# MAGNETIC FIELD DETECTOR

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*How exposed are you to alternating magnetic fields? Build this simple audio/visual detector to locate any "hot spots" around your home.*

WE ARE constantly surrounded by magnetic fields of various types and strengths. Some, like the Earth's own field or those from devices containing permanent magnets, are static in nature. Modern man, however, is ever more often exposed to a variety of alternating magnetic fields of various frequencies, emanating from the huge variety of electrical and electronic devices which now form an integral part of modern living.

Over the last few years these fields have became a source of concern to some people, who feel that constant exposure to them may constitute a hazard to health. A vast amount of research on this has been carried out, much of it by the electricity authorities who are understandably concerned about the safety of their product, but to date results have been inconclusive.

However, since these fields cannot generally be seen, felt or heard, a means of detecting them may be useful to those who wish to minimise their exposure to this sort of risk. The strength of a magnetic field diminishes rapidly with increasing distance from the source so, if one knows it is there, it is relatively easy to avoid spending long periods close to it.

## FIELD EFFECTS

On being told that the author's current project was a magnetic field detector, a number of people responded by saying "You mean from power lines?" Well, power lines do generate magnetic fields, but the chief radiation from the National Grid Company's transmission system is probably electrostatic. A brief explanation of the difference is in order before proceeding.

Electrostatic fields are produced by voltage. A high voltage applied across an insulator, such as the air between a 400kV powerline and the ground below, generates an electrical stress. Minute currents will flow through the insulator, depending upon its conductivity and the applied voltage. To detect such a field, electrodes followed by an amplifier with a very high input impedance would be required.

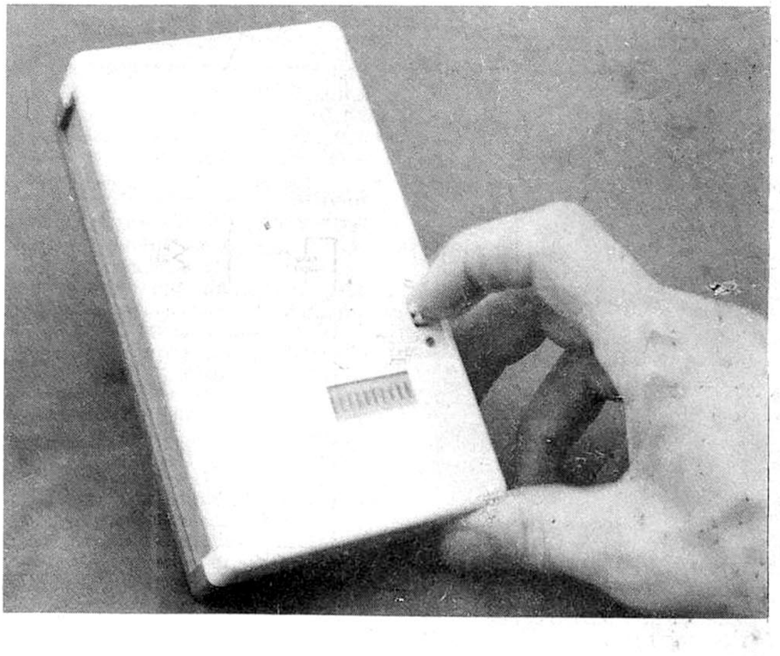
Electromagnetic fields, on the other hand, are the magnetic "lines of force" surrounding the flow of current through a conductor. These are much increased in strength if the current is flowing through a coil where, in effect, the same current is flowing through lots of conductors, each adding to the overall field.

In an average house the voltages are comparatively low, so there will not be much in the way of electrostatic fields to worry about. There will usually be plenty of examples of current-carrying coils, however, often in close proximity to the occupants. Consequently, exposure to alternating magnetic fields, mostly of 50Hz mains frequency, is likely to be high.

Sources include motors, transformers, fluorescent lamp chokes and the house wiring itself, often surrounding the user on every side. The household electricity meter should not be forgotten either. This contains several coils generating magnetic fields for driving the aluminium disc that increments the dials, and a considerable amount of this field escapes into the surrounding space. A recent TV documentary centred upon the possible hazards of long periods spent near an electricity meter.

## SENSITIVITY

Most of the common magnetic fields can be detected with this easy-to-use Magnetic Field Detector project. When brought towards a source of alternating field, it produces an audio tone of rising volume and displays a visual indication of relative strength on a ten-step l.e.d. bargraph. This



has a "logarithmic" response which compensates for the non-linear relationship between field strength and distance from source, and provides coverage of a very wide range of field strengths. It should be noted, however, that the instrument is not calibrated in terms of Tesla values.

