A First-Rate Audio Test Instrument

Part 2: *Construction*

Back

Part 2 of this series completes the trio, adding a super-versatile dummy load to your bench.

By Todd Sharp

With modifications to the sine-wave generator, voltmeter, and respective power supplies completed, it's now time to strip the HP 353a patch panel down to its birthday suit, give it a facelift, and replace its insides with a selectable impedance dummy load (**Photo 1**). Actually, it's much more than a simple dummy load. In addition to providing various load options, you can also add a few other features and a simple attenuator network. Depending on how you set the switches (S1 and S2), you may select the following load options: shorted, open, 4Ω (400W), 8Ω (200W), 16Ω (400W), speaker only.

The 4, 8, 16Ω positions also route the device under test (DUT) signal through a simple attenuator (R9 and R10), which feeds the external speaker jack (J2). You supply the speaker. This provides a "listen through the load" function so that you may load your DUT at high power into its rated load while listening through to the speaker that you have attached to the speaker jack. You can adjust the speaker level (R10) to suit.

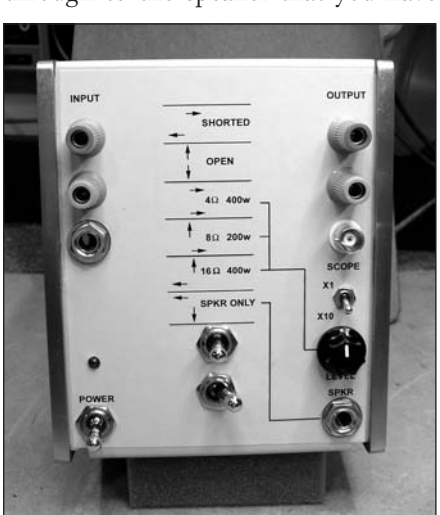


PHOTO 1: Load box front.

This feature offers a negligible amount of error to the actual load impedance, but if you care to modify the pot as I have done, when fully counterclockwise (CCW), it is virtually out of the circuit and introduces no error while also providing a silent mode. You must open up the pot and remove the wafer. With a sharp knife, cut a small separation in the carbon deposited film as shown in **Photo 2**. This opens the circuit when the pot is all the way down and thus lifts the speaker connection completely.

PHOTO 2: Minor pot surgery.

The attenuated signal presented to your speaker will contain a little distortion, but then this function doesn't require high fidelity. This is very handy for troubleshooting the intermittent and "it only cuts out after it's been on a while" kind of troubles as you can listen to, as well as view, high power signals through the load without blowing your head off. This is a virtual 400W signal tracer—at reasonable ear volume.

The other features are: input connections (BP2, BP4, J1), AC voltmeter output terminals (BP1, BP3), and a scope output BNC connector with a built-in ×10 attenuator (SW3, R11, C1). In the SPKR ONLY position, the DUT bypasses straight through to your connected speaker while still offering AC voltmeter and scope monitoring. Be careful with this setting if you are running signal through the dummy load at high power and suddenly switch to SPKR ONLY. If you want to see the cat jump 18′ sideways, this does the trick. Of course, it could also blow your speaker!

Monitoring high power waveforms with your oscilloscope normally requires an attenuator probe, because this signal will exceed the limit of your scope's input. This is commonly called ×10 because when you read your scope's Volts/Div you need to mentally multiply by 10 for the true reading. I built in the ×10 function so that you can simply attach a BNC jumper cable between the load box and your oscilloscope—no probes necessary.

Another feature provided for is a ×10 high frequency compensation adjust (C1). In practice I rarely use my scope for such accuracy of measurement when viewing audio waveforms, but more for an overall picture and easy indicator of waveform distortions. This is what the RMS ACVM is all about and why such a piece is included in the set. The 403b offers a more accurate indication of level, not to mention a dB reference for frequency response measurements. You can also make simple power measurements with the set by applying the power formula: V^2/R (RMS voltage squared (times itself) divided by R (Rload in ohms) = average power.

Note that Ra and Rb are shown as 8Ω 200W resistors. You are actually going to construct these two separate 8Ω 200W resistor networks by wiring up four 8Ω 50W (R1-R4) and (R5-R8) resistors in series/parallel (**Fig. 2**).

FAN CIRCUIT

Finally, you add a fan to dissipate heat. Even though the load resistors have heat fins and are mounted on finned aluminum heatsinks, this does end up being a tightly packed little box with virtually no air flow—so add a tiny but useful 12V fan to pull the heat out and away.

The fan is controlled by a simple temp sensor LM35DT (IC1) powered by a nifty little 12V switching supply (PS Module). You could go to greater lengths with more sensitive circuitry, but this simple circuit does the job just fine.

As with the 204c, I added a power switch (SW4) to the front panel (FP) for this supply along with an LED (CR1). This LED has two functions: it provides a constant load to the 12V supply, while showing on/off status. Past experiences have taught me never to turn on a switching supply without a load attached. Perhaps you have also learned much about electronics by blowing things up! Anyhow, I used a green LED that draws about 25mA. The fan kicks in when the resistors reach about 100˚ F (**Fig. 2**).

