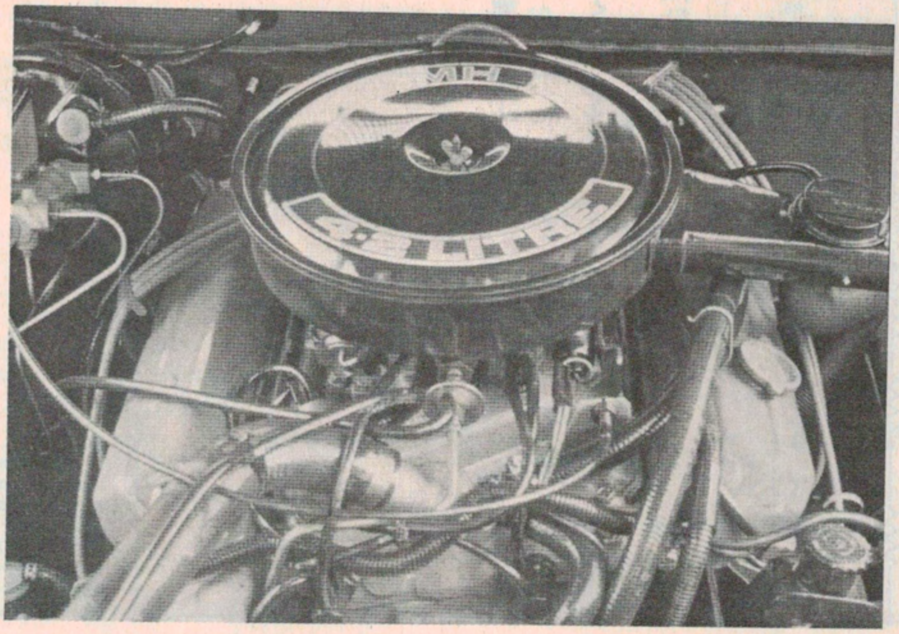


The 'Auto Tester'

Graeme Teesdale

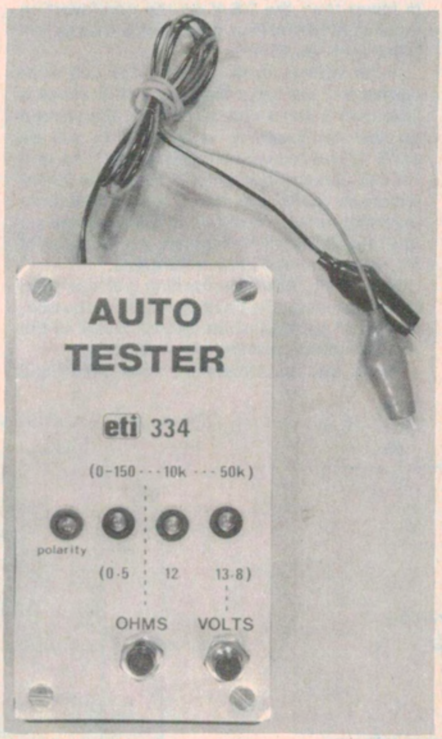
This handy little test gadget will help you sort out all those little bugaboos that can go wrong in automotive electrics. With this, you can check voltage drops, on and off charge battery voltages and resistances.

BUDDING MECHANICS are very often bamboozled by the electrics of a modern motor vehicle. An automotive or electronic type multimeter with its combination scales all crammed together simply adds to the confusion. This project was developed to make fault-finding a little easier by providing simple LED indication of 'set' points in voltage or resistance.

In a vehicle, voltage drop in cables of more than 0.5 volt can bring problems. The Auto Tester provides a clear indication of voltage drops less or greater than 0.5 V. The battery system, to perform up to scratch, must deliver at least 12 V on load and the battery should have a terminal voltage of more than 13.5 V when charging.

Resistances encountered in vehicles tend to have fairly well defined limits. Many devices have resistances under 10 ohms, a few range up to 150 ohms. Thus the first resistance 'set' point is at about 150 ohms. Much higher resistances are encountered in HT suppressors, etc. Generally, these are around 10k or 15k. Trouble can occur if they go faulty and exhibit a high resistance, generally greater than 50k. Thus, two other 'set' points for resistance are at 10k and 50k.

