4 CHANNEL GAS & SMOKE SENTINEL

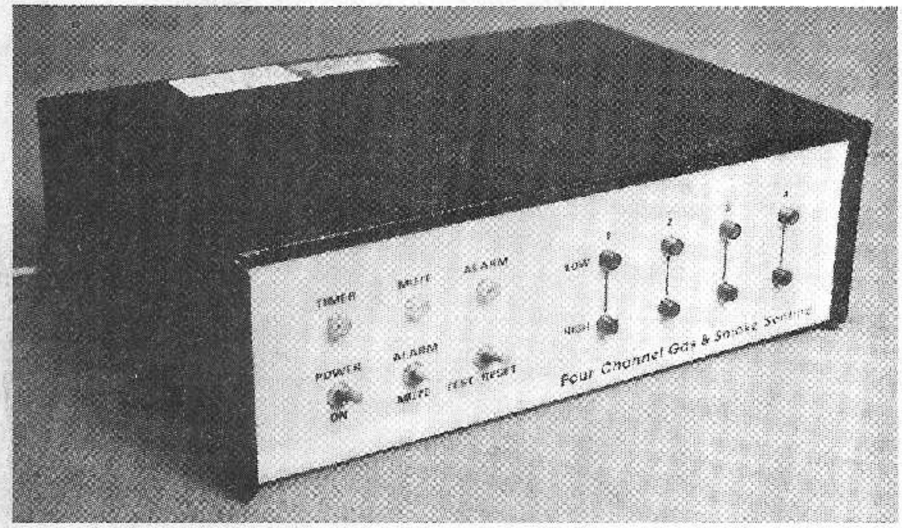
BY A. R. WINSTANLEY

This four-channel monitoring and alarm system gives early warning of gas leaks and also of imminent danger of fire.

Each of the four sensors can be installed in optimum positions to detect either gas leaks or smoke in various parts of the house.

The master control unit is equipped with red and green l.e.d.s which indicate status of each sensor.

External 12V alarms can be connected and extended to any convenient point.



THIS four-channel gas and smoke detection system is an expanded version of the author's "Gas Sentinel" design which was published in EVERYDAY ELECTRONICS, April 1980. The arrangement described here comprises a master control unit into which are connected four remotely-located "TGS" type gas sensors, enabling four areas to be monitored simultaneously.

Each TGS detector is capable of sensing many gases: the system will respond to hydrocarbons (for example, bottled gas like butane and propane), alcohols (propanol, for example) and hydrogen cyanide (significant because this gas is emitted from burning foam-filled furniture and it is highly toxic).

FIRE WARNING

The Sentinel operates as a fire warning system in that it is capable of detecting accumulations of smoke (or, more specifically, carbon monoxide and any toxic gases contained in the smoke). In the case of burning foam-filled furniture, extremely toxic and very dense smoke containing hydrogen cyanide is emitted in the first instance and this smoke will be quite sufficient to trigger the alarm before the furniture has become totally enveloped in flames, providing that the sensor's sensitivity controls are set up sensibly.

Adjustable sensitivity controls are included in each channel and although they are uncalibrated it is possible to set up a triggering level which is well below the accumulation required to cause ignition.

TWO DETECTION MODES

It is therefore clear that the Gas Sentinel has two detection modes: as a **gas leakage detector** or as a **smoke alarm.**

When a sensor is employed to detect gas (preferably use the TGS813 for this) then the sensor should be placed low down, since the relevant gases in question are heavier than air and will accumulate at floor level; however at the same time the detector should be placed near to the gas apparatus where it will have most chance of detecting a leak at the earliest opportunity.

When used as a smoke alarm (TGS812 for this) then since smoke rises, the detector ought to be positioned on one wall about 1–2 feet from the ceiling. Cables can be hidden from view using attractive plastic conduit available for this purpose.

In terms of actual expenditure, the cost of the Four Channel Gas and Smoke Sentinel compares favourably with, say, the total cost of four commercially available domestic smoke detectors at some £10–£15 each. The Sentinel however has the added attraction of being able to sense both gas *and* smoke.

FEATURES OF SYSTEM

The Gas and Smoke Sentinel has several advantageous features:

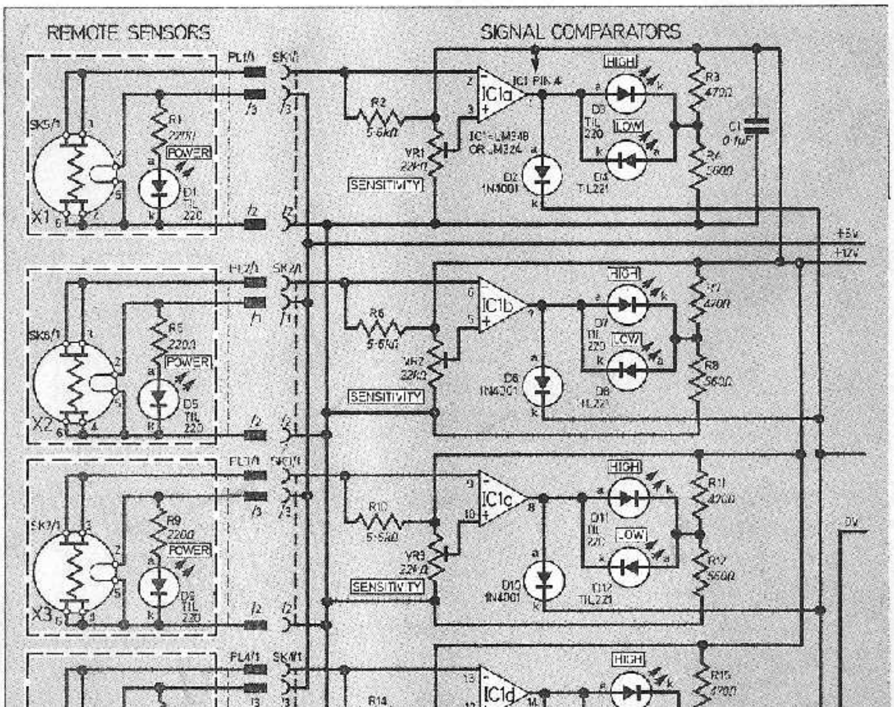
1. All controls and indicators have been brought together into one unit making the overall system very convenient to operate.
2. "Go-no-go" status monitors in the form of red and green lamps have been incorporated in each channel, giving a simple readout of the gas or smoke levels in all four locations.
3. External 12V alarms, whether lamps or buzzers, can be connected and extended to any convenient point.
4. It will respond to both smoke and gas: many readily-available units will detect smoke only.

Therefore, although there is the disadvantage that installation of this system may be a little trickier, since each sensor must be connected by 3-core cable, the many advantages which this design offers will more than compensate for any additional work involved.

CIRCUIT DESCRIPTION

Each of the four channels incorporated within the design is identical and the operation of channel number one will be described: the three remaining channels

Fig. 1. Circuit diagram of the Four-Channel Gas and Smoke Sentinel.



function in a similar manner. The circuit diagram appears in Fig. 1.

Each channel employs an operational amplifier, as in the original Gas Sentinel. Each op-amp is connected in the comparator mode, in which the op-amp compares the difference between the voltages at the non-inverting (+) input and the inverting (−) input.

If the potential at the + input is greater than that at the − input then the output swings high to roughly the same voltage as the positive supply rail. Similarly, if the voltages at both inputs should reverse, so that the non-inverting input is at a lower voltage than the inverting input, then the op-amp will greatly amplify this, the result being that the output swings from a high voltage to roughly zero volts.

OPEN-LOOP GAIN

The open-loop gain (the amplification factor of the op-amp without any feedback network being connected) is so high—usually too high to be of any use—that only a fraction of a millivolt difference need occur between the two inputs to make the op-amp output swing from one voltage to the other. The arrangement therefore is very sensitive.

Since four op-amps are of course needed, then rather than use four separate devices, one single package is employed, type LM348. This contains four general-purpose devices in one 14-pin d.i.l. outfit and is much more convenient to use.

Each op-amp has a selectable reference voltage derived from VR1 in channel one, VR2 in channel two, and so on, hooked up to the non-inverting input and this potentiometer can be adjusted to suit; in fact it forms the sensitivity control for each channel.

SPECIFICATION

POWER SUPPLY REQUIREMENTS
240V a.c. 24VA or 12V d.c. 1·5A maximum

NUMBER OF SENSORS
Four maximum

TYPE OF SENSORS
N-type Tin Oxide semiconductor resistance heated by internal 5V 130mA filament

SENSITIVE TO
Hydrocarbons (e.g. propane, butane)
Alcohols (e.g. ethanol)
Inorganic gases (e.g. carbon monoxide, hydrogen cyanide)
Smoke,
and others

ALARM SYSTEM
Built in audible-warning device and l.e.d.; provision for externally-connected alarm

STATUS MONITORS
Red and green lamps continually illuminated to denote "status" of each channel (alarm level/normal)

AUTOMATIC WARM UP TIMER
Disconnects alarm system for first $1\frac{1}{2}$ minutes (approx.) immediately after switching on: prevents alarms from operating after power failure

The other input also has a voltage divider connected to it, this time in the form of a fixed resistor (R2) and a TGS sensor resistance element X1.

