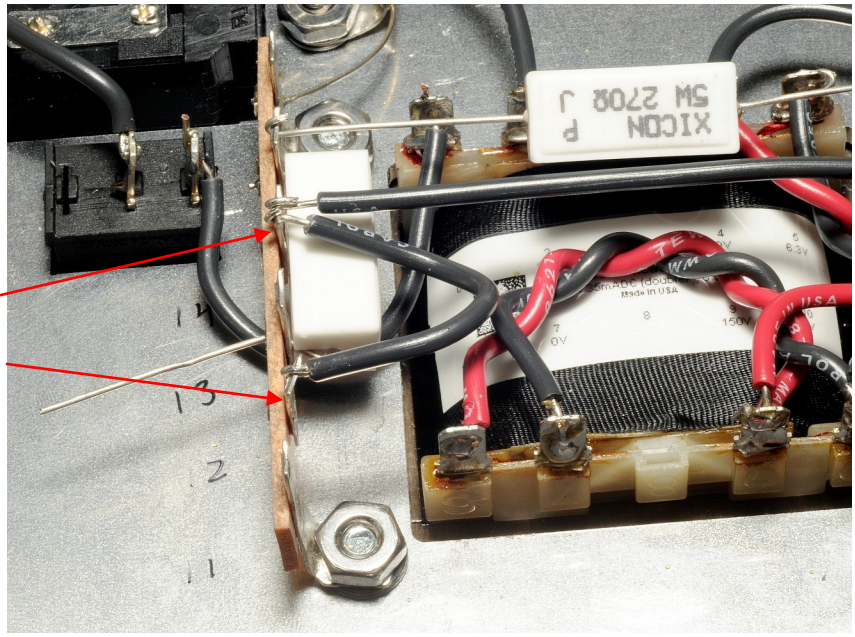


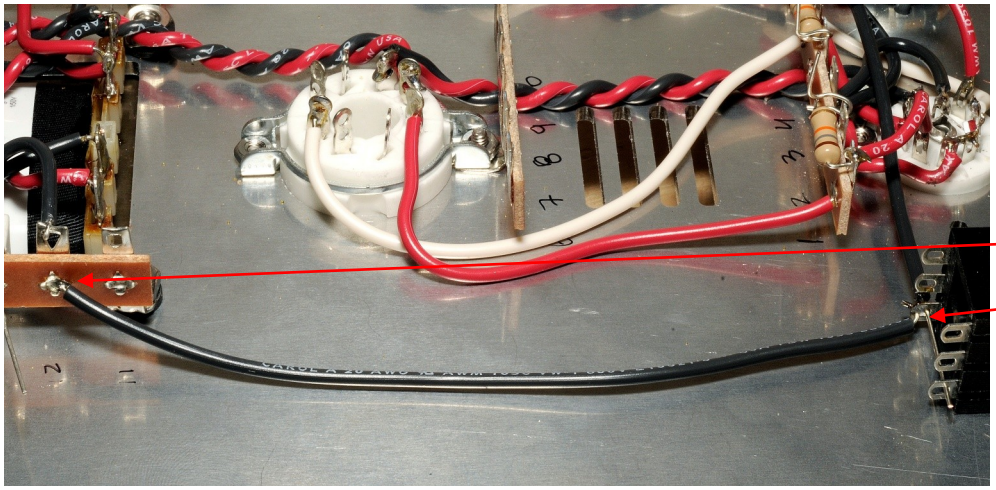
( ) Cut piece of black wire 3/12” (87mm) long and strip both ends back 1/4” (6mm). Attach one end to 20U. Attach the other end to 14U.

( ) Attach one end of a second 270 ohm 5W resistor to terminal 21U. Attach the other end of the resistor to terminal 15U.



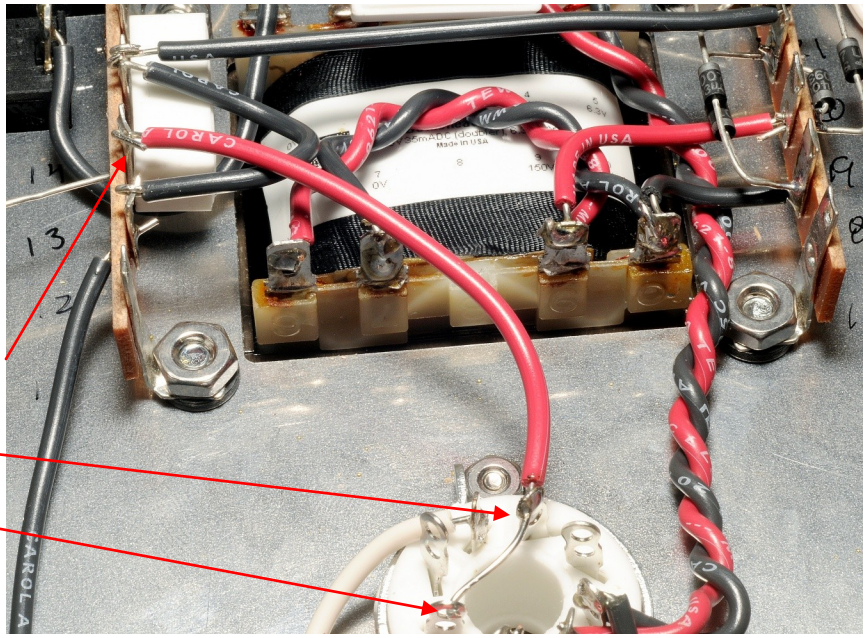
( ) Cut a piece of black wire 2” (50mm) long and strip both ends 1/4” (6mm) Attach one end to terminal 14U Attach the other end to terminal 12U.





