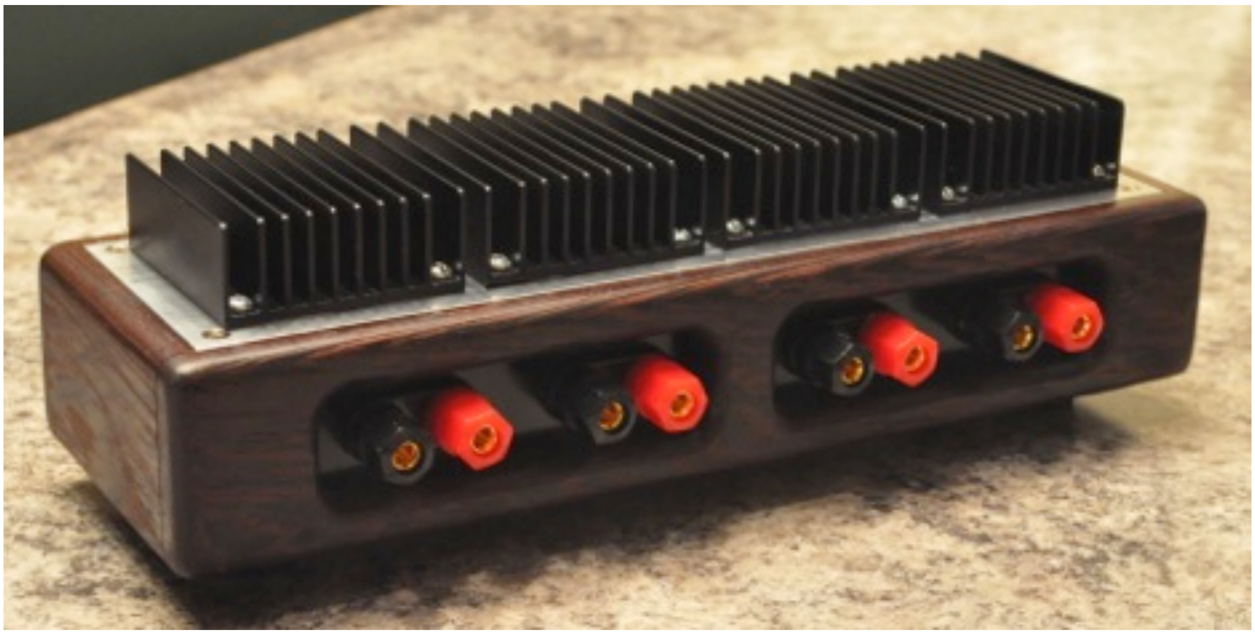
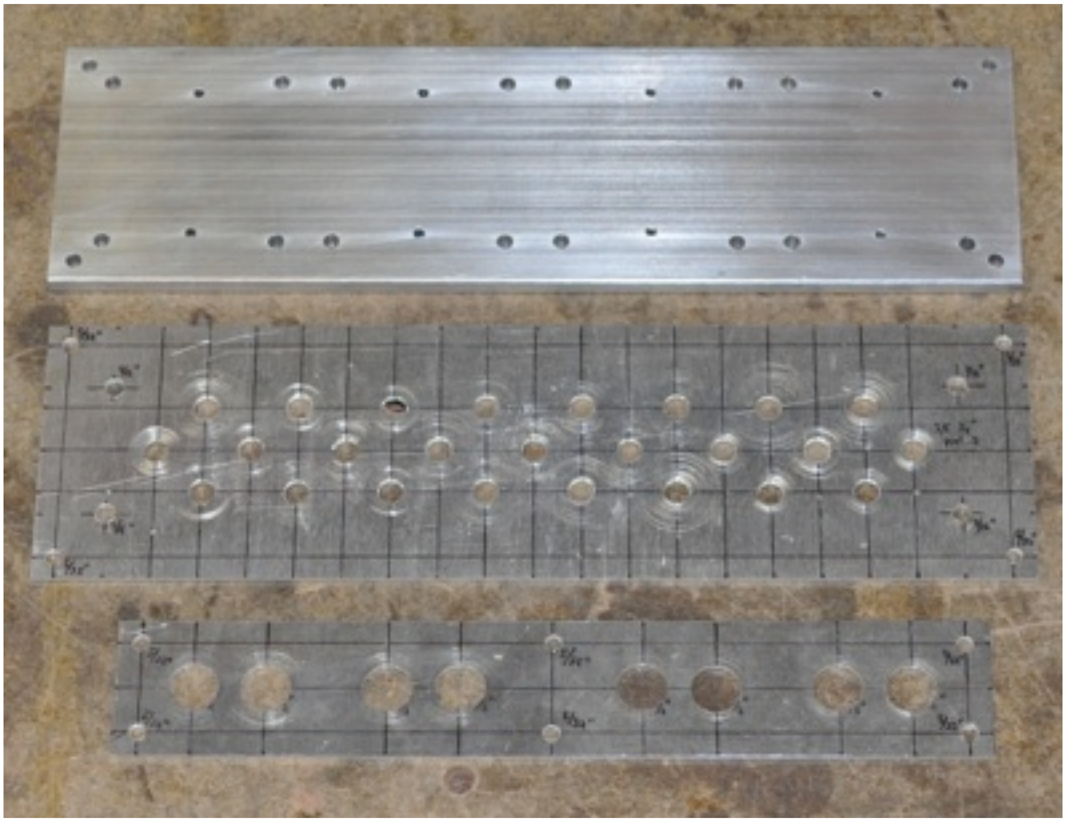
A Reconfigurable Speaker Load Box

