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TM50x Power Module Tester

I designed the CAL-69A module tester after encountering an obstacle at work with our old TM501 power module. The tester is designed to detect weak filter capacitors and degraded or failed power transistors.

Photo 1: The front panel controls for my CAL-69A power module tester include a power supply selection switch, two reference test points, DMM connection jacks, a test point common, and a LED power indicator.

By
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Tektronix made more than 100 different functional plug-ins that it used in its TM50x series of power supply modules. These consisted of the TM501 single-bay power module up to the TM506 six-bay power module. Tektronix also produced several audio test equipment plug-in modules for the TM50x series, including audio oscillators, function generators, and a three-bay distortion test set for the TM503 power module.

My project came about because we had a TM501 with old, weak DC filter capacitors that was being used with a Tektronix AM503A current probe amplifier. The excessive ripple on the DC supply affected the accuracy of the current measurements while important development testing was in progress. To determine the problem, I designed and developed what we designated the CAL-69A power module tester (see **Photo 1**). The tester provides test loads on each of the six internal DC sources of Tektronix 50x power modules, to detect weak filter capacitors and degraded or failed power transistors. **Photo 2a** shows a Tektronix TM501A with three Sprague metal can capacitors removed from the module. **Photo 2b** shows the same module with the three new replacement capacitors installed on the TM501 PCB.

This is not a piece of commercial test equipment. It is a one-off unit that we use in the lab where I work to test and verify Tektronix TM50x power supply module operation. I guess you could call it a "brass board" instead of a breadboard. I appropriated the Tektronix chassis from another plug-in module that was no longer repairable. However, the design has no association with Tektronix.

Description

We use the CAL-69A power module tester to check all six power sources in each compartment bay as well as the two unassigned bipolar power transistors—one NPN and one PNP—for the for TM50x series power modules (e.g., TM501, TM502, TM503, etc.). It also enables us to measure the DC ripple across the three aluminum filter capacitors on the three TM50x internal DC supplies (+33.5 VDC, +11.5 VDC, and -33.5 VDC). The switch positions are marked with a ~ sign to indicate they are used for DC voltage and AC ripple check.

In addition, we use Zener diodes to bias the TM50x internal power transistors as emitter followers to provide +22 VDC and -22 VDC test voltages from the two TM50x isolated 25 VAC

windings. A pair of diodes and a filter capacitor is used to provide -11.5 VDC from the same 17.5 VAC CT winding that provides the +11.5 VDC output. The -11.5 VDC also provides power for the front panel LED indicator. In all, six DC voltages can be checked by the Tester.

The CAL-69A tester plugs into the power module compartments like any other Tektronix plug-in module. The tester has no adjustments. It consists of mostly passive components and diodes. The two reference voltages can be checked at the three pin jacks on the right side of the front panel. The tests and test voltage limits are listed in **Table 1**. The DC voltages can be read with an accurate digital multimeter (DMM), the AC ripple voltages can be viewed on an oscilloscope.

The tester can be removed from the TM50x compartment by pulling on the silver pull knob next to the LED. (Caution: Be sure to turn the power module off before inserting or removing the tester.)

To conduct a TM50x power module performance check, we used the following test equipment: a Fluke, a Tektronix or Keysight (Hewlett-Packard, Agilent) DMM or an accurate equivalent, and an oscilloscope (for power module ripple voltage test).

If the TM50x power module fails the AC ripple millivolt test on the +33.5 V, +11.5 V and/or -33.5 V rotary switch positions, the TM50x filter capacitors may have failed. You can use an oscilloscope connected at the + DMM – banana jacks J1 and J21 to measure the peak-to-peak ripple voltage. (Note: A DMM on the AC volts range will measure the ripple voltage in VRMS, so you have to convert to peak-to-peak by multiplying by √2 (1.414).

Circuit Description

Figure 1 shows the schematic. The left side of the schematic shows the TM50x power module (in this case the TM501) and its receptacle connector and pin designations. Note that the "A" side of the TM50x connectors has reference letters that indicate the actual letter markings on the receptacle. The "B" side of the receptacle is marked with the numbers shown on the schematic. Tektronix decided it would be less confusing to show the same number for the two adjacent connector pins. I put the receptacle letters in parenthesis on the schematic.

TM50x 25 VAC Supply, pins 1A(A) and 1B—Pins 1A(A) and 1B provide 25 VAC at 0.5 A. The 20 nF capacitor across the connector provides spike and electromagnetic interference (EMI) filtering. This AC voltage is full-wave rectified in the tester by D1 and the AC ripple is filtered by C1. Resistor R1 bleeds off the DC voltage across C1 when the tester is removed from the TM50x compartment.

Photo 2: The Tektronix TM501A is shown with three Sprague metal can capacitors removed from the module (a) and the three new replacement capacitors installed on the TM501 PCB (b).

Tests and Test Limits	
Test Jack to DMM (J5, black)	**DC Volt Limits**
J3 Red +22 V	+20.9 to +23.1 VDC
J4 Blue -22 V	-20.9 to -23.1 VDC
Rotary Switch Position	**DC Volt Limits**
+33.5 V	+30.4 to +35.2 VDC
+22 V	+20.5 to +23.5 VDC
+11.5 V	+10.4 to 12.5 VDC
-11.5 V	-10.4 to 12.5 VDC
-22 V	-20.5 to -23.5 VDC
-33.5 V	-30.4 to 35.2 VDC
Rotary Switch Position	**AC Ripple Millivolt Limit**
+33.5 V	100 mVAC maximum
+22 V	200 mVAC maximum
+11.5 V	100 mVAC maximum
-11.5 V	250 mVAC maximum
-22 V	20 mVAC maximum
-33.5 V	100 mVAC maximum

Table 1: The tests and the limits (which need to be repeated for each compartment in a TM50x) are listed.