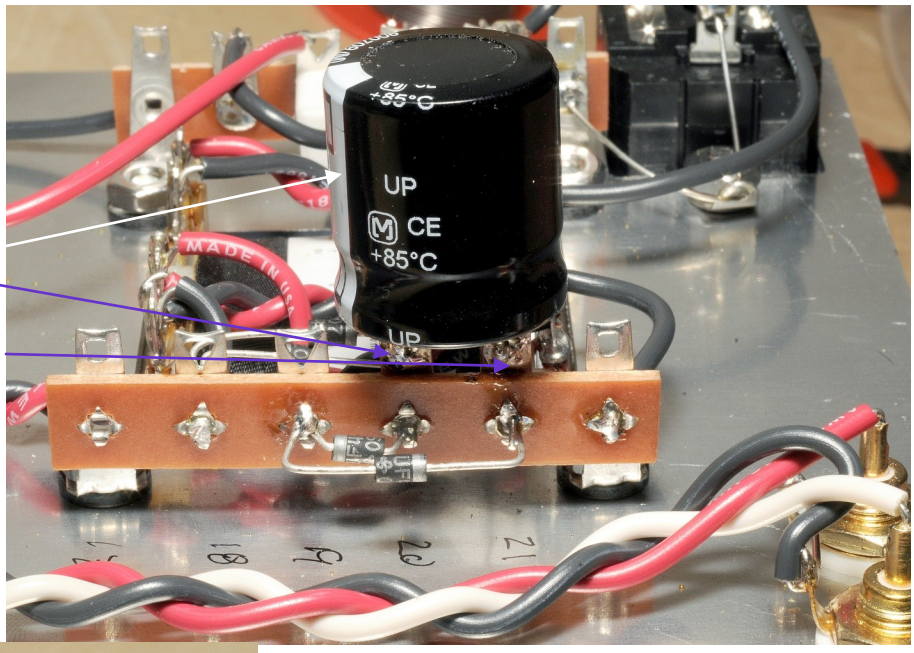
( ) Cut a piece of black wire 6-1/2” (167mm) long and strip both ends 1/4” (6mm) . Attach one end to terminal 12L and solder. Attach the other end to the inboard terminal of the headphone jack that is closest to the chassis plate, and solder.

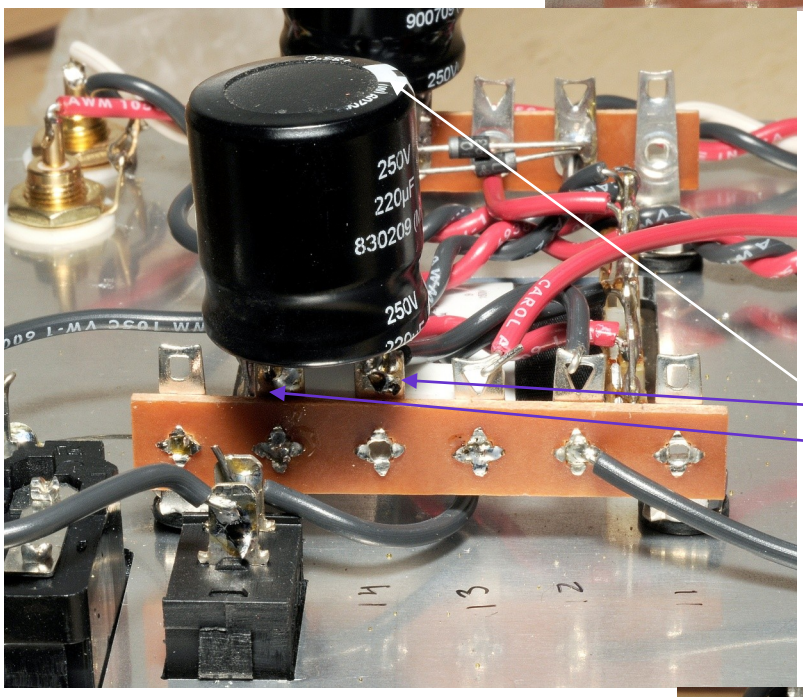
( ) Cut a 4” (100mm) piece of red wire. Strip one end back 1/4” (6mm) and strip the other end back 1” (25mm) Attach the 1/4” stripped end to terminal 13U. Thread the 1” stripped end through terminal B5, then through terminal B2. Solder 13L, solder B5.



Filter Capacitors

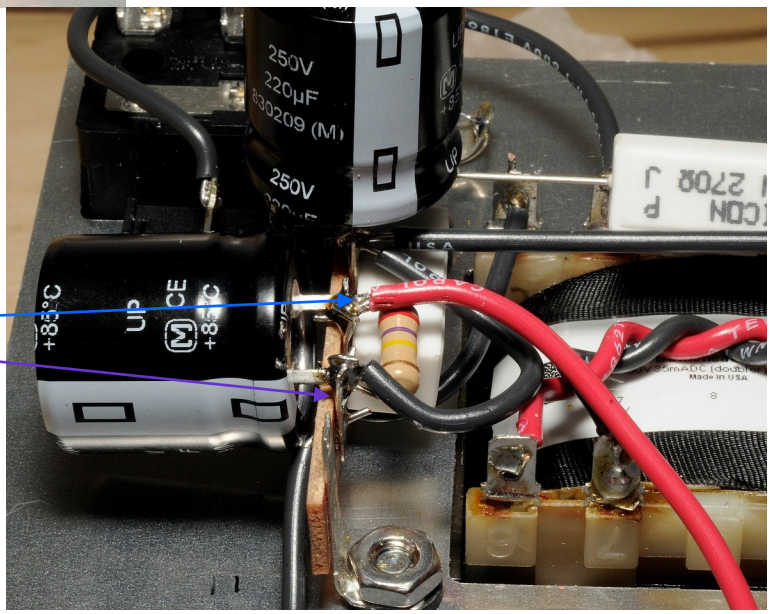
( ) Bend the lugs of a 220uF 250V electrolytic capacitor at 90 degrees. Insert the lug by the striped side of the capacitor into terminal 20U. Insert the non striped side lead into terminal 21U.
Check and recheck the stripe orientation (this is one of the most common assembly errors) and then solder both terminals.