The unit was housed in a small, conveniently-sized jiffy box. The pc board designed for this unit will just fit comfortably into several different types on the market. Four indicator LEDs are provided: a



Pragmatic. Simple, but functional. The project was housed in a small jiffy box with a Scotchcal panel added.

POLARITY indicator, followed by one for each of the three set points in voltage and resistance. Two pushbuttons select which 'mode' you wish to use — VOLTS or OHMS.

Where battery polarity is unknown, or in instances where the Auto Tester may be incorrectly connected, the POLARITY LED will light when the red, or positive, input lead is connected to the battery negative.

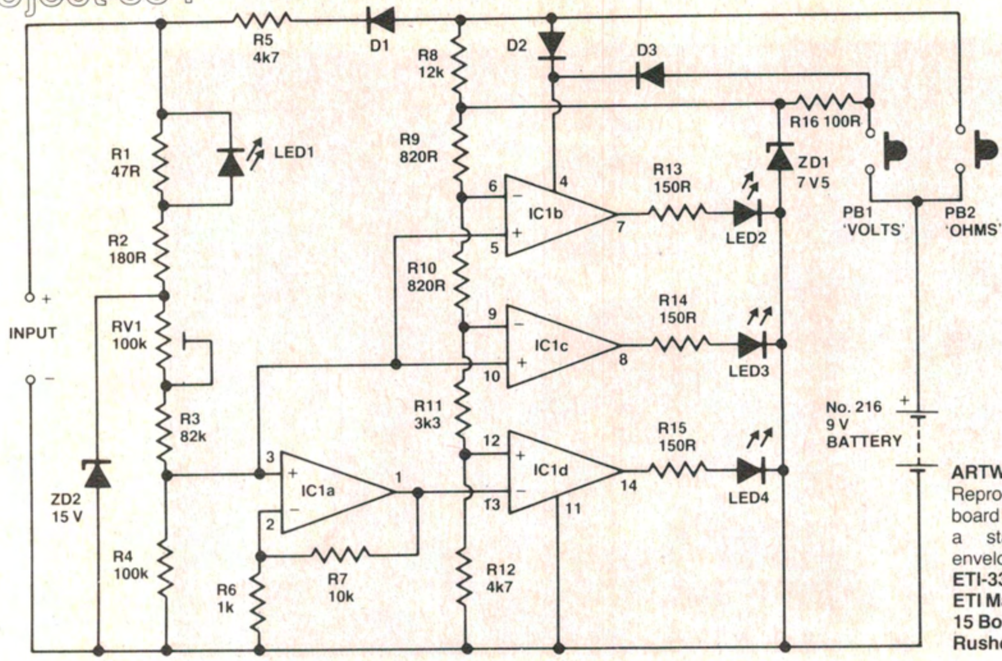
Protection against input overvoltage damage has been incorporated, so that voltage inputs of greater than 15 V are 'clamped' to avoid damaging the IC.

The Auto Tester, unlike most multimeters, will not be damaged if a dc voltage is applied to the input when it is being used in the resistance mode.

The unit is powered from a No. 216, 9 V battery mounted in the jiffy box. The circuit is based around the commonly available, low cost LM324 or uA324 quad op-amp. The battery will likely last its shelf life (probably a year or more) as consumption is only ever momentary, when you take a reading.

Construction

The project pc board has been designed to fit into almost any of the small jiffy boxes available. These are generally all-plastic or plastic cases with a light gauge aluminium 'lid'. We designed a Scotchcal front panel which will suit those boxes measuring 52 x 100 mm or a little larger. ▶



ARTWORK.
Reproductions of the front panel and pc board artwork can be obtained by sending a stamped, self-addressed A4-sized envelope to:
ETI-334 ARTWORK
ETI Magazine
15 Boundary St
Rushcutters Bay NSW 2011

Before assembling the components to the board, check that is has no breaks or shorts between tracks, particularly between the IC pins. Also check that components like RV1, the zener diodes and LEDs have the correct lead hole sizes drilled. The board can be mounted by soldering the two pushbutton switches directly to the board and letting the board hang from their leads — it's quite a robust arrangement. If you're going to do this, see that the holes in the pc board for PB1 and PB2 are drilled the right size.

Next, check that the pc board fits inside the box. Make sure you orient the board correctly when you do this. If the board doesn't fit in without jamming you may have to carefully trim a little off one or both sides with a file until it fits properly. If it doesn't fit at all, get a bigger box!