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The DC voltage is used to check the TM-Q12 NPN power transistor mounted to the chassis/heatsink.

Power to the TM-Q12 emitter follower collector is applied to pin 7B through current limit resistor R7. The +22 V base reference voltage circuit at pin 6A(F) consists of R6, Vbe compensation diode D5 and +22 Vref Zener diode VR1. The VR1 reference is fed directly to +22 REF TP test jack J3 for operational check of the tester reference. R15 limits the current in case of an accidental short at J3.

The emitter of TM-Q12 is connected to the tester at pin 7A(H). When switch S1 is not in the +22 position, TM-Q12 is lightly loaded to 1 W by series resistors R8 and R17. In the +22 switch position R17 is shorted by the S1-B2 LOADS section of S1. Q1 is then loaded to 2.2 W by R8. The Q1 emitter follower voltage is read at J1 via S1-A2 VOLTS section of S1 and current limit resistor R5, which introduces less than 0.1% error in the DMM reading.

TM50x +11.5 VDC Supply, pins 2A(B) and 2B—Pins 2A(B) and 2B provide unregulated full-wave rectified +11.5 VDC at 3.6 A. TM-CR30 and TM-CR32 are the rectifiers, TM-C35 is the filter capacitor, and TM-R35 is a bleed resistor for TM-C35 after power is turned off and any plug-ins are removed.

The tester measures the +11.5 VDC voltage out of the TM50x power module via S1-A3. When switch S1 is in the +11.5 position, a 2.6 W load is also placed on that power supply voltage by the combination of TM-R35, and S1-B3 grounding R4 to load down the supply voltage sufficiently to allow a proper ripple voltage test on TM-C35.

TM50x ±11.5 VDC Ground pins 3A(C), 3B, 4A(D) and 4B—The individual ground pins are connected together, along with the ±33.5 VDC ground pins 9A(K) and 9B on the tester's circuit board.

