

DIY-990

assembly guide

Hairball Audio, LLC

Safety Precautions

Read and understand all of the instructions before assembling this DIY project.

Improper assembly could result in damage to your property or serious injuries. Hairball Audio, LLC is not liable for any damage or injury resulting from the assembly or use of this DIY project.

Use caution when assembling and testing. Make sure you are using the appropriate tools and following the manufactures safety instructions.

Disclaimer of Liability and Warranties

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By downloading and/or following these plans, the user acknowledges that he or she has read and followed the Assembly Instructions and Safety Precautions.

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Introduction

Deane Jensen's now famous JE-990 paper describing the design, testing, and theory behind a powerful ultra low noise operation amplifier, was first introduced in the February 1980 AES journal. The design started with the LM394 dual super matched transistor as the input device. The LM394 is actually a monolithic device consisting of two pairs of 50 transistors connected in parallel to eliminate random variations in the individual devices. In addition to being designed for low noise, the JE-990 is a powerful op-amp capable of adequately driving a 75Ω load.

Many commercial versions of the 990 design are available for purchase today. The John Hardy Co JH-990 is certainly the best and most well respected version. Luckily, it's also one of the most affordable. Unfortunately the JH-990 is potted and not very DIY friendly. Many of the other designs available for purchase fall short of the original design and are 990 op-amps in name only. Shortly after the release of the Lola mic pre, I began considering offering a DIY JE-990 that would be affordable, authentic, and easy to build. Or at least as easy as soldering over 30 components on a one inch square PCB can be. Certainly it would need to a 2520 footprint and I would need to source an affordable LM394 substitute. Luckily much of this work had been completed a few years ago by PCB designer MNATs when he designed a DIY JE-990 2520 layout. I contacted MNATs about reworking the PCB for a different input component to replace the discontinued LM394 and he agreed to give a shot.

The common replacement for the LM394 is the Analog Devices MAT12. The MAT12 is the successor to the MAT02 and is available in a TO-78 thru-hole package. A very elegant component, but not a cheap one. They can cost \$15-\$30 depending on quantity.

Luckily there is another option. Analog devices also offers the SSM2212 which a dual matched transistor surface mount device (SMD) offering even superior performance specs than the LM394 or MAT12. Even better, it can be purchased for a fraction of the cost of the LM394. The Hairball Audio DIY-990 uses this device.

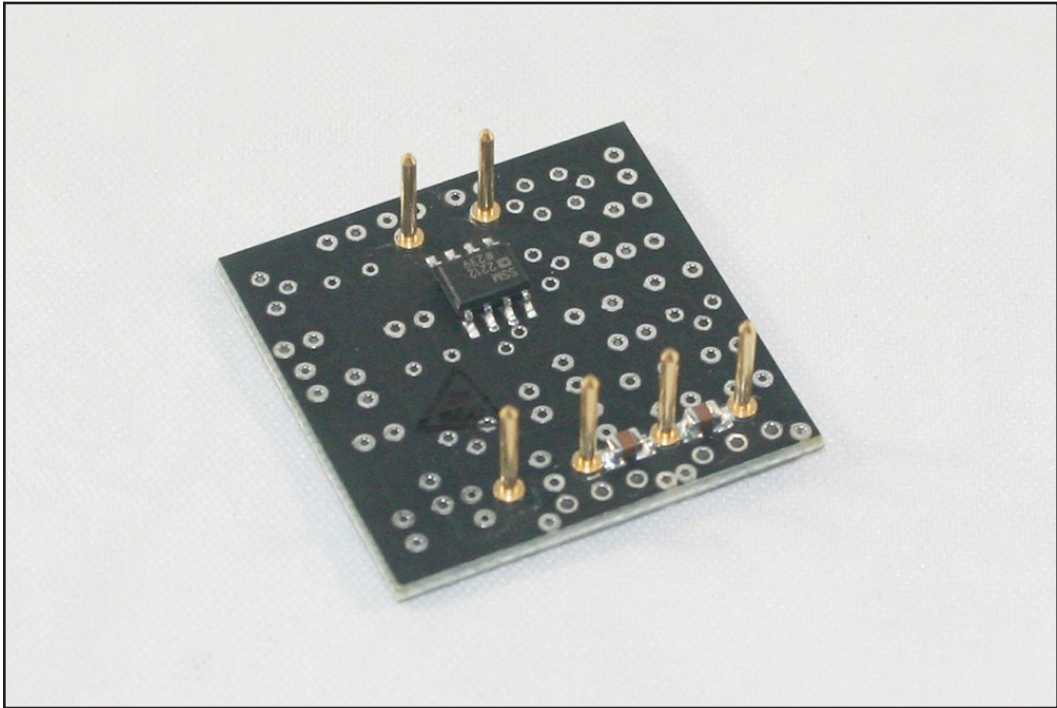
Soldering Guide

Soldering WELL is one of those things that seems easy until you try it. With a small PCB such as the DIY-990, good soldering skills are a must. As always, with solder, less is more. Dave Jones' of the EEVBlog has created an excellent set of video tutorials. The tutorial is presented in three parts: tools, soldering through hole components, and soldering surface mount components. For our purposes, I recommend you watch part 1 and 2. The videos are lengthy at about 25 minutes each, but they are well worth watching. Even I learned a few things. The videos can be seen by visiting:

hairballaudio.com/solder

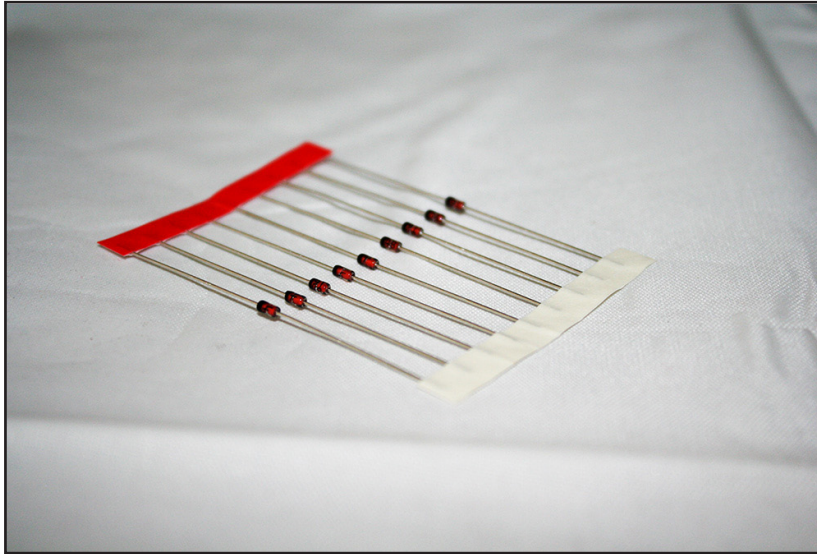
PCB Overview

The DIY-990 arrives with several components already installed. The six PCB mounting pins, two 0.1uF SMD bypass capacitors, and the SMD SSM2212 dual surface mount transistor. These components are mounted on the bottom side of the PCB. **The remaining components are all mounted on the top side.**

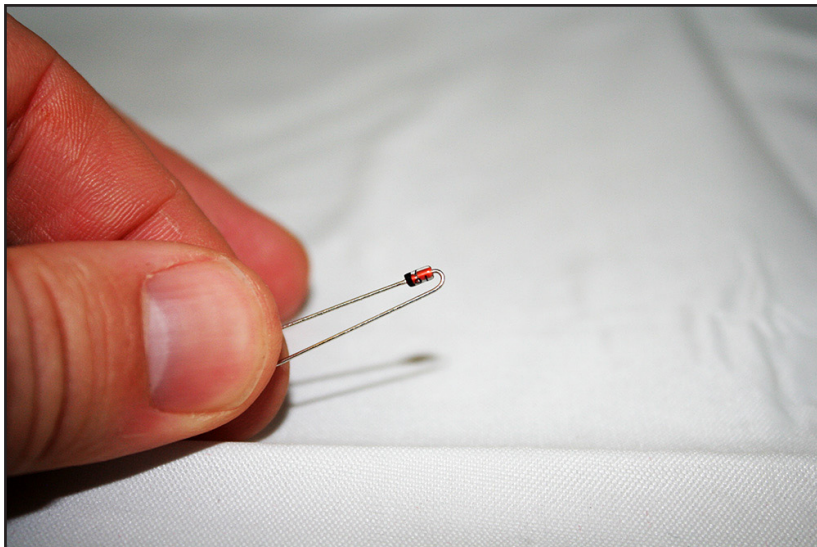


Diodes

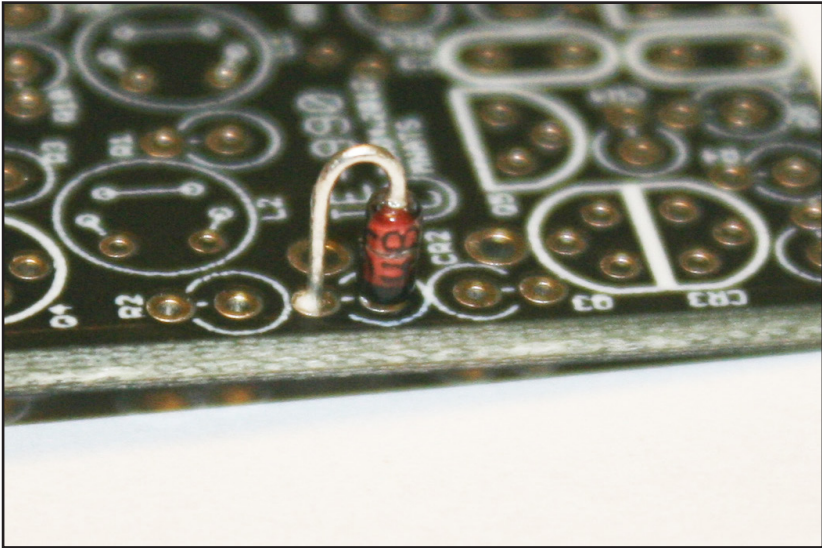
Start by installing the nine 1N914B diodes that are located in the DIODE/TRANSISTORS/CAPCITORS bag. These diodes, along with the resistors you'll install in the next step, are mounted vertically on the PCB.



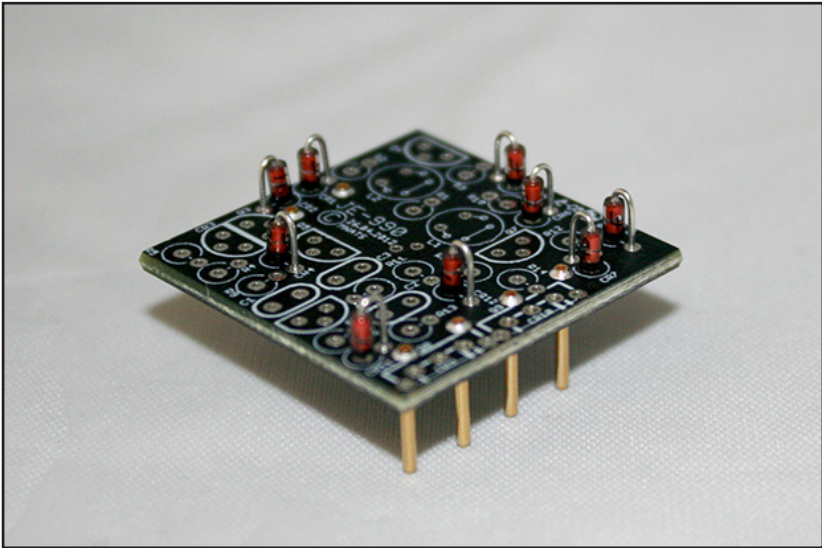
Note that the cathode side of the diodes are labeled with a black stripe. Bend the OPPOSITE lead back towards the body of the diode.