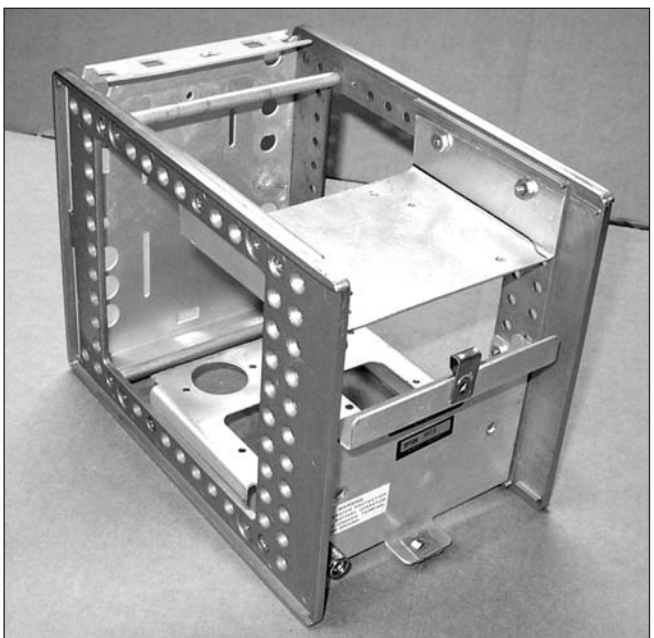


PHOTO 3: Stripped chassis showing bracket location.

CONSTRUCTION

Start by completely disassembling your 353a—taking notice of how it comes apart so you can put it back together later! The only electronic parts you are going to salvage here are the binding posts—that is, if your 353 comes with binding posts. I have noticed that some have TT type jacks instead. We built two of these here at our shop, and found it necessary to accommodate a slightly different front panel layout for the two different (binding post vs TT jack) types. I have made both panel layouts available in pdf form to print on sticker paper for

the cosmetically conscious.

You will also be taking care to isolate every connector in and out of the load box from chassis ground to alleviate grounding complications. These little HP boxes, which are actually quite friendly to work with, come apart and go back together almost like erector sets. There are multiple holes to run your screws through so that you might move the inner brackets and support bars wherever you want them to be.

The picture that you are looking at in **Photo 3**, for the sake of clarity shows an upside-down view of the frame of the load box. This takes advantage of the existing panel holes and puts the fan and heated components at the top of the enclosure where the heat will collect. I promise this will make more sense to you later when you put it all back together.

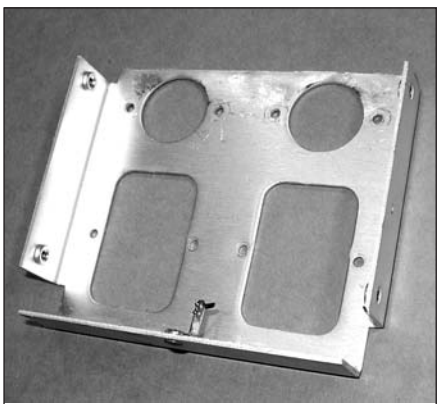


PHOTO 4: Bracket after cut.

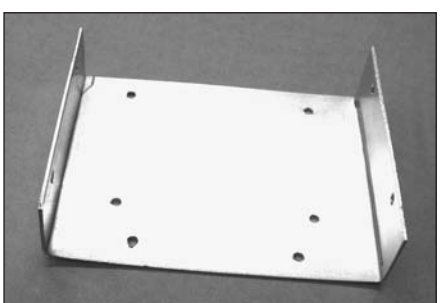


PHOTO 5: Fan supply and temperature sensor circuit mounting bracket.

RESISTOR/HEATSINK MOUNTING BRACKET

Locate the aluminum bracket with the four transformers mounted to it. This will become your resistor/heatsink mounting bracket. Start by removing the transformers, wiring harnesses, and the terminal strip. You will then need to cut one piece off this bracket (**Photo 5**).

The folded edge that had the terminal strip mounted to it and the wiring harnesses going through it must go—in order to make room for some structural changes. The opposite edge with the ground tab remains. A standard hacksaw will do just fine. A bench vise would also come in handy as well as a flat file to smooth edges (**Photo 4**).

FAN SUPPLY AND TEMP SENSOR CIRCUIT MOUNTING BRACKET

You will need to fabricate an additional mounting plate to accommodate your power supply and temp sensing circuitry (**Photo 5**). I made this with some 1/16″ aluminum sheet.

I made cuts with a hacksaw and smoothed edges with a flat file. The cut piece measures 7.0″ × 3.5″. Mark off a line at exactly 1.25″ from each edge (the 7″ length) and initiate a 90° fold at each line. This should end up being a 4.5″ × 3.5″ plate with a 1.25″ "ear" at each end of the 4.5″ length.

If you are not accustomed to working metal like this, it is much easier than you might think. 1⁄16″ aluminum is very easy to cut, drill, and fold with a standard 3″ shop vise by locking the jaws down just a smidge below where you want the fold to break and simply bending it over the top of the vise. Use the resistor/heatsink bracket as a sizing template. Repeat for the other side and you're done, except for the various screw holes you will need to drill for affixing to the HP side rails. Wedge your mounting bracket into place and mark off screw holes for mounting to the side rails. Affix with 6⁄32 hardware.

The next step involves fixing the switching supply board to the bracket you just made. If you are using the Cincon board from Mouser, then you will need to figure how to mount it.