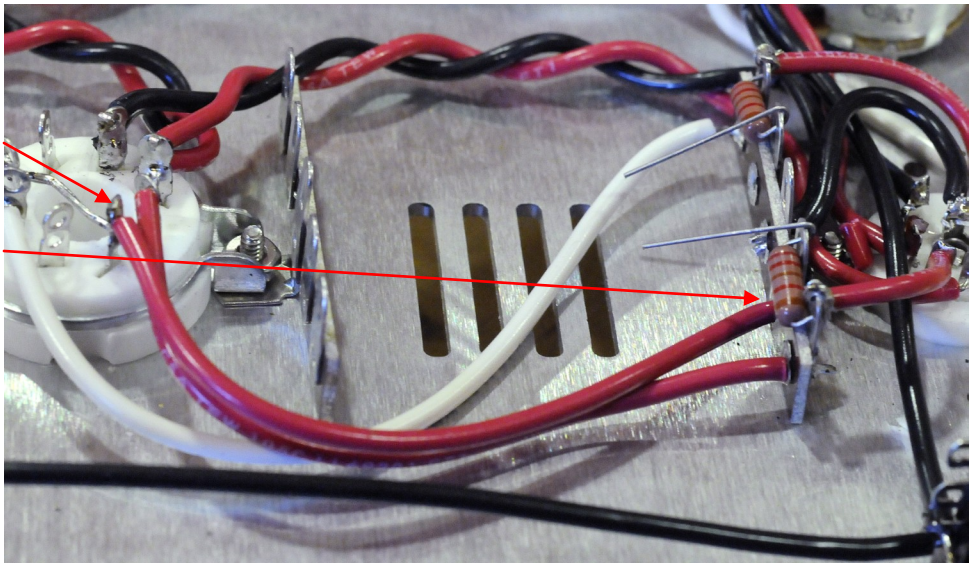
( ) Bend the lugs of a second 220uF 250V electrolytic capacitor at 90 degrees. Insert the lug by the striped side of the capacitor into terminal 14U. Insert the non striped side lead into terminal 15U. Double check orientation and solder.

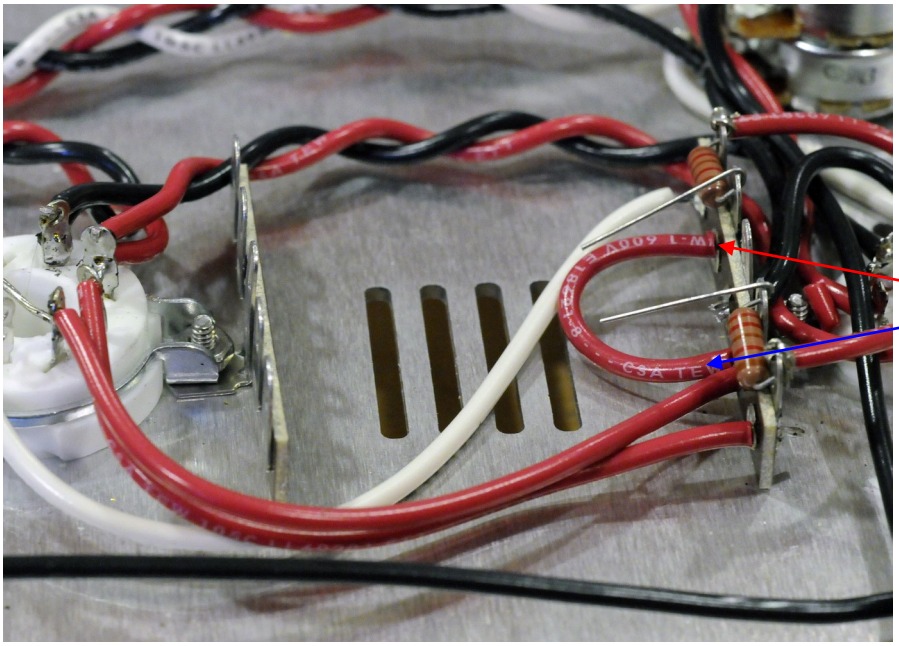
( ) Leave the lugs straight on the third 220uF 250V electrolytic capacitor. Insert the lug by the striped side of the capacitor into terminal 12U. Insert the non striped side lead into terminal 13U. Double check orientation but don't solder yet. Now insert one end of a 270K ohm 1W resistor into terminal 13U and the other end into terminal 12U. Solder both terminals and trim the excess resistor leads.



Output stage wiring

( ) Cut a piece of red wire 4" (100mm) long and strip both ends 1/4” (6mm) . Attach one end to terminal B2 and solder. Attach the other end to terminal 2L.



