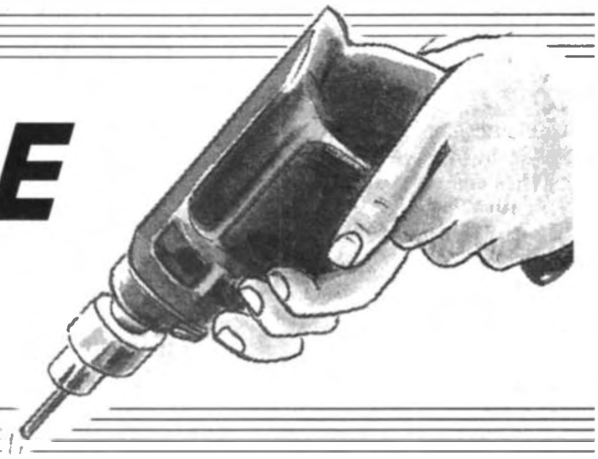
Starter Project

MAINS CABLE DETECTOR



ROBERT PENFOLD

A back-up mains cable locator for your DIY toolbox.

PROBABLY most keen do-it-yourself enthusiasts are aware of the dangers of drilling into the walls of practically any building, and use some form of pipe/cable detector to check that it is safe prior to doing any work of this type. Such precautions should ensure that there are no nasty surprises, but some types of cable can be difficult to detect.

Most pipe and cable locators are actually metal locators that are optimised for this application. They are quite good at finding things like nails in doors and plasterwork, locating metal pipes, and finding cables in metal conduits. However, they tend to be less effective at finding electric cables that are in plastic conduits.

The problem seems to be that there is simply not that much metal in an electric cable, especially a lighting type that is only designed to carry modest currents. This makes such cables difficult to detect unless they are close to the surface of a wall.

MAKING A HUM

The project featured here uses an alternative approach to finding cables, which is to pick up the 50-Hertz mains "hum" signal produced by the cable. This signal seems to be relatively easy to locate, even with a small cable that is buried deep in a wall.

One obvious drawback of this method is that it will not detect any form of pipe or small metal objects such as screws and nails. It is, therefore, best used as a backup to a conventional pipe and cable locator rather than as the sole method of detecting drilling hazards.

SYSTEM OPERATION

Units of this type sometimes use an inductive coupling from the cable to the detector. This requires a current to be flowing in the cable, which effectively becomes the primary winding of a transformer. An inductor at the input of the detector circuit acts as the secondary winding, and a small 50Hz "hum" signal is produced in this inductor if it is close enough to the cable.

Practical tests with this type of cable detector were not very encouraging, and the signal from the inductor was often so weak that it was virtually impossible to detect. The design finally evolved uses the slightly different arrangement shown in the block diagram of Fig.1.

Rather than an inductor, the sensor is a small metal plate. The mains cable and the plate form a very low value capacitor, with the air, etc. between them acting as the dielectric.

This gives an extremely loose coupling from the cable to the input of the detector circuit, but the large signal level in the cable of around 650V peak-to-peak helps to give a reasonable signal level from the plate. A high impedance buffer amplifier at the input of the detector circuit also helps to minimise losses through the capacitive coupling.

This stage is followed by a voltage amplifier that further boosts sensitivity, but only a modest amount of amplification is needed here. The output signal is monitored via a crystal earphone, and it is due to the good sensitivity of this type of earphone that high gain is not needed in the detector circuit.

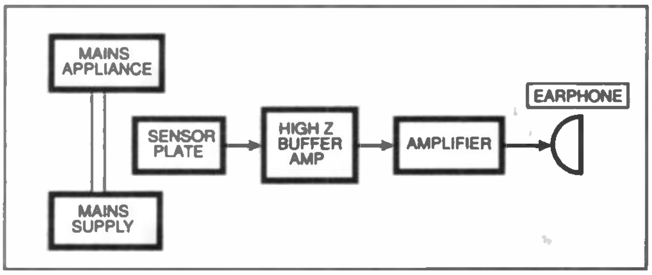


Fig.1. Block diagram for the Mains Cable Detector.

CIRCUIT OPERATION

The full circuit diagram for the Mains Cable Detector appears in Fig.2. In Fig.1 the unit is shown as having separate buffer and voltage amplifier stages, but in the final circuit these have been merged into a single amplifier based on operational amplifier, IC1.