For some reason they manufacture these open frame supply boards without any screw holes or brackets for mounting, and there is no room on the board to drill mount holes. There are simply four turrets sticking out of the bottom that happen to be the input and output connections. I stuck these through a 3.25″ × 2.5″ piece of vector perfboard, and soldered solid wire wraps to the bottom side and then ran them to push in style micro clips (**Photo 6**).

This not only breaks out the in/out points to convenient wiring clips, but it

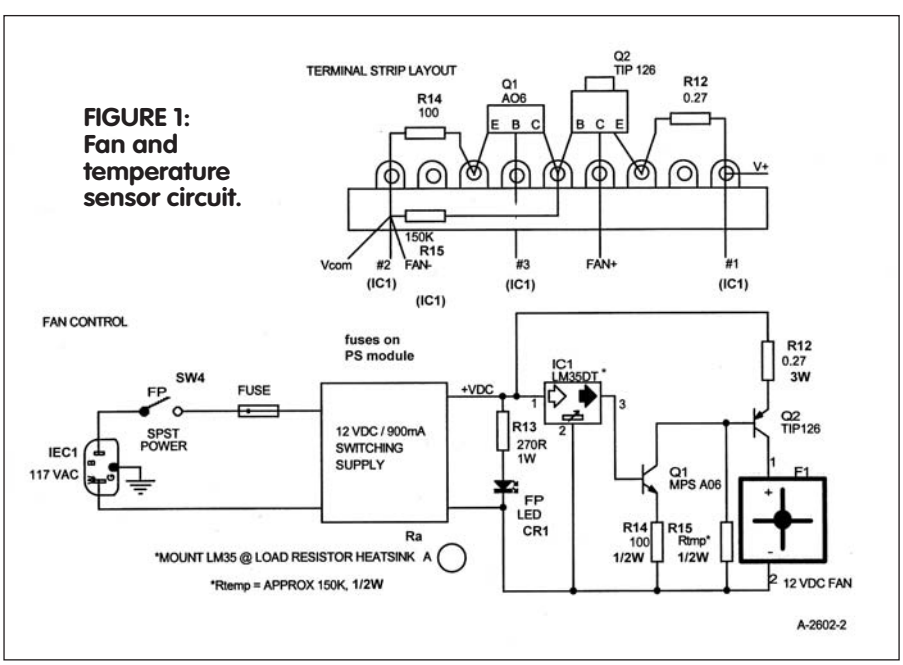


FIGURE 1: Fan and temperature sensor circuit.

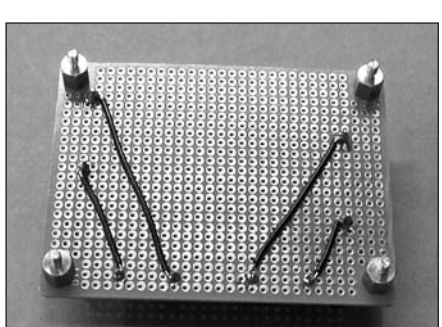


PHOTO 6: Board with wire wraps.

also provides a sturdy mounting to the perfboard, which does have screw holes! Use four 4/40 (0.25″ height) standoffs to mount this board to the bracket. Place your board over the bracket and mark off where you want the screws to come through to mate to the standoffs. Drill these mounting holes and mount your standoffs.

Next mark screw holes for your terminal strip and mount that using 6/32 hardware (**Photo 7**). Wire up the components as shown in **Fig. 1**.

FAN AND IEC CONNECTOR CUTOUT

Next, grab the rear panel section. If you don't own a 3″ circular chassis punch, then you must figure out a way to draw a 3″ diameter hole centered in the back panel as shown in **Photo 8**. Be sure to allow room for the IEC plug in the next step. Drill, cut, file, and cuss your way to a fairly neat 3″ hole. Mark off screw holes, drill and mount the 60mm fan—taking care to note which way the air will flow. You want to pull hot air out of the box, not pull crud *into* the box.

I drilled out four mount holes but used only three screws. I used the remaining hole to run the fan wires through. Take the fan out and set it aside for the moment.

The next trick is to mount an IEC connector next to the fan. Mark off a semi-rectangle to accommodate the IEC connector. Drill and file your way to a suitable rectangle. Mark and drill out the two screw holes to affix the connector to the panel. Use 6/32 hardware.

Attach a 12″ length of black wire (#20 stranded) to the hot terminal of the AC connector and a 9″ length of white (#20 stranded) wire to the neutral terminal of the AC connector. Be sure to insulate these connections with heat-shrink tubing. Attach a 4″ green (#18 wire) to the middle ground terminal and insulate as well. The black wire will go to your front panel power switch, the white to one of the AC inputs on the power supply board, and the green to the chassis tab underneath your heatsinks.

Notice how you attach the heatsinks to the mounting bracket. If you wedge 6/32 screws in at just the right place in the heat fins, you can use already existing mounting holes (**Photo 9**).

Notice the little 90° bracket added at approximately the center of the flat side of the heatsink for stability. You will need to drill and thread a 4/40 screw hole for this bracket. Read ahead a bit further for tips on tapping the heatsink for 4/40 threaded screws. Once you have the heatsink mounting figured out, remove the heatsinks from the bracket and lay out four of the 8Ω 50W resistors on each to see how they will fit.