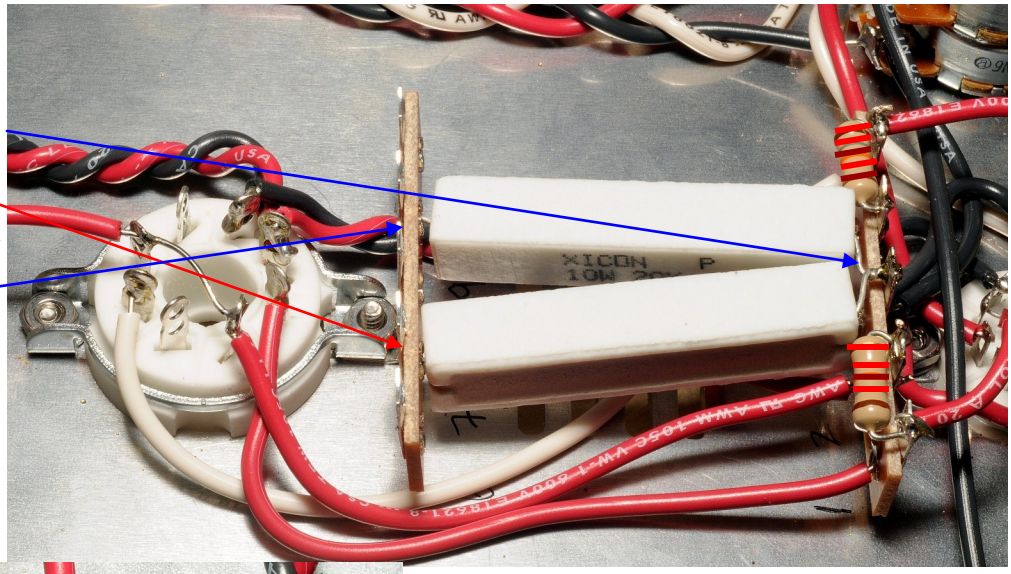


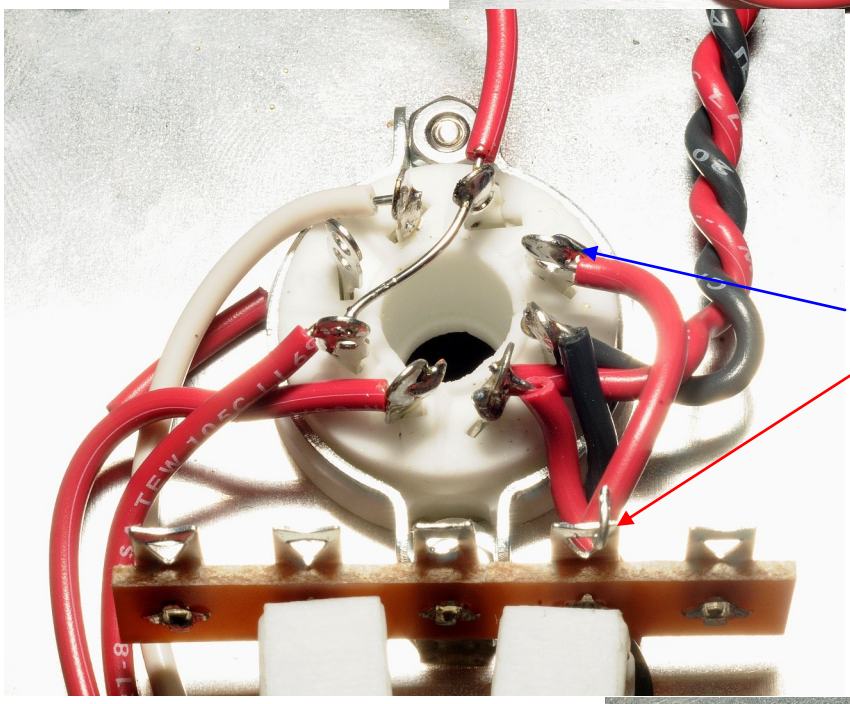
( ) Cut a piece of red wire 2” (50mm) long and strip both ends 1/4” (6mm) . Attach one end to terminal 2L and solder. Attach the other end to terminal 4L and solder. Also solder 2U and 4U and trim any excess leads.

Output stage cathode resistors

( ) Twist one pair of the ends of the 3K ohm wirewound resistors together and solder them.

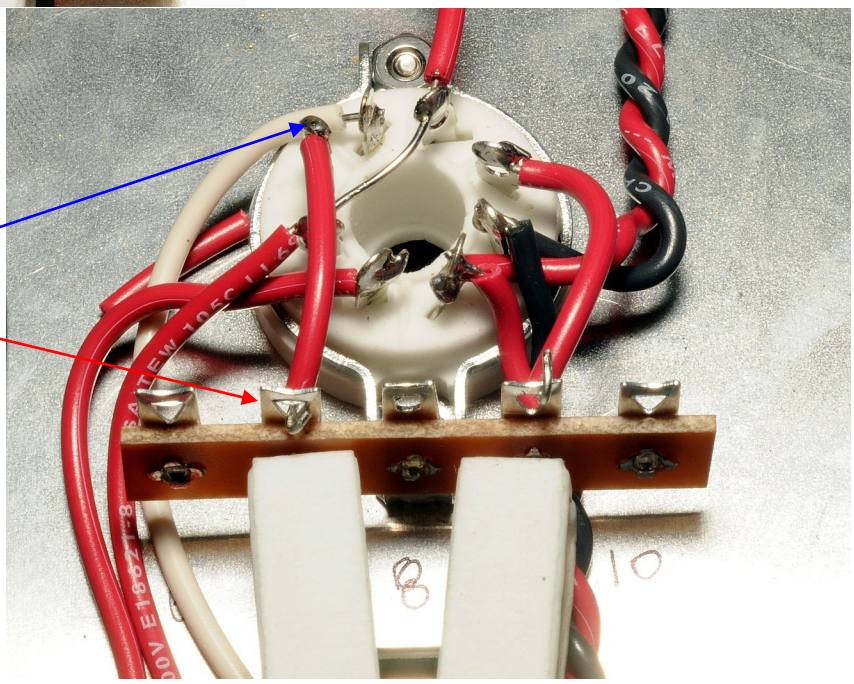
( ) Trim all but 1/4” (6mm) from the twisted end of the resistors and insert the trimmed end into terminal 3U. Insert the free lead of one resistor through terminal7L. Insert the other free resistor lead through terminal 9L. Solder 3U, 7L, 9L and trim the excess leads.

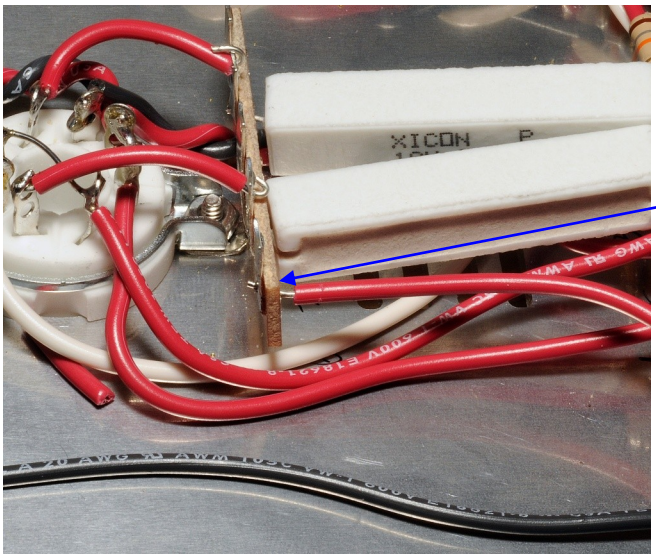




( ) Cut a 1-1/2” (37mm) red wire and strip both ends 1/4”. Attach one end to terminal 9U and attach the other end to B6, Solder B6

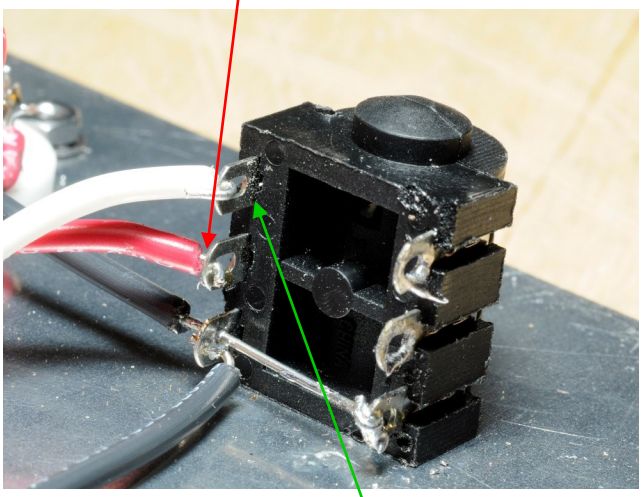
( ) Cut a 1-1/2” (37mm) red wire and strip both ends 1/4”. Attach one end to terminal 7U and attach the other end to B3. Solder B3.

