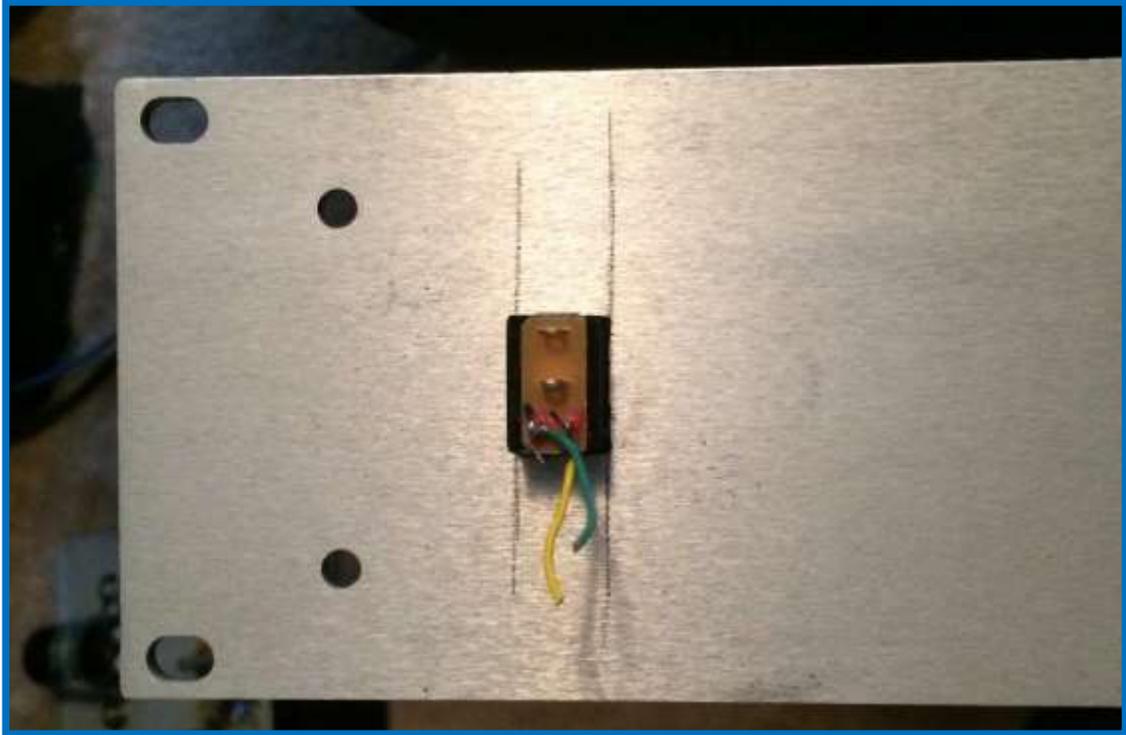


2. *Any burrs around the holes should be removed by spinning a larger size drill bit in the holes with the fingers. Do not use pressure when doing this, or excessive metal can be removed. Double check for burrs by rubbing your fingers along the heat sink surface. All burrs must be removed or they can puncture an insulating wafer and cause a short circuit.” [5]*

5.1.4 The Front Panel

This is one of a couple tricky spots because the front panel is what everyone will see. We only need to make one hole for the power switch. I highly recommend using masking tape to prevent scratches. I also recommend measuring, drilling and sawing from the back side of the front panel. Before you begin, if you’re making multiple amps as I did, you need to make sure all the switches line up as close as possible when stacked on top of each other.

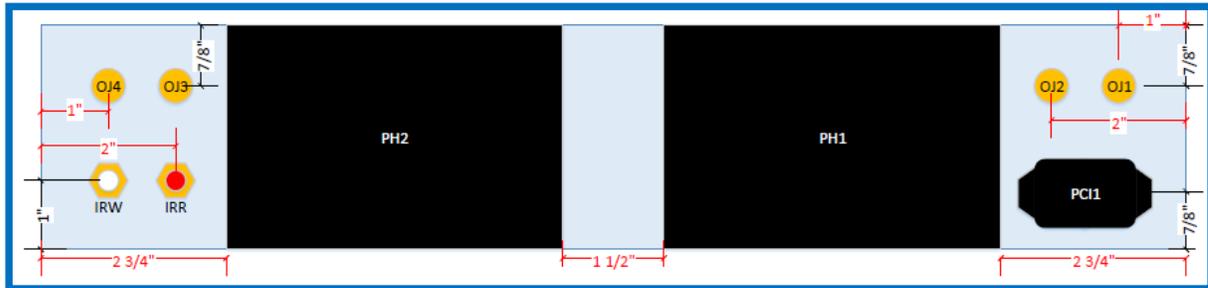
- Use a pencil to mark a vertical line on the inside front panel 2.25” from the left side and another vertical line 2.75” from the left size.
- Use a pencil to mark a horizontal line 2.15” from top and a horizontal line 1.35” from top.
- Now, using a spring loaded center punch, drill bit, jigsaw and file make the square hole inside the four lines you made. You must be extremely careful not to get outside your marks
- Finally, push your switch through the opening you made making sure the switch is facing the outside of the amp. You may need to file it more until it fits. Be sure the light of the switch is facing up. It will illuminate when the amp is turned on. In the picture, the small connectors with the yellow and green wires (they shouldn’t be there BTW) should face up.



5.1.5 The Rear Panel

Let’s follow Dr. Leach’s lead and start the assembly with the rear panel. I have made some changes to his layout so will choose not to show his figure. Instead, I’ve attached a small screen capture of the

layout found in 'Leach Amp Rear Panel Layout & Measurements.pdf' below. You should print a full size version for your reference. This is the view from behind the outside of the amplifier.



You should use the Chassis BOM to determine what the references mean but in this example 'OJ1 – OJ4' mean output jack, IRW means Input RCA White & IRR means Input RCA Red. Follow the guidelines below step by step to assemble the rear panel

- I recommend as Dr. Leach says in his guide to use masking tape on any surfaces that will be touching other metal surfaces to prevent scratching. I did not do this myself and there are noticeable marks on the back but they do not bother me as only the front will be exposed in my media rack.
- Dry fit each component to ensure it fits. The heat sinks I've recommended have no trouble cooling the amp when mounted horizontally as pictured.
- Use a pencil to mark the locations of OJ1, OJ2, OJ3, OJ4, IRW & IRR. Then use the spring mounted center punch to tap the hole locations. Then use a drill press or hand held drill with a 3/8" drill bit to make the holes for each. You might want to use a file to clean up the edges.
- Now find the PCI1 component which will bring the 120V AC power to your amp. Use the lip around the face to trace the hole which we will be cutting out. A mechanical pencil makes this easier. Also poke the pencil through the holes to mark the mounting location. Use the center punch to tap the hole locations then drill the back panel with a 5/32" drill bit. If the #6 stainless steel screws do not fit through the PCI1 component then use the 5/32" drill bit to widen the mounting ears. Note that you want the hole to be square and so do not mark the mounting ears. Cutting this wrong will make it impossible to mount. Guiding pictures below:

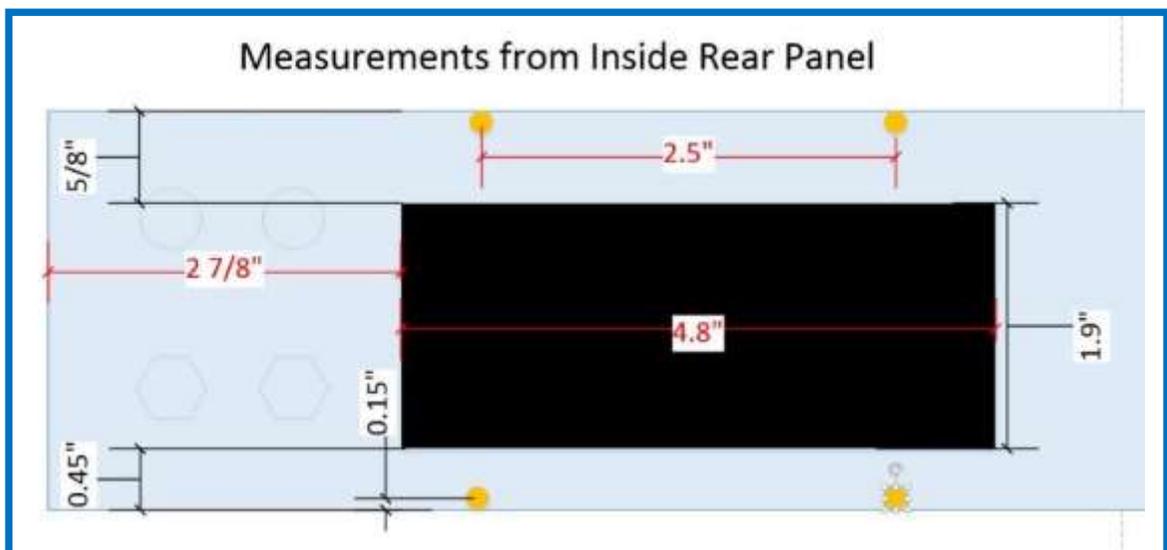


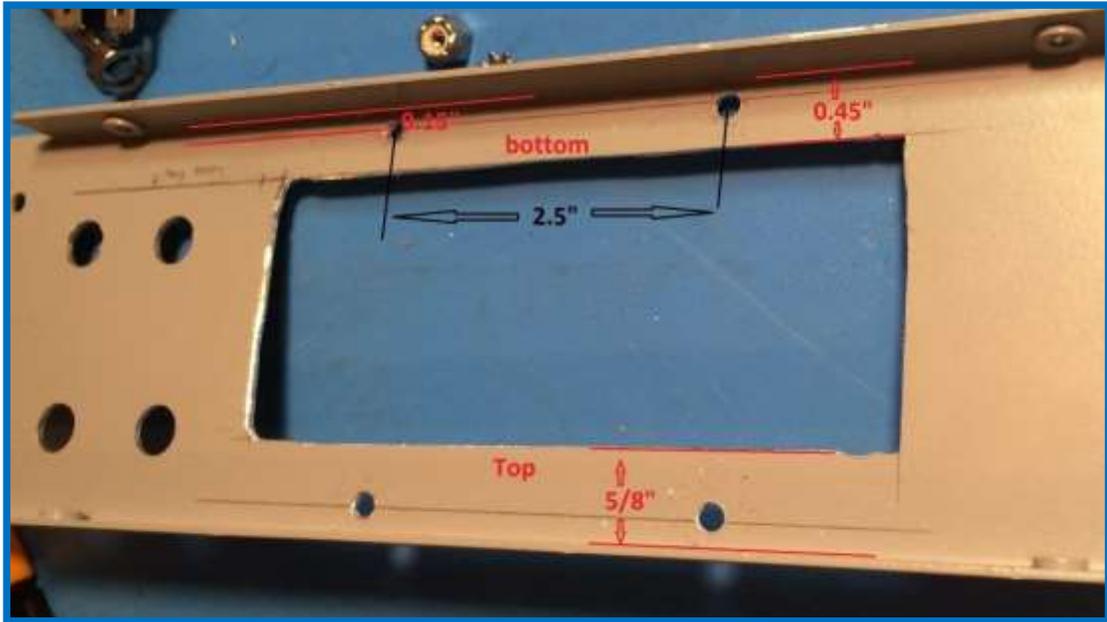
- To complete the hole for PCI1 drill the four corners of the pencil marked square with a drill bit big enough to fit a jig saw blade but making sure the hole does NOT travel outside the marking. Use a jig saw with a fine tooth saw blade to finish out the hole and a file to smooth the edges.
- At this point you still should only have holes, do not mount any components yet as it will interfere with the next steps.

5.1.6 Connecting the Rear and Bottom Panel

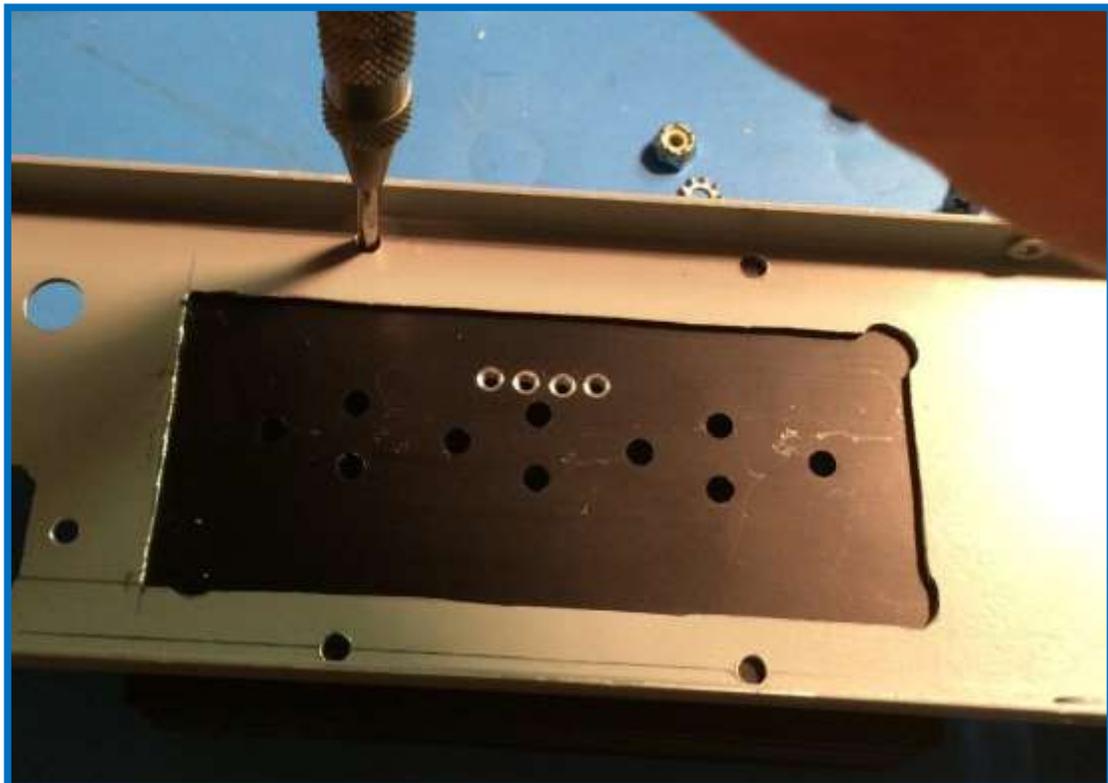
This is the most difficult section because we are going to cut a large hole in the rear panel which cannot be too wide or too tall, mount the rear heat sink which has to be aligned to the PCBs and power transistors.