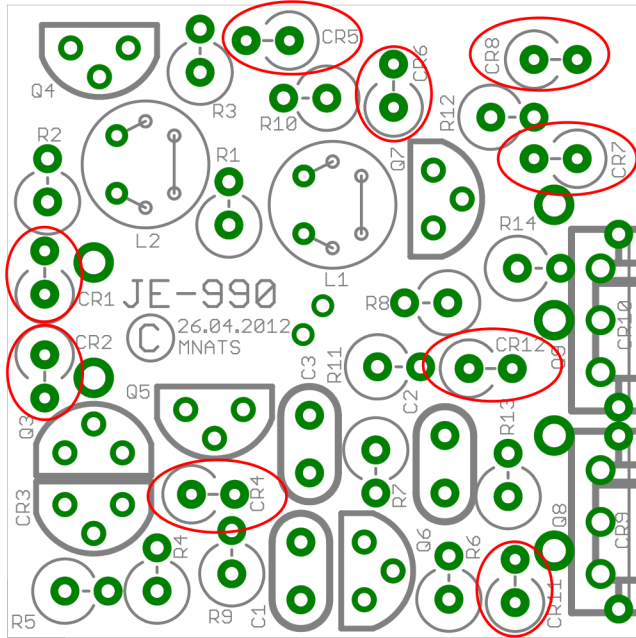
Diodes are POLARIZED devices. They must be mounted in the right direction. For the DIY-990 PCB all diodes are mounded so the cathode, the end with the black stripe, meets the side of the component footprint with the circle around the pad.



The next page shows where these diodes should be placed. When you're done you should have something that looks like the image below.