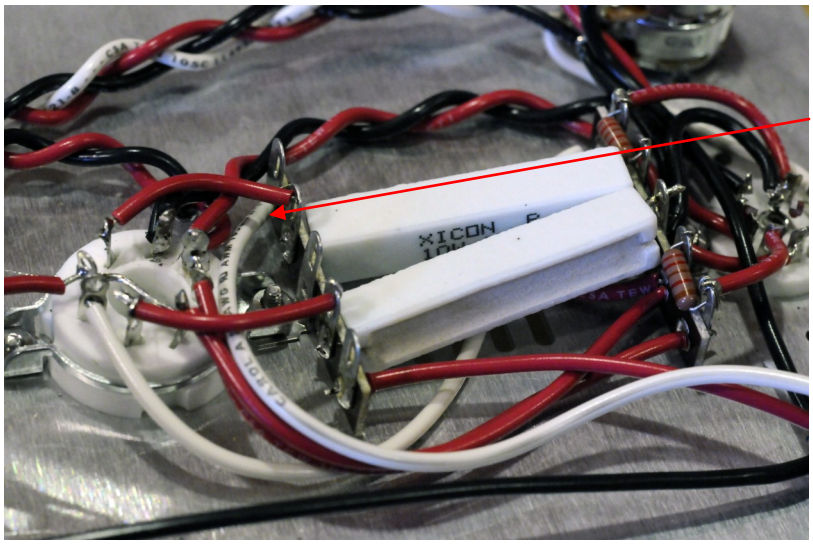




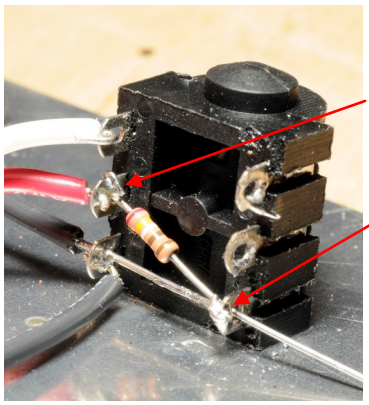
Output jack wiring

( ) Cut a 3-1/2” (87mm) red wire and strip both ends 1/4”. Attach one end to terminal 6L and solder. Attach the other end to inboard Ring terminal of the TRS phone jack.

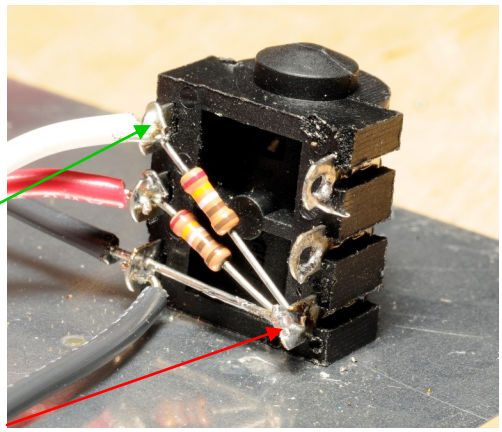


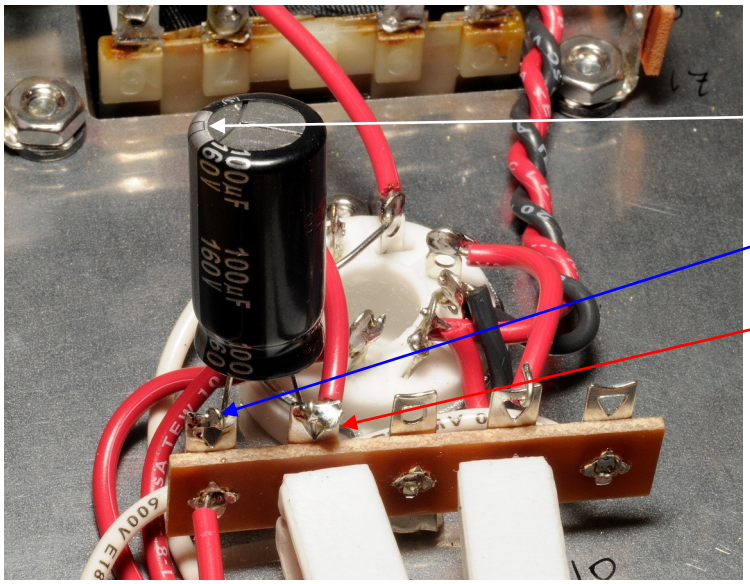


( ) Cut a 5-1/2” (137mm) white wire and strip both ends 1/4”. Attach one end to terminal 10L and solder. Route the wire around the terminal strip as shown. Attach the other end to the inboard Tip terminal of the TRS phone jack.



( ) Attach one end of a 2.49K ohm resistor to the inboard Ring terminal of the headphone jack. Attach the other end to the outboard Sleeve terminal. Attach one end of a 2.49K ohm resistor to the inboard Tip terminal of the headphone jack. Attach the other end to the outboard Sleeve terminal. Solder all three terminals and trim excess leads.

