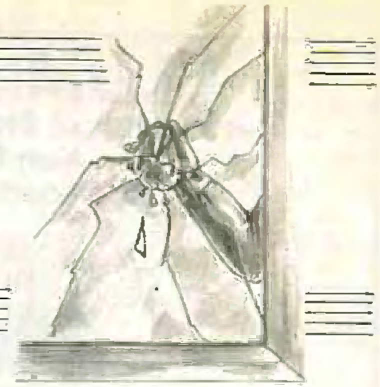
Constructional Project

VIBRALARM

TERRY de VAUX-BALBIRNIE



A multi-purpose vibration-triggered alarm with remarkable sensitivity.

THIS circuit will sound a loud warning when a sensor is subjected to shock or vibration. One application would be to attach the sensor to a window. If an attempt was made to enter the house by breaking the glass, the alarm would be triggered.

Readers will no doubt find other possible uses, such as for protecting personal belongings, perhaps. Note, however, that simply moving the sensor will not operate it.

The sensitivity of the circuit is adjustable and can be set to suit the application. To get an idea of the sensitivity, with the prototype sensor attached to a wooden table, putting a coffee cup down about 1m (3ft) away triggered it.

VIBRALARM OVERVIEW

The Vibralarm comprises two parts. The first is the sensor itself mounted in a small plastic case. The main unit is housed in a larger plastic case (see photographs). The two sections are interconnected using a short piece of light-duty screened wire.

Inside the main unit is the circuit panel, the battery pack and a loud "yelping" car-type alarm siren. On top, there is a key-operated switch which may be used to switch the unit off or cancel operation before the natural time-out period. Of course, an ordinary switch could be used with a corresponding reduction in security.

The operating time is adjustable from about one second (which will be found useful for testing) to two minutes. This could be easily extended if required.

The circuit requires about 250µA on standby. While actually operating, it draws a current which depends on the type of sounder used (in the prototype it was 150mA). The prototype unit was powered using a pack of eight AA-size alkaline cells. In normal use these will last for up to a year.

BI-MORPH ELEMENT

The sensor consists of a bi-morph (2-layer) element, which is a strip of piezo-electric material 15mm long, 1·5mm wide and 0·6mm thick. Its simplified operation is illustrated in Fig.1a, which shows an ordinary wooden ruler. Normally, this is not under any stress.

However, if it is bent as shown in Fig.1b, the lower surface will now be in compression (the distance between the molecules slightly reduced) and the upper one under tension (the distance between the molecules increased).

When a bi-morph element is bent, opposite charges are developed on the surfaces which are under compression and tension due to the piezo-electric effect. This means that a voltage difference appears between them. A current would flow if there was a conducting path between the surfaces but the charges would soon neutralise so this would occur only briefly.

WHAT'S THE DIFFERENCE?

With the piezo ceramic material used here, the voltage difference is significant even with a small amount of bending. When the bi-morph element is subjected to shock, the upper and lower surfaces alternate briefly between compression and tension and the polarity of the voltage will keep changing. In other words, an alternating voltage is produced at a frequency equal to that of the vibration.

Bi-morphs were once used in the crystal-type of record pick-up but, although still sometimes used, they are not seen much now. In these pick-ups, the strip is

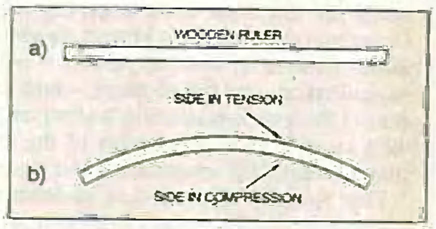


Fig.1. Simplified analogy using a wooden ruler to demonstrate the operation of the bi-morph element.

vibrated by the stylus running in the groove on the surface of the record.