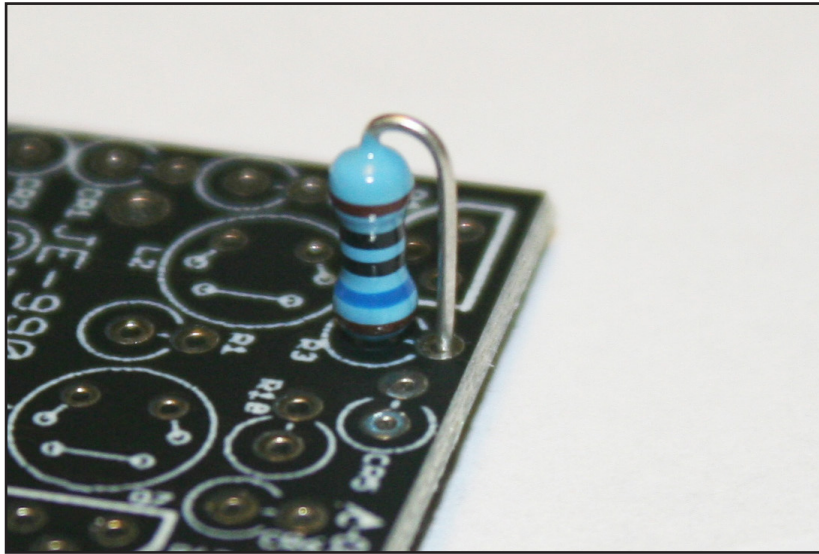


Diode Map

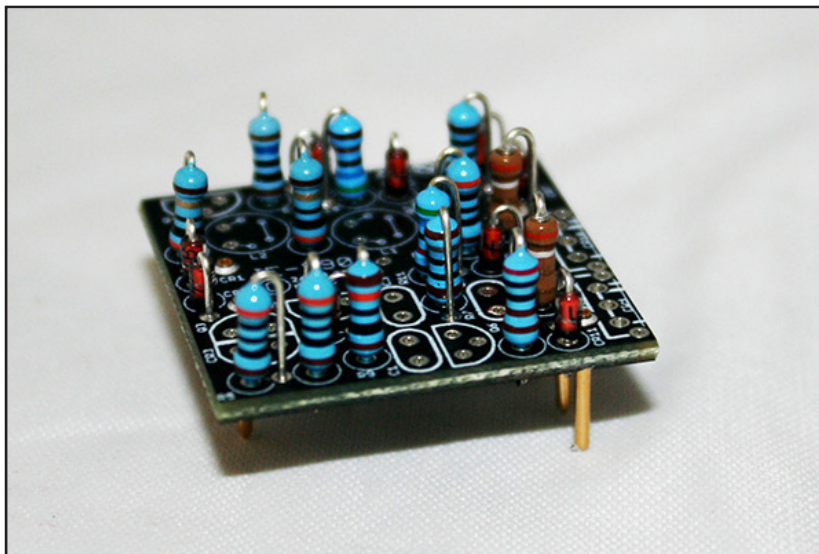


Resistors

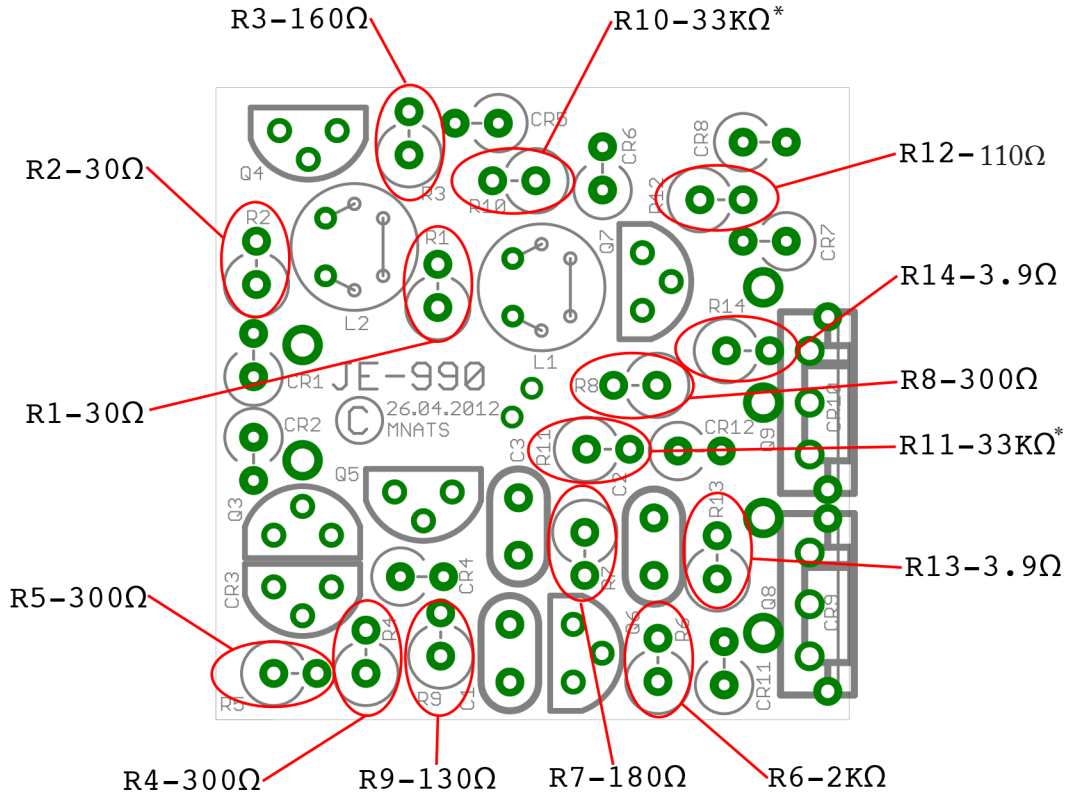
Next you'll install the 14 resistors. Check each resistor with a DMM and sort them using the sorting pages at the end of this document. Although the resistors are not polarized, to avoid leads touching and shorting, you should install them so that the body meets the side of the component footprint with the circle around the pad.



The next page shows where these resistors should be placed. When you're done you should have something that looks like the image below.



Resistor Map



*R10 and R11 are set for 15V/16V operation with resistances of 33K. For 24V operation use 62K Ω resistors for R10 and R11.

Capacitors

Next you'll install the three ceramic caps. These are non-polarized and can be installed in either direction. However, you must install the correct value in the proper place. Two of these values have been changed from the original Jensen paper to accommodate for modern value parts sourcing. The 91pF has been updated to 100pF and the 62pF to 68pF. These small change had no measurable effect.

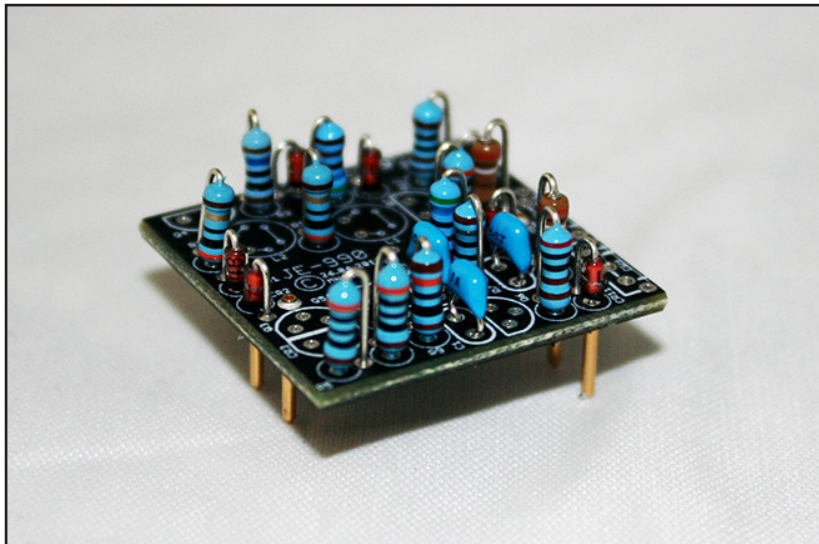
To determine the capacitor values look closely at the capacitor body. On one side you'll see numbers followed by the letter "J". The first two numbers set the value, the third sets the multiplier, and the J indicates a 5% tolerance. For the DIY-990 the values are as follows:

$$68J = 68\text{pF}$$

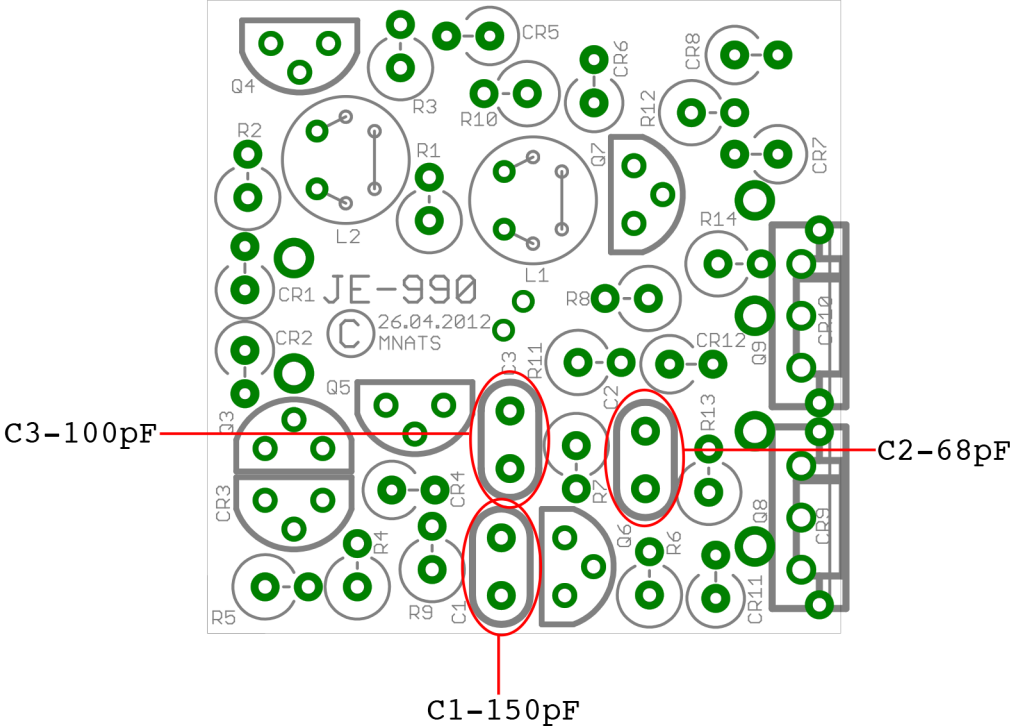
$$101J = 100\text{pF}$$

$$151J = 150\text{pF}$$

The next page shows where these capacitors should be placed. When you're done you should have something that looks like the image below.