At the low end, the instrument is very sensitive indeed. The lowest l.e.d. normally flickers as it is carried around with movement relative to the earth's force-field. When placed against a quartz analogue watch it pulsed strongly at one hertz, in time with the field generated by the watch's internal stepper motor. Since this runs for over a year on a single tiny battery, the field being sensed is obviously very weak indeed.

A useful side-effect is that permanent magnets within equipment can easily be detected. So long as the instrument and magnet are moving relative to each other a reading appears. As soon as the motion ceases output stops. Quite small magnets can be detected at ranges of up to a foot in this way.

When setting out to design this instrument, the first decision concerned the element to be employed for field sensing. Hall effect devices were rejected as perhaps being insufficiently sensitive, leaving a coil of some kind as the most viable cheap option.

Plenty of turns were obviously necessary and experiment suggested that for low-frequency use, something with a large iron core would be preferable. Excellent results were obtained using an old relay coil of about 500 ohms d.c. resistance but these are not, of course, generally available "off the shelf".

A lot of 36s.w.g. wire wound upon a nail also worked, but not as well as hoped. Thinner wire might have brought improvement, but would have been difficult to handle. The characteristics of the iron from which nails are made may not be consistent either! Finally, a small, cheap transformer was chosen for the task.

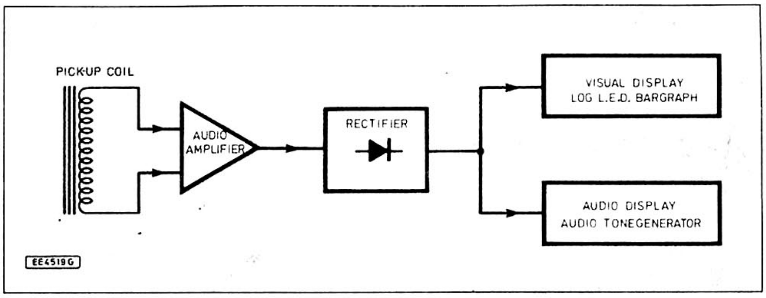



*Fig. 1. Basic block diagram for the Magnetic Field Detector.*

An interesting aspect of this project has been the discovery of the extent to which magnetic flux leaks from small transformers. Efficiency in this area is not their forte! Fortunately, flux leaks into them just as well as it leaks out, resulting in a most effective sensor for field detection. They are even reasonably directional, having greatest sensitivity in line with the winding axis.

## HOW IT WORKS

A simple block diagram of the project appears in Fig. 1. The primary winding of the transformer is used as the signal source, and is coupled into a high-gain amplifier with a frequency response extending well below the normal audio range. This is followed by a rectifier which drives the visual and audio output circuits.

It will be of interest to know that at one point the display was going to be a moving-coil meter. This was abandoned when it was realised that, being an electromagnetic device, the meter would give rise to all sorts of feedback instability problems! Its type and positioning would have been critical.

The full circuit diagram for the Magnetic Field Detector is shown in Fig. 2. Transformer T1 is the sensor, with the primary winding used as the input. The "detected" input signal passes through capacitor C1 to the inverting input of op.amp IC1a which is configured as an a.c. amplifier having a voltage gain of about 200 and a frequency response extending to below 10Hz. Diode D1 ensures rapid settling when the instrument is first switched on.

The output from IC1a is rectified by the circuit around op.amp IC1b, which senses the peak positive value of the waveform input to it. Resistors R9 and R10 give this stage a gain of two, so with an a.c. input of one volt peak-to-peak, with a peak positive value of 0·5V, produces an output of 1V d.c.

Preset potentiometer VR1 facilitates adjustment of "zero" to just above the negative supply voltage, close to the threshold of the first display l.e.d. Resistor R8 and diode D2 prevent large negative excursions of the input voltage to IC1b which might otherwise cause unpredictable results, whilst R11 and C8 reduce ripple, noise and jitter in the output signal.