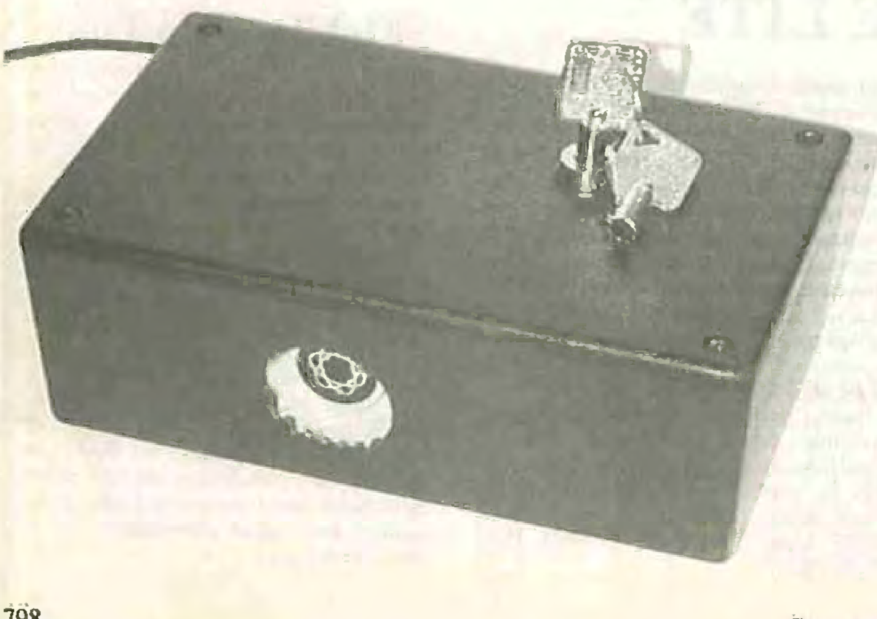
An a.c. output is therefore obtained proportional to the frequency of the sound (assuming the record is turning at the correct speed) and roughly proportional to its amplitude. The signal is then amplified and fed to a loudspeaker.

CIRCUIT DESCRIPTION

The full circuit diagram for the Vibralarm is shown in Fig.2. The bi-morph element is labelled X1. The nominal 12V battery supply is applied to the circuit via key-operated (or other) switch S1, and diode D3. The diode prevents possible damage if the supply were to be connected in the wrong way since it would fail to conduct and nothing would happen.

Any voltage appearing across the bi-morph element is applied to the inverting input (pin 2) of operation amplifier (op.amp), IC1. The network consisting of capacitor C1 and resistor R2 is also connected between this point and the 0V line. These components help to prevent high-frequency oscillation and give a damping effect for the bi-morph element.

Since the impedance of the bi-morph



is very high, the value of R2 must accordingly be extremely high or it would cause excessive damping. The values shown worked well. However, this could be the subject of experiment once the project has been constructed.

The op.amp non-inverting input (pin 3) is connected to the sliding contact (wiper) of preset potentiometer VR1. Its track (outer) connections are connected across Zener diode D1, which operates in conjunction with series resistor R1, to provide a fixed-voltage supply. The voltage at the non-inverting input (pin 3) will exceed that at the inverting one (pin 2). The output, pin 6, will therefore be high (close to the positive supply voltage) and when applied to timer IC2 trigger input (pin 2) there will be no further effect. This is because a low state is needed to trigger this type of device.

IN SHOCK

When the bi-morph element X1 is subjected to shock, an alternating voltage appears across it having a peak-to-peak value relative to the impact strength. Within limits, the negative excursions have no effect. However, they can cause the inverting input to swing below the voltage of the 0V rail and this could damage the i.c. if high enough. There were no problems with the prototype, though, even under heavy shock.

