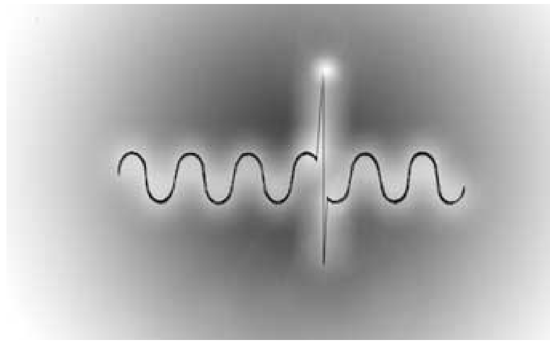
Constructional Project

TRANSIENT TRACKER



THOMAS SCARBOROUGH

Solve a "spiky" problem with this easy-build mains transient detector

DOMESTIC mains outlets provide a nominal 230V a.c. in many parts of the world – or in the USA, a nominal 115V a.c. It is not unusual, however, for sudden "skips" to occur in the mains voltage, measuring up to 1,000V (1kV) and higher. These are called *mains transients* – also referred to as *spikes*. Where such "skips" last longer than 10 milliseconds, they are referred to as *surges*.

It need hardly be said that a piece of equipment which has been designed to run off 230V a.c. could be seriously damaged by a 1,000V transient – in fact by far less than this. A typical transient waveform is shown in Fig.1a.

The point at which damage occurs to various kinds of electrical equipment is hard to quantify. This depends not only on the magnitude of a transient, but on its duration, and on the equipment itself. Having said this, however, the Transient Tracker described here will give a good indication as to when a risk is present, and will enable you, without the aid of expensive or sophisticated equipment, to determine whether such transients exist on your mains supply.

TRACKING TRANSIENTS

While it is very hard to quantify the damage that particular transients are likely to cause, it is possible to give some "ballpark figures" which roughly represent a general consensus. These will of course not apply in every case.

In the case of microprocessor controlled equipment (e.g. a computer system), repetitive transients of 100V (50V in the U.S.A.) are considered sufficient to cause permanent damage *over time*, while single transients of 1,000V (500V in the USA) may cause instant physical damage. According to some estimates, mains transients are responsible for between 70 and 90 per cent of all malfunctions in microprocessor controlled equipment!

Even the smallest power disturbances (as little as 10V or 5V in the USA) are not without peril. These are capable of causing operating errors, downtime, and data loss in microprocessor controlled equipment, which cost time and money. The effects of such disturbances on digital signals is shown in Fig.1b waveform. Other effects might include the spurious triggering of triac-controlled equipment, the resetting of digital clocks, or (in the author's case) the readjustment of a hi-fi system's volume.

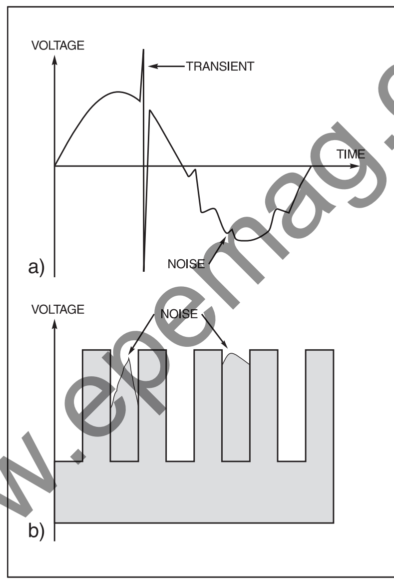


Fig.1a. A typical transient waveform and (b) power disturbance on digital signals.

The Transient Tracker detects mains transients above a selected level, which is adjusted by a front panel dial. It is capable of detecting transients down to less than 1µs, which compares favourably with the typical transient – an oscillatory event which continues for 6µs or 7µs. Its chosen scale of 0V to 270V (0V to 135V in the USA) covers the most active part of the range. This range may be expanded or compressed and will be explained later.

Mains transients are mainly caused by lightning on the one hand, or the discharge of stored energy in inductive or capacitve components on the other. The cause of transients in the second category might include (among other things) an electric drill, a mains transformer, or fluorescent lighting. The author has a desktop lamp which, during testing of the Tracker, produced up to 800V transients while switching on and off!

CIRCUIT DESCRIPTION

The Transient Tracker has three important building blocks and these are shown in the schematic diagram Fig.2. The first is a transformerless power supply, which is chosen for its ease of integration with direct measurements of the a.c. voltage. The second is a comparator (IC1a), which compares the mains voltage with a level selected by a potentiometer (VR2).