Bargraph driver IC3 is an LM3915 which is the "log-scale" version of the

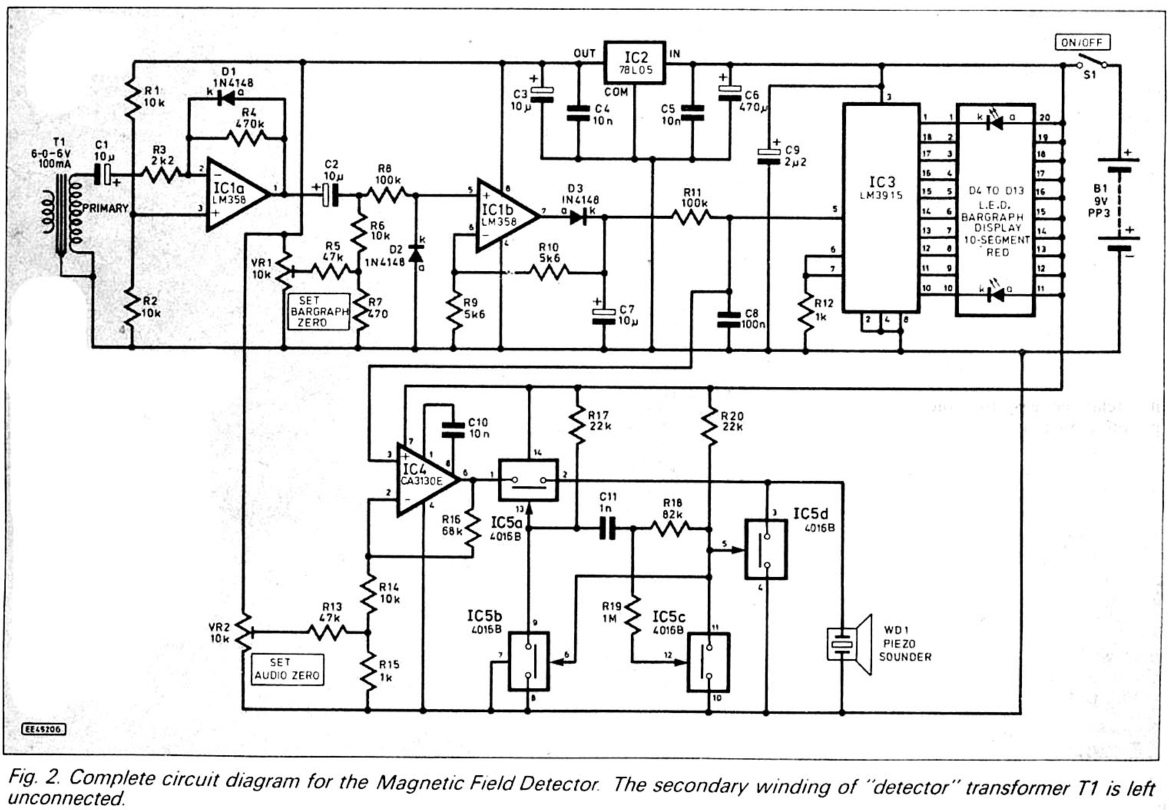



*Fig. 2. Complete circuit diagram for the Magnetic Field Detector. The secondary winding of "detector" transformer T1 is left unconnected.*

linear LM3194 chip. It has a full-scale input of about 1·25V, as set by an internal reference voltage generator. Resistor R12 sets the current to each illuminated l.e.d. to about 10mA. The ten outputs of IC3 sink the ten cathodes (k) of the bargraph l.e.d. array D4 to D13, which has all anodes (a) connected to the positive supply.

From R11 the signal also goes to IC4 which has a gain of about eight to produce full output from the peak input signal. The 3130 amplifier IC4 was chosen in order to obtain the highest output voltage possible, to generate maximum volume from the piezo sounder WD1 used for the audio output. The 3130 output can swing to within millivolts of either supply rail.

Preset VR2 allows the output of this stage to be adjusted to the audio threshold.

To turn the voltage into an audio signal, two CMOS analogue switches, IC5a and IC5d, connect the input of sounder WD1 alternately to the output of IC4 and to the negative supply rail at a frequency of about 4kHz. This results in a signal having amplitude dependant upon the output voltage from IC4. Analogue switches IC5b and IC5c are used to form an oscillator for driving IC5a and IC5d.

Power for the circuit is supplied by a 9V PP3 battery. Regulator IC2 supplies a steady 5V to IC1 to ensure stable operation. This is also used by the two threshold adjusters to minimise drift of their settings.

## CONSTRUCTION AND TESTING

All components for this design, including the display and sounder, are mounted directly onto a printed circuit board (p.c.b.). So that the design can be fitted into a compact case, with the l.e.d. display protruding through a hole cut in the side, construction has been designed to be as "low-profile" as possible. To protrude through the hole, the display must stand slightly proud of all the other components when fitted.