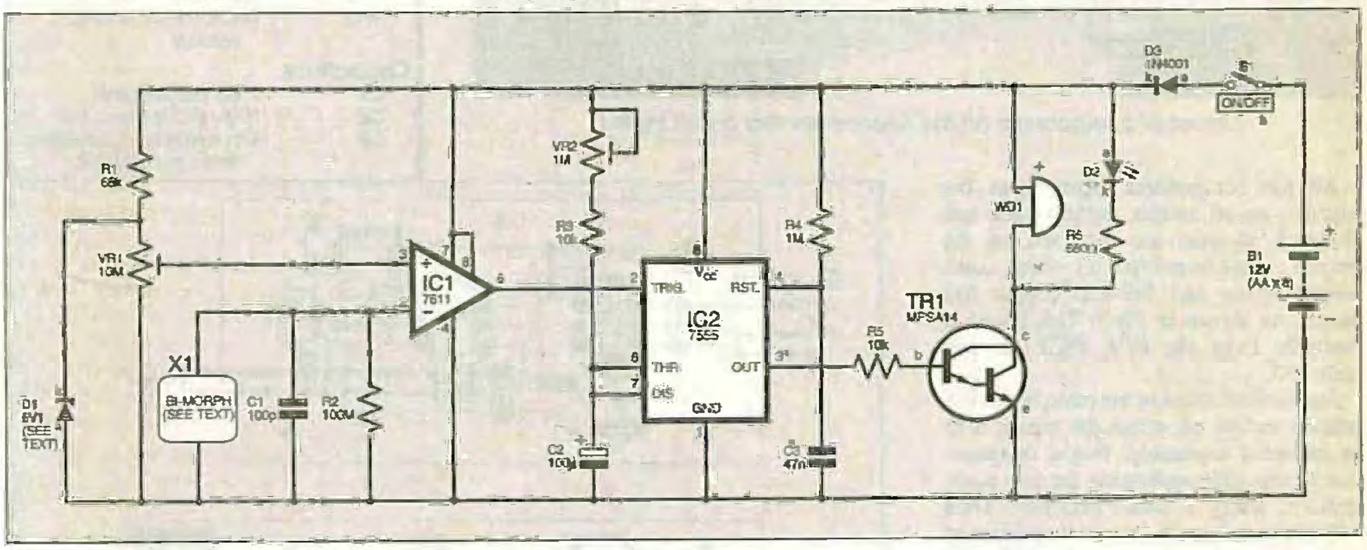


Fig.2. Complete circuit diagram for the vibration-triggered Vibralarm.

the bi-morph is needed to trigger it.

The timing period depends on the value of capacitor C2, resistor R3 and preset VR2. With the values specified, this will be about one second (with VR1 at minimum) and two minutes (when at maximum). If the timing needs to be extended, the easiest way would be to increase the value of C2 in proportion.

When the supply is connected, capacitor C3 maintains IC2's reset input (pin 4) in a low state for a short time until the capacitor has charged sufficiently through R4, so disabling the i.c. from responding to any trigger pulses. After that, pin 4 goes high and the device is enabled. This prevents any tendency for the circuit to self-trigger on powering-up.

voltage appearing at IC1 pin 3 may therefore be adjusted between zero and the Zener breakdown voltage.

ZENER VOLTAGE

It is necessary to provide a stable voltage here because if it was derived from the supply direct, it would fall as the battery aged. Since the voltage appearing across the bi-morph element is independent of the supply voltage, the operating characteristics of the circuit would change as the batteries ran down. The exact value of the Zener voltage is not important but it should be close to the range of specified values.

It will be noted that the value of R1 is relatively high. With a supply of 12V it allows less than 90µA to flow through the Zener diode and this will fall as the battery ages. The current diverted via VR1 is negligible. Using such a small current here reduces the requirement of the circuit as a whole. When using the specified Zener diode (which has been designed for low-current, low-power and low noise applications) there will be no problems.

However, if using a different type of Zener, it might not stabilise and it may be necessary to increase the current. Readers using a different Zener will need to check the stabilisation and reduce the value of R1 if necessary. This procedure is explained at the setting-up stage.

NO VIBRATION

Imagine that preset VR1 is adjusted so that 1V appears at IC1 pin 3. In the absence of any vibration of the bi-morph, there will be no voltage across it and the

Depending on the adjustment of VR1, the positive peaks will exceed the voltage at IC1 pin 3. Each time this happens, the op.amp output (pin 6) will go low instantaneously. The first peak arriving at IC2 pin 2 will trigger it and a timing cycle will begin. Further trigger pulses applied during this period will have no effect. However, any arriving afterwards will start the timing once again.