Just because something *is* a piece of test equipment doesn't necessarily mean that it has to *look* like a piece of test equipment. This proposition is where I started with this particular project. I have a couple of amp projects in progress and was thinking forward to testing as I was putting the chassis together. In the past I've just wired some power resistors across the output terminals for testing and called it good. But, as I looked at a piece of heavy aluminum plate stock sitting on my workbench, I decided that I could do better; and make it look better at the same time. Thus was this project born.



Project Simplicity

Technically, there really isn't much to this project. It's just four 8Ω power resistors, four heat sinks, four connectors, some aluminum, four feet, and some wood. I chose four 8Ω channels because it gives some nice flexibility configuring the load. In a stereo configuration I can get 4Ω loads by paralleling two loads, or 8Ω loads as is, or 16Ω loads by series rigging two loads. In a monaural configuration I can also get 2Ω (all four loads in parallel), 6Ω (three loads in series, in parallel with remaining load) or 32Ω (all four loads in series). What could be simpler? The key here is materials and layout. The top plate is made from a piece of 1/4″ think, 3 inch wide plate aluminum cut to 10-1/2″ long. The nice thing about this stock is that it is thick enough to allow the power resistors to be mounted with 1/4″ long screws in tapped holes, and yet still allow the heat sinks to sit flush on top. Here is the aluminum cut to size, holes drilled, and resistor mounting holes tapped.



The main heat sink is sized for four VHS-95 Extruded heat sinks from V Infinity (www.v-infinity.com) on top and four TMC050 wire wound power resistors from Vishay (www.vishay.com) on the bottom. However, this was not my original configuration. Perhaps I should explain.

A Lesson in Power Resistor Rating and Derating

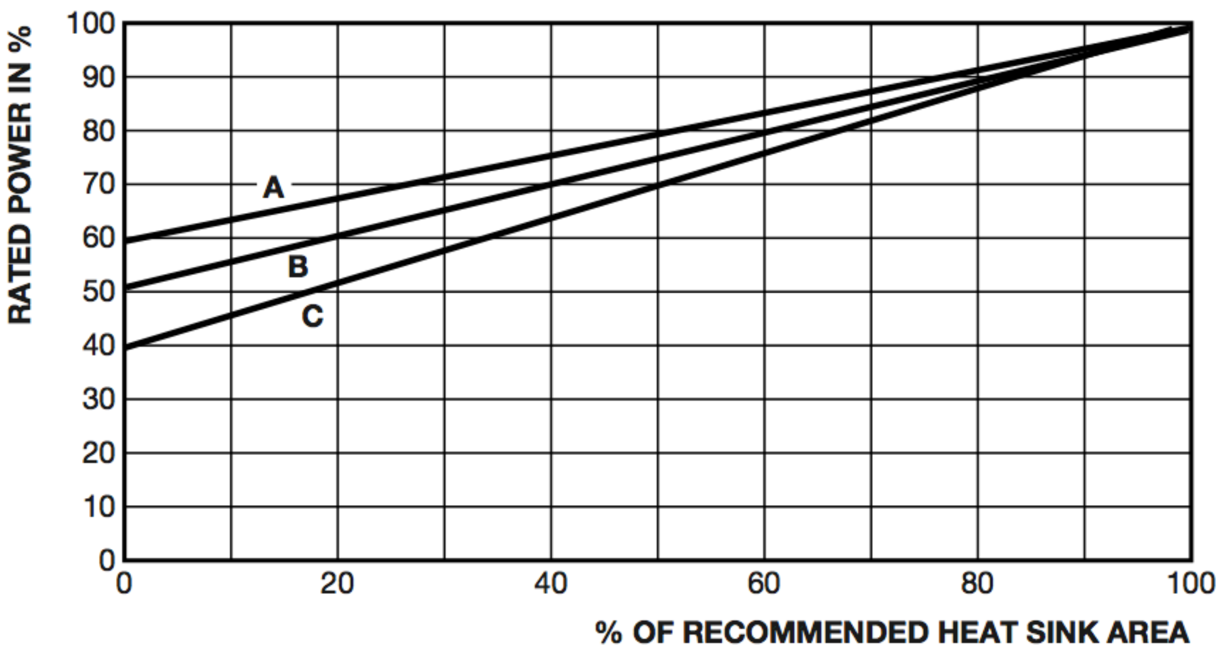
When sourcing parts for this unit, I really wanted to be able to dump significant power into the load. This being the case, I chose what I thought was a reasonable resistor; a chassis mount, wire wound power resistor with a “50W” rating. Here is how they look.