The third is an op.amp oscillator (IC1b), which is enabled by pulses at the output of IC1a. In this case, an op.amp oscillator is chosen specifically because it may be incorporated in a single i.c. with the comparator.

The full circuit diagram for the Transient Tracker is shown in Fig.3. The transformerless power supply is fairly standard – however, it has no transient suppressor, which would normally be wired across the Live and Neutral terminals. It goes without saying that a transient suppressor would not be a particularly good idea for a transient detecting circuit! For this reason, capacitors C1 and C2 have a

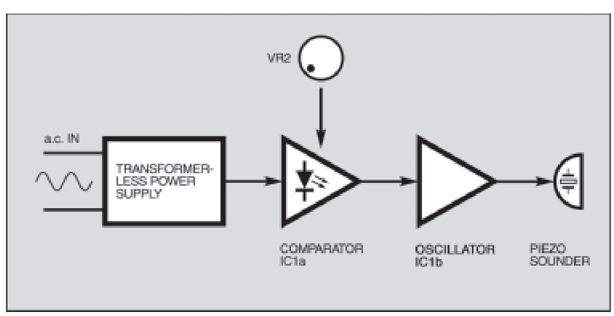


Fig.2. Block schematic diagram for the Transient Tracker.

higher "class Y" rating, which is better able to withstand the absence of the transient suppressor. These capacitors ***must*** be of the specified type and rating.

In brief, the flow of a.c. mains energy is considerably limited by the capacity of C1 and C2. Zener diode D3 then limits the positive voltage rectified by diode D2 to 10V, while diode D1 limits the negative voltage to 0·6V. Capacitor C3 maintains the "Zener voltage" during the mains negative half-cycle. The result is a power supply which provides about 6mA at 10V.

FIRST AID

Fuse FS1 is provided for safety, and resistor R1 limits instantaneous current in case the circuit is connected to the mains at a high voltage point. Resistor R1 additionally limits the absorption of transients by C1 and C2. R2 prevents "reverse shock" from C1 and C2 when the unit is unplugged.

Resistors R1 to R3 ***MUST*** be suitably rated, with a maximum overload voltage of at least 1,200V. For this reason, specific 2W types are specified in the Components listing.

It needs to be borne in mind that the reference voltage at IC1a pin 2 is compared with a representation of the *maximum* a.c. voltage. This is not the same as the 230V (115V in the USA) *r.m.s.* value of the mains voltage. The r.m.s. value is multiplied by the square root of 2 to obtain the maximum value, which is 325V (163V in the USA).

Front panel layout on the completed prototype.