While timing, IC2 output pin 3 goes high and allows current to flow into the base of Darlington transistor TR1, via current-limiting resistor R5. Sounder WD1 then operates due to current flowing in the collector circuit.

Light-emitting diode D2 is also turned on at this time, with its current limited to about 15mA by resistor R6. The l.e.d. will be useful to check the circuit and adjust the time-out period before the sounder is connected.

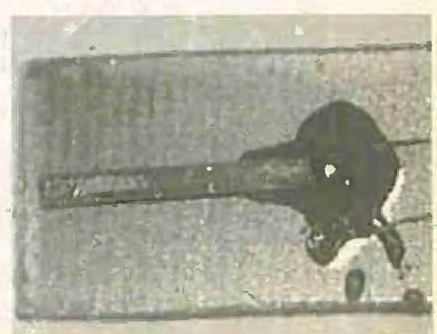
SENSITIVITY

The sensitivity of the circuit may be adjusted at the end by means of VR1. With this set to a little above zero volts, the circuit will be triggered with a relatively small amount of vibration. However, if it is adjusted to a higher value, an increasingly high output from

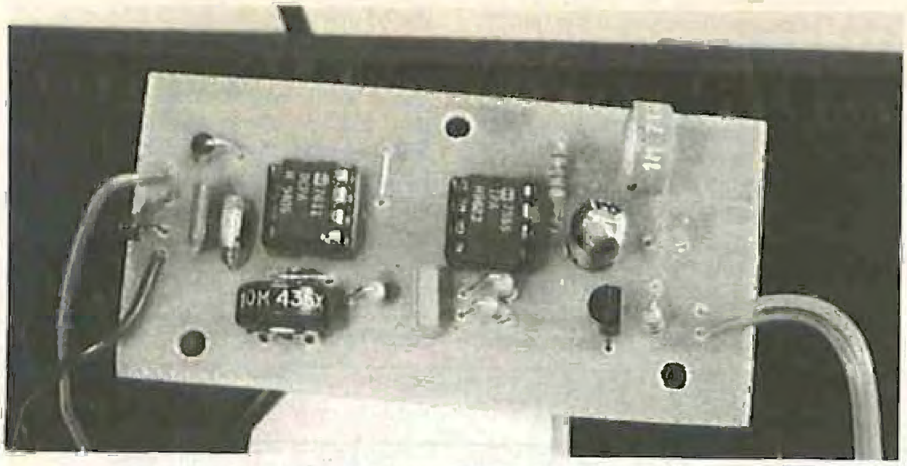
Darlington transistor TR1 could operate a sounder of up to 500mA rating but this would place an unnecessary load on the battery. Very loud devices are available with a current requirement much smaller than this (say 150mA) and one of these was used in the prototype.

CONSTRUCTION

On no account experiment by bending the bi-morph element with the fingers. Anything more than a minute movement is likely to destroy it. Also, take extreme care when handling the end wires because they are easily broken off.



Close-up of the bi-morph element mounted on its p.c.b.



Layout of components on the finished printed circuit board.

COMPONENTS

Resistors

R1	68k
R2	100M cermet film
R3, R5	10k (2 off)
R4	1M
R6	680Ω

All 0·25W 5% carbon film, except R2.

See SHOP TALK page

Potentiometers

VR1	10M sub min. preset, vertical
VR2	1M sub min. preset, vertical

Capacitors

C1	100p polystyrene.
C2	100µ radial elect. 16V
C3	47n metallised polyester, 5mm pin spacing

Semiconductors

D1	5V9 to 6V2 400mW Zener diode, Philips PLVA459A or PLVA462A (see text)
D2	red l.e.d., 3mm
D3	1N4001 50V 1A rectifier diode
TR1	MPSA14 *npn* Darlington transistor
IC1	7611 micropower op.amp
IC2	7555IPA low power timer

Miscellaneous

X1	bi-morph element
WD1	min. alarm sounder, 12V, 150mA (110dB at 1m output)
S1	s.p.s.t. switch (toggle or key-operated)
B1	alkaline AA-size cell (8 off), with holder and connector

Printed circuit board, available from the *EPE PCB Service* code 230; 8-pin d.i.l. socket (2 off); 2A terminal block; plastic case, 158mm×95mm×54mm (external) for main unit; plastic case, 50mm×37mm×24mm (external) for sensor; light-duty single screened wire; small clamps or cable ties (2 off); connecting wire; solder, etc.

