



Assembly and Installation Instructions for White Oak Audio Design PL400 Capacitor Upgrade Kit

Thank you for purchasing White Oak Audio Design's Phase Linear PL400 Capacitor Upgrade Board. White Oak Audio Design products are meticulously engineered and tested to ensure a direct drop in fit with your amplifier and better, more reliable performance than the original Phase Linear equipment.

The assembled and installed capacitor upgrade assembly will enhance the performance of your PL400 Amplifier by providing up to 5 times the energy stored in the main plus(+) and minus(-) power supplies. This will give your amplifier more bass punch than the original capacitors as well as increasing the operating voltage and ripple current capabilities, meaning more reliability. In addition, the peak to peak power supply ripple voltage will be reduced by over 9dB to help produce a quieter noise floor. The design challenge for White Oak Audio Design was to create a capacitor assembly that greatly increased the energy storage capacity but fit in the very limited space originally designed into the PL 400 amp by Bob Carver.

This capacitor kit is a direct drop in replacement for many of the original screw terminal capacitors originally shipped in the Phase Linear 400. No permanent modifications are required to your amplifier so reversal is quick and easy should you decide to return it to its original condition for resale, collecting or other purposes. While the building and installation of this kit takes some technical skill, it is not that difficult for moderately experienced technicians and hobbyists. If your kit does not use screw terminal 1.75" diameter x 4.125" (or up to 4.625 in some amps) long style capacitors, then this kit will not be a direct drop in. The majority of PL400 amplifiers that were built use this capacitor size.

Figures 1-4 below show the dramatic improvement in power supply performance that this kit makes in your PL400. Replacing those original 40+ year old electrolytic capacitors with modern technology capacitors will make a huge audible improvement in the performance of your amplifier.



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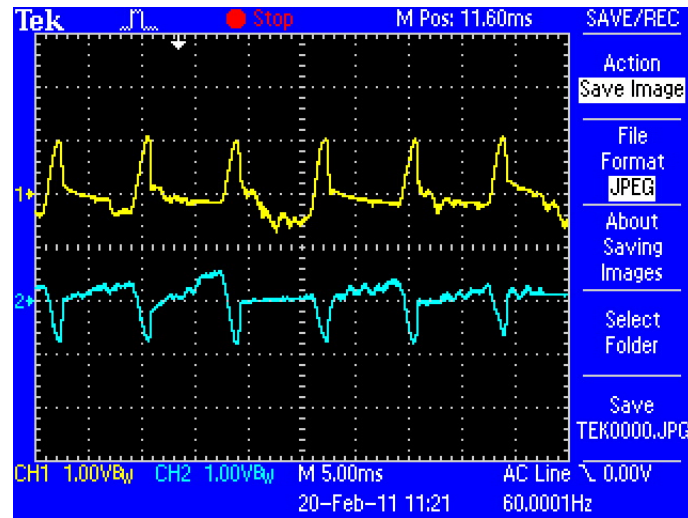


Figure 1. Original 5,900 -7,300 μ F Capacitors – 60 Hz Ripple

Vertical Scale = 1V per division

Time Scale = 5msec per division

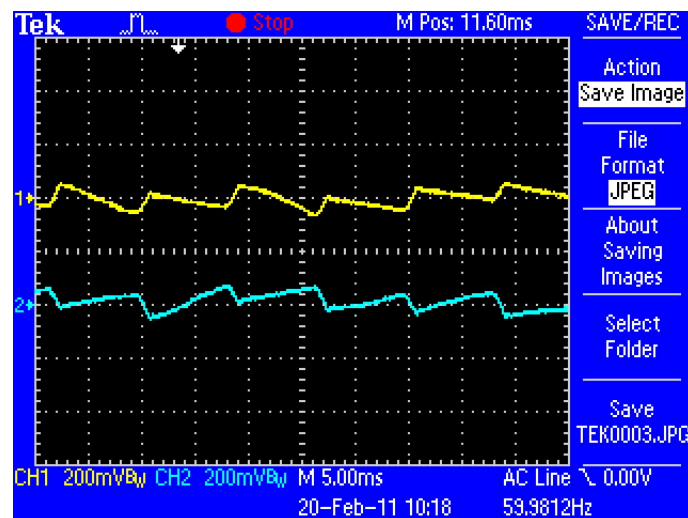


Figure 2. New 20,000 μ F Capacitors – 60 Hz Ripple

Vertical Scale = 200mV per division (note dramatic increase in scale sensitivity from prior trace)

Time Scale = 5msec per division



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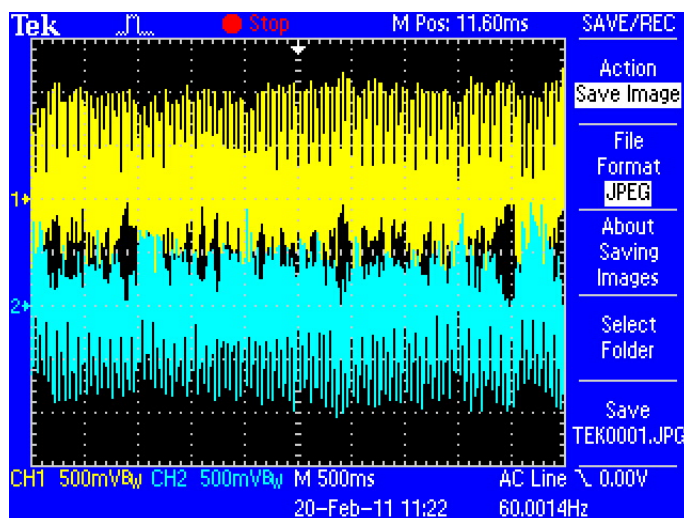