This appears to be a fairly significant resistor. My first though was to simply mount four of these to the heavy plate paint the top black and assemble the unit. Then I started to look at the resistor data sheet. I quickly discovered that a 50W power resistor is not always 50W. I found this interesting little note on the data sheet.

Vishay TMC resistor wattage ratings are based on mounting to the following heat sink:

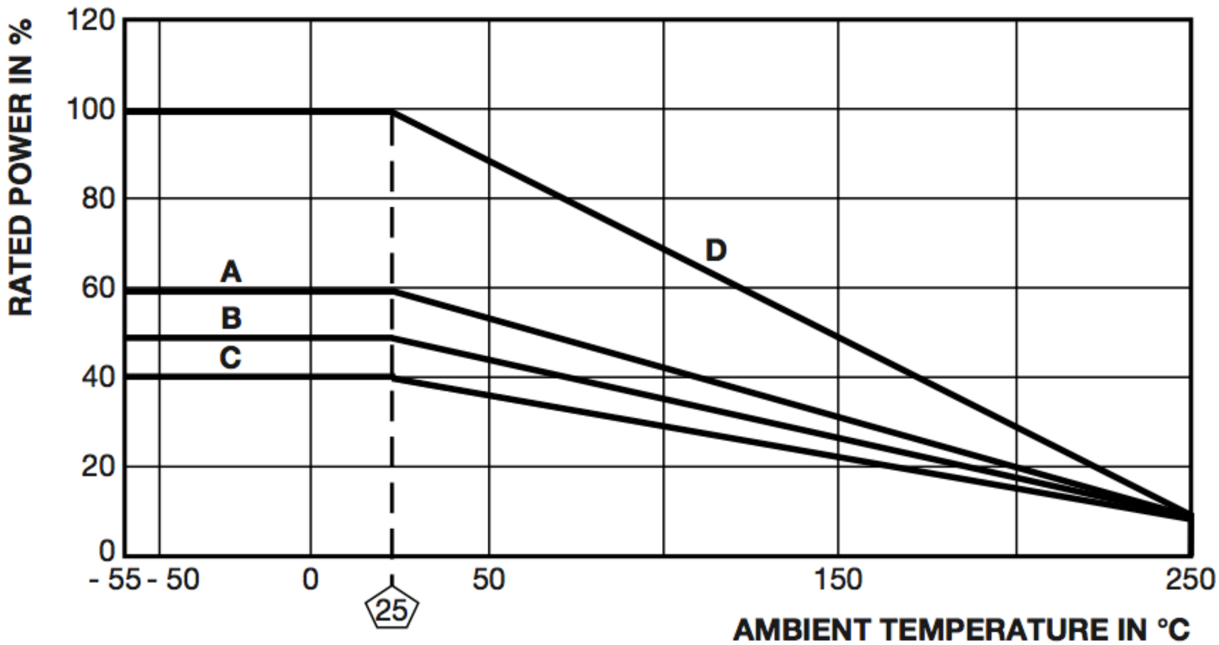
TMC005 and TMC010:	4" x 6" x 2" x 0.040" thick aluminum chassis (129 sq. in. surface area)
TMC025:	5" x 7" x 2" x 0.040" thick aluminum chassis (167 sq. in. surface area)
TMC050:	12" x 12" x 0.059" thick aluminum panel (291 sq. in. surface area)

So apparently my 50W resistor is only a 50W resistor when connected to a bare aluminum heat sink with a total surface area of 291 square inches. My heavy aluminum plate has a total surface area of 69.75 square inches. Divide 69.75 by 4 and you get 17.4 square inches per resistor. This is ≈6% of the required surface area. Looking at the derating for heat sink area we see that the real power rating is much lower than advertised.