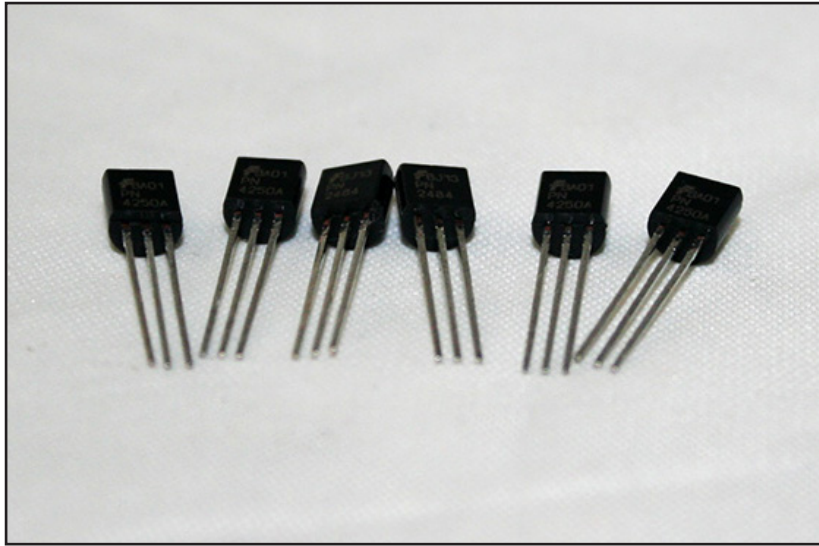


Capcitor Map

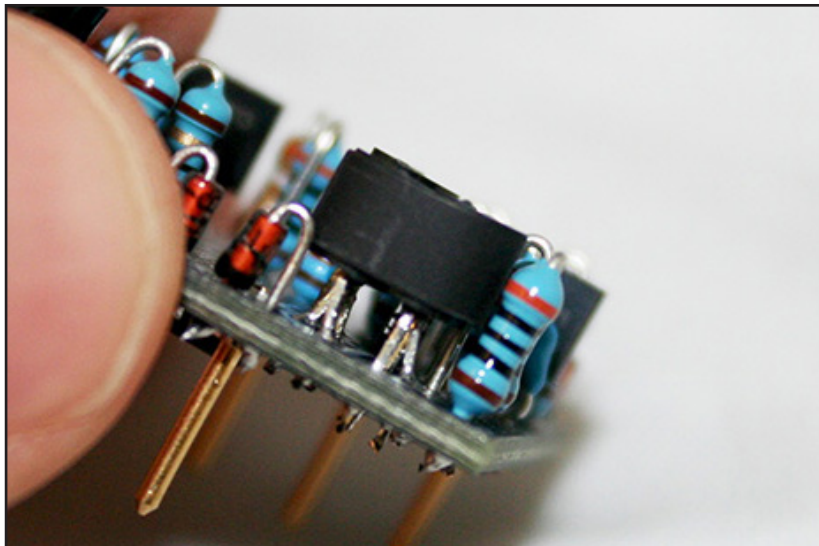


TO-92 Transistors

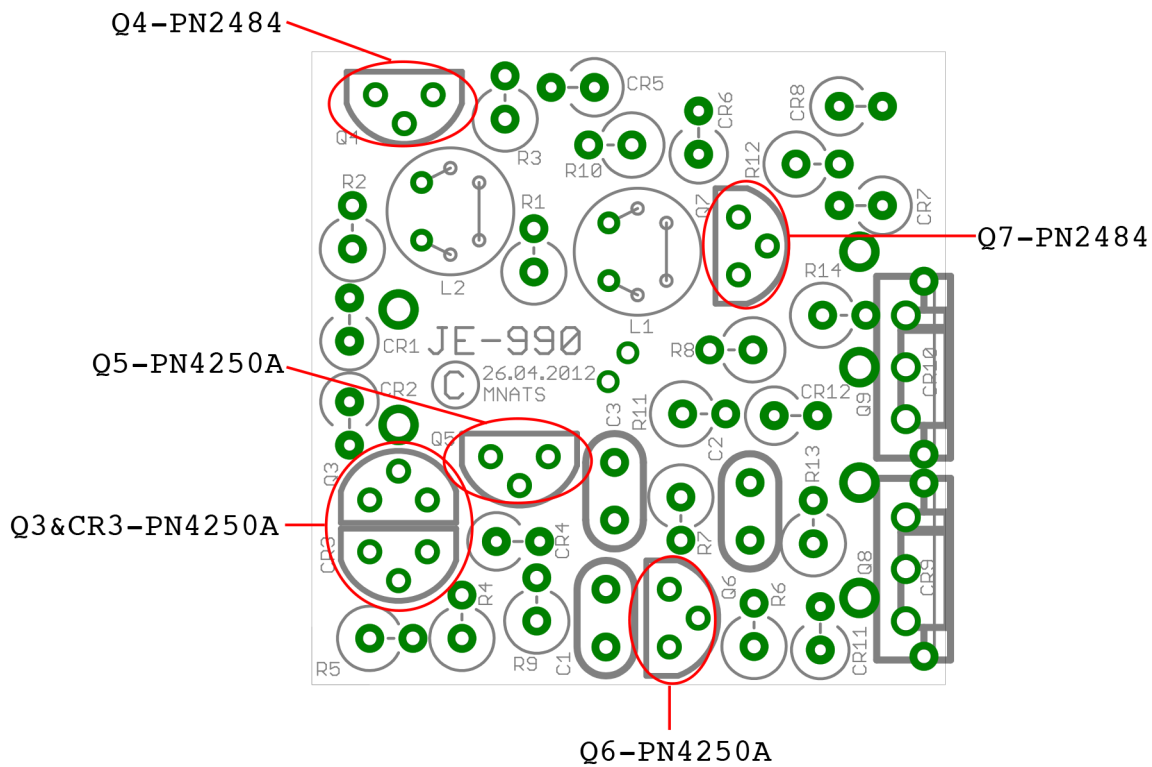
Next you'll install the TO-92 transistors. There are four PN250A and two PN2484 transistors. You can identify them by looking at the identification marks on the flat face of the body.



CR3, though a diode designation, is actually a PN4250A transistor connected as a diode. This allows us to bond the bodies of CR3 and Q3 for thermal coupling as instructed in the AES paper. Before installing these components place the supplied shrink wrap tubing over the transistors and shrink it with a heat gun or hair dryer. Be careful not to over heat and damage the transistors. You can add a bit of thermal adhesive if you like.



Transistor Map

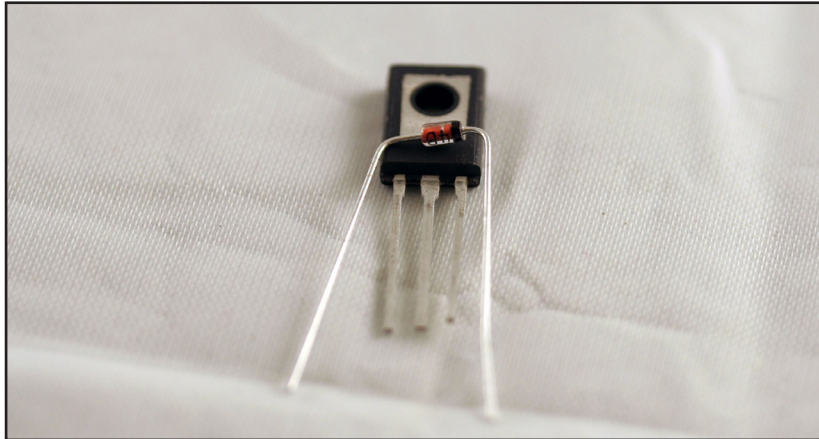


Output Transistors and Diodes

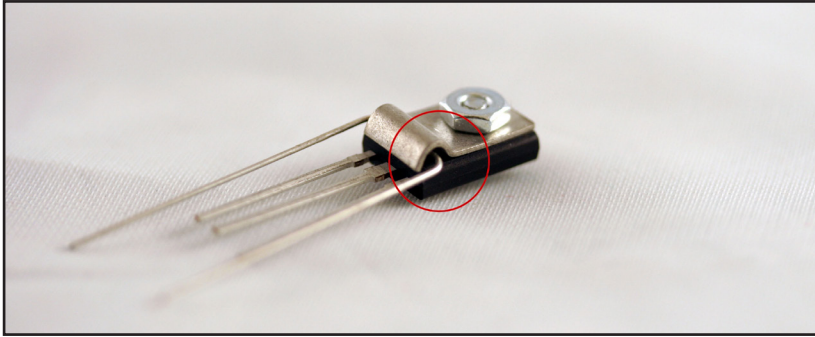
The TO-220 output transistors (Q8 & Q9) must have 1N914B diodes thermally coupled to their bodies to prevent distortion with low-impedance loads. This is achieved by using the supplied clamp. Looking at the PCB silkscreen you'll see that the cathode (black stripe) should be facing right when viewing the TO-220 transistors from the rear (side with metal tab). This is true for both the MJE171 and MJE181.