The electrolytic capacitors C1, C2, C3, C6 and C7 are all placed horizontally. Capacitor C6 would still be too high, so a square hole in the board is provided for it. Regulator IC2 and capacitor C9 can also be positioned horizontally if preferred.

Capacitor C8 is a 100n polyester layer type. These vary in height according to their voltage ratings, so if the one to be used is too tall this may also be placed on its side. In order to maintain a low profile, sockets are not used for the i.c.s, which are soldered directly to the board.

The p.c.b. component layout and full size copper foil track master pattern are shown in Fig. 3. This board is available from the *EPE PCB Service*, code 923.

Construction should commence with the fitting of the link wire and the resistors, presets, capacitors, sounder WD1 and the l.e.d. bargraph-array D4 to D13. Care should be taken with the polarities of the electrolytic capacitors and the diodes, especially with capacitor C9 as the marking on tantalum beads is often difficult to read.

The anode side of the l.e.d. array, which should face capacitor C6, should be on the side of the device carrying the identity markings but constructors may prefer to check this before installation as a mistake would take time and effort to rectify.

Sounder WD1 and the larger electrolytics can benefit from a spot of glue to secure them in place to prevent rattles!

Before any i.c.s are fitted, the circuit can be powered and checked to ensure that the supply current taken is negligible. This is a useful test to verify that everything is satisfactory so far. If a heavy current is taken, it could be due to shorts caused by poor soldering, or incorrect polarity of capacitors C6 or C9. Following this test, regulator IC2 can be fitted and the 5V output of this verified as present and correct. The total drain current should then be about 4mA.

When op.amp IC1 is soldered into place, the supply current should rise to about 5mA. The voltage at pin 1, IC1a output, should be about 2·5V. The positive side of capacitor C7 will be close to 0V, but should be adjustable by preset VR1 to between 20mV to 100mV. Touching the circuit input (the positive side of capacitor C1) may cause a small voltage increase across capacitor C7, depending upon the local "hum" level.

IC3 should be fitted next, noting that it is oriented the opposite way to the others, i.e. pin 1 at bottom right instead of top left. When the board is first powered, a dot of