The "C" curve is the one for the TMC50 series. We can quickly see that at 6% of heat sink area the real power rating is only about 44% or ≈22W. This is not much better than leaving the power resistor unmounted in open air. If I only used two of the four loads, I can assume 12% of the required heat sink area. However, this only is still only about 47% or ≈23.5W.

Reading further I discovered that the power rating (with the heat sink) only applied up to 25°C (77°F). At any higher temperature, the resistor power rating was even lower. I wanted to be able to use the load box in some fairly warm conditions. Here is the published derating curve for ambient temperature.



I decided that a reasonable upper limit for ambient temperature operation (remembering that the inside of the load box could also become quite warm) was 50°C (122°F). From the derating curve ("D" is for heat sink mounted resistors) this equates to ≈88%. So now with everything together, my 50W resistors are really rated (or I should say derated) at 50W x 0.88 x 0.44 ≈ 19.3W. Clearly more heat sink surface area was needed if I want to get anywhere near the advertised resistor power rating. This is when I started to search around on the internet and found these small finned heat sinks designed for switching power supplies.

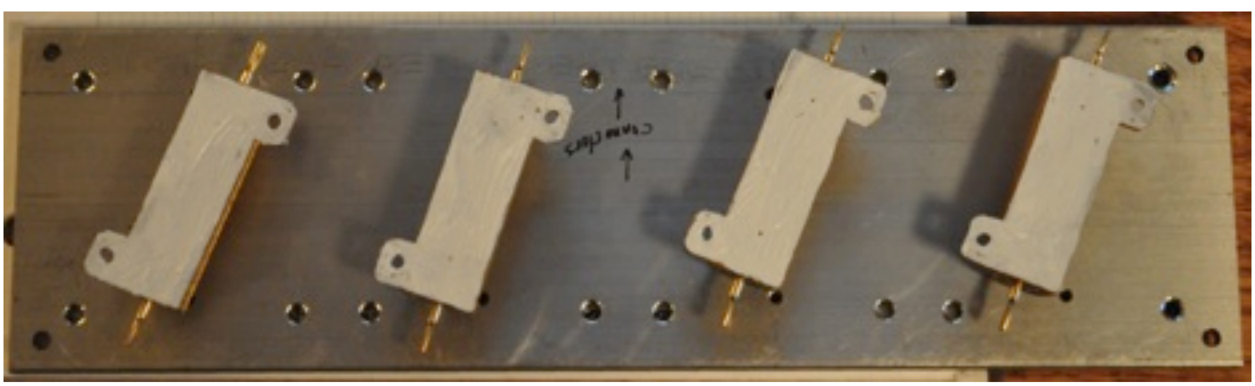
These little heat sinks are 2.28” x 2.4” x 0.94” so four of them fit nicely on top of the unit. I decided that I would position one above each power resistor. A little calculation based on the drawing in the data sheet shows that this heat sink has a total surface area of 52.36 square inches. I was sure that these would make a big difference.

Going back to the derating curve I found that this is still only ≈18% of the recommend surface area for a derating of ≈51%. This raises the total allowed power per load to 50W x 0.88 x 0.51 ≈ 22.4W. A pathetic increase of 3.1W. Now, if only two of the loads are used, this raises the heats sink area to ≈36% and the max power to ≈27.3W (50W x 0.88 x 0.62 ≈ 27.3W). This is better, but still not in the neighborhood of the numbers for which I was looking. The interesting thing is that using two loads in parallel (4Ω configuration) or two loads is series (16Ω configuration) raises the total power per channel to 44.8W. But in each case it takes two resistors to get to that power level.