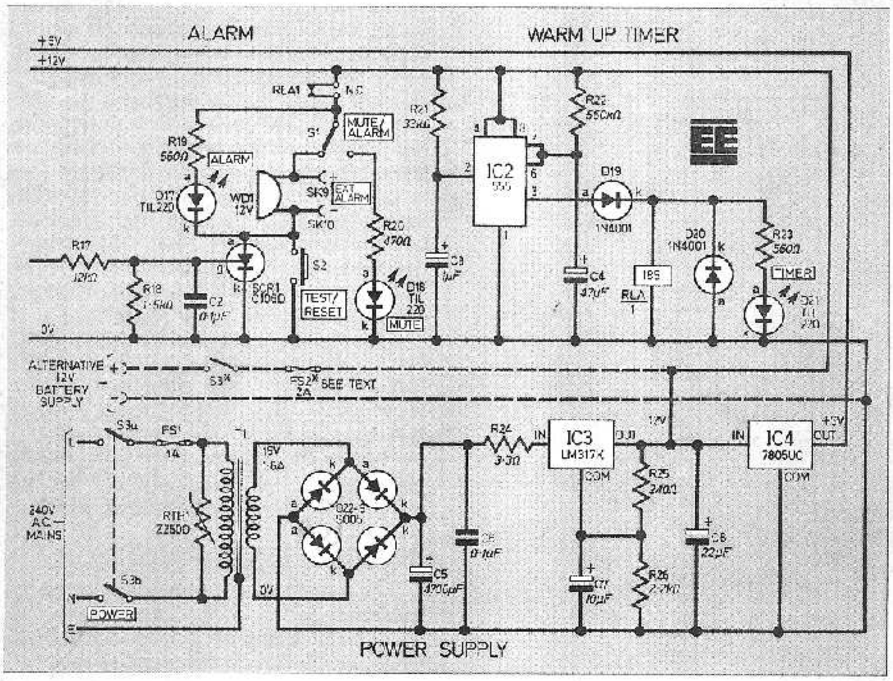
SENSING OPERATION

An increase in ambient gas levels around the TGS detector will bring about a reduction in the detector resistance and, by voltage divider action, means that the voltage at the inverting input (pin 2) of the op-amp will fall until such point when it is less than the voltage reference set up by VR1, when the op-amp output (pin 1) will switch high.

A red light-emitting diode, D3, is wired to the output—R4 being its series current limit resistor—and this l.e.d. will illuminate to serve as an alarm indicator for channel one. Also a "high" triggering signal is transmitted through D2 and via the attenuator R17 and R18 to the gate terminal of the main alarm thyristor SCR1.

The thyristor is now able to conduct, and completes the circuit to the alarm buzzer WD1, which now sounds, and to the "alarm" indicator D17. An external alarm system (specification: 12V d.c. 500mA maximum current) can, if one wishes, be connected to SK9 (positive) and SK10 (negative), and this too will now operate. See "Application Notes" for further information on the external alarm.

Due to the continuous conducting action of SCR1, the alarm system will function until the gas level drops away again (D3 extinguishes) in which case it is possible to reset the alarm section either by temporarily removing the power or by closing S2, the alarm test/reset switch.



Note however, that once the thyristor is triggered, it *remains* in a conducting state until reset at S2; this in turn is only possible once the gas level has diminished, which will remove the constant triggering signal presented to the thyristor gate by the op-amp.

Also, when SCR1 is not conducting, the alarm circuitry will operate if S2 is closed—a useful "alarm test" function.

Until the gas level has dropped it is not possible to silence the alarm except by changing over S1, such that WD1 and any external alarms are removed from circuit. Then D18 (the "alarm mute" reminder lamp) will illuminate, although notice that the "alarm" l.e.d. D17 remains in circuit regardless of the setting of S1, and this will remind you whether the thyristor is conducting or not.

Triggering signals from channels two to four will be fed through diodes D6, D10 and D14, respectively into the thyristor gate attenuator as before.

STATUS INDICATORS

A further l.e.d. indicator has been added to each channel: the green lamp D4 lights when the gas level is "normal", that is, below a level determined by the setting of VR1. The green lamp will extinguish and the red lamp D3 will light when the op-amp output changes from low to high.

The coloured light-emitting diodes form a simple status monitor for each channel, green indicating "normal" and red "danger", and under normal conditions the operator will observe just a row of green lamps.

WARM UP TIMER

Each TGS sensor requires a brief warming-up period. When power is first applied to the TGS filament, the semiconductor resistance drops quite dramatically before rising back to its operating level. The Gas Sentinel would erroneously interpret this as an increase in the gas level and would therefore operate the alarm.

It is then necessary to silence the alarm during the warming-up period and this is achieved by IC2, an NE555 timer chip connected as a monostable. When power is first applied, IC2 is triggered into timing by R21 and C3, and commences timing, activating RLA. The normally closed contacts RLA1 open and remove power from the whole alarm section for approximately $1\frac{1}{2}$ minutes, as measured on the prototype.

The red l.e.d., D21, lights when the 555 is timing and acts as a warm-up indicator; when the lamp extinguishes this signifies that the alarm system has been reconnected. By this time all four detectors should have warmed up and settled to their normal operating resistances.

This useful little timer section will also prevent the alarm from sounding after a power failure, since after resumption of power the sensor resistances could perhaps drop to a low level while warming up.

POWER SUPPLY SECTION

As each TGS filament demands some 150mA each at 5V d.c., it is necessary to substantially boost the original power supply section to enable it to supply this.

IC3 is an LM317K (TO-3 package) regulator set up by means of R25 and R26 to provide 12V d.c. at up to 1·5 amps. This is passed to the timer, op-amps and the alarm. IC4 further reduces the 12V to 5V d.c. regulated, and this feeds all four sensor filaments through pin 3 of the sensor DIN sockets.