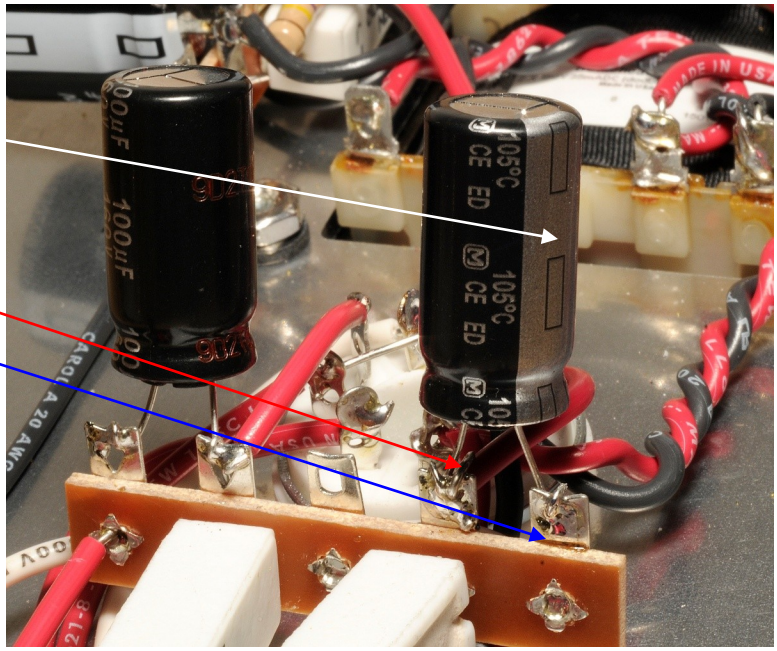




Output capacitor installation

( ) Attach the striped side lead of a 100uF 160V electrolytic capacitor to terminal 6U. Attach the non–striped side lead to terminal 7U. Double check the capacitor stripe orientation and solder 6U and 7U. Trim excess leads.

( ) Attach the striped side lead of a second 100uF 160V electrolytic capacitor to terminal 10U. Attach the non– striped side lead to terminal 9U. Double check the capacitor stripe orientation and solder 10U and 9U. Trim excess leads

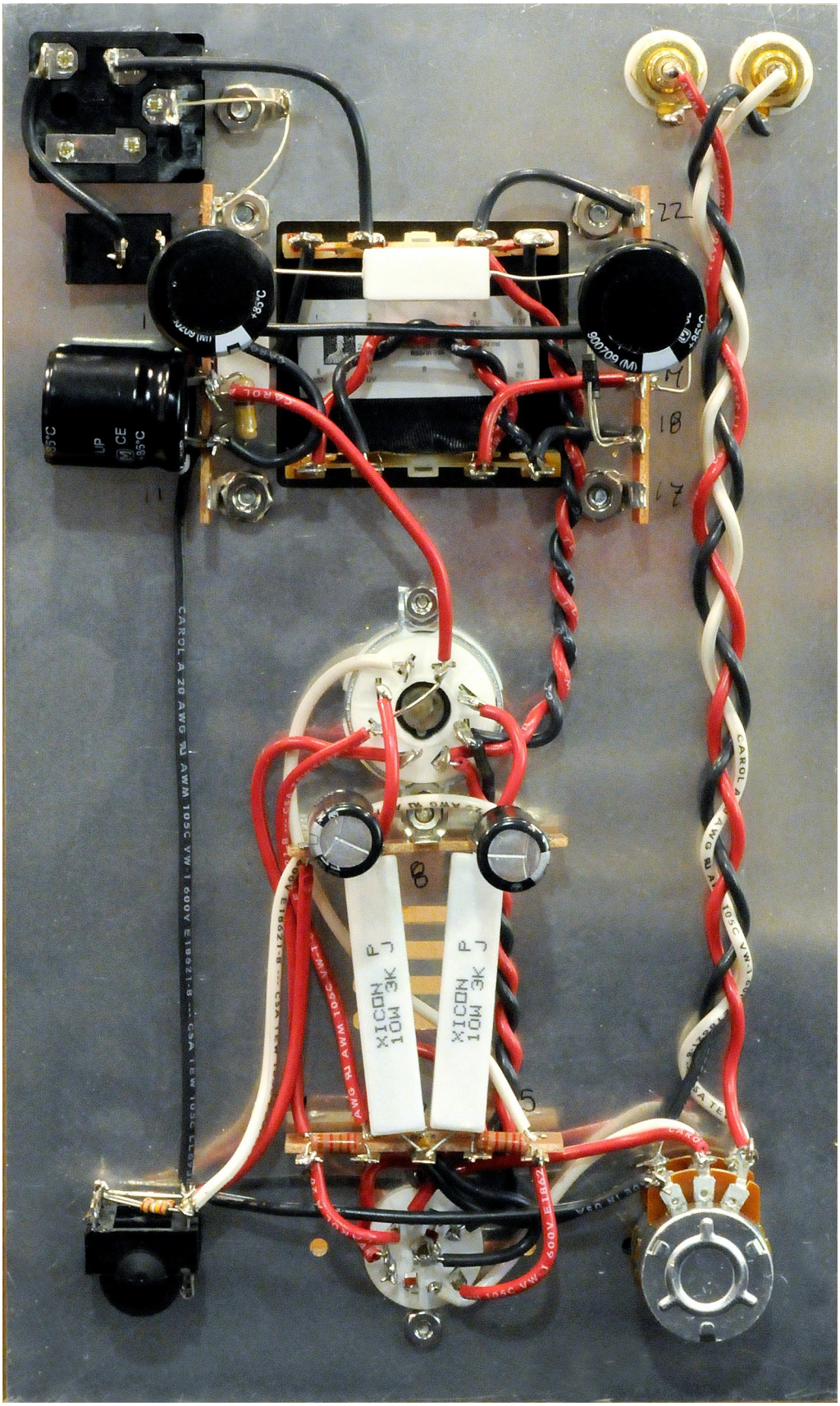


You're done building!

Congratulations! That completes the soldering portion of the assembly. **Now go back and make sure every joint that has components attached is properly soldered.** 90% of the troubleshooting issues that kit builders have are due to bad solder joints. Make sure that any excess leads are trimmed nice and close to the terminal. Double check your connections against the photos to be sure everything is connected to the proper terminal. Make sure that no leads are touching something they should not be touching. Neatness counts! It may help to have someone else look over your work too. Designer Paul Joppa says having someone else check your work will reduce the possibility of a mistake sneaking through by a factor of 1000. He was a math major who once worked as an actuarial compiling huge columns of numbers before he became an acoustical engineer, so he probably knows what he's talking about… Lastly, be sure to pick up the chassis, flip it over so the top is up, and gently shake it to shake out any loose wire trimmings that might short your wiring. Now you may install the knob on the volume potentiometer.

OK, now you can put that hot iron away and grab you're volt-ohmmeter.

The completed Crack output transformerless tube headphone amplifier



Resistance check

Once you have completed a visual inspection of the circuit the next step is to perform a resistance check of the circuit. This will help to assure that parts have been connected to the proper terminals and soldered properly before any AC mains voltage is applied to the circuit.