Figure 3. Original 5,900-7,300 μF Capacitors – Program Material, approx 2W output per channel

Vertical Scale = 500mV per division

Time Scale = 500msec per division

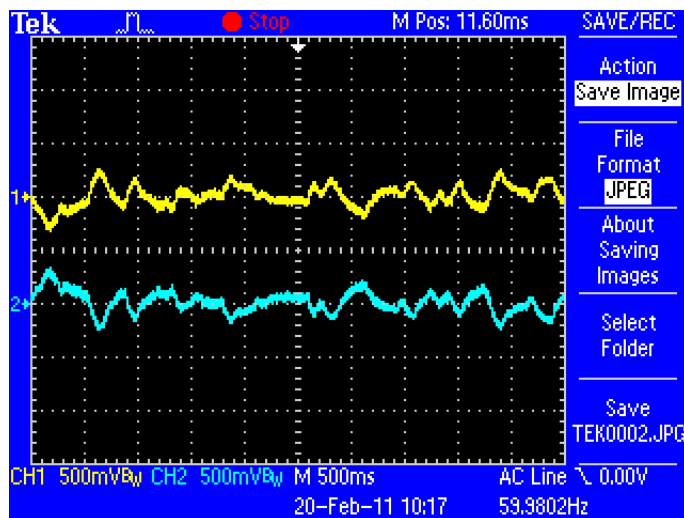


Figure 4. New 20,000 μF Capacitors – Program Material, approx 2W output per channel

Vertical Scale = 500mV per division

Time Scale = 500msec per division

Figure 5 shows how your finished project will look using four 10,000 μF , 100V, 35 x 50mm snap in capacitors (note, capacitor casing color may vary depending on capacitor brand utilized).



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Figure 5. Finished PL400 Amplifier Project with 20,000uF, 100V capacitance per power supply rail installed

Figure 6 shows how your finished project will look using four 15,000 uF, 100V, 35 x 52mm snap in capacitors (note, capacitor casing color may vary depending on capacitor brand utilized).





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Figure 6. Finished PL400 Amplifier Project with 30,000uF, 100V capacitance per power supply rail installed



Figure 7. Original Phase Linear equipment 5,900-7,300uF, 75-85V capacitor installation

Applicability of Kit: The White Oak Audio Design PL400 Capacitor Upgrade Kit replaces only original Phase Linear 400's that are equipped with 1.75" diameter by 4.125" to 4.625" long screw terminal capacitors as shown in Figure 7. It is not for replacement of any other type capacitors or terminal configuration. If your original Phase Linear amplifier does not match these requirements, do not install this kit without contacting White Oak Audio Design first for guidance.



Assembly and Installation Instructions for White Oak Audio Design PL400 Capacitor Upgrade Kit

Section 1: Assembling the capacitor upgrade assembly

Have a printed copy of these instructions with you prior to performing this assembly procedure.

Skills required:

While assembly of this upgrade kit is not a difficult procedure, the assembler should be familiar and comfortable with working on electronic equipment and using a soldering station and associated tools. Ensure good control of soldering iron temperature, not exceeding 600 degrees F, so components and circuit boards are not ruined by excessive heat. If you are not familiar with working on electronic equipment or do not possess the proper equipment, it is recommended that you have this assembly performed by a service technician that can perform the capacitor upgrade kit assembly and installation for you. Allow several hours to perform the assembly and installation of this capacitor upgrade kit while following these step-by-step instructions.



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Tools Required:

1. Temperature controlled soldering station or iron – set to 600 degrees F maximum
2. 63/37 (preferred) or 60/40 rosin core solder - .031 diameter or smaller
3. Good quality Needle nose pliers
4. Good quality Diagonal wire cutters
5. Medium, straight blade screwdriver
6. 7/16" nut driver
7. 3/8" nut driver