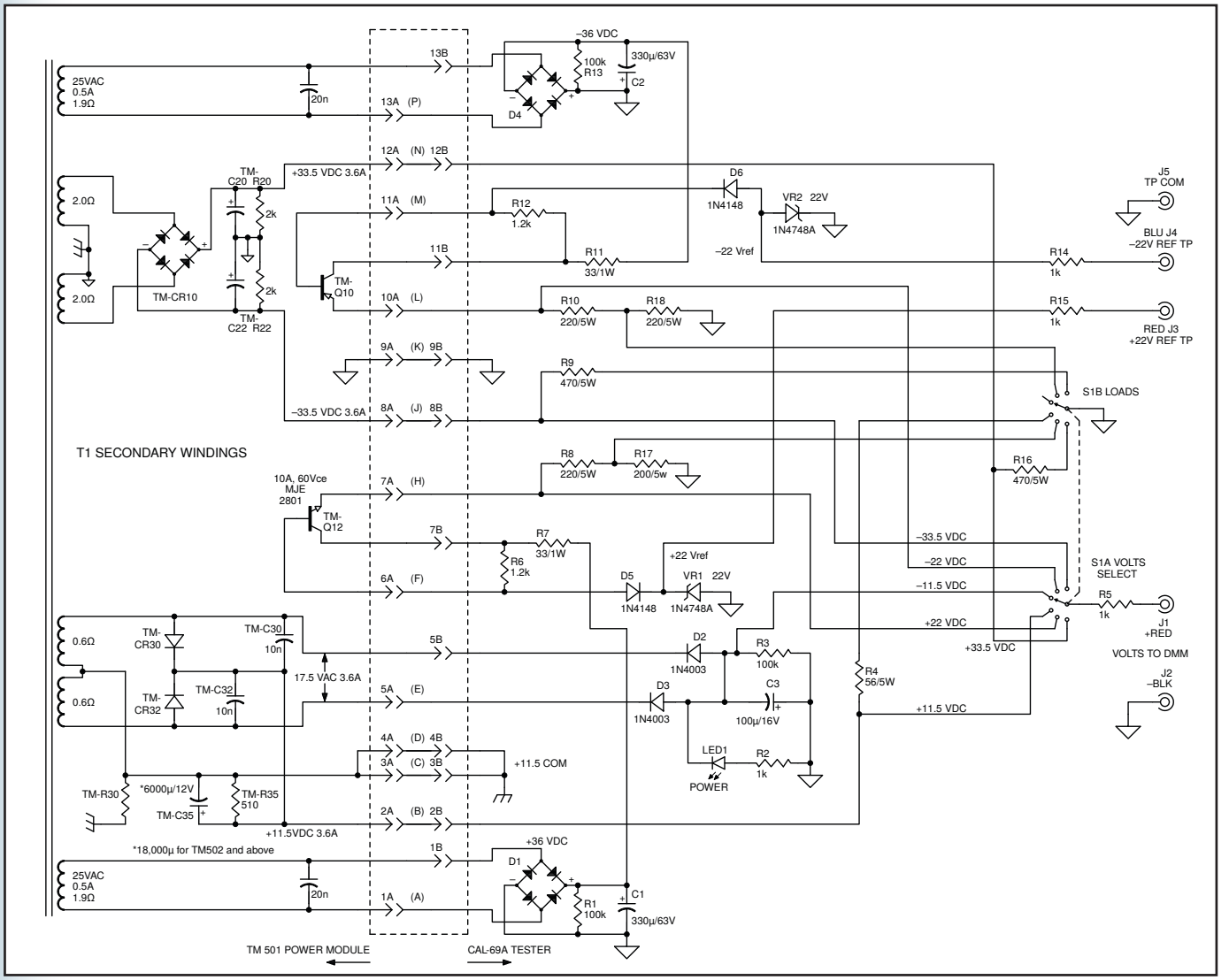

Figure 1: Here is a detailed schematic that should enable you to build your own CAL-69A power module tester.

TM50x +17.5 VAC pins 5A(E) and 5B—This center-tapped AC voltage is used to make the +11.5 VDC unregulated that is output from the TM50x power module at pins 2A(B) and 2B.

In addition, the CAL-69A tester creates a -11.5 VDC supply using D2, D3, filter cap C3, and bleeder resistor R3. This voltage is used to power the red LED1 power indicator on the front panel. It is also measured at S1-A4. No additional DC load is placed on this voltage.

TM50x TM-Q12 pins 6A(F), 7A(H) and 7B—These pins are the connections to TM-Q12 NPN power transistor that is mounted on the TM50x chassis/heatsink.

TM50x -33.5 VDC Supply, pins 8A(J) and 8B—Pins 8A(J) and 8B provide unregulated full-wave rectified -33.5 VDC at 3.6 A. TM-CR10 is the full-wave rectifier, TM-C22 is the filter capacitor and TM-R22 is a bleed resistor for TM-C22 after power is turned off and any plug-ins are removed.

The tester measures the -33.5 VDC directly out of the TM50x power module via S1-A6. When switch S1 is in the -33.5 position, a 2.9 W load is also applied by the combination of TM-R22, and S1-B6 grounding R9 to sufficiently load down the supply voltage to enable a proper ripple voltage test on TM-C22.

TM50x ±33.5 VDC Ground pins 9A(K) and 9B—These individual ground pins are connected together, along with the ±11.5 VDC ground pins 3A(C), 3B, 4A(D) and 4B, on the tester' circuit board.

TM50x TM-Q10 pins 10A(L), 11A(M) and 11B—These pins are the connections to TM-Q1 PNP power transistor that is mounted on the TM50x chassis/heatsink.

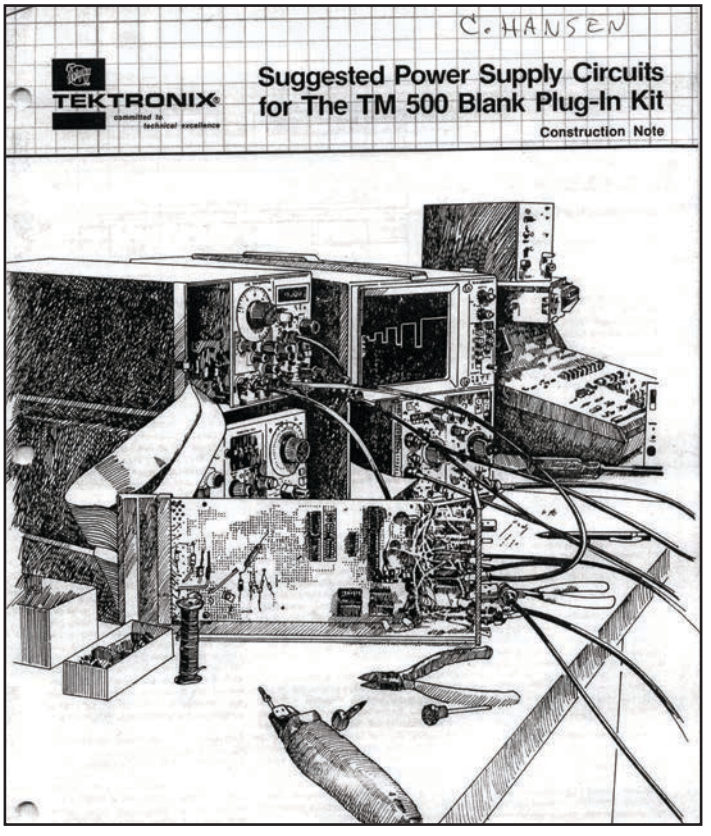

Photo 3: This is the cover of the *Tektronix Power Supply Circuits* manual for the TM 500 Blank Plug-In Kit.

About the Author

Chuck Hansen is an Electrical Engineer who works as a consultant in the aerospace industry. He holds five patents in his field of engineering. Chuck has written two books for Audio Amateur publications and he has more than 260 magazine articles to his credit. He began building vacuum-tube audio equipment in college. He enjoys sailing and playing jazz guitar. He likes to modify guitar amplifiers and effects to reduce noise and distortion, as well as building and restoring audio test equipment.

TM50x -33.5 VDC Supply, pins 8A(J) and 8B—Pins 12A(N) and 12B provide unregulated full-wave rectified +33.5 VDC at 3.6 A. TM-CR10 is the full-wave rectifier, TM-C20 is the filter capacitor and TM-R20 is a bleed resistor for TM-C20 after power is turned off and any plug-ins are removed.