TWO IMPORTANT POINTS!!!

1. These transistors are not the identical. The transistor marked MJE171 is a PNP transistor and needs to be placed in the Q9 footprint and one marked MJE181 in an NPN transistor and needs to be placed in the Q8 footprint.
2. When you clip the diode to the transistor, ensure the diode leads are not touching the clamp or the diode may short across the metal clamp and not perform its function. You can use the transistor body as a jig for bending the diode leads.

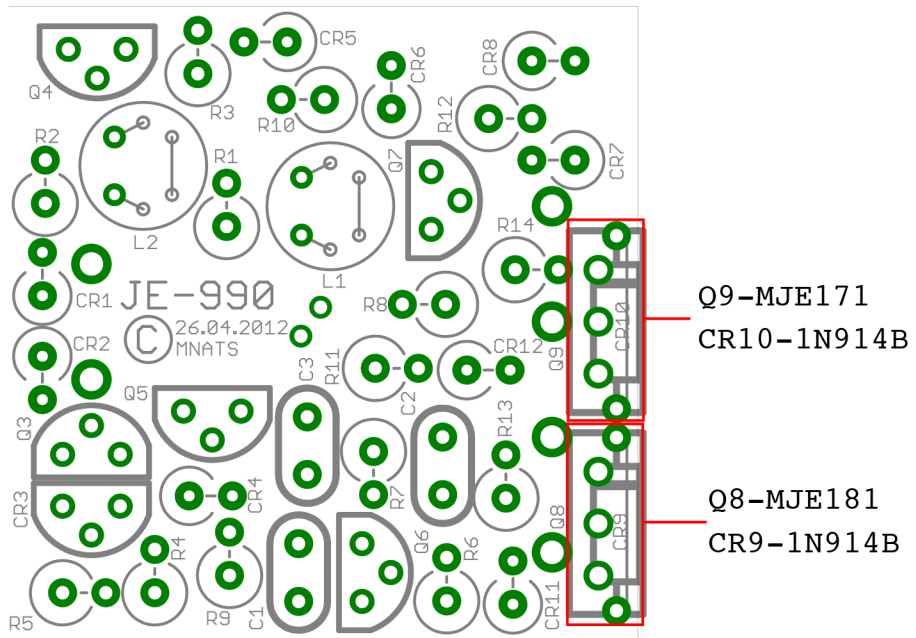


The bottom edge of the clamp wraps around the diode and extends just past the transistor mounting surface fitting snug to the transistor bottom. Center the clip, which should sit flush to the surface, and use the supplied #2 screw and nut to secure the clamp. You can add a bit of thermal adhesive if you like. The pads for the inner leads of each diode are very close on the PCB and may become bridged with solder or make contact. This is ok, they are connected on the circuit.



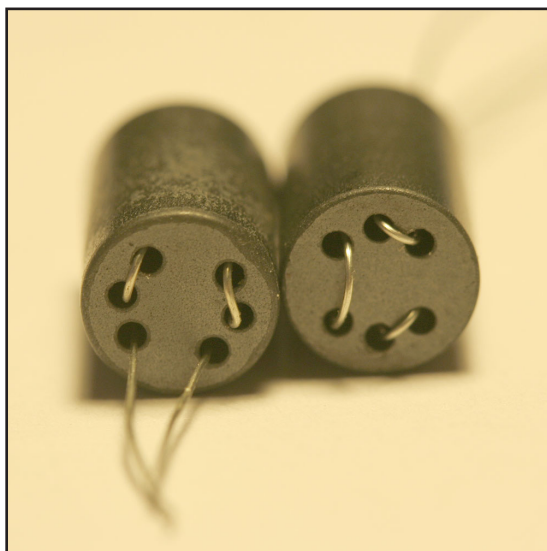
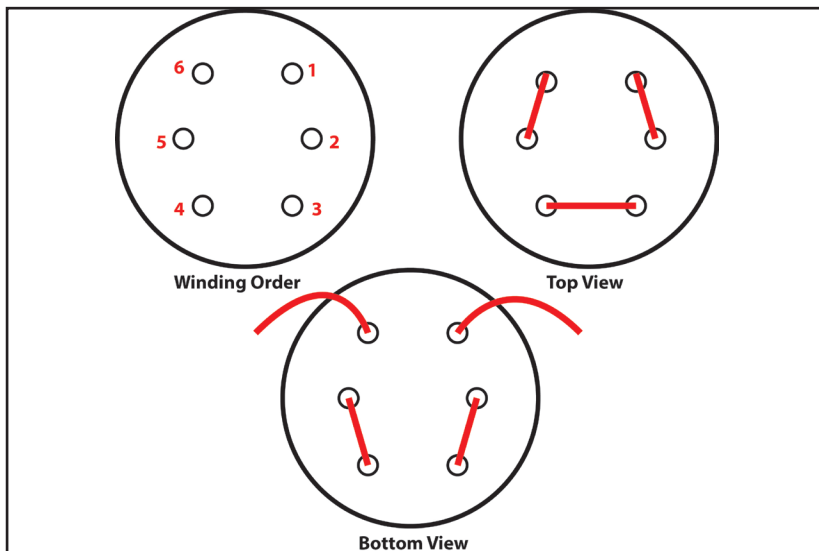
Note the red circle: The diode leg is clear of the clamp