It is essential that the regulators are adequately heatsinked for them to be able to cope with worst-case conditions, and the components list details the recommended heatsinks.

12V OPERATION

It should be possible to power the system from an external 12V d.c. supply as indicated in Fig. 1. Under quiescent conditions the complete system consumes roughly 800mA. A lead-acid battery will be able to supply this for fairly long periods before recharging is required, depending on the battery capacity, of course.

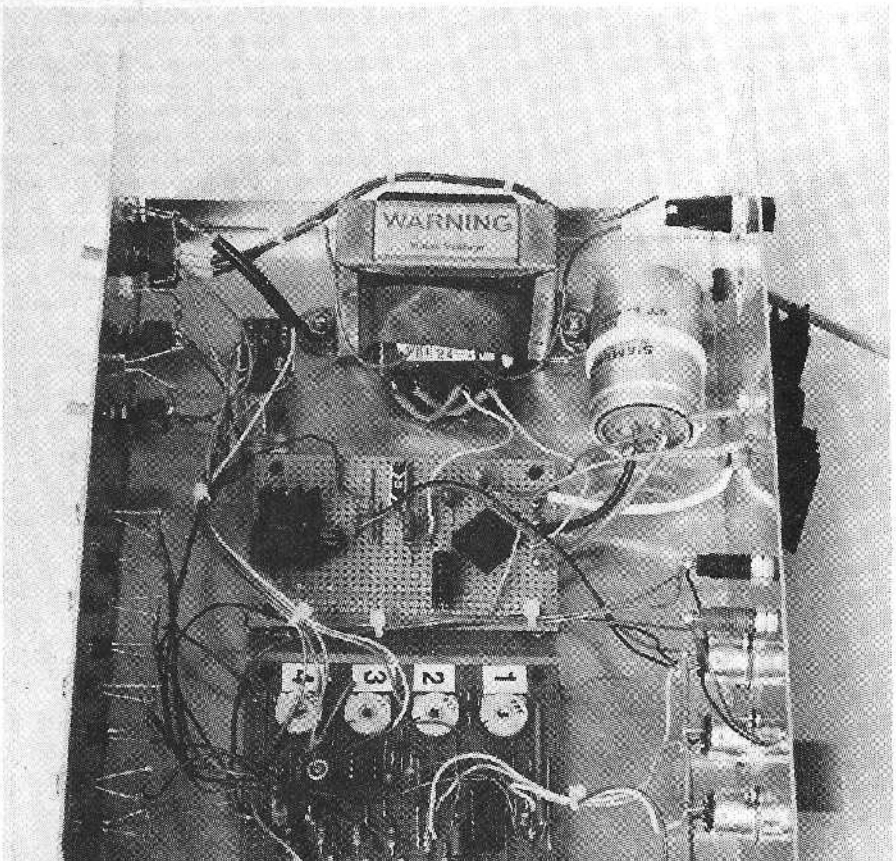
It is naturally essential that the battery is not completely discharged due to excessively long operating periods without being charged up again. A "low voltage" monitor could be incorporated to help prevent this, although such a device was not included on the prototype—there are enough lamps and switches already!

It is worth pointing out that the 12V battery-powered version can be built considerably cheaper than the mains-operated unit, since the expensive mains transformer and 12V regulator, amongst other items, can be dispensed with.

The necessary modifications required for a 12V operation are quite straightforward: simply omit all power supply components which are in circuit prior to IC4. A 12V d.c. input, therefore, should be taken through a single-pole on/off switch and 2-amp fuse directly to the input of IC2. C8 should be left in circuit.

REMOTE SENSOR UNIT

The remote sensor unit is connected by miniature 3-core wire to the master unit at a DIN plug and socket, SK1 and PL1. Cable length can exceed some 15 metres.



A visual indicator, D1, D5, D9, D13 is incorporated into the remote sensors to indicate the system is switched on, should the user happen to be able to glance at the sensor unit. The l.e.d. can be omitted if required.

CONSTRUCTION

The mains-powered model should be constructed in a metal case; that used on the prototype had an aluminium chassis for ease of working and measured 280 × 90 × 200mm. The battery-operated unit could be built into a much smaller case, possibly made of plastic.

There are no less than eleven light-emitting diodes and three switches to be mounted on the front panel. This may seem to be an excessive number and could be construed as overdoing things a little! However, with just a little planning in front panel layout it should be possible to arrive at a final design which is attractive in appearance and is easy to use.

The front panel, then, carries the three switches and eleven lamps. The light-emitting diodes can be fitted in with coloured lens-clips and if the recommended sub-miniature types are used the switches can be affixed through $\frac{1}{4}$in diameter holes.

POWER SUPPLY BOARD

Inside the main unit, two pieces of 0·1in matrix stripboard accommodate all the electronics. Firstly the power supply, with the exception of C1 and IC1, is assembled on a standard-sized stripboard of 24 strips × 37 holes, see Fig. 2.