Approx. Cost Guidance Only £24

All the components, apart from the sounder, on-off switch, battery pack and bi-morph element are mounted on the printed circuit board (p.c.b.) whose component layout and full-size copper foil master are shown in Fig.3. This board is available from the *EPE PCB Service*, code 230.

Supplied attached to the main board is a smaller section on which the sensor is to be mounted separately. Begin construction by carefully separating the two p.c.b. sections, using a small hacksaw. Then drill the three marked mounting holes in the main board, and a mounting hole in a suitable place on the small board.

Referring to the main board, solder the link wire in position and follow with the i.c. sockets (but do not insert the i.c.s yet), all resistors (including the presets) and capacitors (except C2). Next mount diode D3, Zener diode D1, l.e.d. D2 and capacitor C2, taking care to solder these components the correct way round.

Referring to the wiring diagram in Fig.4, connect up the power supply. It will be kinder on the ears if you do not connect the sounder yet, but when you do, connect it via a piece of 2A screw terminal block to prevent the WD1 wires from short-circuiting.

Adjust VR1 fully anti-clockwise, then slightly clockwise (as viewed from the bottom edge of the p.c.b.) and VR2 fully clockwise (as viewed from the right-hand edge of the p.c.b.) for minimum timing.

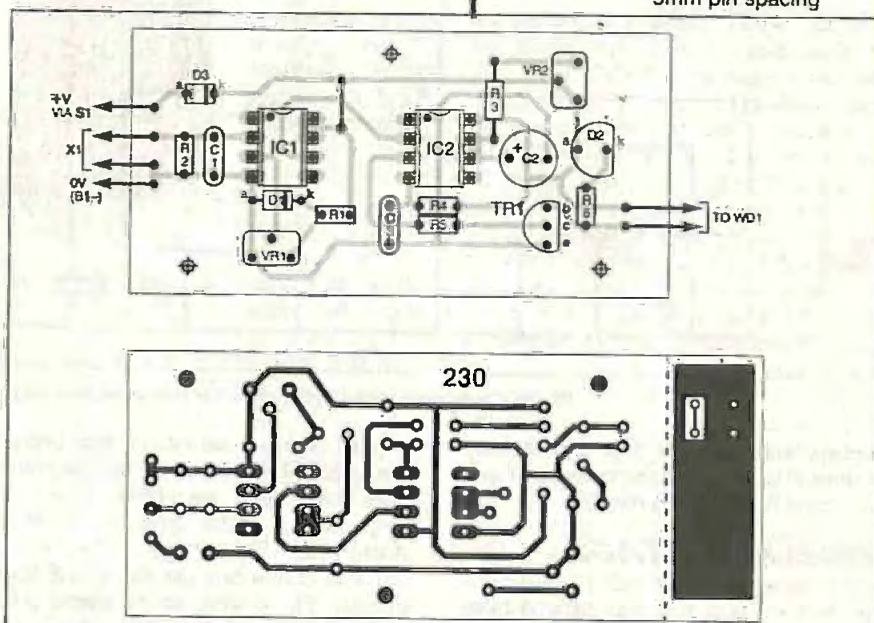


Fig.3. Vibralarm printed circuit board component layout, foil master and sensor board master.