( ) Turn the volume control all the way down.

( )Attach the negative lead (typically black) of a volt-ohm meter to ground. A good spot to do so is at terminal 12. Use of a clip lead to connect the black test lead to the ground will free one hand, making testing much easier.

Using the positive lead (typically red) of the volt-ohm meter, check the resistance of the following terminals. They should read roughly like this:

*Note that the term K denotes x1000, and the term Ω denotes ohms, so 1KΩ equals 1000 ohms. 1MegΩ equals 1,000,000 ohms. The values signified with a * are going to vary from ohmmeter to ohmmeter because these terminals are connected to the filter capacitors, which try to charge themselves off the battery in the meter, causing a fluctuating reading. If the circuit is connected properly these readings will wander in the tens or hundreds of Kohms or higher range. What you want to watch out for is a zero reading at one of these terminals, which would indicate that something is mis-wired.*

Terminal	Resistance
1	*
2	*
3	0 ohms
4	*
5	*
6	2.4K ohms
7	2.9K ohms
8	0 ohms
9	2.9K ohms
10	2.4K ohms
12	0 ohms
13	* will climb slowly toward 270K ohms
14	0 ohms
20	0 ohms
22	0 ohms
B3	2.9K ohms
B6	2.9K ohms
RCA jacks:	
Ground lug	0 ohms
Center pin	90K ohms—100K ohms

Voltage Check
Once you have completed the resistance check of the circuit the next step is to perform a voltage check of the circuit. This will help to assure that parts have been connected to the proper terminals and soldered properly before you connect a source and headphones to the circuit.

DO NOT PROCEED if you have not successfully passed all of your resistance checks.
If a terminal was listed as 0 ohms, and measured greater than 1 ohm, **DO NOT PROCEED.**
If a terminal was not listed as 0 ohms, and measured less than 1 ohm, **DO NOT PROCEED.**
This is both for your own safety and and the safety of the amplifier. **DO NOT APPLY VOLTAGE TO AN AMPLIFIER WITH FAULTY WIRING!!!**

( ) Turn the volume control all the way down.
( ) Install the 12AU7 and 6080/6AS7 tubes in their sockets.
( ) Clip the fuse into the fuse cover and insert the cover into the power entry module.
( ) Plug the IEC power cord into the power entry module and turn on the power switch. Do not plug the cord into the wall yet.
( ) Turn the chassis over and attach the negative lead (typically black) of a volt-ohm meter to ground. A good spot to do so is at terminal 12. Use of a clip lead to connect the black test lead to the ground will free one hand, making testing much easier and safer. Switch the meter to read DC volts on the 400V or higher scale.
( ) Plug in the amplifier to the wall socket. If the tube filaments do not glow after a few seconds, power down and check the fuse. If it is blown, recheck your wiring one more time. Correct mis-wires, replace the fuse and try again.
( ) If the tube filaments glow properly, wait at least thirty seconds and then CAREFULLY measure voltages using the positive lead (typically red) of the volt-ohm meter at the following terminals:

WHOA! SAFETY CHECK!

ALWAYS USE EXTREME CAUTION WHEN MAKING VOLTAGE MEASUREMENTS ON A LIVE PIECE OF ELECTRONIC GEAR.

Always wear rubber soled shoes when working on electronic gear, particularly if you are working on a concrete floor. Don't work in socks or bare feet. A circuit can be created from the live preamplifier to ground through your feet.

NEVER, REPEAT, **NEVER** TOUCH THE LIVE AMPLIFIER WITH BOTH HANDS WHEN TESTING. IF YOU CREATE A CLOSED CIRCUIT THROUGH YOUR HANDS AND ARMS, THE VOLTAGE AND CURRENT CAN STOP YOUR HEART. The old timers would keep one hand in their pocket when working with live gear to avoid a fatal slip up. Also, it is a bit safer to use your right hand than your left to touch the chassis, as any current passing through your hand to the ground would be less likely to pass through your heart. The following voltages have been made with an AC mains voltage of 119VAC:

Terminal	**Voltage** (VDC unless otherwise specified)
1	75-90
2	170
3	0
4	170
5	75-90
6	0

7	100
8	0
9	100
10	0
11	0
12	0
13	170
14	0
15	185
20	0
21	206
A1	90
A2	0
A4	0
A5	0
A6	90
A7	0
A9	0
B1	90
B2	170
B3	100
B4	90
B5	170
B6	100
B7	0
B8	0

Don't worry if your voltages are not exactly these figures. Line voltage variations and tube tolerance variations can change them by up to 10-15%. If everything checks out go on to the next step.

If you do have a voltage problem and can't sort it out or you run into any other hitches, try asking for help on the Bottlehead Forum. It's a wonderful tech support resource— http://www.bottlehead.com/smf/index.php/

Final check—important!

Power the amp down and wait for 5 minutes. With the red probe now touching either the Tip or Ring terminal on the headphone TRS jack, switch the amplifier on and monitor the voltage of the tip or ring for about 30 seconds. It should not climb higher than about 9 volts and should then drop to zero. If it climbs much higher and/or does not reduce to zero do not plug in headphones until you have worked out the issue and the voltage stays below 9V.

OK, if everything checks out, shut it down and disconnect the meter.
( ) Connect a source to the inputs.
( ) Plug in your headphones.

So what are you waiting for? Throw on some music! But do make sure the volume is turned down first so you don't inadvertently damage your headphones.

Basic Troubleshooting - A Rationale

One of the most tense and frustrating moments in the adventures of a Do-It-Yourselfer is when the project we have finished fails to "start right up the first time".
Fear not, this happens to everyone, even veterans with years of construction experience.
There are a few general, logical techniques to troubleshooting that can make the process a lot less painful and actually quite a rewarding lesson. Remember, we don't learn from doing something right, we learn from our mistakes. So forget the panic, take a deep breath, and get analytical for a moment…

Equipment

While a really hot shot tech might be able to diagnose a few problems based entirely on his past experience with a particular circuit, one really needs a minimal collection of test gear to sort out a problem. Most important (and most likely to show the location of the typical problem) is the Volt-Ohm meter, whether an analog meter or a digital voltmeter (a.k.a. DVM or DMM). Along with this a few clip leads can be a tremendous help in hooking up meters, substitute parts, etc. For real "tough dogs" and new designs an oscilloscope is almost mandatory, but we will deal here with the more straight forward kinds of problems that are usually encountered when one completes an electronics kit.