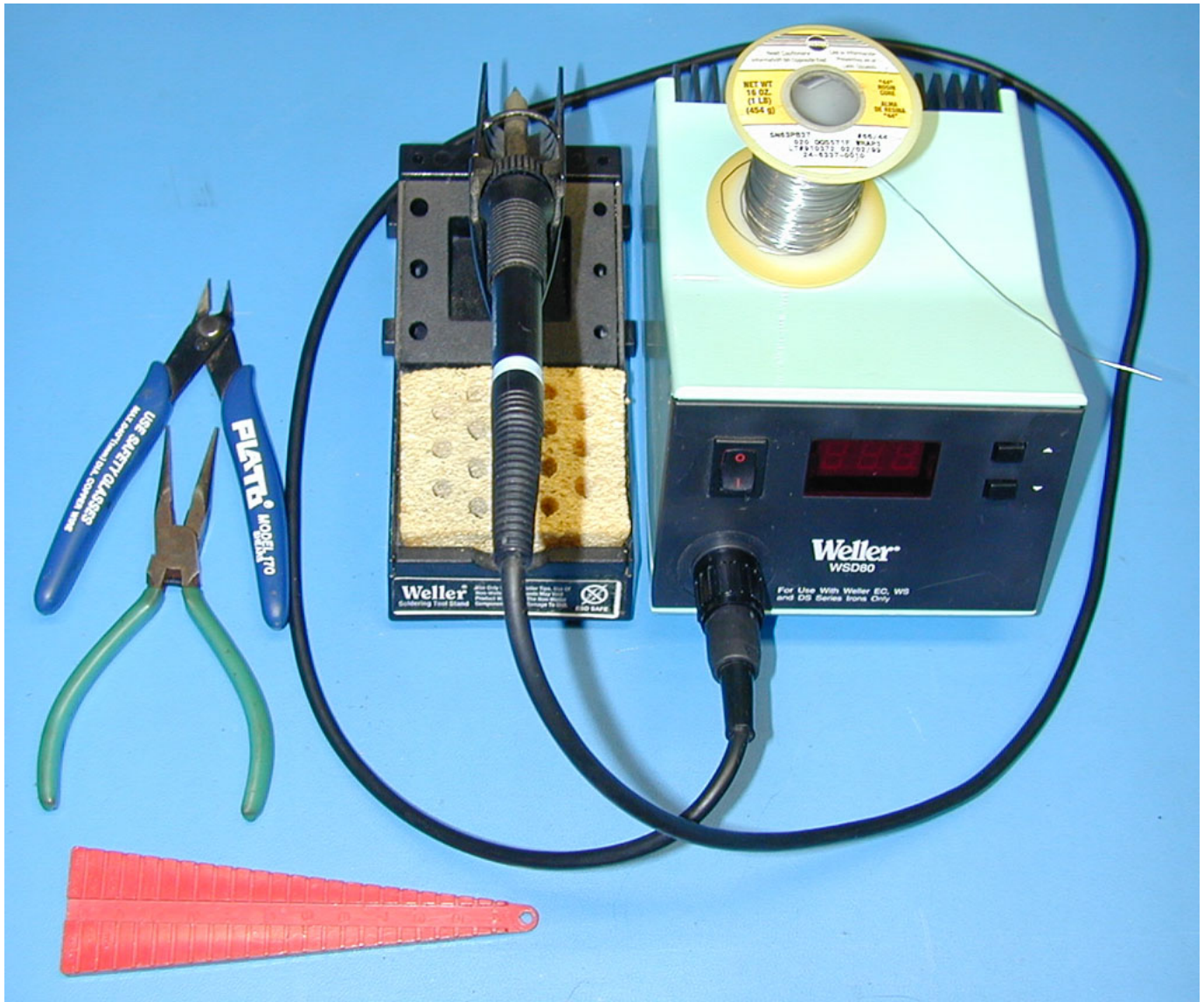


Figure 8. Tools Required



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Optional Tools:

1. A Panavise with board holder is handy for assembling this project but is not required.



Figure 9. Optional Tools – Panavise PCB holder



Assembly and Installation Instructions for White Oak Audio Design PL400 Capacitor Upgrade Kit

Table 1. PL400 Capacitor Upgrade Board Parts List

Item	Qty	Part Number	Description	Ref.	Price Ea.	Ext. Price
1a	4	Nippon Chemicon KMG	Capacitor, Electrolytic 10,000 uF, 20%, 100V, Nippon Chemicon 35 x 50mm	C1-C4	\$6.99	\$27.96
<u>OR</u>						
1b	4	Hitachi HCC	Capacitor, Electrolytic 15,000 uF, 20%, 100V, Hitachi 35 x 55mm <u>Parts supplied with Kit</u>	C1-C4	\$15.50	\$62.00
2	20"	Tinned Copper Bus Wire, 16AWG	Length of 16AWG tinned bus wire	P1-P4	N/A	N/A
3	20"	Clear PVC insulating tubing, Size 15	Length of size 15 PVC tubing	P1-P4	N/A	N/A
4	4	RAF 3077-B-1032-B	Swage standoffs, 5/16" diameter x 3/16" high, 10-32 threaded.	+ and -	N/A	N/A
5	4	Screw, Pan Head, 10-32 x 1/4"	10-32 screws (1 installed in each swage standoff)	+ and -	N/A	N/A
6	1	Hold_Down_Plate	White Oak Audio aluminum hold down plate	N/A	N/A	N/A
7	4	WOAD Cap PCB	Blank PCB, White Oak Audio Design PL400 Cap Board	BD1-BD4	N/A	N/A
8	2	Nut, Hex, 10-24	10-24 Hex Nut (to install hold down plate and bridge rectifier)	N/A	N/A	N/A
9	5	Washer, internal tooth, #10	Internal tooth lockwashers for capacitor terminals and hold down plate.	+ and -		
10	2"	Threaded rod, 10-24	Section of threaded rod (to install hold down plate and bridge rectifier)	N/A	N/A	N/A

Notes:

- 1) If you ordered just the bare board kit from White Oak Audio Design you will receive all the part items 2-10. Order items 1a or 1b for the board assembly from your source. Pricing and/or part numbers of items above are typical and for reference only. Please consult White Oak Audio Design if one or more of the part numbers listed above has become obsolete or is not available. We will work with you to provide suitable alternative part numbers.
- 2) If you ordered the complete kit from White Oak Audio Design, you will receive all part items 1(a or b)-10.

If you ordered a kit or assembled version of the PL400 Capacitor Upgrade, then the components in the above parts list will be supplied as part of that kit or assembly.