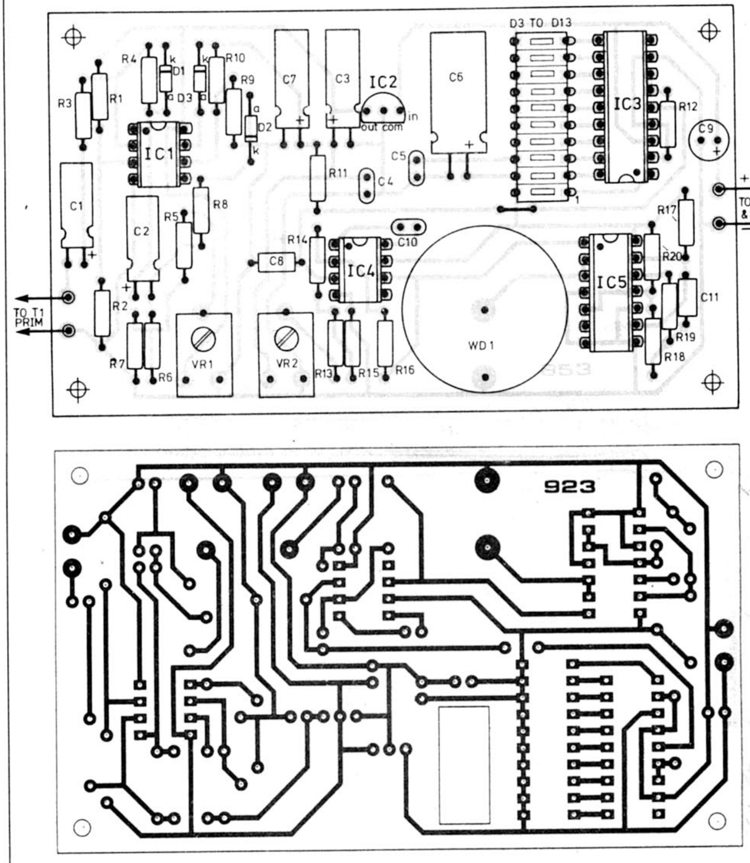
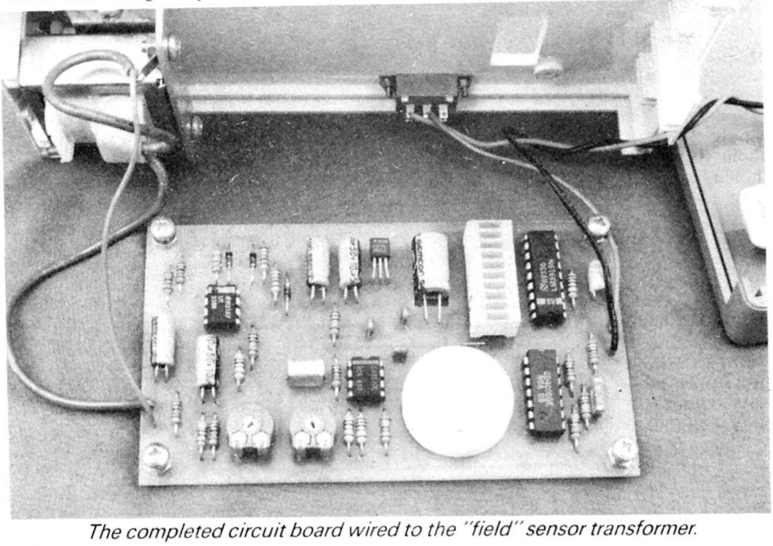
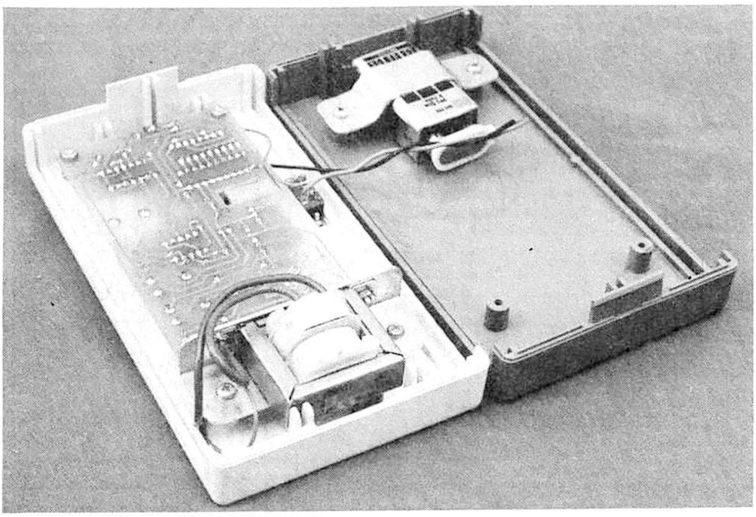



*Fig. 3. Printed circuit board component layout and full size copper foil master pattern for the Magnetic Field Detector.*



*The completed circuit board wired to the "field" sensor transformer.*



*Layout of components inside the case.*

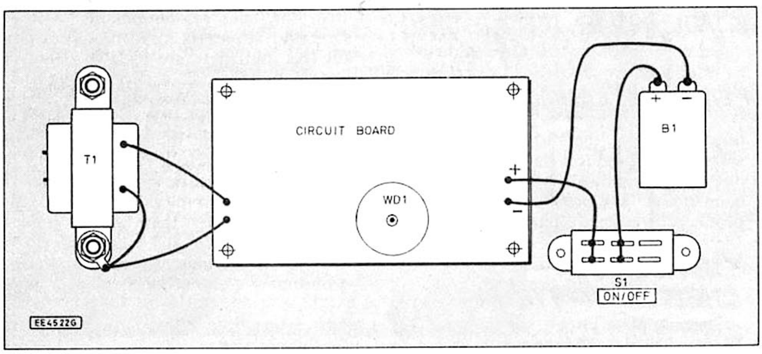



*Fig. 4. Interwiring to all off-board components.*

light will probably flicker along the display as the circuit settles. One of the lower l.e.d.s may remain on.

Preset VR1 should be adjusted carefully so that the lowest l.e.d. just ceases to glow.

Touching the input will probably now produce a reading on the display. The on-chip reference voltage of IC3, about 1·25V, should appear across resistor R12 but it is not necessary to check this unless problems are experienced.

## AUDIO STAGE

Progressing to the audio side, IC4 should be soldered in next. This chip, and IC5 are both CMOS devices, so the usual handling precautions are advised to prevent damage.

The output from IC4 pin 6 should be variable by preset VR2 between zero and about 400mV. Starting at the high end, it should be adjusted downwards until it just reaches zero.