The large smoothing capacitor, C5, is a "can" type and is fitted to the chassis with a horizontal mounting clip. Two flying leads should be made with 18 s.w.g. tinned copper wire insulated with pvc sleeving, and these connect C5 to the power supply board. The two wires should be kept as short as possible to keep their resistance to a minimum, and it is *essential* that the component is soldered the right way round in the circuit.

On the prototype the regulator IC4 was fixed, together with its heatsink, to the stripboard using a single 6BA bolt—no insulating kit is required for the regulator.

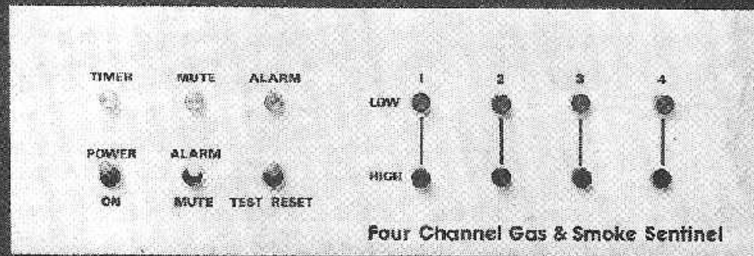
On the other hand the LM317K regulator, IC3, must be fully insulated from the chassis with a standard TO-3 insulating kit, comprising a mica washer and two bushes for the mounting bolts.

The only other point on the power board is that the wirewound resistor R24 should not be soldered flush with the stripboard, but should be stood off approximately 1cm, to enable it to dissipate heat more efficiently.

MAIN COMPONENT BOARD

The other stripboard is of dimensions 30 strips × 37 holes, 0·1in matrix. This carries the remainder of the electronics,

COMPONENTS



Resistors

R1	220Ω
R2	5·6kΩ
R3	470Ω
R4	560Ω
R5	220Ω
R6	5·6kΩ
R7	470Ω
R8	560Ω
R9	220Ω
R10	5·6kΩ
R11	470Ω
R12	560Ω
R13	220Ω
R14	5·6kΩ
R15	470Ω
R16	560Ω
R17	12kΩ
R18	1·5kΩ
R19	560Ω
R20	470Ω
R21	33kΩ
R22	560kΩ
R23	560Ω
R24	3·3Ω 7W w.w.
R25	240Ω
R26	2·2kΩ

All $\frac{1}{4}$W 5% carbon, except R24

Potentiometers

VR1–4	22kΩ horizontal skeleton preset (4 off)

Capacitors

C1	0·1µF polyester
C2	0·1µF ceramic tube
C3	1µF 35V tantalum bead
C4	47µF 25V elect.
C5	4700µF 40V elect.
C6	0·1µF polyester
C7	10µF 35V tantalum bead
C8	22µF 25V elect.

Semiconductors

D1,5,9,13	TIL220 0·2in red l.e.d. (4 off)
D2,6,10,14	1N4001 50 PIV 1A silicon diode (4 off)
D3,7,11,15	TIL220 0·2in red l.e.d. (4 off)
D4,8,12,16	TIL221 0·2in green l.e.d. (4 off)
D17	TIL220 0·2in red l.e.d.
D18	TIL223 0·2in yellow l.e.d.
D19,20	1N4001 50 PIV 1A silicon diode (2 off)
D21	TIL220 0·2in red l.e.d.
D22,23,24,25	S005 50 PIV 2A bridge rectifier
IC1	LM348 or LM324 quad op-amp
IC2	NE555V timer
IC3	LM317K 1·5A variable regulator, TO-3 pack
IC4	7805UC 5V 1A regulator, TO-220 pack
SCR1	C106D 4A thyristor

Switches

S1	sub-miniature s.p.d.t. toggle
S2	sub-miniature s.p.d.t. toggle, biased one way
S3	sub-miniature d.p.d.t. toggle 2A 250V a.c.

Connectors

PL1–4	3-pin DIN plug (4 off)
SK1–4	3-pin DIN socket (4 off)
SK5–8	TGS socket (4 off)
SK9,10	4mm, one red, one black (2 off)

Miscellaneous

FS1	1A 20mm panel fuseholder/quick-blow fuse
RLA	12V 185 ohm continental relay
T1	mains transformer, 240V primary, 2×15V 800mA secondaries (ITT BR24-15)
WD1	9V–12V 15mA audible warning device
X1–4	TGS812 or TGS813 low-voltage gas sensor (4 off)

0·1in matrix stripboard: one each, and 24 strips × 37 holes and 30 strips × 37 holes; instrument case "NORMAN" type 280 × 90 × 200mm; Verobox type 20124, 72 × 47 × 25mm (4 off); TO-220 heatsink TV5 drilled offset 17°C/W or better; 2Y-TO3 heatsink (Redpoint) 6·2°C/W or better (ElectroValue); TO-3 insulation kit; red lens clips (8 off); green l.e.d. lens clips (4 off); transparent l.e.d. lens clips (3 off); horizontal capacitor clip to fit C1; 8-pin d.i.l. socket; 14 pin d.i.l. socket; mains 6A 3-core cable; miniature 3-core cable, to suit; hook up wire, nuts, bolts, spacers, solder etc.