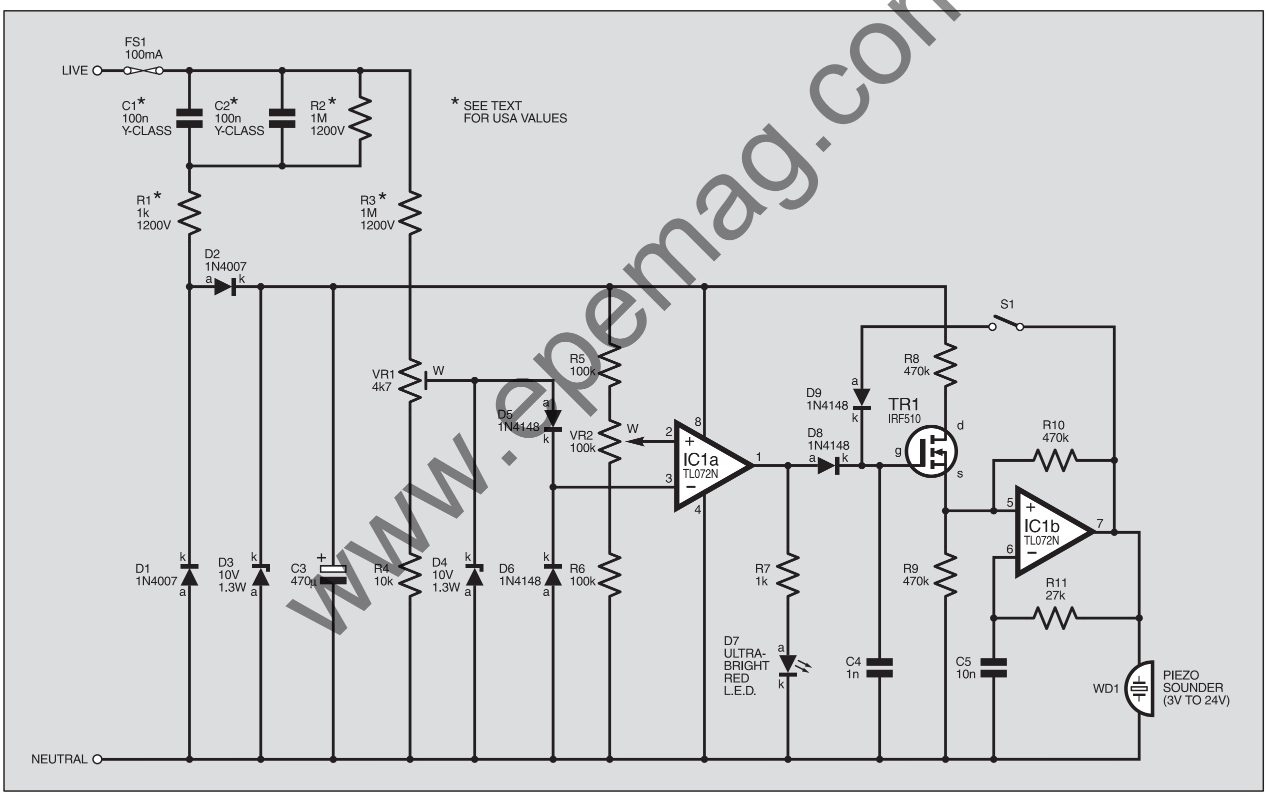


*Fig.3. Complete circuit diagram for the Transient Tracker. You **must** use high quality Class-Y capacitors and high voltage resistors where indicated – see text.*

IN COMPARISON

A simple comparator, formed by IC1a, compares the voltage of the mains potential divider network R3-VR1-R4 at the input pin 3 with the reference voltage at input pin 2. The reference voltage is set by potentiometer VR2, which provides detection of transients above a selected level between 0V and 270V (0V to 135V in the USA).

Zener diode D4 prevents over-voltages at IC1a input pin 3. Diodes D5 and D6 provide bi-phase rectification of the a.c. voltage at IC1a pin 3.

OSCILLATOR CIRCUIT

Op.amp IC1b forms a standard oscillator, which oscillates at a high audio frequency, determined by the values of resistor R11 and capacitor C5. This oscillator is enabled when transistor TR1 conducts. An IRF510 *n*-channel power MOSFET is chosen here, not for its power handling capability, but for its "logic MOSFET" characteristics.

Assuming that TR1 is conducting when power is applied to the circuit, capacitor C5 begins in a discharged state, with the result that IC1b's inverting input pin 5 is negative of the non-inverting input pin 6. The output (pin 7) of IC1b is therefore "high", causing resistor R10 to be effectively in parallel with R8. Two-thirds of the supply voltage is therefore present at non-inverting input pin 6. Capacitor C5 charges via resistor R11 until the voltage across it reaches two-thirds of supply voltage, whereupon the the op.amp output starts to go negative, and so on . . .

When TR1 is in its non-conducting state, input pin 5 of IC1b is held "low", so that IC1b is unable to sustain oscillation. When capacitor C4 is charged through a pulse from IC1a output pin 1, TR1 conducts, and IC1b is able to oscillate. As the charge on capacitor C4 drops, so does the conductance of TR1, causing the pitch of the oscillator to rapidly fall. Mains transients are thus reported with a falling "pioooo!" sound from the piezo sounder WD1.

Finally, diode D9 and switch S1 provide an important innovation. These return the output of oscillator IC1b to the "positive plate" of C4 when switch S1 is closed. This essentially turns D9 and C4 into a diode pump, and holds TR1's gate permanently "high" when a transient is detected. In this way, the Transient Tracker may be used as a simple "logger", which reports any transient above a selected level within a desired period.

Note that if the Transient Tracker is to be constructed in the USA, the following modifications need to be made:

Add two more 100n "Y-class" capacitors in parallel with C1 and C2.

Increase the size of the case as required.

Replace R2 with an identically rated 470k resistor.

Replace the 0V to 270V calibrated scale with a 0V to 135V scale.

CONSTRUCTION

The Transient Tracker is built up on a small single-sided printed circuit board (p.c.b.), measuring 55mm × 80mm. Details of the topside component layout, together with the full-size underside master, are shown in Fig.4. This board is available from the *EPE PCB Service*, code 372.