The tester measures the +33.5 VDC directly out of the TM50x power module via S1-A1. When switch S1 is in the +33.5 position, a 2.9 W load is also applied by the combination of TM-R20, and S1-B1 grounding R16 to load down the supply voltage sufficiently to allow a proper ripple voltage test on TM-C20.

TM50x 25 VAC Supply, pins 13A(P) and 13B—Pins 13A(P) and 13B provide 25 VAC at 0.5 A. The 20 nF capacitor across the connector provides spike and EMI filtering. This AC voltage is full-wave rectified in the Tester by D4 and the ac ripple is filtered by C2. Resistor R13 bleeds off the DC voltage across C2 when the Tester is removed from the TM50x compartment. This DC voltage is used to check the TM-Q10 PNP power transistor mounted to the TM50x chassis/heatsink.

Power to the TM-Q10 emitter follower collector is applied to pin 11B through current limit resistor R11. The -22 V base reference voltage circuit at pin 11A(M) consists of R12, Vbe compensation diode D6 and -22 Vref Zener diode VR2. The VR2 reference is fed directly to -22 REF TP test jack J4 for operational check of the Tester reference. R14 limits the current in case of an accidental short at J4.

The emitter of TM-Q10 is connected to the CAL-69A tester at pin 10A(L). When switch S1 is not in the -22 position, TM-Q10 is lightly loaded to 1 W by series resistors R10 and R18. In the -22 switch position R18 is shorted by the S1-B5 LOADS section of S1. TM-Q10 is loaded to 2.2 W by R10. The TM-Q10 emitter follower voltage is read at J1 via S1-A5.

CAL-69A Power Module Tester Parts List

Symbol	Value	Description	PC Span	Manufacturer
C1-C2	330 uF, 63 V, 20%	Aluminum cap, 105°C	2.0	Vishay
C3	100 uF, 16 V, 20%	Aluminum cap, 105°C	1.1	Vishay
D2-D3	1N4003	Diode, 200 V, 1 A	0.4	Fairchild
D1, D4	W02G	Diode bridge, 200 V, 1.5 A	0.3 x 0.4	Vishay
D5-D6	IN4148	Diode, 80 V, 0.5 A	0.5	Fairchild
J1		Banana Jack, Red		Emerson
J2		Banana Jack, Black		Emerson
J3		Tip Jack 0.08, Red		Emerson
J4		Tip Jack 0.08, Blue		Emerson
J5		Tip Jack 0.08, Black		Emerson
(All Resistors, 5% tolerance)				
R1, R3, R13	100 kΩ, 0.5 W	Carbon Film	0.5	Xicon
R2, R5, R14, R15	1 kΩ, 0.5 W	Carbon Film	0.5	Xicon
R4	56 Ω, 5 W	Wirewound	1.3	Dale/Vishay
R6, R11	33 Ω, 2 W	Metal Oxide	1.1	Xicon
R7, R12	1.2 kΩ, 0.5 W	Carbon Film	0.5	Xicon
R8, R10	220 Ω, 5 W	Wirewound	1.3	Dale/Vishay
R9, R16	470 Ω, 5 W	Wirewound	1.3	Dale/Vishay
S1		6P ST Rotary Switch		Lorlin CK1030
VR1, VR2	1N4748A	Zener, 22 V 1 W 5%	0.5	Fairchild
	Vector 3662-2 plug board Plastic knob, 0.75"			Vector (special)

Construction

I salvaged a Tektronix plug-in chassis from a non-working plug-in from Pulse Engineering. I found these are readily available online as non-working units. Other manufacturers who also made non-Tektronix plug-ins are Ball-Efratom, Laser Precision, Metrotek, MOS Aid, Spectracom, Signetics, and others.

Tektronix used to offer custom auxiliary blank plug-in breadboard kits with chassis for people or organizations who wanted to make custom plug-ins compatible with the TM501 and TM502 power modules, but with functions particular to their own purposes. The units, Tektronix models 040-0652-01 and 040-0754-00, respectively, had a Vector-style perf board with a card-edge connector that aligned with the fixed receptacles in the power modules. However, they are no longer offered. **Photo 3** shows the cover of the *Tektronix Power Supply Circuits* manual for the TM 500 Blank Plug-In Kit.

Fortunately, Vector still makes a perf board (Part Number 3662-2) plug board that, with a slight modification, will align with the TM50x receptacle.

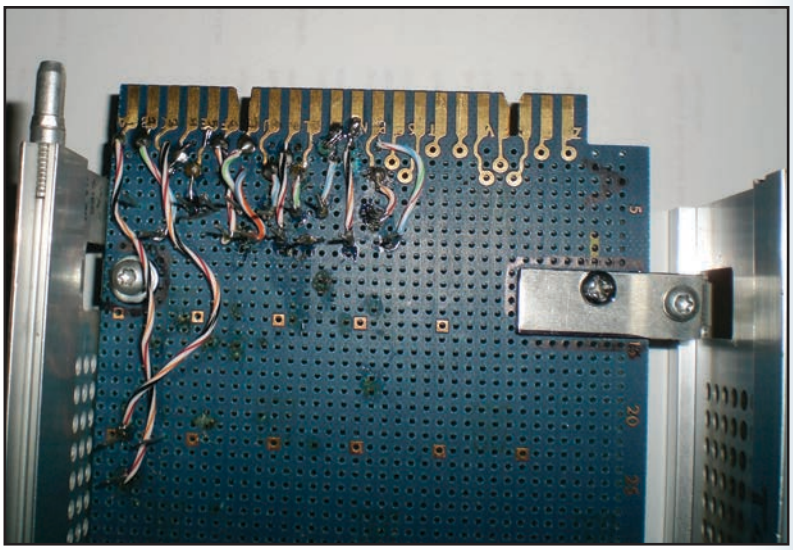

Photo 4: I made several modifications to the Vector plug board.