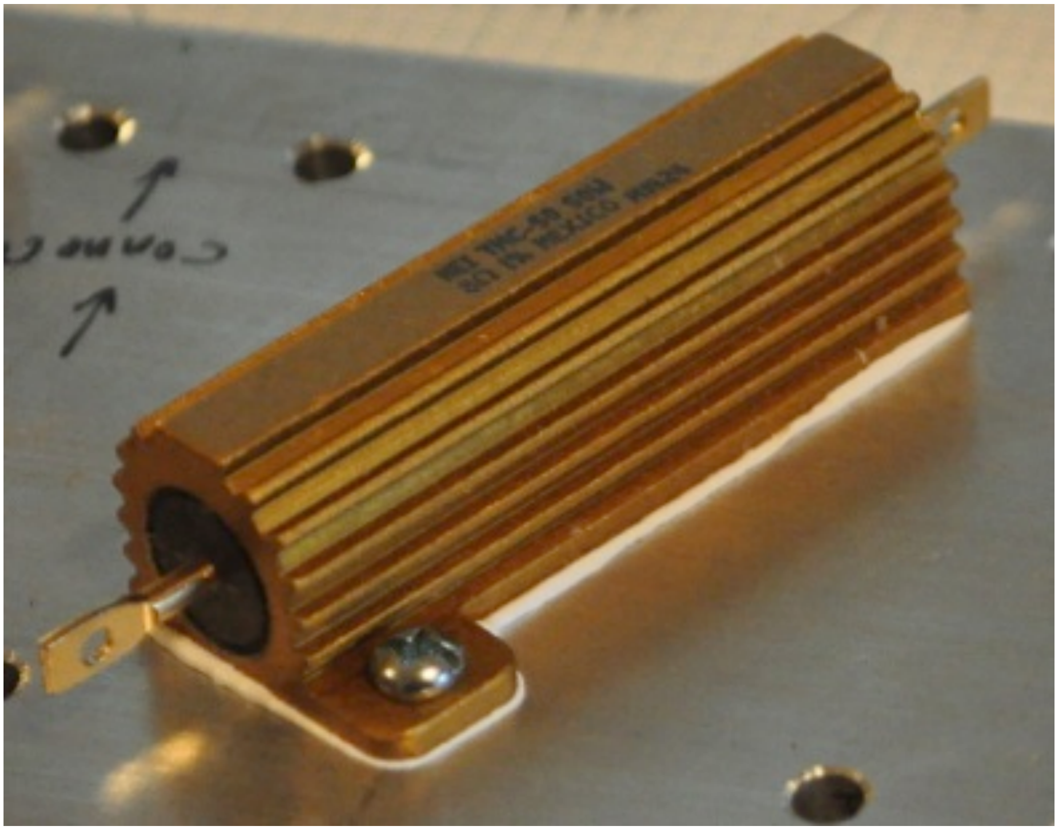
Frankly I was expecting these heat sinks to provide a much larger boost than they did. I assumed that with all that fin area, I would get a significant boost in resistor rating. With some air movement across the fins, it appears that the heat sinks become much more efficient at dumping heat. Unfortunately, the heat sink data sheet ratings are given in thermal resistance to ambient (°C/W) vs. air flow velocity (LFM). This makes accurate calculations particularly problematic since we don’t have max element temperature ratings and thermal resistances for the resistor cases. I guess that I’ll have to live with the fact that the load is really only 22W/channel. This has been a lesson on chassis mount power resistors which I won’t soon forget.

Heat Sink Assembly

So moving forward, disappointed but wiser, I grabbed some thermal heat sink compound and went to work. I decided to leave the upper plate bare so as to minimize any thermal resistance between the resistors and heat sinks. I started by applying a thin even coating of thermal compound to the power resistor bases.