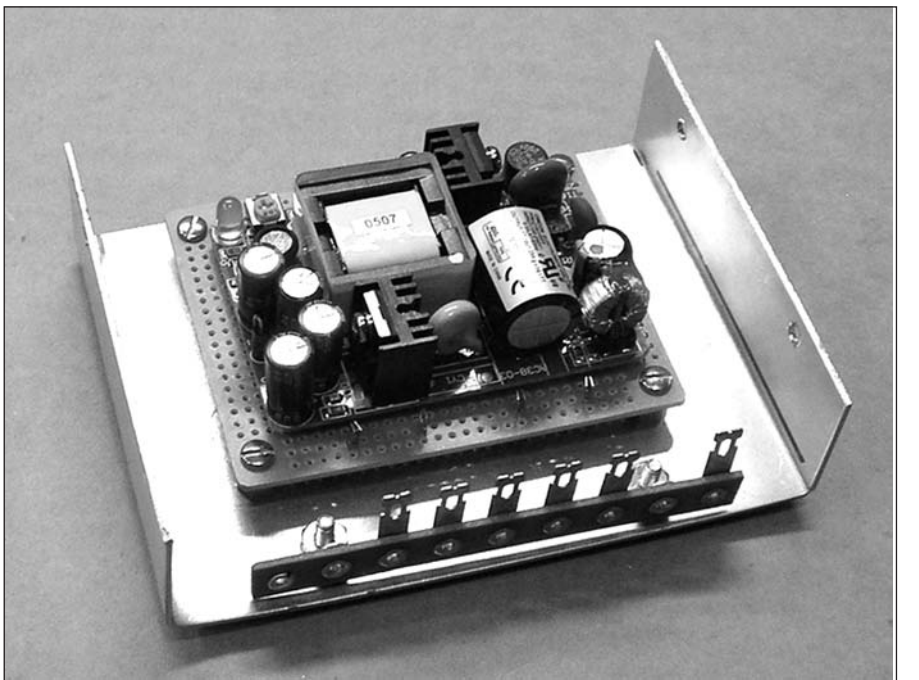


PHOTO 7: Mounting board to bracket.

MOUNT RESISTORS TO HEATSINKS

You will make up two resistor network blocks, Ra and Rb, each consisting of four 8Ω 50W resistors wired in series parallel. Refer to **Fig. 2**. Notice that Ra and Rb are indicated on the schematic as 8Ω 200W resistors. See **Photo 10** for mounting layout.

Note that these particular heatsinks have a few nubs protruding. You can work around them if you place the finned resistors just right. Place the resistors and mark screw holes. Take extra care to mark, center punch, and drill your holes in exactly the right places. Drill your screw holes with a 7⁄64 drill bit.

Once you have the holes drilled, insert a 4⁄40 threading tap and tap the holes. Use caution here and use some cutting oil. A tapping die bit will snap off mid turn if you force it even a little when it wants to stop. If you feel it resist, back up a little to clear the cut thread and try again until it continues to cut thread with as little force as possible. The items you need, along with a tap "T" handle, should be available at any good hardware store. Buy an extra 4⁄40 tapping bit in case you break the first bit (**Photo 9**).

Mount the resistors on the heatsinks, four on each using 4⁄40 screws. Apply some thermal grease before mounting. Wire the resistors together, but just tack-solder the ends, where you will later attach hookup wires. I used #16 solid to join the resistors.

The LM35 sensor (TO220 type package) will need to go down first, underneath the joined connection of one of the resistor network blocks. Note how the sensor is located on the right resistor block with its legs pointed out. This will be your "8Ω" load resistor.

Notice on the schematic that the 4 and 16Ω settings use both resistor networks (400W), while the 8Ω setting uses only one block (200W). Make sure

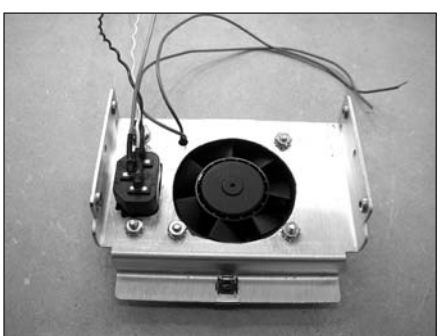


PHOTO 8: 3˝ cutout.

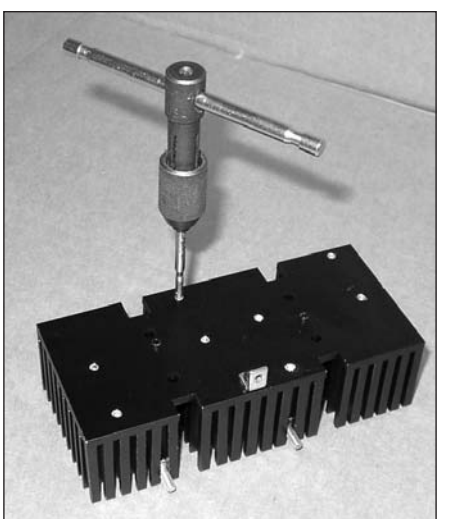


PHOTO 9: Attaching heatsinks to the mounting bracket.