Using the front panel artwork, mark out and drill the front panel, or lid, of the box. Fit the four LED mounts.

Once the board is ready to go, commence assembly by soldering all the resistors in

HOW IT WORKS — ETI 334

The clearest way of seeing how this circuit works is to break it down into simplified sections. The Auto Tester performs three main functions: voltage drop measurement, 12/13.8 V measurement and resistance measurement. In addition, an indication of reverse polarity connection is provided along with input overvoltage protection.

The whole circuit is built around an LM324 (or uA324) quad op-amp, IC1. Three op-amps from this are arranged as comparators and one as an amplifier. Let's look at the voltage drop measurement stage first. This portion of the circuit is shown in Figure 1.

Only the relevant components are included. When PB1 is pressed, power is supplied to IC1 via D3. Note that R1, LED1, R2 and ZD2 play no part here. RV1, R3 and R4 form a voltage divider. IC1a is arranged as an amplifier and IC1d as a comparator.

If the input leads are then connected across a cable having a voltage drop of less than half a volt, say 0.2 V, the voltage appearing at the non-inverting input of IC1a will be about 0.1 V (half the input volts) due to the divider action of RV1, R3 and R4. RV1 is set to provide this division ratio of about two. IC1a provides a gain of 10, and thus the output will be 1 V. This is lower than the 2.6 V on the non-inverting input of IC1d and thus its output will be driven high, lighting LED4.

If the voltage drop on the cable you have connected the input leads across reaches a little over a half a volt, say 0.55 V, the voltage on the non-inverting input of IC1a will be 0.275 V. The voltage on the output of IC1a, and thus the inverting input of IC1d, will be 2.75 V which exceeds the 2.6 V on IC1d's non-inverting input. The output of IC1d will thus go low and LED4 will extinguish, warning you of excessive voltage drop in the cable.

Note that, when performing voltage drop measurements, the positive lead must be connected at the end of the cable closest to the positive terminal of the vehicle battery.

When the input leads are open circuit and PB1 is pressed, D1 will be forward biased as it is connected to the 7.5 V rail (from ZD1) via R8. Thus, something a little under 7 V will appear at the 'top' of RV1, and about 3.5 V at pins 3, 5 and 10 of IC1. This will drive the output of IC1d low, and LED4 will be unlit. It won't change the condition of either IC1c or IC1d, so LEDs 2 and 3 will also be unlit. Thus, nothing happens if you press PB1 ('VOLTS') when the leads are not connected to anything.

Let us look at the other voltage measurements now. This section of the circuitry is shown in Figure 2. IC1b and IC1c are connected as comparators. Each has their inverting input connected to the voltage divider R9, 10, 11 and 12. This voltage divider is supplied from a regulated 7.5 volts, derived by ZD1 and R16. Thus, battery voltage variations will not affect circuit operation, provided the battery voltage doesn't fall to about 8 V or less. IC1b and IC1c have their non-inverting inputs connected together and these are attached to the input voltage divider.

Figure 1. Voltage drop measurement.