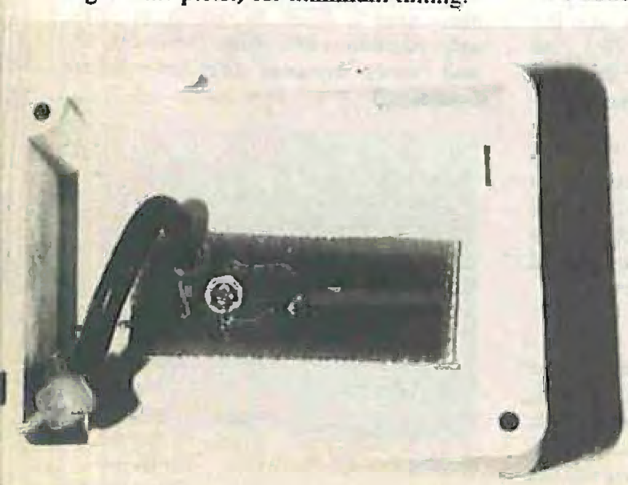
SENSOR UNIT

Solder the bi-morph to the small board and reinforce its physical stability by using a little quick-setting epoxy resin adhesive. The blob of adhesive should be thick enough to allow the other end of the bi-morph to remain clear of the board by a millimetre or so.

This will allow it to bend slightly when the mounting board is subjected to shock. If necessary, use a piece of thin cardboard underneath the free end to hold it in position until the adhesive has thoroughly hardened.

Decide on the length of wire needed between the sensor and the main unit. Pieces up to five metres long were tested and worked well. However, very long runs will introduce problems of interference pick-up and poor sensitivity.

Use light-duty single (mono) screened wire (such as microphone cable).



The bi-morph board installed in a small plastic case.

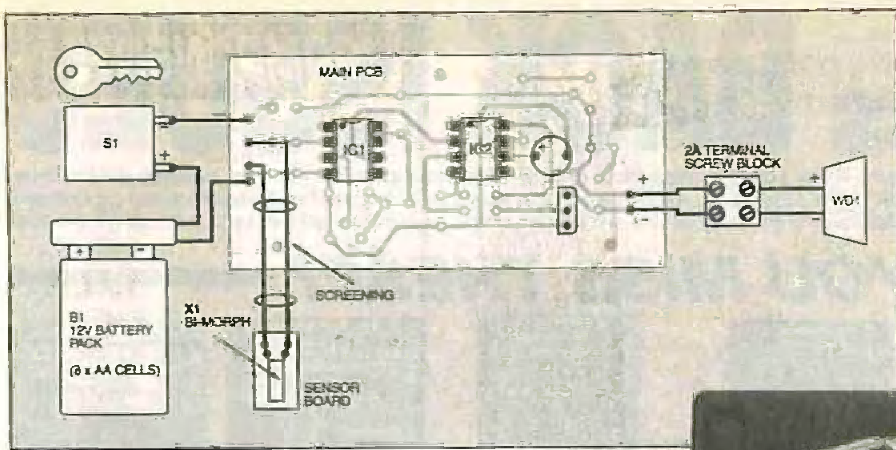


Fig.4. Interwiring between the circuit board and the off-board components, including the bi-morph board.

Ordinary wire is not satisfactory because it allows the pick-up of random signals, including a.c. mains "hum". This could cause false triggering.

A small plastic box is used to house the sensor, and it is worth mounting the sensor in this now before moving on further. Mark the mounting hole on the base and drill this through. Note that the bolt which will be used to attach it will need to have a countersunk head. This will allow the bottom of the box to make good contact with the surface on which it will be used.

Drill a hole in one side of the case for the connecting cable. Pass this through and apply a small clamp or tight cable tie a short distance from the end (see photograph). Allow enough cable to reach the sensor pads plus a little slack. Pull on the cable to make sure it is secure and tighten the tie if necessary.

Solder the cable wires to the pads on the sensor p.c.b. with the screening connected to the large "land" area. Separate the joints to prevent short-circuits and secure them in place using a little quick-setting epoxy-resin adhesive.

Attach the sensor board to the bottom of the box using a small nut and bolt with a short plastic spacer.