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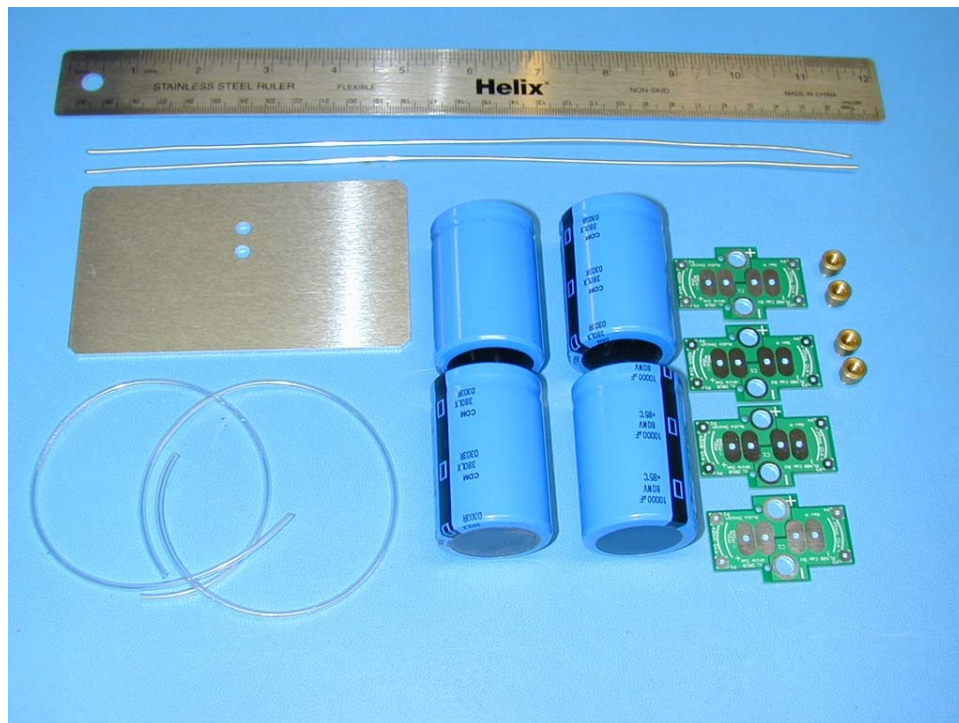


Figure 10. PL400 Capacitor Upgrade Board Kit Contents-Complete

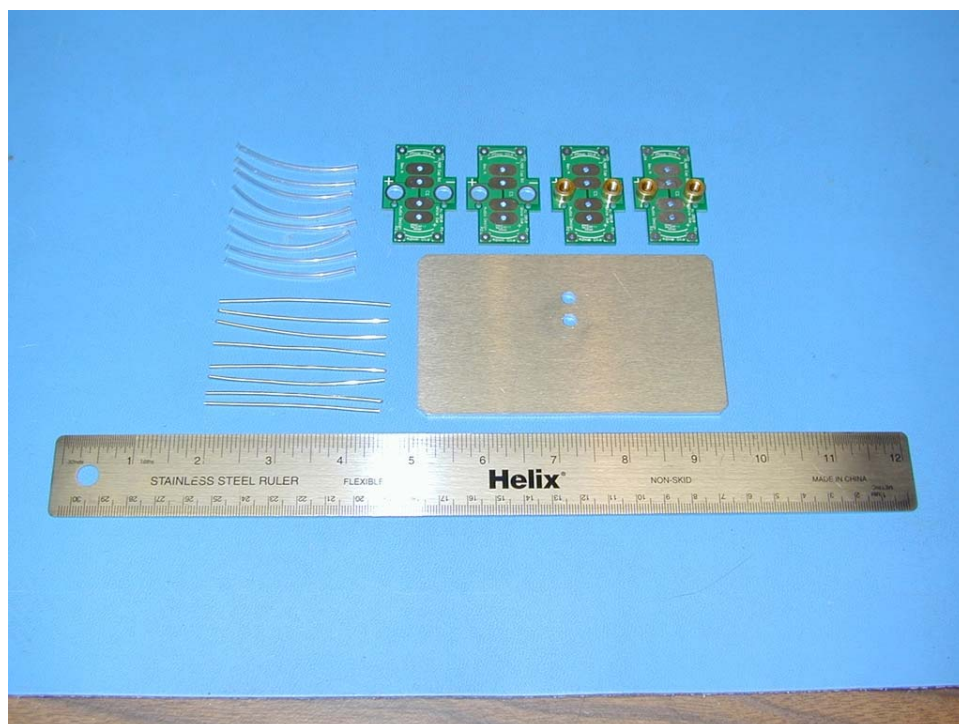


Figure 11. PL400 Capacitor Upgrade Board Kit Contents-PCB Only



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Assemble each board to the top of the capacitors first (as shown in Figure 12 and 13):

1. [] The kit includes 2 PCBs with the 3/16" tall by 5/16" diameter, 10-32 threaded swage standoffs that come pre-installed and soldered and 2 PCBs without standoffs. Locate these. These will be installed onto the 4 capacitors in the next step.
2. [] Locate the polarity marks on each capacitor. Generally, there is a wide black band adjacent the negative capacitor terminal with minus (-) sign markings within the black band. This signifies the minus terminal of the capacitor.
3. [] Locate the plus and minus polarity marks that are printed in the silkscreen on each PCB. There is a smaller PLUS and MINUS indication next to the 4 hole patterns for mounting of the snap in capacitors as well as a larger PLUS and MINUS indication for the output terminals.
4. [] Line up each of the 4 capacitors with the closer spaced set of holes in the PCB carefully observing correct polarity orientation. With the silkscreen surface of the PCB facing up, snap each PCB onto its respective capacitor, fully seating the PCB surface flat on the top of the capacitor. **DOUBLE CHECK THE POLARITY BEFORE PROCEEDING.** It will be very difficult to rework later if this step is not done properly. The result should look like Figure 12 below