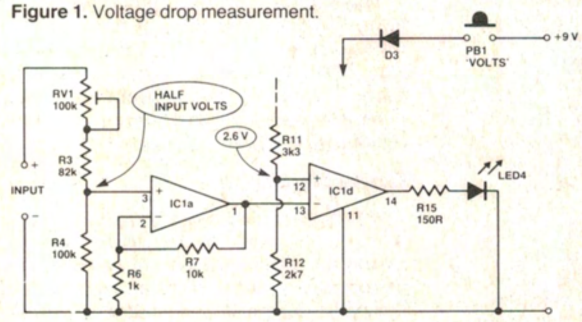
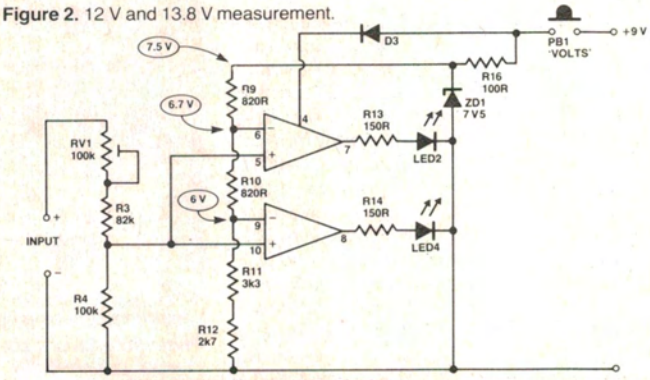
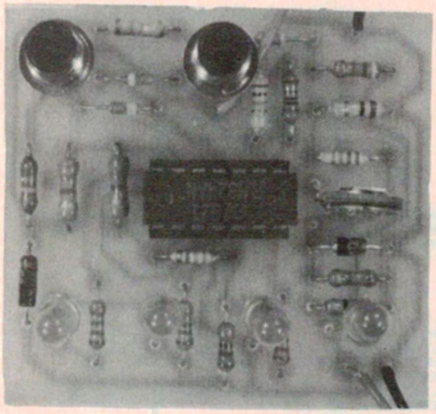
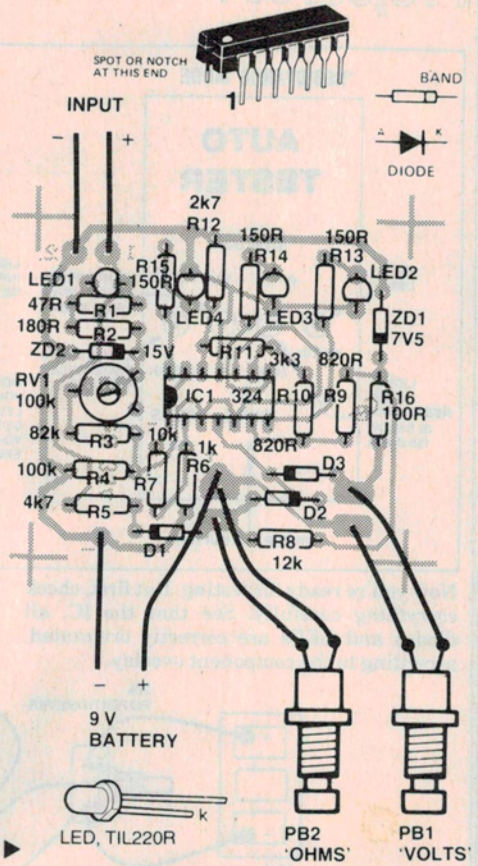


Figure 2. 12 V and 13.8 V measurement.







place, then the diodes D1, 2 and 3, followed by the two zener diodes. Make sure you get all the diodes in the correct way round.

If you're mounting the board to PB1 and PB2, solder these in place now, making sure their mounting 'shoulders' are level. Insert the four LEDs next, but don't solder them in place. Make sure you orient them correctly and don't trim off their leads. Temporarily mount the board to the front panel of the case. Push the LEDs into position and then solder and trim their leads. De-mount the board from the panel and fit IC1, RV1, the battery clip lead and the two input leads. ▶

PARTS LIST — ETI-334

Resistors	all ¼W, 5% unless noted
R1	47R
R2	180R
R3	82k
R4	100k
R5	4k7
R6	1k
R7	10k
R8	12k
R9, R10	820R
R11	3k3
R12	4k7
R13, 14, 15	150R
R16	100R
RV1	100k min. trimpot, horizontal or vertical mount.
Semiconductors	
D1, 2, 3	1N914, 1N4148 etc
IC1	LM324, uA324
LED1, 2, 3, 4	TIL220R red LEDs
ZD1	7V5 zener diode
ZD2	15 V zener diode
Miscellaneous	
PB1, PB2	press-on pushbutton switches

ETI-334 pc board; jiffy box 52 x 30 x 100 mm or thereabout; No. 216 battery and battery clip lead; two alligator clips and leads, one red, one black; Scotchcal front panel, etc.

Price estimate $15 — $17

When PB1 is pressed, power is supplied to IC1 via D3, as before. With no input voltage, the outputs of IC1b and c will both be low and LEDs 2 and 3 will be unlit. When the input leads are connected to a voltage a little over 12 V, the voltage on pin 10 of IC1c will be a little over 6 V. This will drive the output of IC1c high, lighting LED3. When the input voltage rises above about 13.5 V, the voltage on the pin 5 of IC1b will be a little over 6.7 V, driving the output of IC1b high, now lighting LED2 also.