Since this circuit is connected directly to the mains, it is of *crucial importance* that components should be correctly rated, inserted the right way round, and that there should be no solder bridges on the board. Also, apart from using nylon nuts and bolts to mount the p.c.b. inside the case, you should, for added safety, cover the underside mains-bearing copper tracks with insulating tape to avoid any possibility of shorting tracks together.

Alternatively, you can use self-adhesive plastic (nylon) stand-off "feet" to mount the p.c.b. inside the case. Metal mounting bolts ***must not*** be used as the "heads" will be exposed on the outside of the case.

Commence construction by soldering in position the solder pins and the dual-in-line (d.i.l.) socket on the board. Then solder the resistors, diodes, and l.e.d., continuing with the capacitors and transistor. Attach the "peripheral components" S1, VR2, D7, and WD1 to the solder pins via lengths of insulated multistrand wire.

COMPONENTS

See SHOP TALK page

Resistors

R1	1k 2W (1200V max. overload voltage)
R2, R3	1M 2W (1200V max. overload voltage (2 off)
R4	10k
R5, R6	100k (2 off)
R7	1k
R8, R9, R10	470k (3 off)
R11	27k

All carbon film 0·25W 10%, except R1 to R3

Potentiometers

VR1	4k7 enclosed carbon preset
VR2	100k rotary carbon, lin. with plastic case and spindle

Capacitors

C1, C2	100n Y-Class metallised paper or polypropylene 250V/275V a.c. (2 off)
C3	470µ radial elect. 16V
C4	1n radial tubular foil polystyrene
C5	10n ceramic

Semiconductors

D1, D2	1N4007 1000V 1A rec. diode (2 off)
D3, D4	10V 1·3W Zener diode (2 off)
D5, D6, D8, D9	1N4148 signal diode (4 off)
D7	ultra-bright red l.e.d.
TR1	IRF510 *n*-channel power MOSFET
IC1	TL072CN dual j.f.e.t. op.amp

Miscellaneous

X1	3V to 24V piezoelectric sounder
S1	s.p.s.t. mains rated slimline rocker switch
FS1	100mA 20mm cartridge fuse, with p.c.b. mounting holder

Printed circuit board available from the *EPE PCB Service*, code 372; plastic case, size 100mm x 62mm x 26mm approx.; 8-pin d.i.l. socket; plastic knob, with pointer, multistrand connecting wire; mains cable; cable grommet; cable tie; mains plug; nylon nuts and bolts; solder pins; solder etc.