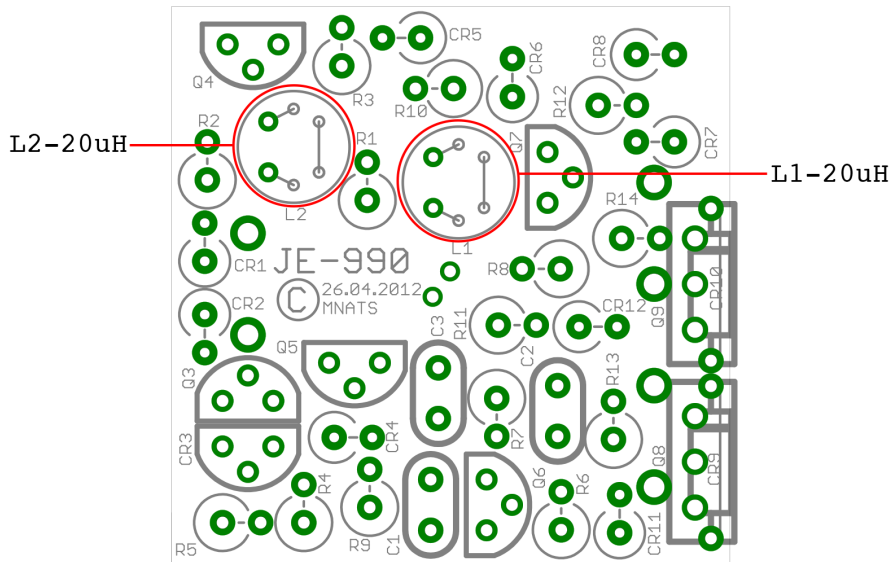
Output Transistor and Diode Map



Inductors

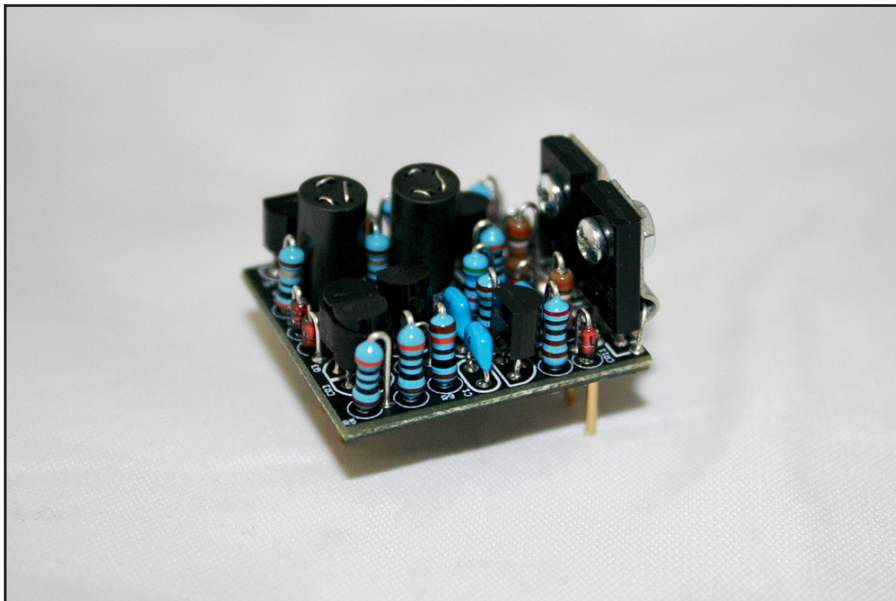
The two 20uH inductors are often missed in many 990 designs. Included are two Jensen inductors you will wind with the supplied 30 AWG wire as described in the AES paper. Once installed you can add some lacquer or nail polish to the top of the inductor to prevent wire corrosion. Winding is simple, there is no top or bottom side, just six holes in two rows of three. You can start at either end of the two rows, below I have started in the upper right. Cut about 8" of wire from your supplied spool then follow the numbers in order to complete the pattern. Pull the wire through slowly and try to avoid kinking or leaving it too loose. Do not pull too tight, or the wire will break. We've supplied some extra wire for just in case.





Final Thoughts

You're done! Congratulations, you've built a JE-990 to the specifications of the famous Jensen AES paper. All that's left is to insert it into your circuit or design a circuit around it. Be sure that the supply voltage is appropriate for the values of R10 and R11.



Resistors and Inductors Bag

Value	Name	QTY
3.9Ω	R13,R14	2

Value	Name	QTY
30Ω	R1,R2	2

Value	Name	QTY
110Ω	R12	1

Value	Name	QTY
130Ω	R9	1

Value	Name	QTY
160Ω	R3	1

Value	Name	QTY
180Ω	R7	1

Value	Name	QTY
300Ω	R4,R5,R8	3

Value	Name	QTY
2KΩ	R6	1

Value	Name	QTY
33KΩ	R10,R11	2

Value	Name	QTY
20uH	L1,L2	2

Diodes, Transistors and Capacitors Bag

Value	Type	QTY
1N194B	Diode	9

Value	Type	QTY
PN2484	Transistor	2

Value	Type	QTY
PN4250A	Transistors	4

Value	Type	QTY
68pF	Capacitor	1

Value	Type	QTY
100pF	Capacitor	1

Value	Type	QTY
150pF	Capacitor	1

Output Transistors, Diodes and Hardware

Value	Type	QTY
MJE171	Transistor	1

Value	Type	QTY
MJE181	Transistors	1

Value	Type	QTY
1N914B	Diode	2

Value	Type	QTY
-	Clamp	2

Value	Type	QTY
-	#2 Screw	2

Value	Type	QTY
-	#2 Nut	2

Value	Type	QTY
-	Shrink Tube	1

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