- Decide which heat sink will be left and which will be right. It doesn't really matter at this point, just make a choice and mark the 'R' and 'L' with pencil on the inside middle above the diode holes. Do the same on the rear panel, mark 'R' and 'L' for future reference.
- Using the diagrams below, measure and outline with a pencil the square and mounting holes. I'm only showing one side but it is symmetric so use the same to mark both sides.

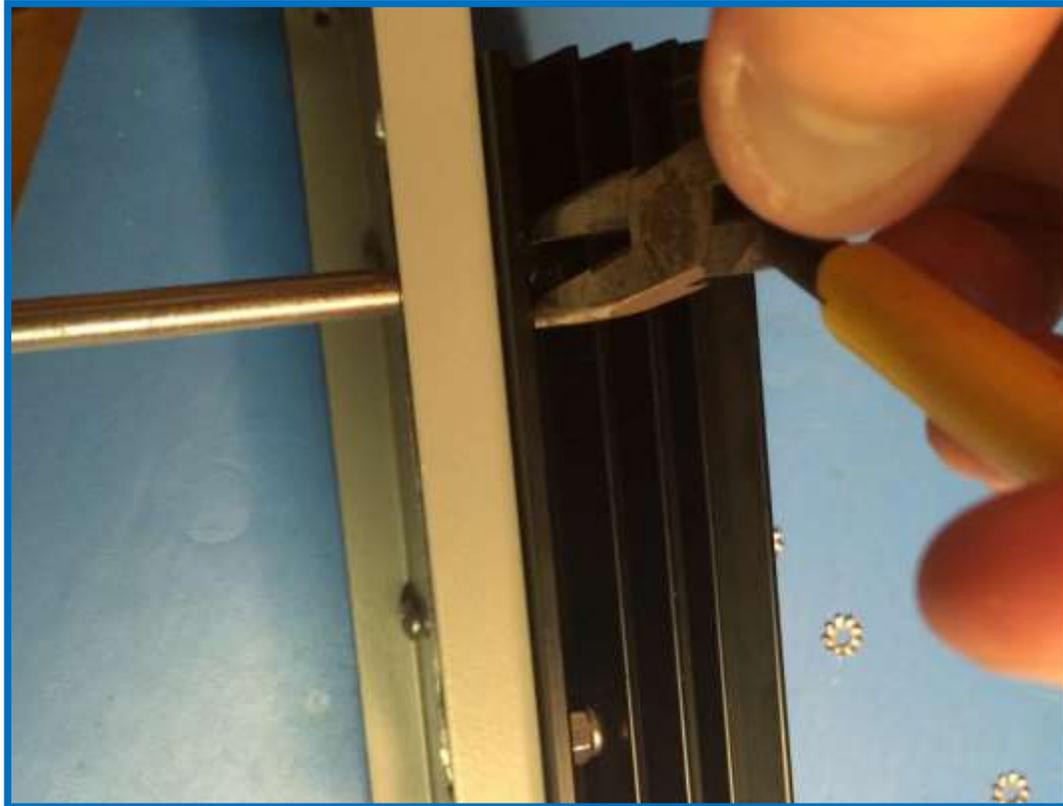




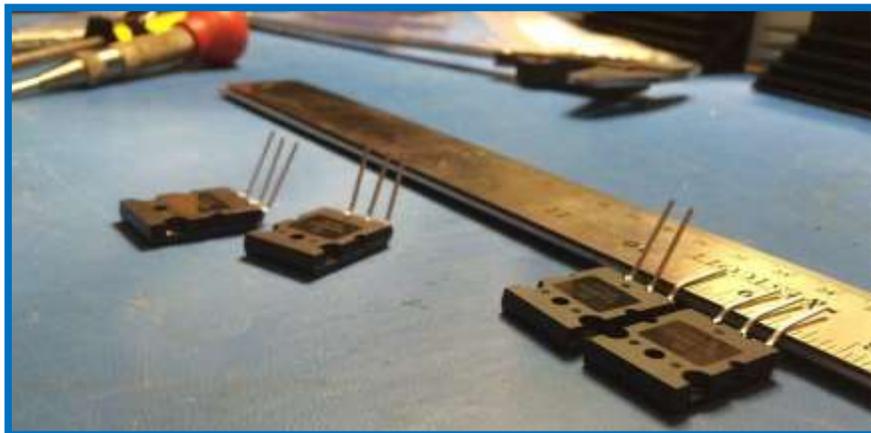
- Use a drill bit large enough to fit a jig saw blade and drill each corner then use the saw to open up the square hole being very careful not to cut outside the marks. Use a file to clean the edges and burrs.
- Use a center punch to mark the mounting holes then use a drill bit size $3/16$ " to make the holes for mounting the heat sink.
- Carefully align the heat sink below the rear panel such that no gaps appear on either side and make sure any hang over on top and bottom is equal. Use the center punch to mark the mounting holes on the heatsink through the rear pane