Gas & Smoke Sentinel

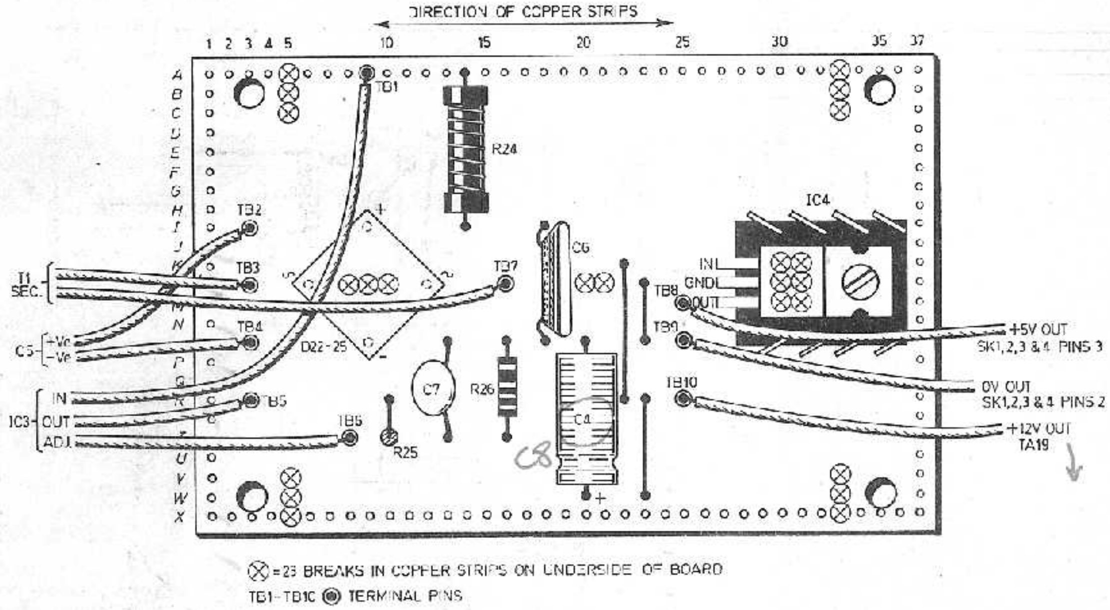
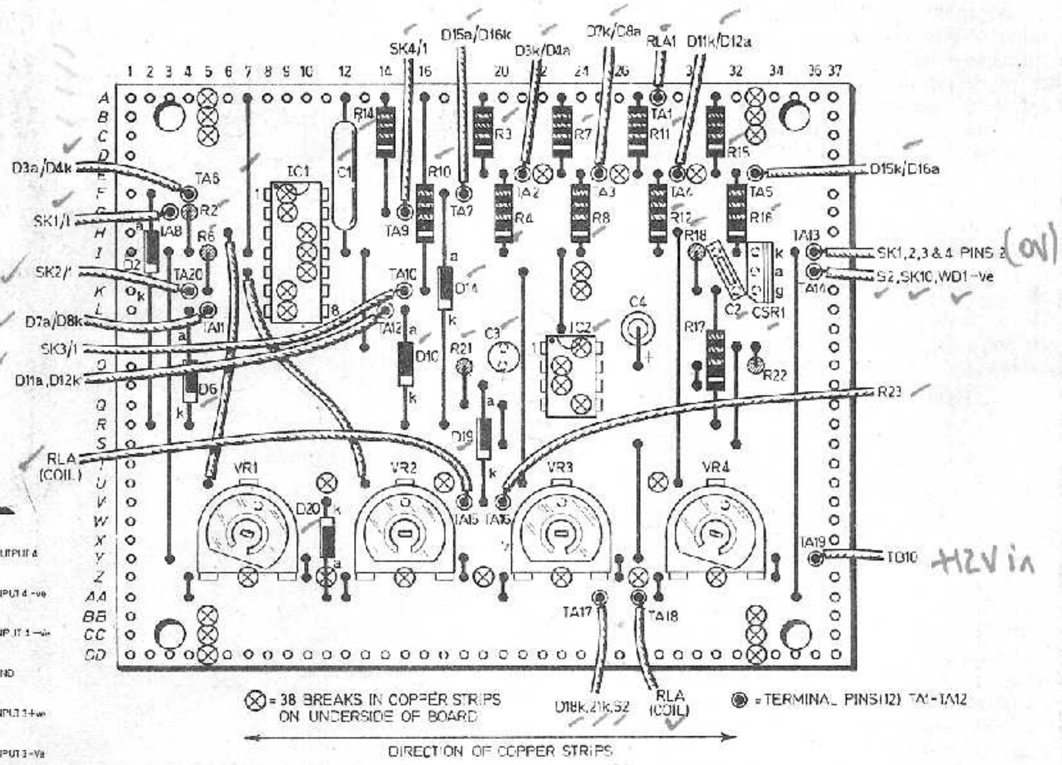


Fig. 2. Power supply board.