Figure 12. PCBs snapped onto the top of each capacitor

5. [] Carefully solder each of the 2 capacitor terminals to the respective PCB pads. Leave the soldering iron on the solder joint long enough to flow the solder evenly and ensure that a cold solder joint does not result. Using diagonal cutters, clip off the majority of the excess capacitor lead above the PCB, leaving approximately 1/32 to 1/16 inch. Inspect each joint and touch up if necessary. The result should look like Figure 13 below.



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Figure 13. Finished capacitor subassemblies, soldered and with leads clipped.

6. [] Next, two capacitors will be stack soldered together to form one larger value capacitor. A finished stack is shown in Figure 18.
7. [] Cut the supplied 16AWG tinned copper bus wire into 8 sections, each 2.5" in length. Also cut the supplied #15 clear PVC insulating tubing into 8 sections, each 2.0" in length. The finished result should look like Figure 14 (4 sections of each shown). These will be used to interconnect 2 capacitor subassemblies into one final assembly.



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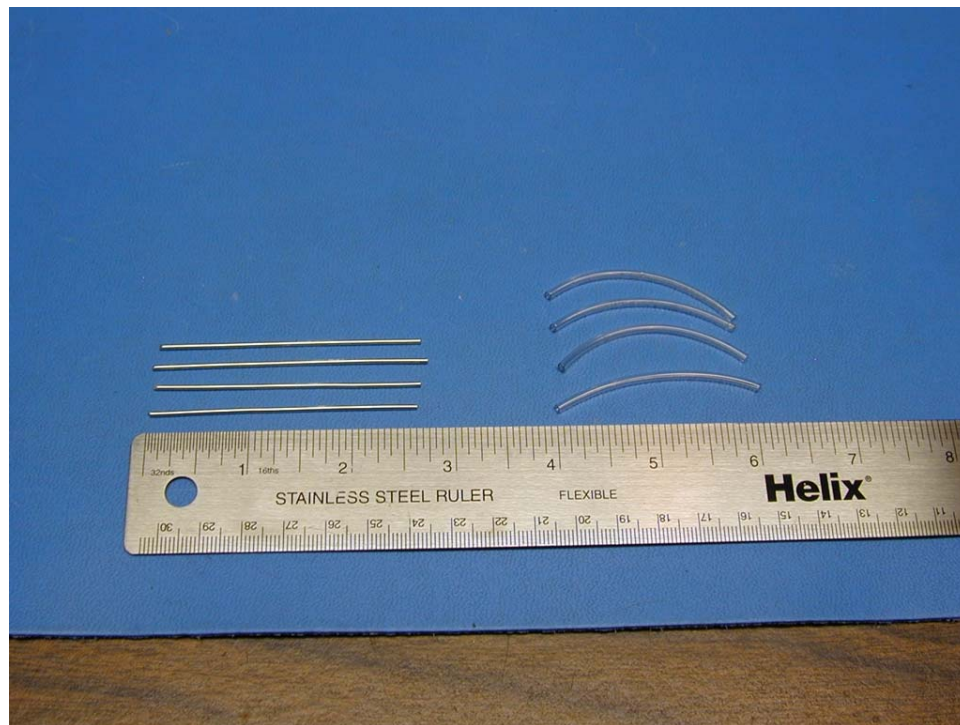


Figure 14. Jumper wires and insulating tubing cut to length

8. [] If you have a Panavise similar to that shown in Figure 9, arrange one capacitor with screw terminals (in front) and one without (behind the other one) in-line as shown in Figure 5. Insert a small piece of thin (~0.025" thick) cardboard (use a piece of backing cardboard from a paper pad) in between to form a space gap to keep the terminals from the behind capacitor from rubbing against the base of the front capacitor (after the cardboard is removed). This arrangement is shown clearly in Figure 9. Orient the front and back capacitors observing the proper polarity, PLUS to PLUS and MINUS to MINUS using the markings on the PCB silkscreen.



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Figure 15. Install first jumper wire and insulating tubing

9. [] Referring to Figure 15, slide a 2" piece of insulating tubing onto the outside of one of the pre-cut 2.5" lengths of 16AWG bus wire. Install the first length of 16AWG bus wire between one of the 4 holes in the front PCB and the respective hole in the back PCB. Ensure that the front and back capacitors are touching with the cardboard shim in between. Carefully solder this wire into the front and back PCB. Apply enough heat to properly reflow the solder but be careful not to melt the insulating tubing. Soldering from the outside ends of the wire is the easiest method to accomplish this.



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Figure 16. Install second, third and fourth jumper wire and insulating tubing

10. [] Referring to Figure 16, slide a 2.5" piece of 16AWG wire through one of the remaining four holes in the front board while at the same time sliding the insulating tubing onto the outside of this wire. Once the tubing is fully on the wire, guide the wire into the respective hole in the rear board. Ensure that the front and back capacitors are touching with the cardboard shim in between. Carefully solder this wire into the front and back PCB. Apply enough heat to properly reflow the solder but be careful not to melt the insulating tubing. Soldering from the outside ends of the wire is the easiest method to accomplish this.
11. [] Repeat step 10 for the 3rd and 4th wire. When complete, use the diagonal cutters to trim the ends of each of the 4 bus wires to 1/16th of an inch from the solder joint.
12. [] Repeat step 6 to 11 for the second capacitor stack.