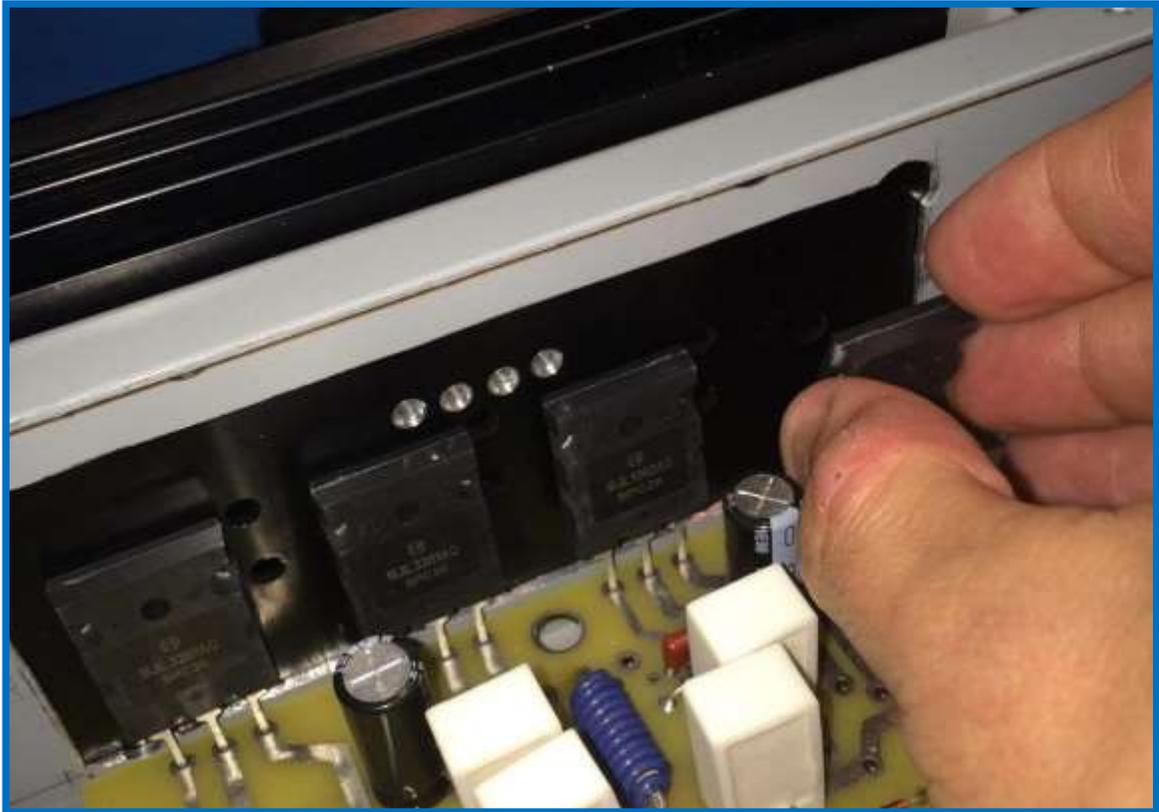
- Use a drill press with 3/16" bit to drill the mounting holes in the heat sink being careful not to drill too deep as you only want to go through a single layer of metal.
- Using needle nose pliers, #2 Philips screwdriver, Pan head, SS 18-8, #8-32 x 7/16" & #8-32 lock nut to mount the TOP two screws
- Using needle nose pliers, #2 Philips screwdriver, Flat head, SS 18-8, #8-32 x 7/16" & #8-32 lock nut to mount the BOTTOM two screws



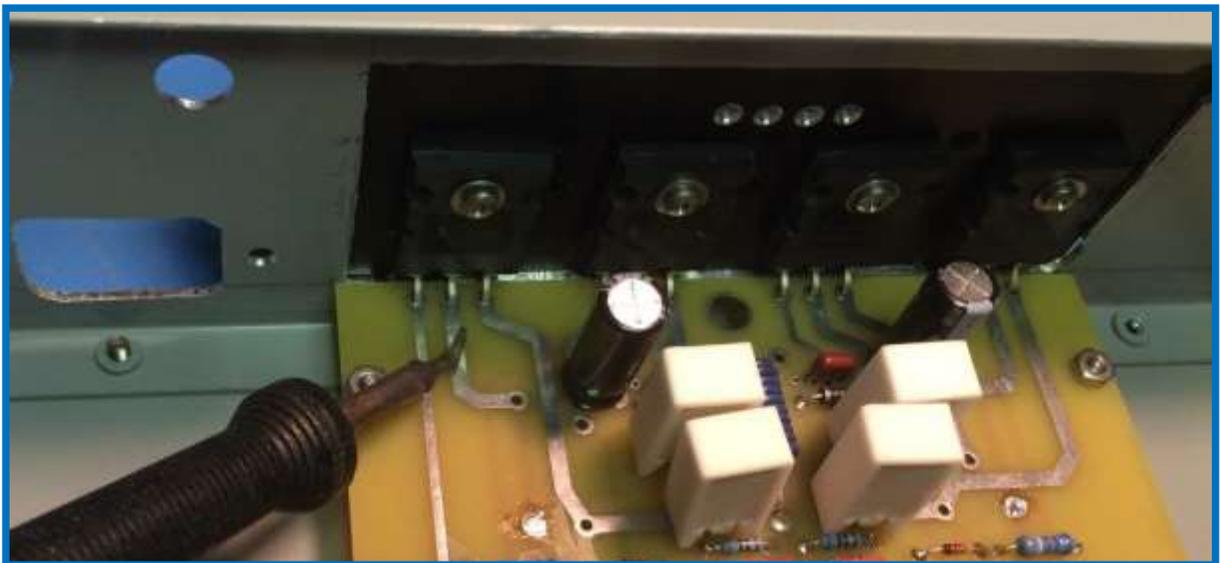
- After you've mounted both heat sinks on the rear panel, temporarily mount the rear panel to the bottom panel using the #6-32 3/8" flat head screws.
- Now we need to bend the leads of the power transistors for Q18 – Q21. Bend the leads up about 45 degrees starting from where the lead gets skinny. Next, bend the leads back down about 45 degrees starting about 2-3mm. See the picture for reference.



- Use the power transistors as templates and cut the silpad thermal conductive pads to shape.
- Screw the PCBs down to the bottom panel if you have not done so already.
- Clip the leads so it is not too long as to touch the chassis when placed in the PCB but not too short. Dry fit the transistors being sure to place them correctly. Use the 'Leach Amp board components.gif' to ensure you've placed them on the correct side.



- Bend over or clip any leads that are too long.
- Temporarily mount the transistors to the heat sink with the #4-40 x 5/8" and nuts. Solder the leads to the PCB.



- Remove the bolts from the transistors and remove the rear panel for the next steps. Be careful not to bend the leads of the power transistors as you finish the assembly.