Approx. Cost Guidance Only **£15** *excl. case*

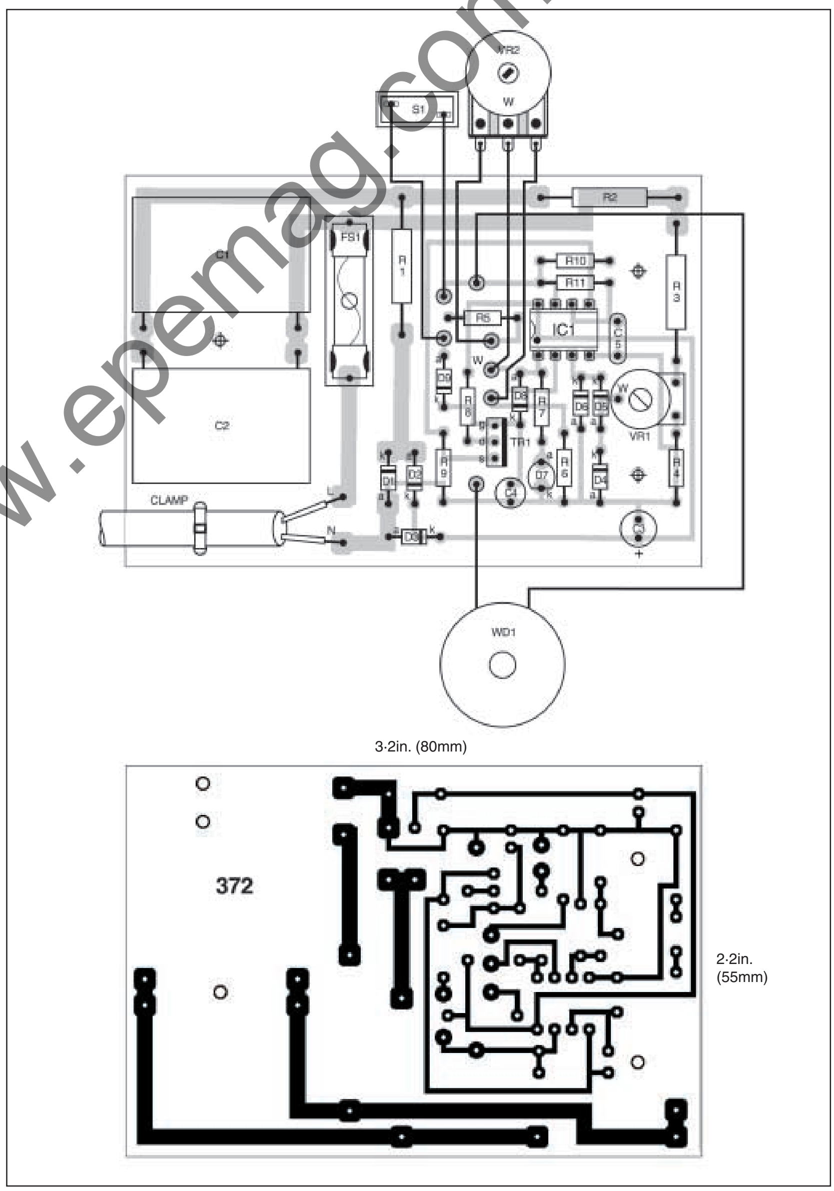


Fig.4. Printed circuit board topside component layout, wiring and full-size copper foil master for the Transient Tracker.

ASSEMBLY

A plastic case ***must*** be used to house the circuit board with no metal parts passing through the case to be exposed on the outside of the unit. The author used a small handheld type measuring just 100mm × 62mm × 26mm. This left no room for p.c.b. mounting plastic stand-off feet and the board was mounted using nylon nuts and bolts.

Attach a plug to a mains cable. Insert the mains cable through a grommet in the side of the case. Attach the Live and Neutral wires to the two solder pins as shown, using a cable tie to secure the mains cable firmly to the board (see photographs) – this is passed through the two holes provided. Finally, insert the 100mA fuse in the fuse-holder, and IC1 in the 8-pin d.i.l. socket. Fix a knob with pointer to the shaft of VR2, and add a calibrated scale.

TAKE NOTE

If R5 and VR2 are replaced with a 220k potentiometer, the scale is increased to 920V (460V in the USA). Alternatively, if VR2 is replaced with a 47k potentiometer and a 56k resistor in series (with the 56k resistor being connected to R5), the scale is reduced to 130V (65V in the USA).

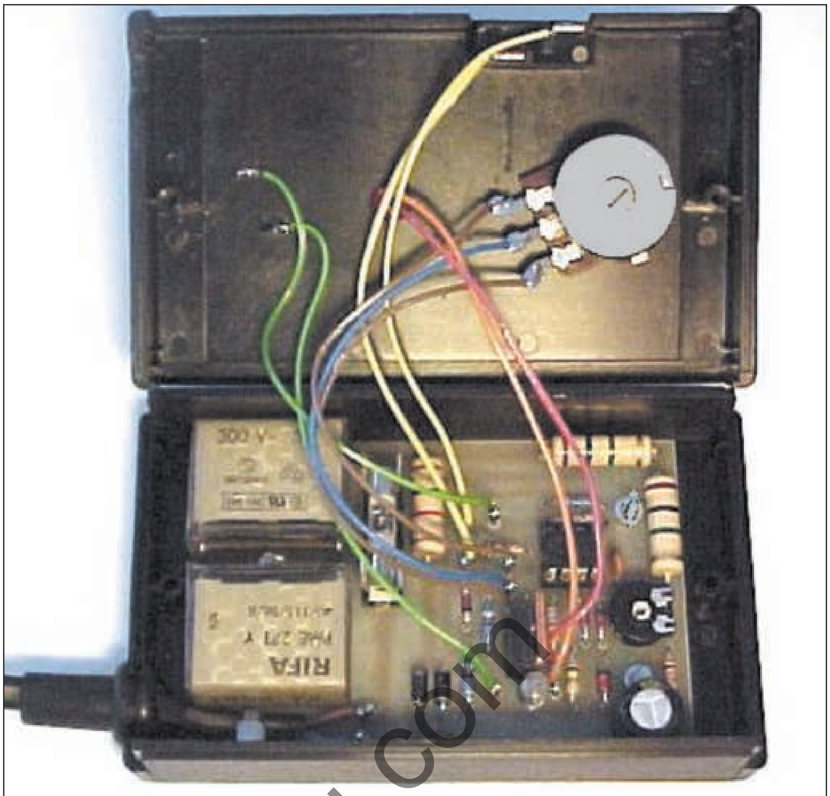
Component tolerances may vary, therefore if the piezo sounder WD1 remains silent at all settings of VR1 and VR2, increase the value of resistor R4. If it continually sounds, decrease the value of R4.