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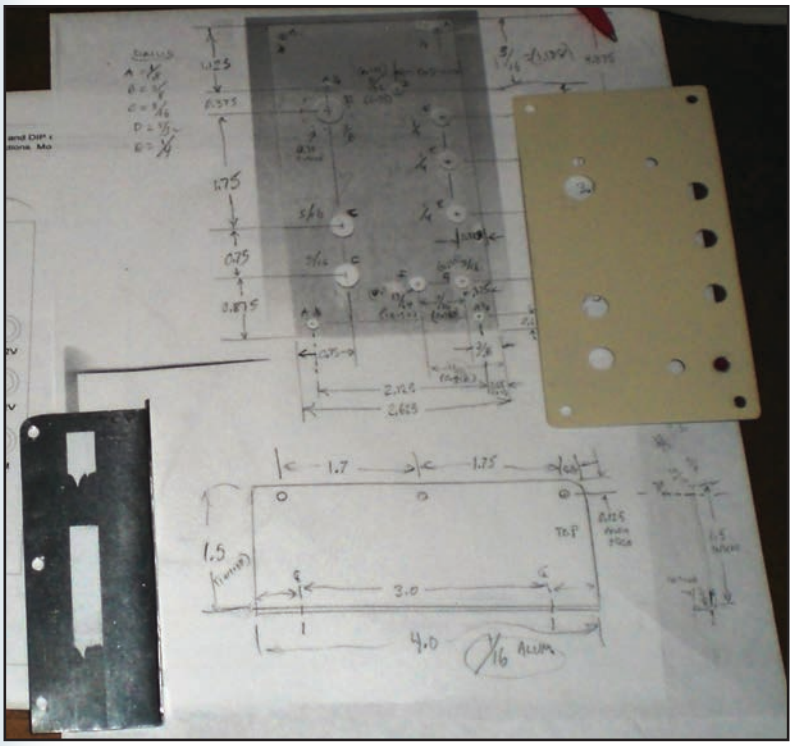

Photo 5: I made a right angle bend to attach to the front control panel. Pictured are the front mounting bracket, the front control panel, hand drawn dimensions, and drill codes.

It is a bit shorter in overall length than the original Tektronix perf board, but that would not be an issue with most custom breadboards that you would want to make. The plug board is a non-stocked special order at Mouser.

The modification requires cutting off the bottom (pin 1, A) side of the perf board (see **Photo 4**). I found the easiest way to do this is to insert two pieces of 1′ × 2′ trim boards between the jaws of a wood-workers vise. The boards need to be a bit longer than the plug board. Clamp the bottom edge of the plug board in the vise right where the cut has to be. Then, score the front and back of the board with a utility knife blade, using the top edges of the boards as a guide. With the board still clamped in the vise, press it to one side and it will snap across the scored lines.

(Caution: You have to score between the rows of holes to prevent cutting off the solder pad for edge connector pin 1. Score the plug board cut line deep enough so it won't accidentally snap off along a row of holes. Use the square solder pads across the plug board to help as a reference location for where to clamp the plug board.)

Next, drill two holes in the bottom of the plug board as shown, to align with the existing PCB mounting tabs. The back edge of the connector must be exactly 0.75″ out from the back edge of the plug-in aluminum chassis sides.

The plug board does not reach the two top mounting pads on the chassis. I made two 0.5″ × 2″ pieces of 1/16″ thick aluminum to connect