5.1.7 The Bias Diodes

Dr. Leach summarizes this portion very well so his guidance is given below:

“You should be careful when you assemble and install the bias diodes. If a diode is forced into a hole in the heat sink that is too small, its case can crack. I once saw a student's amplifier that randomly blew power supply fuses. We traced the problem to a cracked diode. He was lucky that the power transistors didn't blow. Figure 6 illustrates the installation of the diodes in the heat sink walls. There are 6 bent leads which must be insulated with insulation removed from hookup wire before being bent. There are 5 joints which must be tie wrapped, soldered, and insulated with heat shrink tubing. The diodes are glued into the heat sink with instant bonding glue. Do not use the gel version of this glue. It does not flow and will end up on the outside of the heat sink.

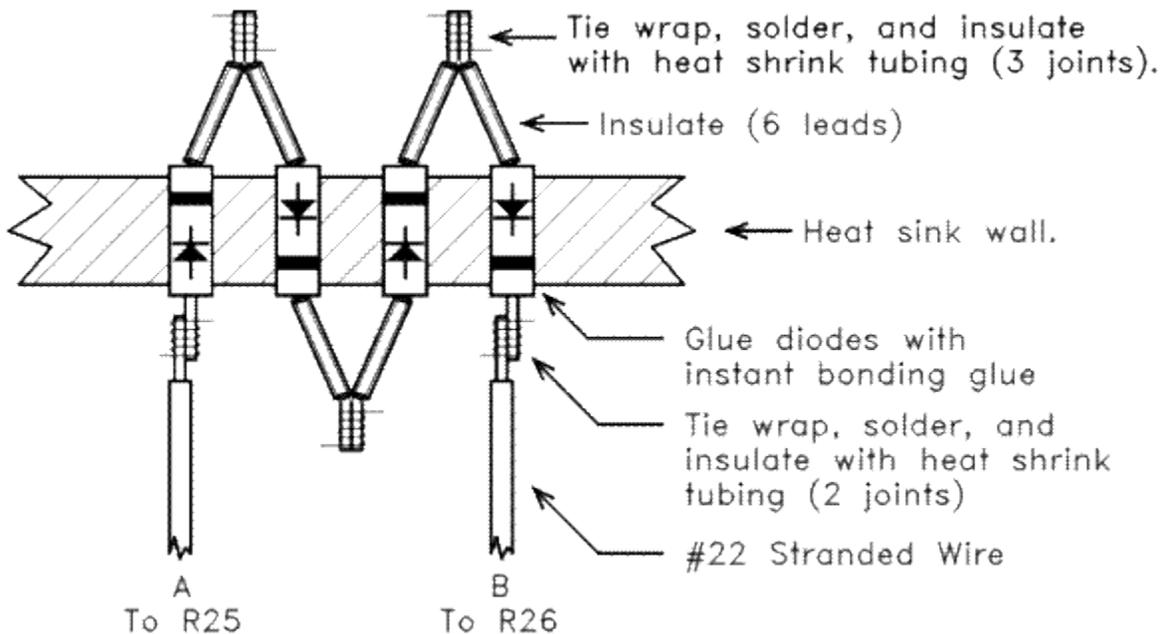


Figure 6. View of diodes in heat sink wall.

Use the following procedure to install the diodes:

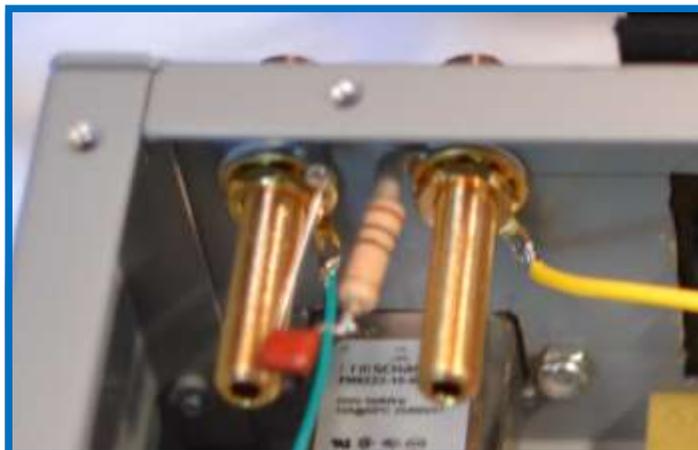
- The first step is to prepare the two wires which connect diodes D1 and D4 to the circuit boards. The current which flows in these wires is very small. For this reason, you do not need to use a large size wire. I recommend #22 stranded (never use solid) wire. Strip about 3/16 inch of insulation from one end of each wire.
- The next step is to tie wrap the wires to D1 and D4. Use a single strand from a piece of #22 stranded hookup wire to tie one wire to each diode. I find this easier to do before I cut the diode leads. One wire connects to the unbanded end of D1 and the other connects to the banded end of D4. Hold the diode lead, the #22 wire, and the single strand between the fingers of one hand. Grasp the single strand with the fingers of the other hand and spiral wrap four or five turns around the diode lead and the #22 wire.

- *Solder the wrapped joint. I like to clamp the diode in a small vice when doing this. Then cut off the excess diode lead and the two ends of the single strand of wire. Insulate the joint with heat shrink tubing.*
- *Install the four diodes in each heat sink using instant bonding glue to secure them. Do not force a diode into its heat sink hole. Any raised spot on the body of a diode can be filed off to make the diode fit.*
- *After the glue sets up, put a 3/8 inch length of insulation stripped from a piece of hookup wire over the 6 exposed diode leads. Push the insulation down until it is flush with the diode body so that a diode lead cannot make contact to the heat sink..*
- *Bend the 6 insulated diode leads as shown in Figure 6 so that they are at an angle of approximately 45 degrees with the heat sink wall. Bend the ends of the leads so that they are parallel as shown in the figure. Tie wrap the parallel leads together with a spiral wrapped single strand from #22 stranded hookup wire. Two needle nose pliers make this tedious operation simpler. Solder the wrapped wires.*
- *Cut off the excess diode lead lengths and insulate the solder joints with heat shrink tubing.*
- *The #22 stranded wires connected to D1 and D4 should be loosely twisted together before soldering to the circuit board.*
- *Double check the diode assembly. If a diode is backward, the output transistors can blow. You can check the diode polarities one at a time with an ohmmeter. The ohmmeter will not have enough test voltage to forward bias all 4 diodes simultaneously. If there is a short circuit between a diode lead and the heat sink metal, the amplifier will not work and the output transistors can be blown.” [6]*

5.1.8 Assembly of Rear Panel

At this point I’m assuming you only have the heat sinks mounted to the rear panel. It’s time to mount the rest. From Dr. Leach:

- *Install the input jacks. Insulating washers must be used around each jack to insulate the ground side from the panel. Some of these washers are designed so that you use 2 shoulder washers on each jack. Others are designed so that you use one shoulder washer and one flat washer. If you use a second shoulder washer in place of the flat washer for the second type, it may be impossible to tighten the nut on the jack so that it cannot rotate in the panel. [7]*
- *Before installing the output jacks, use the 5/16 ring terminal to install C25 and R50 across the terminals as shown in the terrible quality reference picture.*



- Mount the output jacks with the ring terminals between the washer and the white bulkhead gasket.
- Finally, mount the PCI1 AC input power

5.1.9 Finishing assembly

Time to finish the mechanical assembly portion of your construction.