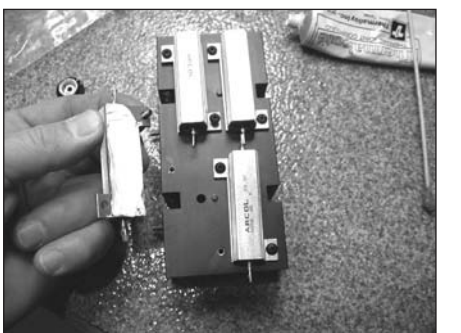


PHOTO 10: Mounting resistors to heatsink.

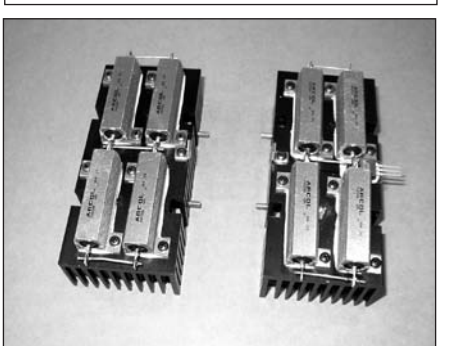
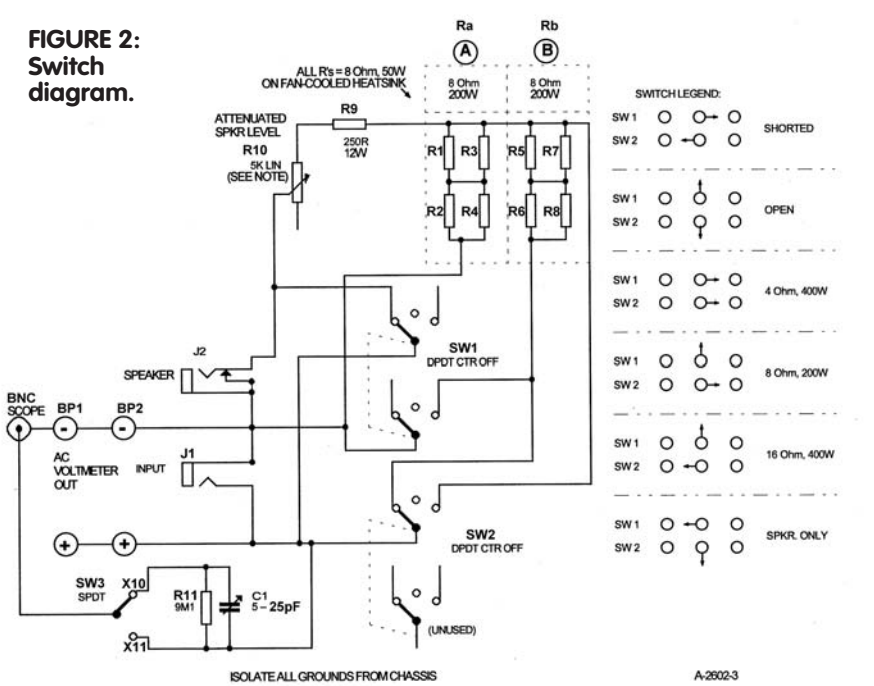


PHOTO 11: Load resistor.

PHOTO 12: Chassis bracket.

FIGURE 2: Switch diagram.



that the one with the sensor is your 8Ω load resistor (**Photo 10**). Use the same drill and tap materials for the LM35 temp sensor mounting. Use a mica insulator, insulated shoulder washer, and thermal compound.

Once you have affixed the eight resistors and the LM35 sensor to the heatsinks (**Photo 11**), you can mount them to the chassis bracket (**Photo 12**).

X10 TRIM ADJUST CAP

Affix the ×10 hf trimmer cap (C1) to side rail. You will need to drill additional mounting holes in the side rail (**Photo 13**) and then countersink the screw heads with a slightly larger diameter drill bit in order to affix your adjustable trimmer in place. Attach two leads about 3″ in length and let them dangle until you get ready to wire up the front panel. Make sure the trimmer is isolated from the chassis. Drill an access hole in the side cover later for easy adjustment access.

FRONT PANEL

Once you have the front panel disassembled completely, download and print out a plain paper copy of the front panel template layout and use this to line up and center-punch the "X" points for the three new holes you'll be drilling in the front panel according to the template designations. Trim this print out and apply a little transparent tape to hold it in place. As far as I know, there are two types of HP 353a patch panels: one with binding post in and outs, and the other with TT type patch plugs. Use this layout for the binding post type: www.amprepair.com/LBfrontpanelBP.zip. Use this for the TT style: http://www.amprepair.com/LBfrontpanelTT.zip.

Drill small pilot holes and then your final-size holes. The SW1 and SW2 holes below the legend need to be ½″, the X1/X10 SW hole ¼″, and the speaker jack and power switch holes must be widened to ½″. When all your holes are drilled and de-burred, sand it down to get the old lettering off (3M nylon dish scouring pad works well).

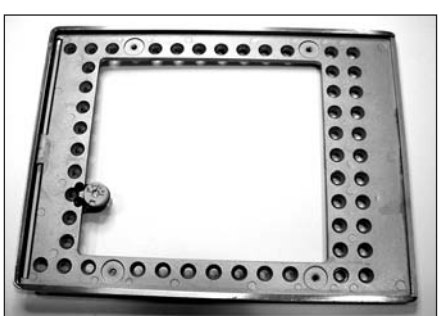


PHOTO 13: Trimmer cap mounting.