Look at resistance measurement now. For this explanation, refer to the complete circuit diagram. As before, R1, LED1, R2 and ZD2 play no part here.

When PB2 is pressed, power is supplied to IC1 via D2. Some current is supplied to the resistive divider network, R9-10-11-12, by R8. This establishes a different set of voltages on the three comparator inputs. Pin 6, IC1b will now have about 3.8 V on it, pin 9, IC1c about 3 V on it and pin 12, IC1d about 1.3 V on it.

When the leads are connected to a resistance, current will be supplied to the resistance via D1 and R5. Say the resistance is 100 ohms. About 1.8 mA will be driven through it because there is about 8.5 V on the cathode of D1 and 8.5 divided by 4800 ohms gives about 1.8 mA. Thus, there will be a voltage drop across the 100 ohms of resistance of about 0.18 V. About 0.09 volts will appear on pin 3, IC1a. The output of IC1a will drive the inverting input of IC1d to about 0.9 V which is less than the 1.2 V on IC1d's non-inverting input. Thus the output of IC1d will be high, lighting LED4. If the resistance across the input is say 180 ohms, the voltage across the input leads will be about 0.32 V. About 0.16 V appears on pin 3, IC1a and 1.6 V on pin 13, IC1d. The output of IC1d will therefore go low, and LED4 will not light.

If the resistance across the input terminals is between 150 ohms and 10k, say 5000 ohms or so, then the voltage across it will be about 4 V. The voltage on pin 10, IC1c will be about 2 V, which is less than that on pin 9 and the output of IC1c will be low and LED3 will be unlit. If the resistance across the input leads is about 15k, say (such as a spark plug suppressor resistor), then the voltage across the input will be about 6.4 V and the voltage presented to pin 10, IC1c will be about 3.2 V. This is above the 3 V on pin 9 and the output will thus go high, turning on LED3.

If the resistance across the input leads is about 50k, then the voltage across the input will be about 7.8 V. The voltage on pin 5, IC1b will be about 3.9 V and the output of IC1b will therefore be high, turning LED2 on. Note that LED3 will also be on as the voltage on pin 10, IC1c is above that on pin 9 and IC1c's output will be high also. Thus, for all resistances above 50k (including an open circuit) LED2 and LED3 will light.

Followed that so far? Alright, let's look at the reverse polarity indication. The relevant portion of the circuit is shown in Figure 3.

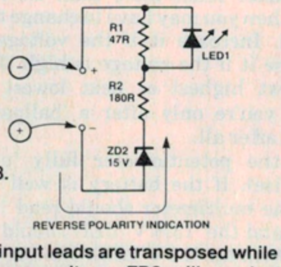


Figure 3.

If the input leads are transposed while trying to measure voltage, ZD2 will conduct as a diode in the forward direction (as shown by the arrow), passing current through LED1, which will turn on. It will also pass some current through R1, but that's immaterial. R1 is there so that current can pass to RV1 when the leads are correctly connected, otherwise no current would pass through LED1 as it would appear as a reverse-biased diode.

If you reverse the input leads while attempting to measure voltage drop, LED1 will only come on if the voltage drop is above about 1.3 V or so. Thus, it is important to watch lead polarity when measuring voltage drop in cables.

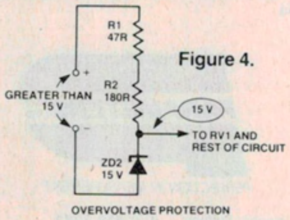
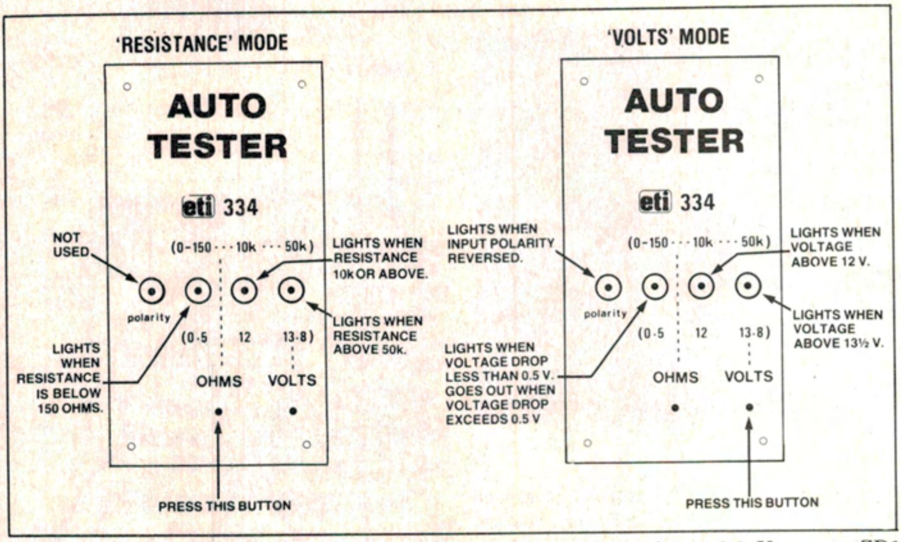