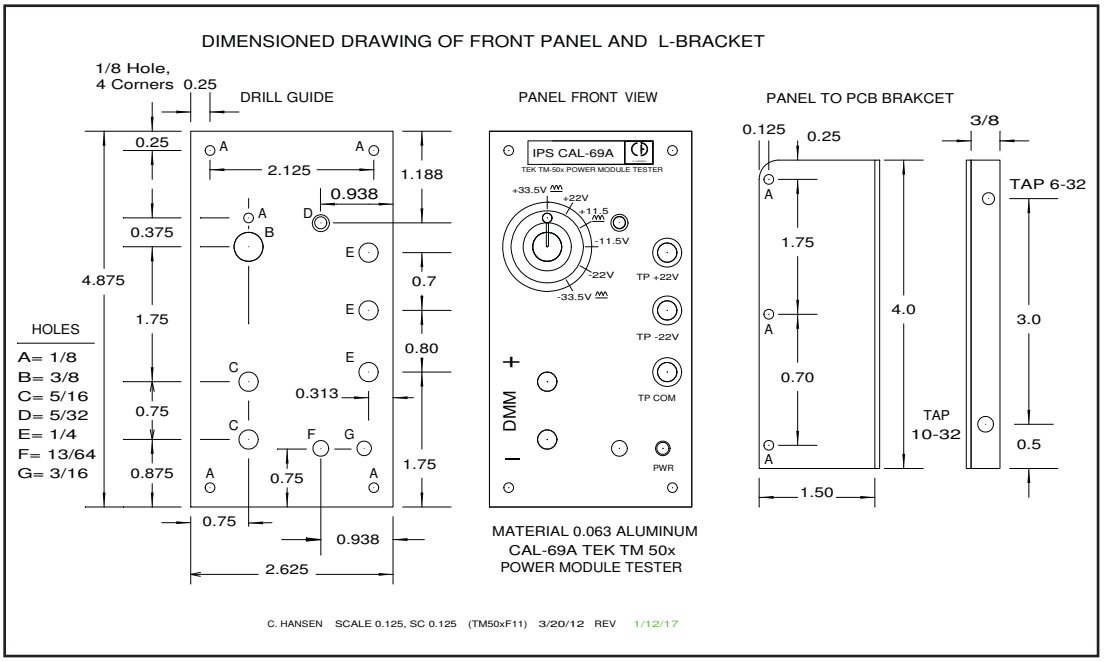

Figure 2: This is a dimensioned drawing of the two aluminum panels (the front panel and the L-bracket).

the upper part of the plug board to the top PCB mounting tabs. Since the plug board is not long enough to reach the front panel of the Tektronix plug-in chassis, I made another aluminum L-bracket to connect the back edge of the plug board to the front control panel. I attached the front end of the bracket to the back of the front panel with one 6/32 flat head screw on top and an 8/32 knurled knob at the bottom. The knurled knob is spaced away from the front panel by a thick #8 washer to be used as a pull to remove the CAL-69A power module tester from the TM50x power module bay. This was previously done with a nylon latch release pull on the bottom-left of the control panel, but time had deteriorated the nylon so much that the front tab broke off from the release mechanism inside the chassis. I removed the remains of the latch so it would not interfere with the tester.

The L-bracket started out as a 2.5″ × 4″ piece of 1/16″ aluminum. I made a 3/8″ deep right angle

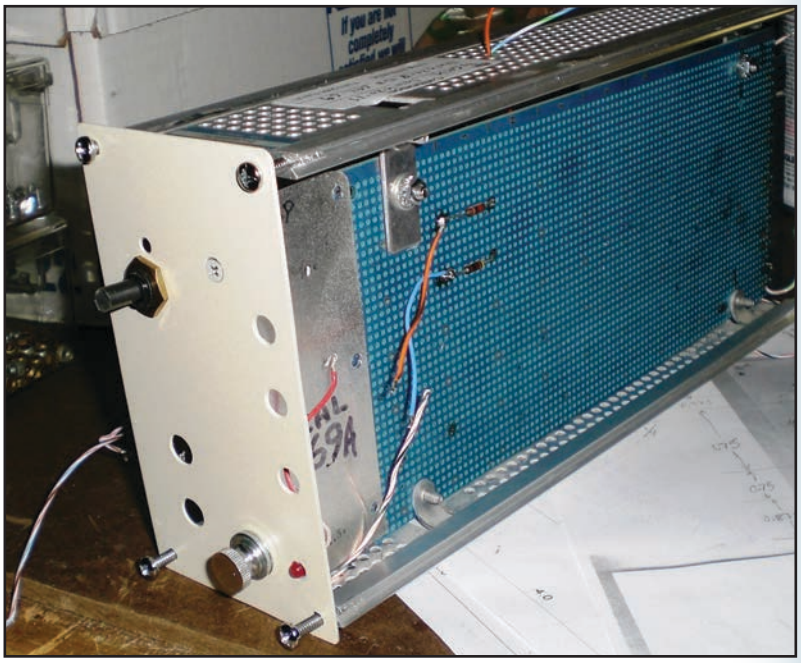

Photo 6: I checked the alignment for the front panel and the front L-bracket hardware.

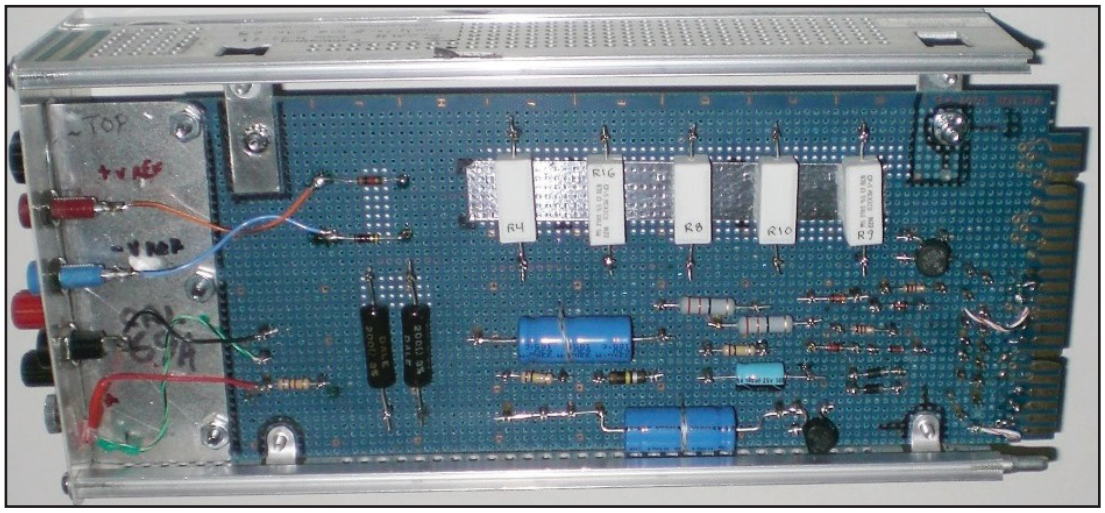

Photo 7: Here you can see the plug board components.