Once all the front panel work is done, print out the panel pdf again on sticker paper such as Avery #3383. Tip: let the ink set on the printed paper for about an hour before applying to your panel. Line up your front panel print and cut to size with a sharp razor and straight edge and apply to your front panel.

Put a protective piece of paper or backing material over your panel sticker to burnish down to the face plate, making sure it's free of bubbles or ripples, trim around each hole where needed with an X-acto knife (**Photo 14**). Test all your "fittings." When you are satisfied everything is just right, apply a coat of polyurethane spray. I recommend about three coats.

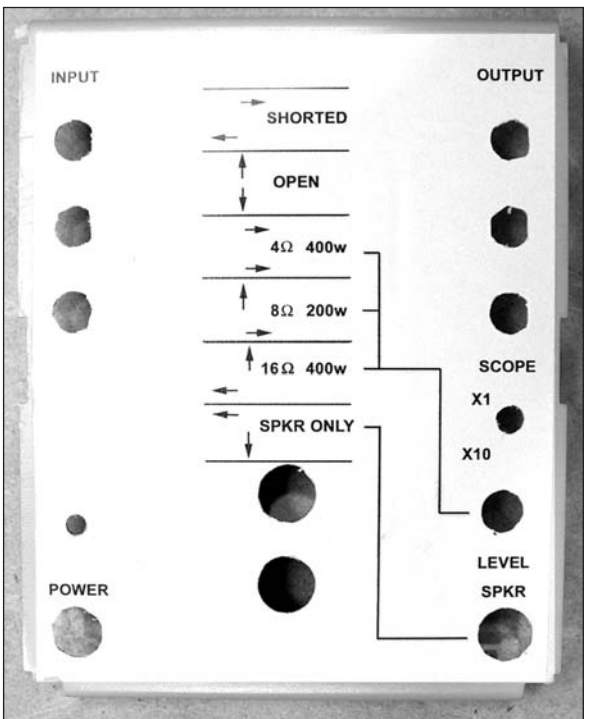


PHOTO 14: Front panel layout.

Another tip: don't try to cover the panel with thick coats—thin applications and more of them always look best.

You should let the final coat of polyurethane set up for 24 hours before assembling. I cut my front sticker so that it just covers the front and does not fold over the top or bottom, nor does it extend on to the outer tabs that snap in to the side supports. I figured this way the panel would fit better, hold up better, and stay flat and clean looking. Now that you have the cutting, drilling, and mounting done, it is time to mount components on the front panel and wire it up.

Don't over-torque your front panel nuts. The sticker label looks nice, but it is really a poor man's silk screen and it will wrinkle if you torque too hard. I recommend that you use the heaviest gauge wire that you can work with for the load hookups. I think #16 stranded should be fine, but #14 would be better. I wired one up with #12 stranded wire (a noble attempt), but found it to be just too big and bulky in such a small space. You will appreciate the flexibility of stranded wire, which will allow you to easily pull the front panel away for ease of wireup. Leave about 2˝ slack for front panel pull-away room.

Check the SW1 and SW2 switch contacts with an ohmmeter before you wire them up. I have seen certain types "make" in the same position as the bat, and others work the opposite. If you use the part specified for SW1 and SW2, they should "make" opposite to the bat position.

Wire up the front panel components as shown in **Fig. 2**. Heavy wire is not needed for the scope connections. All connections in and out of the unit should be isolated from the chassis and ground. Use the specified fiber and shoulder washers where needed.

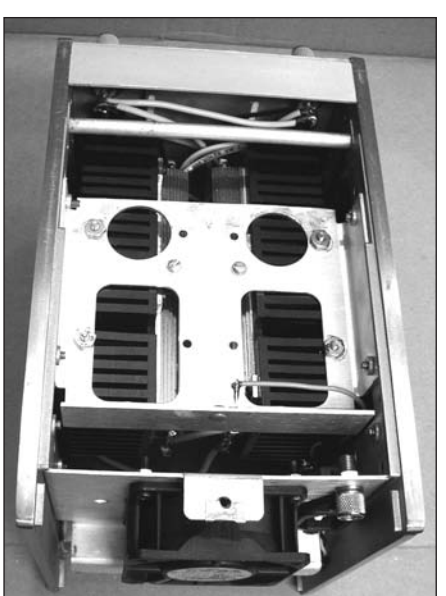


PHOTO 15: Assembly (top view).

FINAL ASSEMBLY

Finger-tight-assemble all the components in place while leaving the side, top, and bottom covers off. Attach an ohmmeter to either set of binding posts and verify that you have everything wired up right—that the SW1 and SW2 positioning matches the front panel legend. Check that the speaker only connects to the speaker jack correctly, and so on.