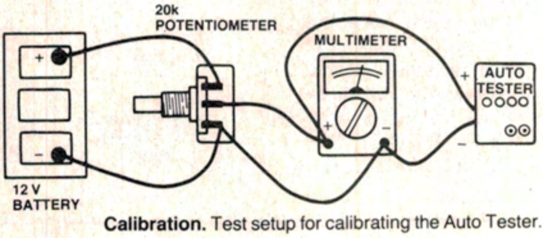
Figure 4.

Overvoltage protection is provided by ZD2. Why have it? Well, if a battery cable comes adrift and you're attempting to measure voltages while the motor is running the generator/alternator can quite easily deliver outputs of 20 V or so. This can possibly destroy the LM324. In addition, it is not unusual to get inductively-produced voltage 'spikes' on the supply lines in a vehicle, which can also destroy the IC. If a voltage of greater than 15 V appears on the input leads to the Auto Tester, ZD2 will ensure that the voltage delivered to the LM324 does not exceed 15 V.

The various voltages and resistances given here can vary by +/− 10% or so without grossly affecting your interpretation of readings. What you are after, after all, is 'ballpark' measurements which will indicate if all is well, or not.



Now you're ready for testing. But first, check *everything* carefully. See that the IC, all diodes and LEDs are correctly orientated, according to the component overlay.



Calibration. Test setup for calibrating the Auto Tester.

Testing the unit

Fit a 9 V, No. 216 battery. Short the input clips together and press the VOLTS button. The 0.5 V LED should come on. If not, check component orientations, then resistor values. Fix any faults. Once you have that corrected, try again. When you get the 0.5 V LED to light, unclip the input leads and it should go out.

To calibrate the unit, you'll need to get hold of a multimeter, a well charged 12 V battery and a 20k potentiometer. Hookup the circuit shown here and adjust the potentiometer to give a 12 V reading on the multimeter. Press the VOLTS button and adjust RV1 so that the '12 V' LED just lights. Then, reset the potentiometer to get a 0.5 V reading, or a little more, on the multimeter. The '0.5 V' LED should just light. If it doesn't light, vary the potentiometer slightly until it lights. If the '0.5 V' LED lights when the multimeter reads more than ±0.1 V from 0.5 V, then you may have to change the value of R12. Increase it if the voltage is low, decrease it if the voltage is high. Just take the next highest or next lowest resistor value, you're only after a 'ballpark' indication, after all.

Set the potentiometer fully 'up' (fully clockwise). If the battery is well charged, then the multimeter should read 13.5 V or above and the '13.8 V' LED should turn on, along with the '12 V' LED. Now, reverse the Auto Tester input leads. The POLARITY LED should come on.

If you can't get the proper indications, check with the multimeter that you are getting 7.5 V (within ±0.3 V) across ZD1 when you press the VOLTS button. Also check the voltages on pins 6, 9 and 12 of IC1 when you press the VOLTS button and see they are close to those given in the How It Works.

If all is well, proceed with testing the OHMS mode. Disconnect the 12 V battery. Set the multimeter to read resistance (should be the X1 scale). Adjust the potentiometer until the multimeter reads about 100 ohms. Press the OHMS button and the '0-150' LED should come on. Turn the potentiometer until that LED goes out and keep turning till the '10k' LED turns on. It should turn on when the multimeter reads somewhere in the vicinity of 10k.

With the Auto Tester leads open circuit, both the '10k' and '50k' LEDs should turn on.

You are now ready for use. Happy fault-finding!

Full size pc board artwork.