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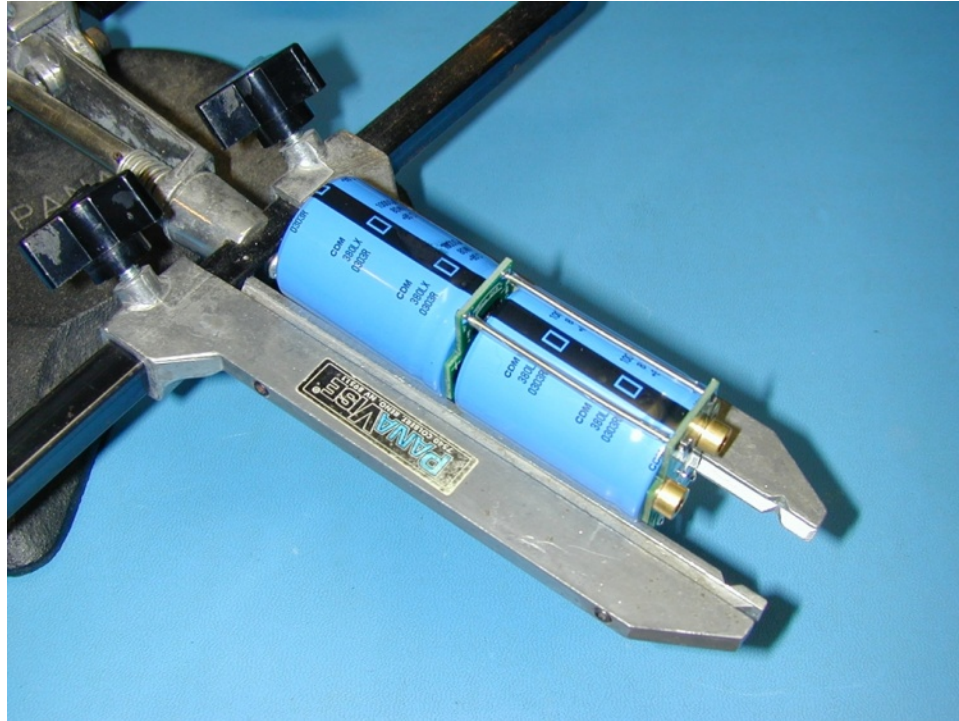


Figure 17. Using the Panavise to line up capacitors while assembling



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Figure 18. Finished double stacked capacitor assemblies



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Figure 19. Another view of finished double stack capacitors



13.

Figure 20. Completed double stack capacitor assembly
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15. [] This completes the Capacitor Upgrade assembly operations that can be performed independently from the amplifier. The next assembly steps involve physically installing the capacitors into the amplifier and attaching the wire connections from the amplifier to the Capacitor Upgrade. These steps involve partial disassembly of your PL400 amplifier.
16. [] Inspect the finished capacitor assemblies for solder shorts or splashes and for proper component orientation and polarity. Touch up as necessary.
17. [] The Capacitor Upgrade is now ready for assembly into your amplifier. The next steps assist you in moving the wires from the original capacitors onto your new Capacitor Upgrade.



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Section 2: Installing the Capacitor Upgrade into the amplifier.

Have a printed copy of these instructions with you prior to performing this installation procedure.

Skill required:

While installation is not a difficult procedure, the installer should be familiar and comfortable with working on electronic equipment and using associated tools. If you are not familiar with working on electronic equipment or do not possess the proper equipment, it is recommended that you take your amplifier to a service technician that can perform the LED Light Board for you.

Tools required:

1. Needle nose pliers
2. #2 Philips screwdriver
3. Medium straight blade screwdriver
4. 3/8" nut driver (to remove and install capacitor hold down plate)
5. 7/16" nut driver (to remove 4 nuts securing aluminum amplifier faceplate)

Step by step installation procedure:

1. [] Disconnect power and all connections from the PL400 amplifier. Unplug your amplifier before performing any service operation on it. **WARNING! Wait at least 30 minutes for the electrolytic capacitors to properly discharge after unplugging the amplifier! The capacitors you will be removing hold high voltage residual charge for a long time, especially the negative rail capacitor located towards the bottom floor of the amplifier. Failure to discharge the caps can lead to inadvertent contact to other components during the upgrade operation and damage your amplifier or cause hazardous electric shock.**
2. [] Move the amplifier to a suitable, clean work area. It is recommended that a clean sheet of bubble wrap be placed under the amplifier in the work area to prevent damage to cosmetic surfaces of the amplifier.
3. [] Using the 7/16" nut driver, carefully remove the 4 nuts from the backside of the front faceplate screws. Remove the washers that were underneath the hex nuts and carefully extract the decorative faceplate attachment bolts from the faceplate
4. [] After removing the front faceplate bolts, carefully pivot the front faceplate down onto the work surface (protected by bubble wrap to prevent cosmetic damage)
5. [] Remove the top cover by removing the 5 sheet metal screws using the #2 Philips screwdriver.
6. [] Put all loose hardware and covers in a safe place for reassembly later.
7. [] Remove the four 10-32 screws from the main power supply capacitors. As you remove each screw, note the stackup order of the ring lugs and other hardware so you can put it in back in the same order when installing the Capacitor Upgrade. Be careful not to drop any loose washers into the amplifier. There are generally internal tooth lockwashers installed on these 10-32 screws. Put the screws and washers in a safe place for reassembly later. Carefully move the wires that were attached to these capacitor terminals out of the way.
8. [] Using the 3/8" nut driver, remove the single 10-24 nut securing the capacitor hold down plate in place. Remove any washers and remove the original capacitor hold down plate and put it aside. It will be replaced by the new hold down plate provided with your Capacitor Upgrade Kit.
9. **Note Well:** some vintage PL400 amplifiers have build variations from what is pictured in these instructions. You should use the parts supplied with this kit to end up with an installation that looks like the pictures shown in Figure 21 and 22. Some build vintages have the bridge rectifier installed onto the transformer die cast base using a self tapping, 10-24 screw with the capacitors held in place with double sided foam tape. Some build vintages have the bridge rectifier installed