Here again, touching the circuit input at capacitors C1 may produce a rise in output voltage. The setting of preset VR1 influences the setting of VR2, so these two adjustments must be carried out in sequence.

Finally, IC5 can be fitted. There should now be a "bleep" with the flicker of the bargraph when power is applied, and touching capacitor C1 should produce both audio and visual outputs. The overall supply current depends on what is being driven, but as a rough guide it will be about 10mA to 15mA when the display is not illuminated, rising to around 30mA when an input is present.

## ENCLOSURE

The general layout in the case can be seen from the photographs, and the various wiring connections are shown in Fig. 4. The transformer is mounted on an aluminium bracket, steel being inadvisable as it could distort the field being sensed.

The transformer primary winding is connected to the circuit input and the secondary is left unconnected. It is essential that the secondary leads should not touch, however, as this would seriously reduce sensitivity. They can be cut short and insulated if necessary. The transformer metalwork is connected to the negative side of the input to reduce stray pickup.

A hole is cut in the case for the bargraph to project through, and the position of the p.c.b. is adjusted with four screws, one at each corner, with nuts either side for accurate height setting. A small slide switch, S1, provides the power on-off function.

## PRACTICAL USE

In use, the instrument is simply switched on and pointed towards suspected sources of alternating magnetic field. Constructors will probably be surprised at some of these. Most of the small plug-in power supplies so common these days radiate strongly and can be detected from well over a foot away.

Electric fan motors produce strong fields. Some dimmer switches are quite strong sources when operating, probably because of their suppression chokes. Fluorescent lamp chokes are strong producers.

Fridges and freezers seem relatively low-level in comparison, probably because of their steel cases, whilst the electricity meter often basks in a field that can be picked up at several feet. Those living in terraced houses may find high-level "hot-spots" on walls where their neighbours have appliances on the other side!

Of the other sources that can be detected, it will probably be noticed that the lowest l.e.d. flickers a little when the instrument is carried around, even outside and well away from any known source. The instant it is put down, this will usually stop. The most likely cause of this effect is movement through the earth's magnetic field.

Magnets of any description *moving* nearby will cause a strong response. Finally, as mentioned earlier, a quartz analogue watch usually has a stepper motor with a coil that is pulsed once a second, and when placed very close, the instrument may be able to detect this. □

## COMPONENTS

**Resistors**

| | |
|---|---|
| R1, R2, R6, R14 | 10k (4 off) |
| R3 | 2k2 |
| R4 | 470k |
| R5, R13 | 47k (2 off) |
| R7 | 470 |
| R8, R11 | 100k (2 off) |
| R9, R10 | 5k6 (2 off) |
| R12, R15 | 1k (2 off) |
| R16 | 68k |
| R17, R20 | 22k (2 off) |
| R18 | 82k |
| R19 | 1M |

All 0·6W 1% metal film

**See SHOP TALK Page**

**Potentiometers**

| | |
|---|---|
| VR1, VR2, | 10k horizontal preset. (2 off). |

**Capacitors**

| | |
|---|---|
| C1, C2, C3, C7 | 10µ radial elect. 50V (4 off) |
| C4, C5, C10 | 10n monolithic ceramic (3 off) |
| C6 | 470µ radial elect. 16V |
| C8 | 100n polyester layer |
| C9 | 2µ2 tantalum bead. 35V |
| C11 | 1n polyester layer. |

**Semiconductors**

| | |
|---|---|
| D1, D2, D3 | 1N4148 silicon diode |
| D4 to D13 | 10-segment bargraph l.e.d. array, red |
| IC1 | LM358 dual op.amp |
| IC2 | 78L05 +5V 100mA voltage regulator |
| IC3 | LM3915 log. bargraph display driver |
| IC4 | CA3130E CMOS op.amp. |
| IC5 | 4016B CMOS quad switch |

**Miscellaneous**

| | |
|---|---|
| T1 | 6V-0V-6V 100mA sub-min. mains transformer |
| WD1 | piezo buzzer, p.c.b. mounting |
| S1 | s.p.s.t. slide switch |

Printed circuit board available from *EPE PCB Service*, code 923; two-part plastic case with aluminium front and back panels, size 153mm x 84mm x 39·5mm (w x d x h); 9V PP3 battery, with clips; multistrand connecting wire; aluminium bracket; mounting nuts and bolts; solder etc.

**Approx cost guidance only £23**