If everything looks good, proceed

AUDIO LOAD PARTS SOURCES

Component	Description	Source	Part Number	Quantity
Resistors				
R1-R8	8Ω 50W aluminum resistor	Mouser	284-HS50-8.0F	8
R9	250R 12W resistor	Digi-Key	B12J250_ND	1
R10	5K CTS pot	Digi-Key	CT 2158-ND	1
R11	9M1 1W pot	Mouser	294-9.1M	1
R12	.27R 3W resistor	Mouser	71-CPF3-G-0.27	1
R13	270R 1W resistor	Mouser	294-270	1
R14	100R 1/2W resistor	Mouser	660-CF1/2L 101J	1
R15	150K 1/2W (Rtemp) (see text)	Mouser	660-CF1/2L 154J	1
C1	Trimmer cap (5-25pF)	Electronic Goldmine	G9371	1
Connectors				
J1, J2	Switchcraft 11	Mouser	502-11	2
	Shoulder washer	Mouser	534-3069	12
	Fiber washer	Mouser	534-3222	12
BNC	BNC connector (isolated sleeve)	Mouser	571-227726-2	1
BP1, BP2	Binding post (Blk) (if needed)	Mouser	530-111-0103-1	2
BP3, BP4	Binding post (Red) (if needed)	Mouser	530-111-0102-1	2
Switches				
SW1, SW2	Carling DPDT ON-OFF-ON	Mouser	691-2GM51-73	2
SW3	Alco SPDT mini toggle	Mouser	506-A101SYZQ	1
SW4	Carling SPST power switch	Mouser	691-110-73	1
Semiconductors				
Q1	MPS A06	Digi-Key	MPSA06-ND	1
Q2	Tip 126 pnp Darlington	Digi-Key	TIP126OS-ND	1
CR1	LED	Digi-Key	160-1504-ND	1
IC1	LM 35DT temp sensor	Digi-Key	LM35DT-ND	1
Fan & Power Supply				
PS module	12V DC switching supply	Mouser	418-CFM1002S	1
IEC1	IEC connector	Mouser	161-0707-1	1
Line cord cable	IEC power cord (90° angle)	Mouser	686-17536	1
	12V DC 2.5W fan 60 × 25mm	Electronic Goldmine	G13229	1 [1]
	Fan guard	Digi-Key	CR 221-ND	1
Misc				
HP 353A patch panel (part of HP 3550B test set, see text)				1
8 point terminal strip		Mouser	58-1008	1
Heatsinks (HS 10198)		Electronic Goldmine	G 2209	2 [2]
Vector board				
Vector T-42 push in terminals				
Hardware				
Heatsink (TO220) kit		Mouser	534-4724	1
4/40 standoffs for power supply PC mounting		Mouser	534-8714	4
A handful of 4/40 hardware & a 4/40 tap set for mounting power resistors to heatsink				
A handful of 6/32 hardware (screws, nuts, lockwashers). Thermal compound.				
1– *Alternate fan source*		Digi-Key	P-9995-ND	1

2– *approx 4.75˝ L × 2.25˝ W × 1.25˝ D finned aluminum heatsink. A similar sized .5˝ slab of aluminum will work sufficiently. The author has a fair quantity of these heatsinks if the listed source is out of stock. Email me at* www.amprepair.com.

Mouser	*www.mouser.com*	800-346-6873
Digi-Key	*www.digikey.com*	800-344-4539
Electronic Goldmine	*www.goldmine-elec.com*	800-445-0697

to check the 12V supply and fan operation. Make sure the LED is attached before you turn on the power switch. You will need to heat up the load resistor sensor in order to verify that the temp sensing circuit is functioning properly. You can do this with a heat gun or maybe a hair dryer or, of course, you could hook an amp up at 8Ω and run a sine wave into it till the 8Ω load resistor becomes hot. The sensor should kick the fan in at about 100° F. Adjust Rtemp (R15) to tweak the threshold if you need to (typically 100k to 150k).

If the fan circuitry is working right, then it is time to check the other functions. Attach an 8Ω 100W (or whatever you prefer) speaker to the speaker jack (J2). Check the speaker-only function. Next place the load setting to the appropriate position for your DUT, apply a signal to the input (BP2, BP4, J1), and check the attenuator through to speaker function.

Hook up the AC voltmeter and scope. Check that these connections are functioning properly.

The ×1 scope setting passes the signal at the input straight to the scope, while the ×10 divides the input signal to the scope by a factor of 10. Line up the side panel on the right side. Mark off and drill a 5⁄16 hole so the trimmer cap may be accessed. Tighten down all your screws; install the top, bottom, and both side panels before adjusting high-frequency compensation.

The high-frequency compensation trimmer is most easily set by viewing a 10V peak to peak 1kHz square wave: square-wave generator straight into the load box, load box set to "open" scope switch (SW3) at ×1, with your scope attached and set to 2V per div. Observe that the square wave is flat. Without touching the square-wave generator, flip the switch (SW3) to ×10 and change your scope's Vdiv to .2V per division. Adjust the trimmer cap for a flat square wave. A nonconductive adjustment tool works best for this. Note that the placement of the wires attached to the trimmer cap will affect this adjustment.

If you don't have a square wave, use the 204c sine generator; establish the same reference 10V p-p level as above at 1kHz. Without touching the 204c amplitude setting, change SW3 to the x10 setting and change the scope input to .2V per division. Sweep from 1kHz to 20kHz while adjusting trimmer (C1) for a flat response. Repeat this procedure any time you change BNC cable or oscilloscope.