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onto the transformer die cast base using a self tapping, 10-24 screw with a double U shaped steel bracket secured under the bridge rectifier. For these build types, install the supplied 10-24 threaded rod section, hex nut and internal tooth lock washer to allow the amp upgrade to be converted to that shown in Figures 21 and 22. If your original caps were held in place with double sided foam tape, be sure to carefully remove any residual foam tape and adhesive residue before installing this upgrade kit to ensure the capacitors sit firmly and squarely on the transformer die cast cradle (Failure to do this may cause the capacitor hold down plate to interfere with the leftmost meter connection stud on the left channel meter, possibly shorting the negative meter terminal to ground. This will cause the left channel meter not to work at all or intermittently). When installing the threaded rod, remove the self tapping screw holding the bridge rectifier in place and thread in the section of threaded rod. Do not thread it in too far or it will damage windings on the transformer. You should be able to thread this rod in using your fingers, if you feel resistance stop and figure out why before proceeding any further. The rod is cut to be 1-7/8" long. Thread it into the transformer die cast approximately 1/2" to leave 1-3/8" protruding from the base of the transformer die-cast. There are 2 holes in the transformer die cast (you can see the unused right hole in Figures 21 and 22). You will be using the left hand hole (when looking from the front of the amp, this hole is closest to the left hand wall of the amp), NOT the right hand hole. Place it through the top of the bridge rectifier and then thread it into the die cast transformer mount. Then place an internal tooth lock washer on top of the bridge rectifier around the shank of the threaded rod. Next thread one of the supplied 10-24 hex nuts onto the threaded rod and finger tighten it up against the top of the bridge rectifier. Tighten this hex nut gently but securely using a hollow shank 3/8" nut driver. After tightening, you should not be able to spin or twist the bridge rectifier. Do not over tighten the nut or you may risk stripping out the threaded rod from the aluminum transformer die-cast. After accomplishing this, your amp should look like Figure 21 and you are ready to move on to the remainder of the installation.

10. [] Remove the 2 original capacitors and put them aside. These will not be reused.
11. [] Seat the new upgrade capacitors in the spaces that you just removed the original caps as shown in Figure 21 (If your original caps were held in place with double sided foam tape, be sure to carefully remove any residual foam tape and adhesive residue before installing this upgrade kit to ensure the capacitors sit firmly and squarely on the transformer die cast cradle). Orient the polarity of the capacitors carefully. Wiring these capacitors incorrectly (reversed polarity) can damage your amplifier and cause the capacitors to vent or explode unexpectedly.



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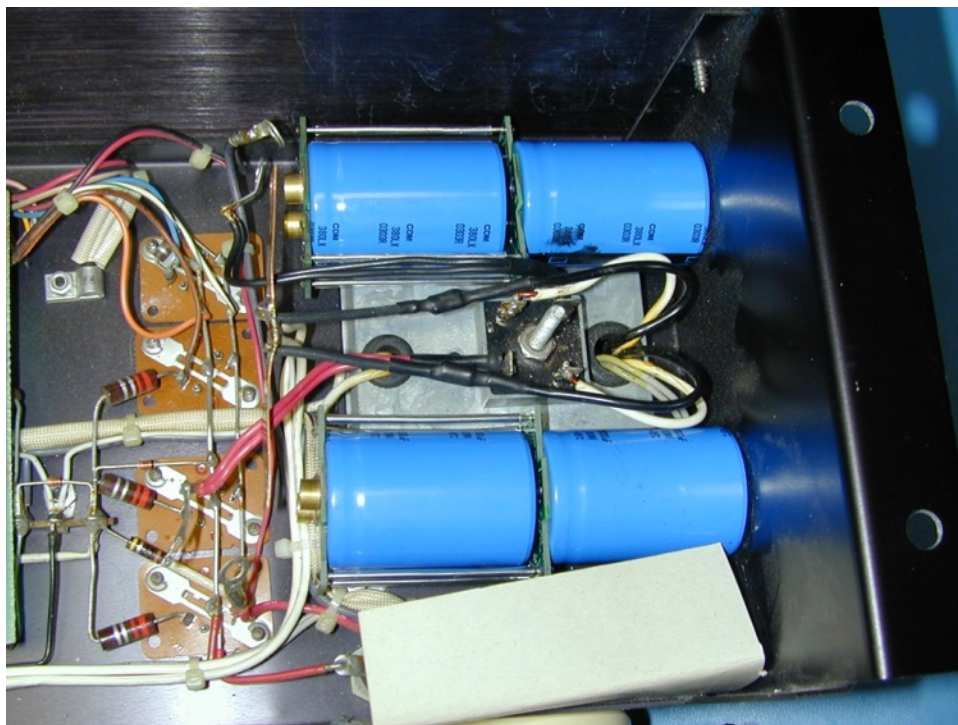