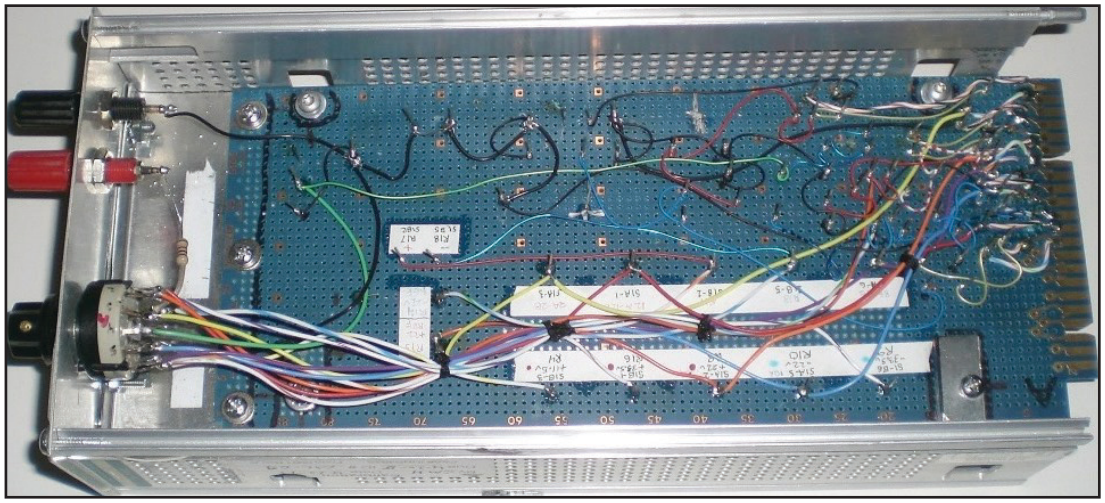

Photo 8: This is the wiring side of the tester.

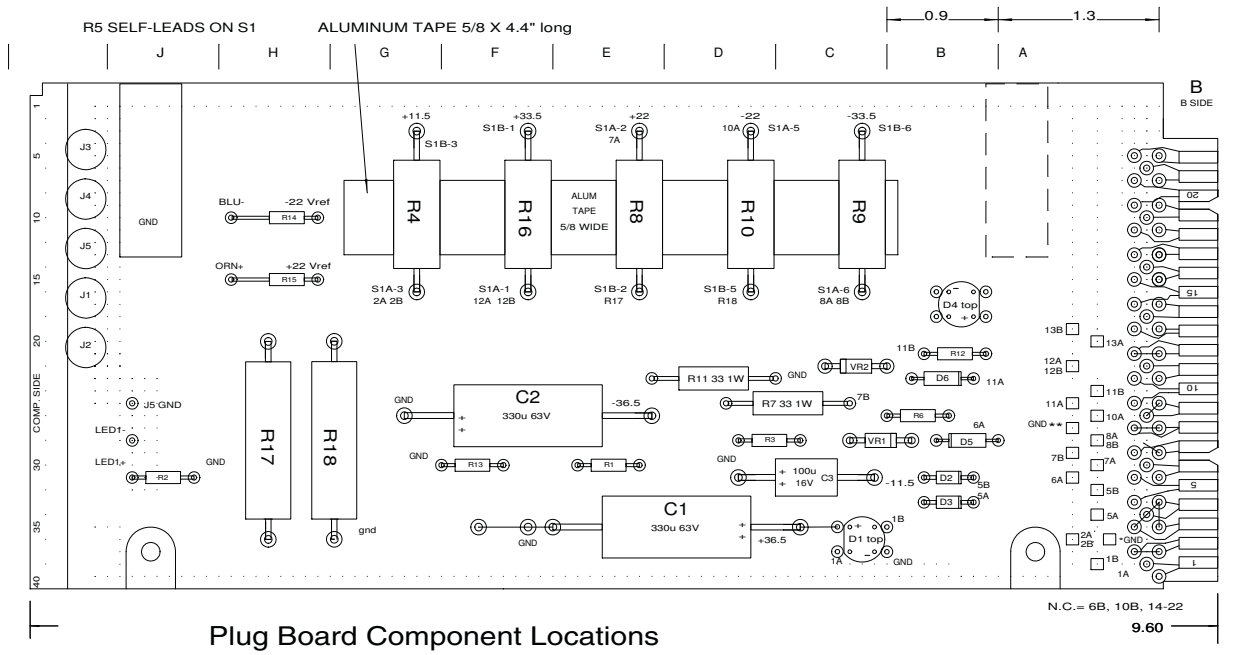

Figure 3: This drawing details the plug board component locations.