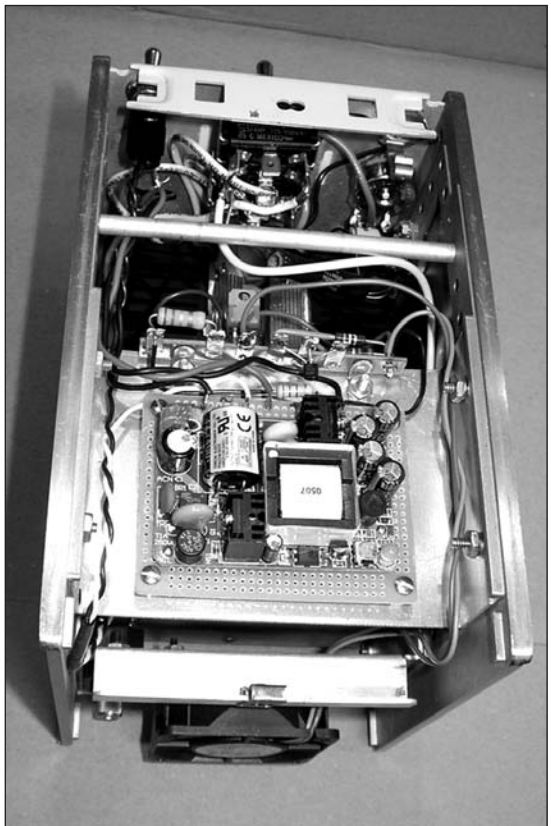


PHOTO 16: Assembly (bottom).

PHOTO 17: Fan vent cutout.

INTO THE CARRY CASE

You could, of course, install these three components on your bench separately or mount the load box back into the carry case. You will need to access the wiring to the existing IEC inlet on the steel carry case and attach the additional AC cord (line cord) 90° angle type IEC plug for the load box.

Measure off where the fan will want to vent at the back of the steel case. I planted the load box in the center, so in my unit this turned out to be 9⅜″ from the right side and 8⁹⁄₁₆″ from the left side, 2⅞″ from the top, and 4¾″ from the bottom. All these measurements direct you to the center point of the fan and are made with the unit sitting on its

PHOTO 18: Completed rear view.

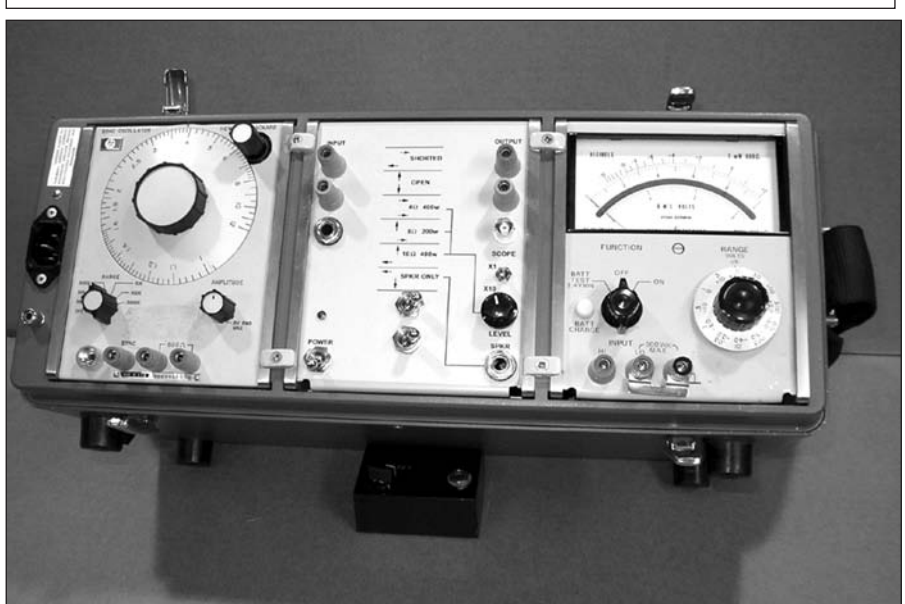


PHOTO 19: Completed restored unit.

face. This is the kind of thing that you definitely want to measure six times and cut once (**Photo 17**).

Did I say steel case? Again, if you are the proud owner of a 3˝ circular chassis punch, you may now throw your head back and laugh out loud at how easy this 3˝ hole is going to be.

The less fortunate will now prepare for a workout regimen of drilling, filing, cussing, breaking a few metal coping saw blades, and so on. As you can see, I placed a protective fan guard over the cutout.

A few final words about using this or any "dummy load": It is generally not a good idea to run a sine wave, or any other constant amplitude waveform, into a loaded amplifier at high power for extended periods. In other words, don't let your 100W amp sit there burning an 85W sine wave into your dummy load for an hour, to see how well it will hold up. The reason is that the average amplifier's power transformer will in time likely overheat when reproducing a constant amplitude signal such as from a waveform generator.

It is best to "burn in" an output-loaded amp with a fluctuating input source such as a radio or music CD. When using such fluctuating input source, by all means test the amp at high power for extended periods—after all, that would be what an amp is supposed to do. There are exceptions to this statement (industrial- and laboratory-grade amplifiers), and you may generally identify them by their massive power transformers. AC grounding note: to avoid ground loops and other gremlins, I always ground the DUT and lift all the external test equipment grounds.

I am sure you will find this set to be an extremely useful multifunctional test, troubleshooting, and evaluation tool (**Photo 19**). I would like to thank Mr. Thorpe McKenzie for providing the impetus for this project and article. Submit any comments you may have to the letters column in *aX*. Thanks and happy building. *aX*