- Screw the rear panel into the to the bottom panel
- Place a silpad between each power transistor (Q18-Q21) and the heat sink. Place a bolt and washer through each transistor and place a lock washer and nut on the heat sink side to permanently mount the transistors.
- Mount T1 to the chassis bottom by first placing the transformer with the wires facing toward the back of the amp, then the rubber gasket which came with it, followed by a fender washer. Push the 3" #10 bolt from the bottom and finally, use the lock nut to finish.
- Using the #6-32 3/8" screws, connect the side panels of the chassis. Then, using the pan head screws that came with the chassis, connect the front panel and handles.
- We are now ready to begin wiring

5.2 Electrical

Notes from Dr. Leach to remember as you wire your amp:

"Important points to remember: (a) Keep the wires from the power transistors to the circuit boards as short as possible, but long enough so that the circuit boards can be folded down in case a component has to be unsoldered. (b) Keep the leads to the input jacks away from all other wiring to the circuit boards. Otherwise, the output signal can capacitively couple back into the input leads and cause damaging oscillations. (c) Keep the leads to the input jacks away from the power cord. Otherwise, a hum signal can be induced in the input. (d) If you use a shielded twisted cable for the input leads, ground the shield at only one end. (e) The routing of the 2 ground wires that go from the circuit board to the central ground seems to play a role in hum pickup. You may have to experimentally route these wires to minimize the hum." [8]

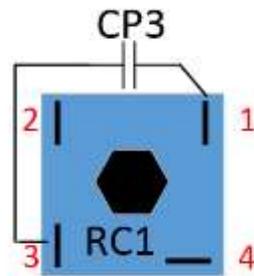
5.2.1 AC Power

I find it easiest to wire the power first. We'll start with AC

- Find the P+, Load PE & N' markings on the top flat label of PCI1. Route N' (right tab viewing from behind) to the grey and brown wires of T1 with #18 gauge stranded black wire. Route Load PE (center tab) to the ground lug with #20 stranded green wire. Use the #10 ring terminal to make the connection to the ground lug clean. Connect IL1 (inrush limiter) from P+ to FH (fuse holder) which holes F5. See picture for reference.



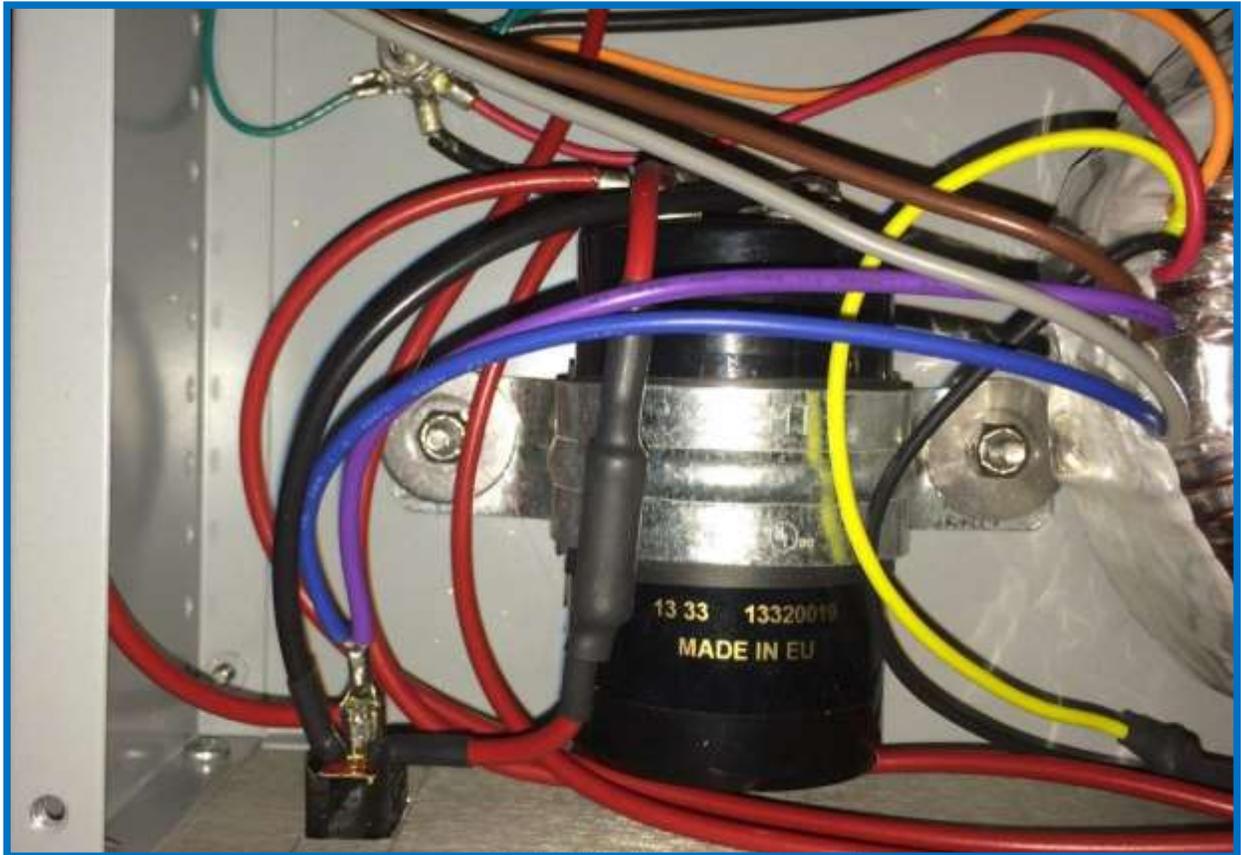
- Route #18 guage stranded red wire from the fuse holder FH to one side of switch PS1. Route the other side of the switch to the blue and purple wire of T1.
- Route the orange and red wire from T1 to the ground lug using the #10 ring terminal. Route the yellow wire from T1 to pin 1 of RC1 using red #18 wire to extend. Route the black wire from T1 to pin 3 of RC1 using black #18 wire to extend. Mount CP3 across pins 1 & 3 of RC1.