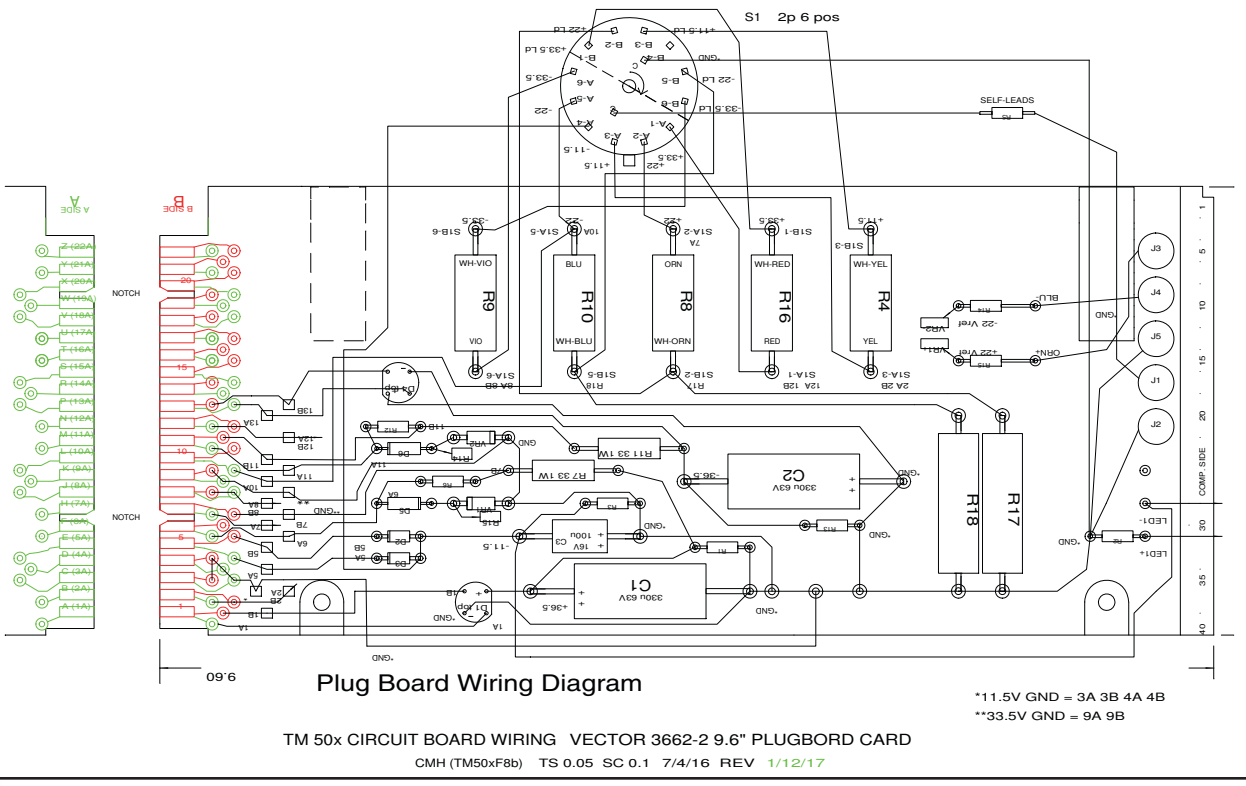

Figure 4: The diagram indicates the proper wiring locations for the tester.

bend to attach it to the front control panel (see **Photo 5**). The front control panel is a 2-5/8" × 4-3/8" flat aluminum plate. A dimensioned drawing of the two aluminum panels is shown in **Figure 2**.

The plug board's card edge has to be notched in two placed to mate with receptacle keys in the TM50x power modules. I did this with my band saw. You can see the notches shown in **Photo 4**, placed between contacts 6 and 7, which is needed for all TM50x power modules. There is another notch between contacts 19 and 20, which is needed for some TM50x power modules. Be careful not to remove any of the gold-plated contact material. Then check that there is no continuity between the two adjacent contacts or between the front and back contacts in the same locations on the plug board.

Photo 6 shows the hardware alignment check I made between the front control panel blank, the L-bracket and the plug board. Once everything was properly aligned, I drilled the L-bracket mounting holes into the back end of the plug board, using the three pre-drilled holes in the L-bracket. I used the existing 6-32 tapped channels in the top and bottom sections of the chassis for my new front panel.

Once I had the front panel, L-bracket, and plug board aligned to the plug-in chassis, I did a fit-check into a TM501 power module and verified the plug board's card-edge connector properly mated with the power module, with no shorts between any adjacent contacts.

Next, I wired the plug board and installed all the perf board components. I used Vector T49 push-in terminal pins since there were no copper pads in the proper locations. I wired the tester from the card-edge contact pads to the first rear row of T49 pins with AWG 24 Teflon covered wire. Some of the TM50x receptacle pins are shorted together for higher current capability, so I shorted card-edge connector pads in the same location together with bare AWG 22 soft-drawn tin-plated copper hook-up wire (Alpha Part Number 298). All of the hard-wired connections from the front panel to the plug board were also made with color-coded Teflon wire.

I made the lettered front panel with my CAD program and printed it to mat-finished clear Chartpak DAF8 permanent adhesive-backed film. The plug board component locations are shown in both **Figure 3** and **Photo 7**. **Figure 4** details how to do the wiring and **Photo 8** shows how the wiring should look once it is completed.

The CAL-69A module tester can be used with the more than 100 Tektronix 500-series plug-ins (see **Photo 9**). I have included an Excel file listing all of the plug-ins in a Supplementary Material file found on the audioXpress website.

Photo 9: This is the completed, calibrated CAL-69A power module tester.

Project Files

To download additional material and files, visit http://audioxpress.com/page/audioXpress-Supplementary-Material.html

Resources

"List of TM500 and TM5000 equipment," TekWiki, http://w140.com/tekwiki/wiki/List_of_TM500_and_TM5000_equipment.

Tektronix, Inc., www.tek.com