An Example

Let's create a scenario to help us understand the troubleshooting process. You've been playing your preamp for a couple of hours, and suddenly you started hearing a noise in one channel of your system. It's making you crazy, and you're wondering how you ever talked yourself into the idea that you could build your own gear.

Rule number ONE

Break the system into its component parts

I cannot emphasize this enough. The first step is to determine where in the system and/or where in the component the problem lies. This is done by the process of elimination.
So let's slow down and get logical. Start by eliminating the parts that we know aren't broken. First we know the problem is only in one channel. So let's not bother with the other channel, in fact if we can turn the amp off on the channel that's OK, let's do so.
Now let's disconnect the preamp from the amp on the noisy side. Shut the amp and preamp off and disconnect the interconnect between them. What we want to do now is to short the input of the amp. You can do this with a shorting plug, which is just an RCA plug that has the center pin connected to the outer shell, or you can just use a clip lead to short the center conductor of the RCA jack in the amp to the ground tab on the RCA jack. Turn on the amp and see if you hear the noise.
For grins let's say you don't hear the noise. OK, now you know that the problem is not in the amp. So it must be in the preamp or the source component ahead of the preamp (i.e. your CD player, DAC, or phono setup). Now shut everything down again, hook the preamp back up to the amp, and disconnect the source component from the preamp input. Once again use your shorting jack or trusty clip lead, this time on the preamp input. Fire the system up and listen.
Let's assume that we hear the noise. OK, now we know that it's not the amp, not the source, so it must be a problem in the preamp.

Rule number TWO

Analyze the component parts of the equipment in question

Now we need to figure out exactly what is wrong inside our preamp.
First off, let's think about how the circuit is developed. For sake of argument let's assume we are looking at a Foreplay preamp. There's a power supply, and following that there's two separate preamp circuits, one for each channel. Each of those preamp circuits is divided into a gain stage and a cathode follower stage.
OK, what can we assume so far? Well, we know that the noise is only in one channel. And we know that the same power supply supplies both channels. So we may deduce that the problem lies somewhere beyond the power supply in this case, or it would affect both channels.

Rule number THREE

Start with the easy stuff

OK, so the problem must be in the preamp circuit of the channel that's making the noise. So, what's the most obvious, easy thing to try first? Of course it's swapping the tubes from side to side. If we swap tubes between the left and right channels, and the noise follows one of the tubes, you are done. Time to get a new tube.
But let's not just end our story here. We'll assume the noise stayed in the same channel when we swapped tubes.

Rule number FOUR

Measure your voltages

At this point it's time to turn our preamp over and examine it's guts. You need to go back through the check out voltage measurements for the channel in question. Better yet, re-measure all your voltages. Log this info, so that if you need to call us for advice, we have some info to work with.
Let's say you've checked to make sure that your component wiring matches the drawing or photo provided in your kit, but you find a funny voltage in there somewhere. Look at the components attached to the terminal you are measuring. In particular, make sure they are in the right place, and that the solder joints look good. Shut the preamp off, and measure the resistance at the same points as you measured the voltages. A funny reading may lead you to the problem.

Rule number FIVE

Resolder your joints

In our case of a funny noise being generated, one of my hunches would be that we have a broken ground somewhere. The most likely culprit would be a bad solder joint. Once again I must get on my high horse. **Just looking at a solder joint tells you absolutely nothing about it's electrical integrity**. The only way to be sure a solder joint in question is good is to carefully re-solder it, adding a little solder in the process. And then re-measuring the resistance and voltage measurement at the terminal in question. Heat and patience are the solution.
The old kit companies like Heathkit and Dynaco had a statement in their manuals that 99% of problems with a kit were due to cold solder joints. Still holds true today.
In our case, we found a cold solder joint at the ground buss, resoldered it, and now we have clean uninterrupted music.

Some tips

Different sounds can indicate different problems.

Deep hum without any buzz - this is 120Hz hum, and is usually encountered in DHT amps. Usually a touch up of the hum balance pot will eliminate it

Buzzy hum, like a bee - This usually means a lifted ground connection. Usually fixed with a careful examination of solder joints and an arbitrary re-solder job

Scratchy sound, hissing, crackling, popping - usually a bad tube, but if just one of these four types of noises is heard, it can also be caused by a bad capacitor or resistor.

Popping on start-up - usually a grid short in the output tube causes this. It will often clear itself and the amp will play OK.

Microphony, a tendency to ring when tapped or a loud musical transient plays - again this is most often due to a bad tube, but on rare occasion a capacitor can create this symptom too.

No sound - something isn't getting voltage or it isn't getting signal. Before you dive in to tear things apart, check the obvious - are your speaker cables hooked up properly? Interconnects? Is everything switched on? We see some slightly embarrassing moments at Bottlehead meetings, where the equipment is often swapped in and out of the system at a frantic pace. About 95% of the time a "dead" piece of gear just isn't hooked up right.

Muffled sound - this usually means something is not getting all the voltage it is supposed to get, and that you need to get inside the equipment and start taking voltage measurements.

Pay attention to the LEDs on C4S boards

If a board doesn't light up, be sure to check out your component numbers, orientation on the PC board, and solder joints. To test the transistors, put your meter leads across each of the three possible combinations of transistor leads and test for resistance. If you get a very low resistance reading at any pair, the transistor is blown. Reversed LEDs are another fairly common problem.

Last tip -

If you see smoke, SHUT IT OFF!!!

Doc B.

Guarantee

Bottlehead Corp. guarantees prompt replacement of any parts which may be missing from the kit upon receipt. Call 206-451-4275 to receive replacements for missing parts. If any parts have been damaged in shipment, replacements will be sent to the purchaser upon return of the damaged parts.

Bottlehead Corp. is unable to accept for refund any kit upon which assembly has begun. Returns of unbuilt kits require prior authorization and must be returned within two weeks of receipt.

If you wish to have the kit assembled for you, contact us at 206-451-4275 and we will refer you to a factory authorized assembly technician.

If you have technical questions regarding assembly of the kit, call 206-451-4275 during regular business hours or visit the Bottlehead Forum at http://www.bottlehead.com/smf/index.php

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