- Route pin 2 from RC1 to the negative (-) pin of CP2 using black #18 wire and a #10 ring terminal
- Route pin 4 from RC1 to the positive (+) pin of CP1 using red #18 wire and a #10 ring terminal

5.2.2 DC Power

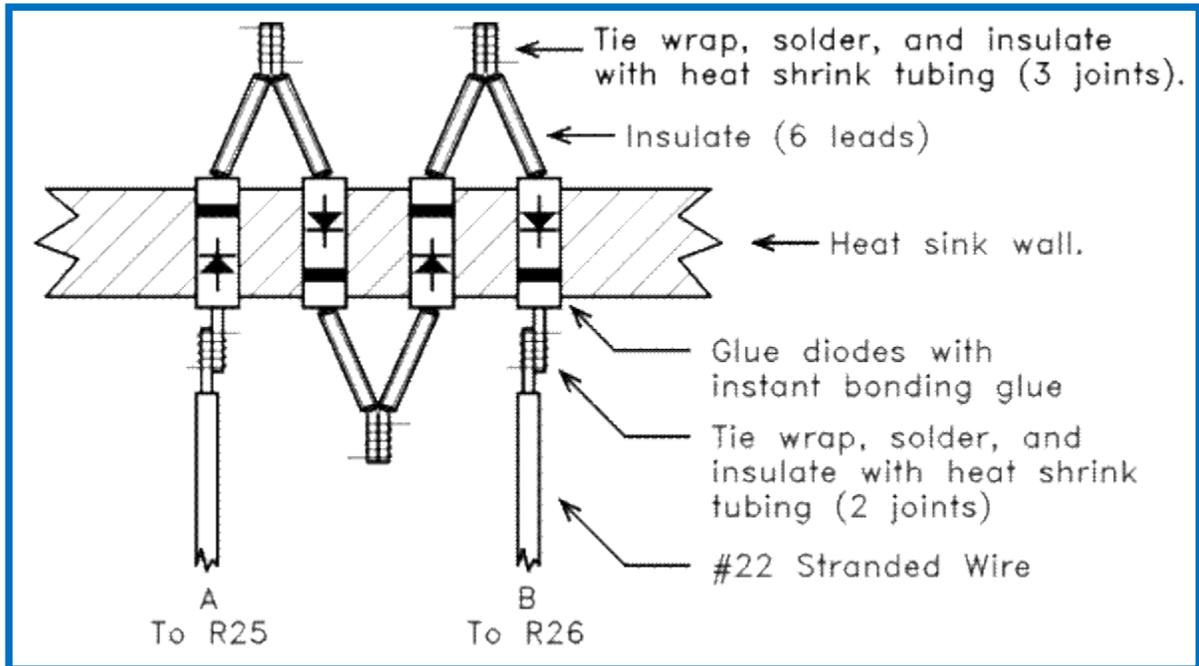
- To get the LED power light working route the left small pin to the negative (-) pin of CP1 using the ring terminal via black #18 wire. Route the right small pin to RS1 resistor then to the positive (+) pin of CP1 using the ring terminal via red #18 wire. Protect the resistor with shrink tubing



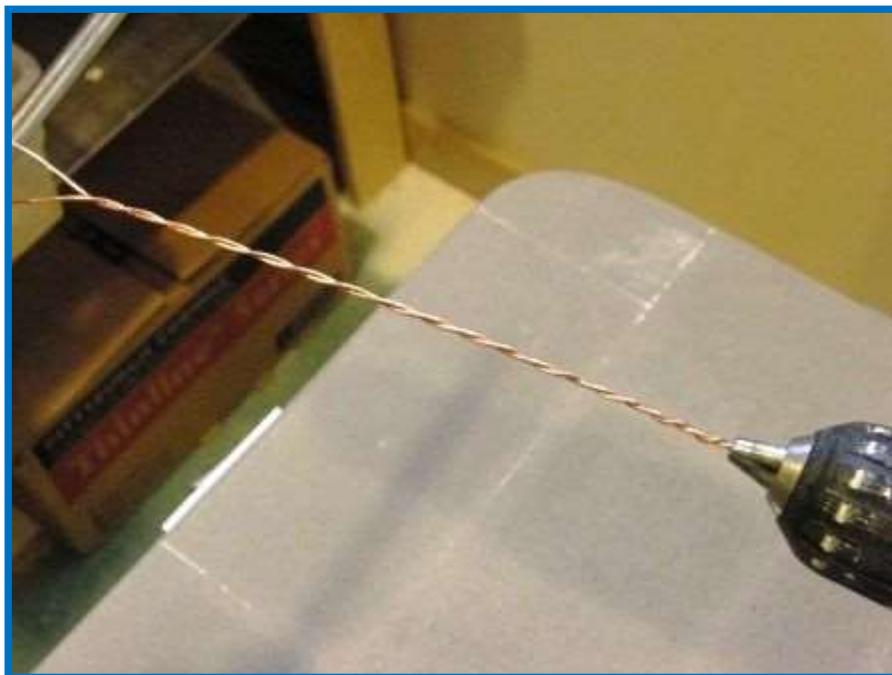
- Connect CP1 negative (-) to the ground lug via #18 black wire using #10 ring terminals on both sides. Connect CP2 positive (+) to the ground lug via #18 black wire using #10 ring terminals on both sides. The last wires from these capacitors are from CP1 positive (+) to two back right pins on QFH via #18 red wire for F1 & F2. Connect CP2 negative (-) to the two front right pins on QFH via #18 black wire for F3 & F4.
- Connect F4 from the QFH tab to PCB2 (-Vcc) via #18 black wire. Solder directly to the PCB.
- Connect F3 from the QFH tab to PCB1 (-Vcc) via #18 black wire. Solder directly to the PCB.
- Connect F2 from the QFH tab to PCB2 (+Vcc) via #18 Red wire. Solder directly to the PCB.
- Connect F1 from the QFH tab to PCB1 (+Vcc) via #18 Red wire. Solder directly to the PCB.

5.2.3 Signals

- Connect PCB1 (output) to OJ2 solder tab via #22 yellow wire. Connect PCB2 (output) to OJ4 solder tab via #22 yellow wire
- Connect PCB1 & PCB2 (ground) [to the left of the output] to the ground lug using #20 green wire and #10 ring terminal.
- Connect bias diodes to the PCBs via orange #20 solid wire. I'll show the diagram of 'A' and 'B' again for your reference.



- Route PCB1 (central gnd) to the ground lug using #20 green wire and #10 ring terminal.
- DO NOT route PCB2 (central gnd). If you have routed this wire, please cut it now. Instead, connect the ring terminal of R1R and R1W together with #20 green wire. Note: that you will need to solder another wire in there so it might be better to wait a step or to until you solder.
- Grab the blue and orange hookup wire (doesn't matter that they are different gauge wire). Unspool a good length (5 feet should be enough) of wire and place the two closely together in a vice or have a friend hold that end. Put the other end close together into the chuck or a hand drill. Twist until you have a tight twisted pair wire. Picture below taken from the internet



[9]

- Connect the blue wire to signal gnd of PCB1 to RIW ground ring terminal (also solder that green wire now).
- Connect the blue wire to signal gnd of PCB2 to RIR ground ring terminal (also solder that green wire now).
- Connect the yellow wire to Signal in of PCB1 to RIW center pin
- Connect the yellow wire to Signal in of PCB2 to RIR center pin



- Congrats! You now have a leach amp! Do NOT power it on until you follow the next steps.