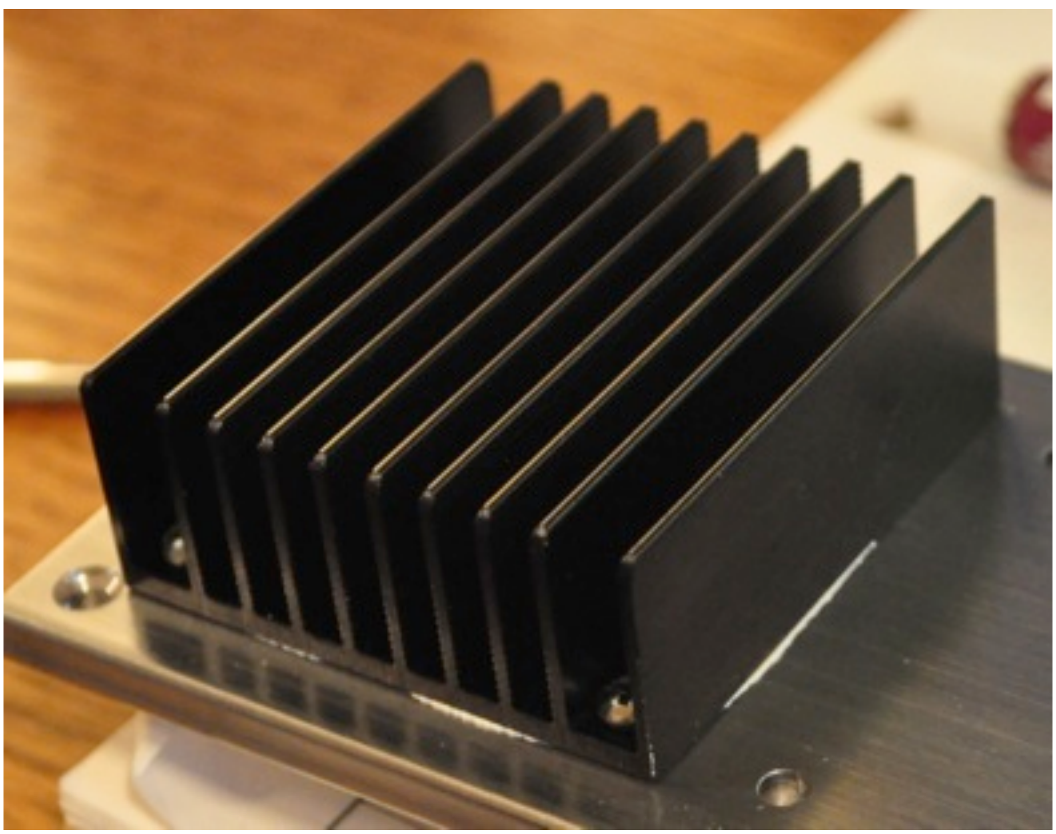


These are going to be in the case so a little squeeze out is acceptable. The object is to get just enough thermal grease on the surfaces to ensure that there are no unfilled voids between the two assemblies. When the screws holding the resistors are tightened, any excess grease will squeeze out the sides. Here is a picture showing the squeeze out around a mounted resistor.



This is just about the right amount of squeeze out you want to achieve. Once the four resistors were mounted I went to work on the heat sinks. When Applying grease to these units I intentionally held back from the edges by about 1/8th of an inch. This is because I did not want an excessive amount of squeeze out to have to clean from the top. Here is how I applied the thermal grease to the heat sinks.

This is good for minimizing the squeeze out and still getting good coverage. When the heat sinks were mounted, the squeeze out looked like this.

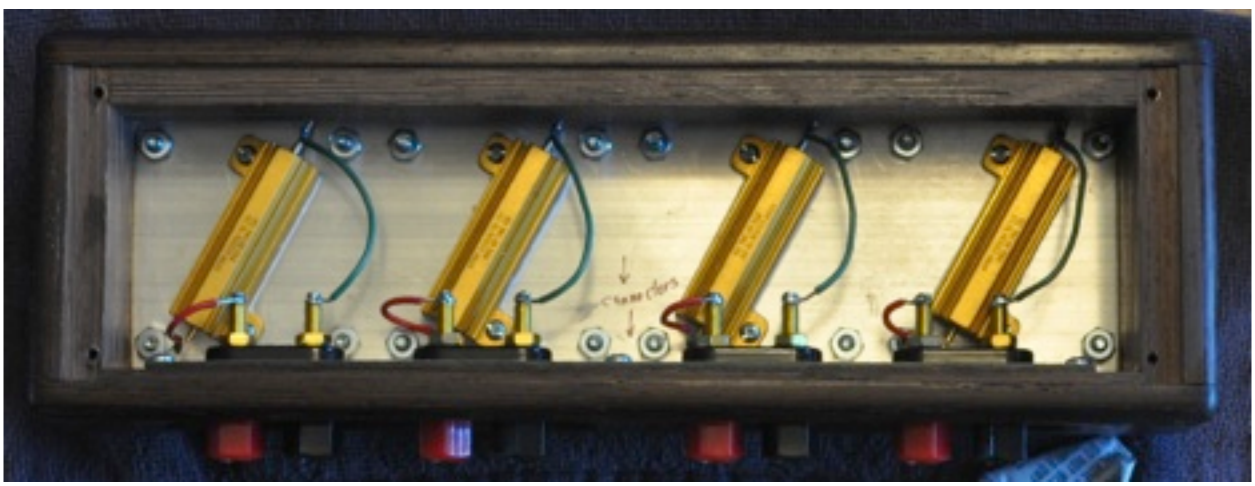


There was additional squeeze out for a day or so as the pressurized thermal grease made it's way to the edges of the heat sink. This resulted in a good thermal bond. Here is a picture of the entire "heat sink unit" all assembled showing both sides.