VOLTAGE STABILITY

As stated earlier, for any Zener diode other than the specified unit, it will be necessary to check the voltage stability. It will be convenient to do this work before the i.c.s are inserted into their sockets.

You will need a digital voltmeter (this will generally have an input impedance of 10MΩ or more, which will be satisfactory). You will also need two sets of batteries – one new and the other run down so that the terminal voltage is about 9V or 10V. Of course, you could also use a suitable bench power supply unit.

With the new set of batteries installed switch on. Apply the meter probes to the outer tags of VR1 and note the voltage. This should be close to the stated Zener breakdown voltage. Now use the run-down batteries or a 9V supply from the PSU. Note the meter reading once again.

The second voltage reading should be the same or only slightly lower than the first – less than 0·05V difference. The stabilisation aspect is not very critical and the circuit should work well even with a difference of 0·1V.

However, if it is much more than this, reduce the value of R1 until the criterion above is met. It is thought that a value as low as 33kΩ would be acceptable (about 180µA at 12V) but it would increase the current requirement of the circuit to about 350µA and this would have an effect on battery life.

Layout of components in the main unit. Note the siren sound exit hole, 2-way terminal block and battery holder.

FINAL TESTS

It would now be a good idea to test the circuit as a whole before mounting the main p.c.b. in its box. Referring to Fig.4, connect the sensor cable wires temporarily to the board as shown. Still leave the sounder unconnected. Insert the i.c.s into their sockets. It is possible to damage these devices with static charge which might exist on your body so, as a precaution, touch something which is earthed (such as a water tap) immediately before handling the pins.

Attach the sensor unit to the work surface temporarily using Blu-Tack. Insert the (good) cells into their holder and switch on. The l.e.d. should remain off.

Drop a pen on the table – the circuit should trigger and the l.e.d. come on for one second or so. If this does not work, make the circuit more sensitive by adjusting VR1 slightly anti-clockwise (as viewed from the lower edge of the p.c.b.). Note, however, that if this is overdone, the circuit may remain triggered. Do not move the bi-morph element by hand or subject it to violent shock.

The current requirement of the circuit rises above the normal value when set to a short time period – about 1mA in the prototype. For this reason, when testing is complete, adjust VR2 to about mid-track position (giving a timing of about one minute). Observing the anti-static precautions as before, remove the i.c.s and desolder the sensor wires from the p.c.b.

MAIN CASING

Prepare the main-unit case by marking the mounting holes and drilling them through. Drill holes also for the sounder, the key-operated switch and for the sensor lead which will pass through. Drill holes (if necessary) to enable the presets to be adjusted from the outside using a thin screwdriver or trimming tool. Pass the sensor lead through its hole and apply a clamp or cable tie as in the sensor. Check that it is secure.

Solder the wires back on to the p.c.b. pads and, observing the anti-static precautions, insert the i.c.s into their sockets again. Mount the p.c.b. using plastic spacers on the bolt shanks. Attach the sounder noting that the hole must not be obstructed in any way to allow as much as possible of the sound to emerge. However, for testing, it would be wise to tape over the hole temporarily to reduce the sound output because it will be very loud.

Again refer to Fig.4. Connect the sounder wires to the screw terminal block observing the polarity. Attach the battery pack by means of a small bracket or another method of your choice. Make final tests and adjust VR2 to the required time period.

Attach self-adhesive plastic feet to the base to prevent scratching the work surface. Experiment to find the best position for the sensor attaching it temporarily using Blu-Tack. Note, however, that if it is placed too close to the main unit or mounted on the same surface, the sound from the audible warning device reaching it may be sufficient to keep the alarm triggered. This will be evident if the circuit fails to time-out.

When satisfied, glue the sensor unit in position. Obviously, if the sensor is subjected to a very violent shock, such as with shattering glass, it could be damaged, but this seems a small price to pay for security.

If using the Vibralarm as part of an intruder deterrent system, ensure that its sensitivity is suitably adjusted to prevent accidental triggering by, for example, the window cleaner, or thunder! □