6. First Power One

6.1 Testing

Now it is time to power on for the first time.

- Turn P1 (potentiometer) all the way CCW (counter clock wise) to the highest resistance setting.
- Make sure the switch on the amp is turned off. Use the special power cord discussed in '3.3 building accessories' in this document above with the 25 watt light bulb to plug the power then follow Dr. Leach's instructions below:
- *"Test the power supply before installing fuses F2 - F5. The dc voltages should correspond to the values given in the power supply parts list for the transformer used. If the power supply is wired wrong, fuse F1 will blow.*
- *The filter caps must be discharged before installing F2 - F5. Do not short circuit the capacitors to discharge them! You will get a loud pop and a big spark. A 100 ohm 2 W resistor is recommended to*

discharge the capacitors, but it can get hot! Use pliers to hold the resistor across the terminals of each capacitor for at least 30 seconds to discharge the caps.”

- *The P1 should be twisted to max resistance CCW (counter clock-wise) then “install the power supply fuses. If the previous tests have been successful, you can proceed to the next step where you power up the amplifier. Again, I recommend the use of a variac to slowly increase the AC input voltage from 0 V to 120 V for this test. If you are unsure of anything, remove F2 - F5. Substitute a 100 ohm 1/4 W resistor for each of these fuses. You may wish to power up only one channel at a time.*
- *With no load connected to the amp, it can be powered up. If anything is wrong, the 100 ohm resistors in place of the power supply fuses will limit the current. They will also smoke! The dc voltage drop across the 100 ohm resistors should be less than about 2.5 V (25 mA or less) if nothing is wrong. If this test is successful, turn the amp off and wait for the power supply to discharge. Remove the 100 ohm resistors and install F2 through F5.” [10]*

6.2 Setting Bias Current

If the preceding tests are successful, the next step is to set the bias currents in the output stages. This is done as follows:

- *“The power should be turned off and the power supply discharged.*
- *Remove F2 and clip an ammeter across the fuse terminals.*
- *Power the amp up with no input signal or load. Adjust P1 for the channel connected to F2 for a current of 100 mA. Be careful. Once I accidentally blew the output transistors in one channel of an amplifier I was building when I mistakenly tried to adjust P1 for the wrong channel.*
- *As the amp warms up, the current will drift. Readjust P1 until the drift stops. This will take about 10 minutes.*
- *Turn the amp off. Wait until the power supply discharges, then install F2.*
- *Remove F3 and repeat this procedure for the other channel.*

When the bias is adjusted properly, a dc voltmeter will read close to 3.4 V across Q7, i.e. across the collectors of Q12 and Q13. The collector of these transistors is the round metal case” [11]

6.3 Is there a hum in the loudspeaker

- *“If a hum is encountered with the amp, install a 2-prong to 3-prong adapter on the AC input plug. This will eliminate any hum caused by a ground loop in the external AC wiring. However, the amplifier chassis will no longer be connected to safety ground. If the adaptor fails to get rid of the hum, it might be caused by a ground loop inside the amplifier. The following procedure can be used to determine if this is the case:*
- *Turn the amplifier off and wait for the power supply to discharge.*
- *Disconnect one input cable.*

- *Turn the amplifier back on.*
- *If the hum is gone, it is due to an internal ground loop. If the hum remains in the channel that has its input connected, the hum is probably in the source.*
- *If you are sure that the hum is due to an internal ground loop, the procedure for breaking this loop is as follows:*
- *Turn the amplifier off and wait for the power supply to discharge. Do not perform this procedure with the amplifier on.*
- *Cut the wire to the central ground on the input side of one circuit board.*
- *Solder a short circuit jumper wire between the ground lugs on the two input jacks.*
- *The circuit board with the cut ground wire is now grounded back through its input ground lead to the ground of the other circuit board. Use an ohmmeter to verify the new ground connection before turning the amp back on.” [12]*

6.4 Hints if problems are encountered

- *“If problems are encountered, a list of things to check is as follows:*
- *Double check all wiring.*
- *Check to see that the bias diodes D1 - D4 are installed correctly, that none are cracked, and that the attaching leads make proper contact.*
- *Check the orientation of each diode and the polarity of each electrolytic capacitor.*
- *Check the orientations of Q1 through Q11.*
- *Are all transistor part numbers correct?*
- *Are any NPN and PNP transistors interchanged? I have embarrassed many students when I found this error in their amplifiers.*
- *Do the leads to the heat sinks connect to the right points on the circuit boards? I recently saw a student's amplifier where the base leads for the npn and pnp output transistors on one channel were reversed on the circuit board. The bias potentiometer would not adjust the bias current in that channel.*
- *Are all resistor values correct? (The resistor color code is: 0-black, 1-brown, 2-red, 3-orange, 4-yellow, 5-green, 6-blue, 7-violet, 8-grey, 9-white. The third color band is the multiplier, i.e. the number of zeros. As an example, brown-red-orange is 12000 ohm).*
- *Check for short circuits from ground to the leads of each power transistor. This indicates a short circuit in the heat sinks.*
- *Is the loudspeaker output shorted to one or both power supply leads? If so, one or more power transistors are blown.*

- *Does the ohmmeter give a short circuit between the collector and emitter of any transistor? If so, that transistor is probably blown. Bad transistors usually become a short circuit from collector to emitter.*
- *I have occasionally seen protection circuit transistors Q8 and/or Q9 shorted from collector to emitter. The amplifier will be completely dead if this happens.” [13]*

7. A Final Word

I hope this guide has enabled you to build where you might have been reluctant before. I will publish in a few locations but you should feel free to forward to anyone who is interested. Again, if you have any feedback, encounter issues or have better ideas about citations & credit or just feel like saying thanks feel free to email me at leachamp2u@gmail.com and I will do my very best to get back to you.

CITATIONS:

- [1] <http://users.ece.gatech.edu/~mleach/lowtim/parts.html> -Dr. Leach
- [2] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [3] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [4] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [5] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [6] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [7] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [8] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [9] <http://www.instructables.com/id/A-Perfect-Twist/> - user: barefootbohemian
- [10] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [11] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [12] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach
- [13] <http://users.ece.gatech.edu/~mleach/lowtim/part2.html> -Dr. Leach