Here the heat sinks are on the top of the plate; held in place by four 6-32 screws for each. The power resistors are mounted to the underside, one under each heat sink, with 1/4″ 4-40 screws into tapped holes. This configuration assures a good short thermal path between the power resistors and the heats sinks.

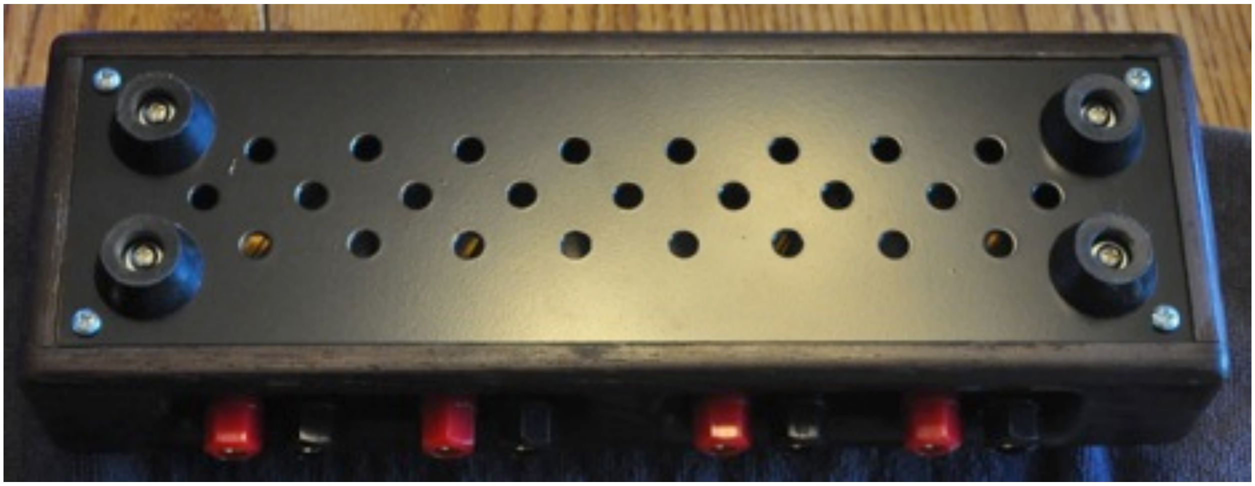
Final Assembly

The wiring is inside just a s simple as the heat sink. Just eight wires to connect the four load resistors to the four connectors. Here is a picture of the internal wiring.



As can be seen from the wiring, each load is completely independent. This means that testing stereo amplifiers with global feed back (where feed back may be from either side of the output transformer depending on the number and type of amplifier stages) will not be an issue.

One more important thing to remember is that the derating of the resistors is dependent on the ambient temperature *where the resistors and heat sinks are located*. This means that it is critical to vent the enclosure to help prevent heat build up. Here is a picture of the underside showing the venting holes.



These 25 holes are the equivalent of a 1.2 square inch hole in the base plate. This should be more then sufficient to keep it from getting too hot inside the chassis.

The Final Result

It was not the most complicated or difficult thing I’ve ever built, however I am pleased with the results. The chassis was made from a scrap of 3/4″ thick African Wenge wood with a couple of coats of oil applied and polished. With the very dark wood, the black heat sinks, and the accent of polished aluminum on top, I think it looks pretty good. In addition, I happened to learn something about the ratings of some power resistors and the true effects of heat sinks on those resistors.

Overall this little unit is a great success. At about 3.25” high, 11.25” long, and 4” deep it’s nice and compact and looks great sitting on my bench. After all the machinations, it may only be rated for 22.4W per channel but this should suffice for continuous output pure tone testing on all but the biggest of tube amps. This simple little unit will give me years and years of service on my test bench. And it will never look like something I just cobbled together.