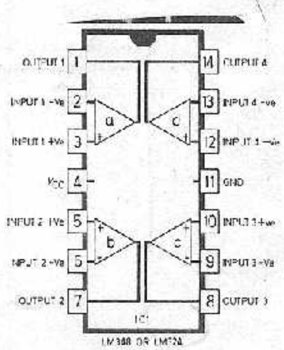


Fig. 3. Main component board.

Gas & Smoke Sentinel

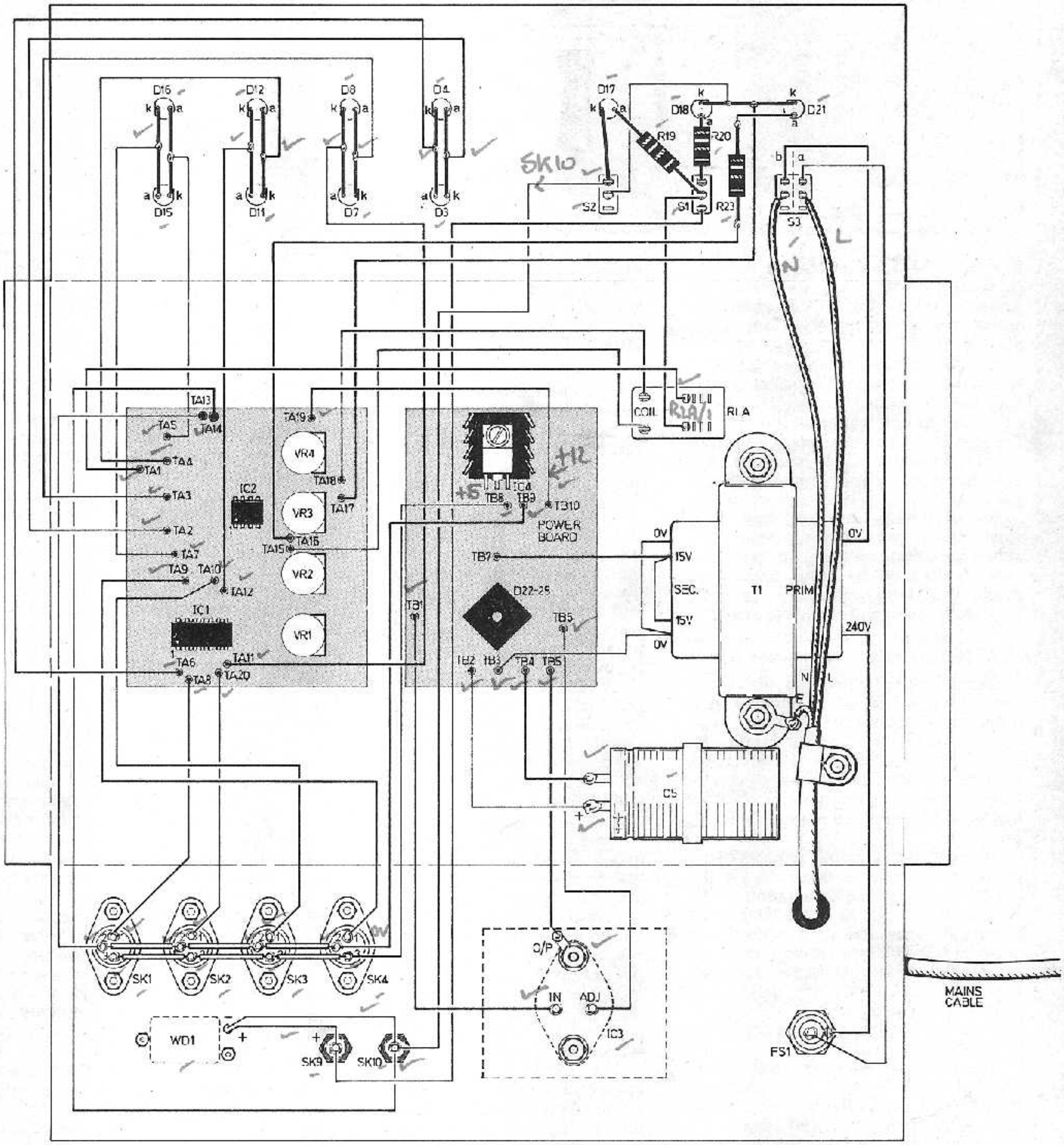


Fig. 4. Interwiring between the two boards and the chassis-mounted components.

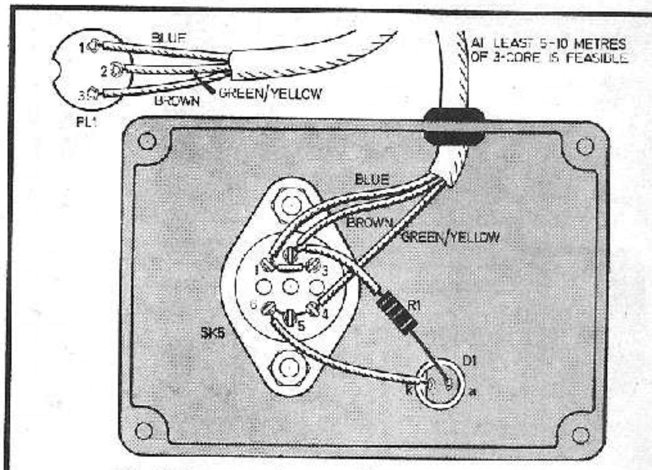


Fig. 5. Sensor unit assembly and wiring details.

including the four sensitivity controls. Assembly of this should be straightforward. Fig. 3 illustrates the layout used in the prototype but this is not critical.