Since this circuit is directly connected to the mains, it is important that all components should meet the minimum ratings shown in the Components list.

CALIBRATION

Calibration is "a snap". First make sure that all electrical equipment in the home is momentarily switched off, and that there is not likely to be any electrical activity of any kind next door, or any electrical storms in the vicinity. Switch S1 to the "off" position. Turn preset VR1 to its mid position. Turn back potentiometer VR2 completely.

Plug the Transient Tracker into a nearby mains outlet. Piezo disc WD1 may or may not sound continuously. Holding one hand behind your back (so that the mains supply will under no circumstances find a path across the heart), and using an *insulated* screwdriver, adjust preset VR1 so that WD1 *just* stops sounding. ***Be careful not to touch any of the circuitry – a shock from the mains can kill you***.



Completed prototype showing wiring to top panel mounted components.

The Transient Tracker has now been set up. Securely close the case, ensuring that the p.c.b. is fully enclosed, and that no live circuitry can be touched. Ensure that the "peripheral components" are so positioned that there are no short circuits inside the case.

To test the unit, try plugging an inductive load (for instance, a vacuum cleaner or electric drill) into the same wall outlet as the Transient Tracker, switching this load on and off a few times. In all likelihood, this will trigger the Tracker – in some cases at its highest setting.

IN USE

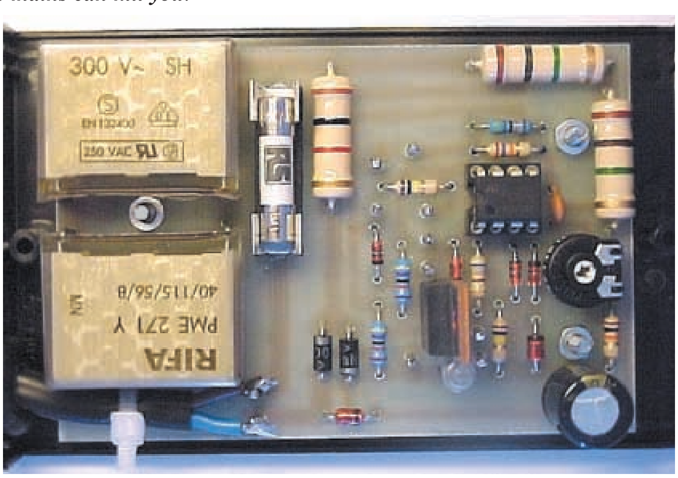
When a mains transient is detected above the selected level, the ultra-bright l.e.d. D7 flashes, and piezo disc WD1 sounds. Also, one may gain some impression as to the severity of a transient according to the intensity of the l.e.d.'s flash, and the pitch of WD1. The unit may respond to individual mains transients, or (more likely) streams of mains transients that will keep WD1 sounding for minutes at a time – especially at its lower settings.

The transients which hold the greatest risk may be those caused by equipment (such as the author's desktop lamp) which is plugged into the same mains outlet as the equipment wanting protection. This makes it a particularly bad idea, for instance, to run a vacuum cleaner and a computer off the same wall outlet. Electrical storms also pose a particular risk, and if these should draw near (three seconds between the lightning and thunder), it would be best to unplug your electrical equipment – particularly microprocessor controlled equipment.

TIME LOG

If switch S1 is in the "on" position, a transient above the selected level will cause WD1 to sound continually until it is switched off, thus acting as a "logger". The Tracker is much more sensitive in this "on" position, since feedback causes even the briefest of transients to register. Some transients may otherwise be so brief that they will barely be seen or heard. With switch S1 in the "on" position, the Transient Tracker is better suited to detecting spikes, while in the "off" position it is better suited to detecting surges.

It may soon become apparent what is causing mains transients, but in some cases these may be caused by electrical equipment that is hidden, such as a hot water heater, or even an item in a neighbour's home. By selecting a level of 100V (50V in the USA), one may identify sources of mains transients which may place microprocessor controlled equipment physically at risk – as well as testing protective measures such as surge suppressors and transient voltage surge suppression systems. □



Completed p.c.b. mounted in its case. Note the strain relief tie securing the mains cable.