Figure 21. Installing the finished capacitor assemblies into the PL400 Amplifier

12. [] Refer to Figure 23. Install the new capacitor hold down plate that was supplied with your kit to keep the capacitors in place and loosely reinstall the 10-24 nut. Do not tighten any more than finger tight at this point.
13. [] Refer to Figure 22. For the capacitor that is located closest to the amplifier bottom floor, the negative terminal of this capacitor is attached to the 2 black wires (some vintage amps have different wire colors) with ring lugs (this is the amplifier negative rail). The positive terminal of this capacitor is attached to the wide copper strap that ties the 2 capacitors together (this is the amplifier ground). Loosely install the 10-32 screws and any internal tooth washers in the same order as you removed them from the original capacitor. Finger-tighten only at this point.
14. [] Refer to Figure 22. For the capacitor that is located closest to the amplifier top cover, the positive terminal of this capacitor is attached to the 2 red wires (some vintage amps have different wire colors) with ring lugs (this is the amplifier positive rail). The negative terminal of this capacitor is attached to the wide copper strap that ties the 2 capacitors together (this is the amplifier ground).). Loosely install the 10-32 screws and any internal tooth washers in the same order as you removed them from the original capacitor. Finger-tighten only at this point.



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Figure 22. Installing the finished capacitor assemblies into the PL400 Amplifier

15. [] At this point, double check the capacitor orientation and connection polarity. Neaten the wiring up and make sure everything fits nicely and appears as the photo in Figure 22. **Ensure the wires from the transformer to the bridge rectifier are below the tops of the capacitors. They are stiff wires so will have to be arranged carefully without breaking any solder joints to the bridge rectifier. Failure to do this properly will cause shorts of the wires to the hold down plate which will blow fuses or cause the hold down plate to interfere with the left channel meter. There is not a lot of room in here so spend some time getting this step done neatly and carefully.**
16. [] Drop the capacitor hold down plate onto the threaded 10-24 stud. There are multiple holes in the plate to give you some flexibility to install it in a way that works best in your application. The best orientation is that which puts the plate edge closest to the far left wall of the amp and away from the meters. Drop the other internal tooth lock washer and thread the 10-24 nut that were supplied with your kit onto the threaded rod. Using the 3/8" nut driver, carefully tighten the capacitor hold down bracket to secure the capacitor assemblies. Do not over tighten this hold down plate or you will damage the capacitors. Tighten only enough to keep the capacitors securely in place and flush to the die cast transformer bracket. Tighten only enough to keep the hold down plate from spinning on top of the capacitors. **If this step is not accomplished properly the capacitor hold down plate will interfere with the leftmost meter connection stud on the left channel meter, possibly shorting the negative meter terminal to ground. This will cause the left channel meter not to work at all or intermittently!**
17. [] Using the straight bladed screwdriver, carefully tighten each of the 4 screws into the capacitor terminals. Do not over tighten or you will damage the capacitor boards or capacitor snap in terminals. Be careful not to contact or damage components on the PL14 control board while tightening these screws.



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18. [] Double check your work, neaten any wiring and be careful that you did not inadvertently short out any wires in the process of installing this upgrade.
19. [] Once installation is complete, your Capacitor Upgrade will look like the illustration in Figure 22 below. Make any minor adjustments to the wire dressing to neaten it up.



Figure 23. Finished PL400 Amplifier Project with 20,000uF, 80V capacitance per power supply rail installed

20. [] Pivot the front faceplate back up into place while ensuring that there is not interference with any amplifier components or any wire pinching. **Check the clearance from the capacitor hold down plate to the leftmost meter connection stud on the left channel meter to ensure the stud is not shorted to the hold down plate. There should be approximately 1/8" between the back of the leftmost meter stud and the capacitor hold down plate. If this clearance does not exist, there is the possibility of shorting the negative meter terminal to ground. This will cause the left channel meter not to work at all or intermittently**
21. [] Secure the front faceplate using the original hardware in the reverse order of Section 2, step 3 through 4. Do not over-tighten the faceplate screws or you may damage the amplifier cosmetics. Reinstall the top cover that you removed in step 5
22. [] Enjoy your amplifier's new Capacitor Upgrade. Tell your fellow vintage audio enthusiasts about White Oak Audio Design and our fine products. Check out our other products on the website. We are constantly adding new products to our portfolio. [White Oak Audio Design Website](http://www.whiteoakaudiodesign.com)



Assembly and Installation Instructions for White Oak Audio Design PL400 Capacitor Upgrade Kit

Revision Table

Revision	Revision Notes	Revision Date	Revised By
A	Original Release	2/25/2011	JPK
B	Minor updates to add instructions for amps where bridge rectifier is held with a self tapping 10-24 screw instead of threaded rod	4/24/2011	JPK
C	Updated to add more detail about adding threaded rod support in older amps	8/7/2011	JPK