Use d.i.l. sockets to carry the two integrated circuits in order that the devices will not be heated excessively during soldering. Also, it will be best to solder in the four preset potentiometers last of all, as this will enable you to insert the adjacent tinned copper jumper wires with little difficulty.

The relay RLA can simply be glued or stuck upside down to the chassis floor. When connecting the relay up, take extra care not to heat the relay contacts too much, since the plastic base into which they are moulded will melt quite easily.

INTERWIRING

Except where stated, all interwiring can be fabricated from standard pvc-insulated stranded-core hook-up wire. Use as many different colours as possible since there are rather a lot of interconnections to be made, and the use of colour-coded wires will speed up any checking that must be performed prior to switching on.

Mains wiring of course requires that a heavier-duty cable be used and for this the author recommends a rating of 6A wire, 24/0·2mm gauge. If *too thick* a wire is used, however, it will be impossible to make a safe soldered connection to the rather small solder tags on the rear of S3. Fig. 4 gives all interwiring details, and should be followed closely.

Note that the two secondary windings on T1 are wired in parallel.

It is important that the metal case (if used) is soundly earthed. This is achieved by soldering the earth input to a solder tag of appropriate size, and placing this under one of the transformer mounting bolts. It is further essential that the cable passes through a grommet in the rear panel and is secured properly with a nylon "P" clip or other cable strain relief clip. *This is most important.*

You may probably want to label the switches and lamps on the front panel, in which case use rub down lettering which is then protected with a few coats of lacquer.

REMOTE SENSOR UNITS

Assembly of the remotely-located sensor units is illustrated in Fig. 5 and should be straightforward. The TGS units can be plugged either way round into their sockets once construction is complete.

TESTING AND SETTING UP

After having completed the not inconsiderable job of building this project it is wise to check out most thoroughly all of the system prior to switching on. Having done this, plug the four remote sensors into their respective DIN sockets on the main unit, set the four sensitivity controls to their midway positions and then apply the power.

On the front panel the "TIMING" l.e.d. (D21) should light and the four green status monitors should be glowing. Shortly afterwards the status monitors will temporarily change to red, although not necessarily simultaneously, and eventually revert to green. This is a correct indication that the sensors are warming up.

Once the timing l.e.d. extinguishes (you may hear the relay click out) then it is a matter of ensuring that all the switches and l.e.d.s function correctly.

It is possible to perform a simple test on the detectors by simply dampening a cotton-wool swab with some lighter fuel (for example) and then place this next to a particular TGS sensor. The vapour from the lighter fuel should cause the appropriate status lamps to change and the alarm should hopefully also function.

The setting-up procedure for each channel is rather a trial and error affair (to be expected in a simple circuit such as this) and consists of adjusting each preset over a period of about a week or more. The objective is to attain maximum sensitivity without there being any false alarms generated by cigarette smoke or similar.

The author's own tests showed that a control setting position for the preset potentiometers of $\frac{1}{4}$ to $\frac{1}{3}$ from the fully clockwise position produced a response time of 2 to 3 seconds in a steady stream of not-too-dense smoke.

APPLICATION NOTES

There are a few things to watch when positioning the four remote sensors. Firstly, many types of gases are heavier than air and will initially accumulate in pockets at floor level. It is best to position each sensor about 45–60cm above ground level, but in any case, where you think pockets of escaping gas may first gather.

Smoke, on the other hand, rises to the ceiling first; you may then have to compromise a little with the fixing points of the detectors to enable the system to sense both smoke and gas as effectively as possible.

Keep the TGS pick-ups away from sources of direct heat (engines, radiators, etc.) and steam or other excessive humidity. Also it is obviously important that they are not placed where they would continuously be knocked by passers-by or otherwise mechanically damaged.

If considering employing an external alarm unit connected to SK9 and SK10, then for maximum safety a spark-proof device should be used to avoid the risk of ignition if dense accumulations of gas should build up. This rules out electro-mechanical bells and buzzers: a device such as the author's "Siren Module" (EVERYDAY ELECTRONICS, January 1982) would be ideal in this application. Alternatively, a piezo-electric horn sounder such as Maplin Electronics XQ71N could be employed, as this appears to be spark-proof.

Finally, two types of low-voltage TGS detectors are available. The TGS812 is slightly more suited to being a smoke alarm as it is somewhat more sensitive to carbon monoxide. However, the TGS813 responds more desirably to hydrocarbons like butane and propane. It has a lower sensitivity to carbon monoxide—and smoke therefore—and so there is slightly less chance of causing a false alarm with cigarette smoke. If you cannot decide which type, then opt for the TGS813. □