Having a very high input impedance plus some voltage gain in a single stage can cause problems with stray feedback and consequent instability. However, in this case the voltage gain of the circuit is quite low and no stability problems were encountered.

The circuit is basically just a non-inverting mode amplifier. The non-inverting input (pin 3) of IC1 is biased to half the supply voltage by resistors R1 to R4. IC1 is a bifet device that has a j.f.e.t. input stage and an extremely high input impedance. In fact, its input impedance at low frequencies is so high that it can be ignored. The input impedance of the circuit as a whole is

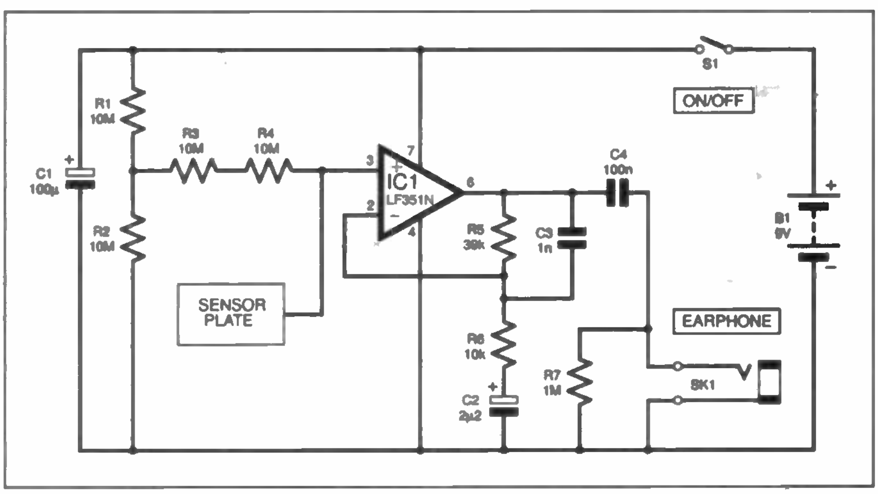


Fig.2. Complete circuit diagram for the Mains Cable Detector.

therefore equal to the parallel resistance of R1 and R2 in series with R3 and R4, or some 25 megohms.

LOOP GAIN

The closed loop voltage gain of IC1 is controlled by negative feedback resistors R5 and R6, and is equal to (R5 + R6)/R6, or approximately five times in other words. Capacitor C3 provides increased negative feedback at middle audio frequencies and above, and therefore provides a progressive roll-off in the gain of the circuit over this frequency range.

The "hum" signal is predominantly at low frequencies, and the high frequency roll-off does not reduce the sensitivity of the unit to this signal. It does help to reduce general noise and breakthrough of r.f. (radio frequency) signals. It also reduces the risk of instability due to stray feedback at high frequencies.

Capacitor C4 and resistor R7 couple the output signal to the crystal earphone and remove the d.c. component in the signal at the output of IC1. The unit is unlikely to work properly using any other type of earphone or headphones. A small 9V battery is adequate to power the circuit, which has a current consumption of less than two milliamps.

CONSTRUCTION

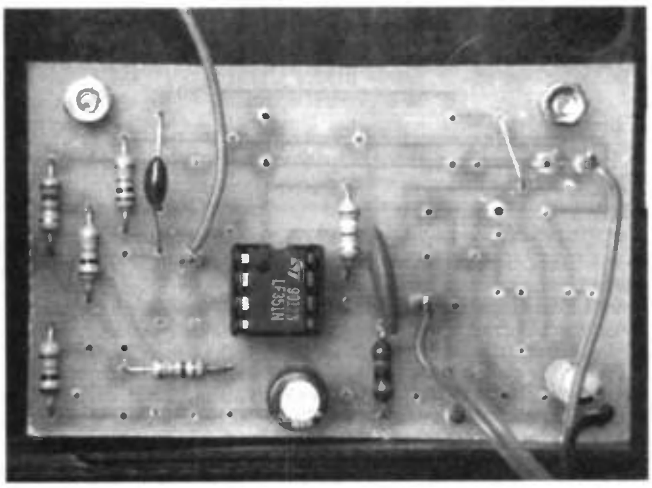
The Mains Cable Detector *starter project* is based on the *EPE* multi-project printed circuit board. This board is available from the *EPE PCB Service,* code 932. The component layout, together with the actual size foil master pattern and interwiring are shown in Fig.3.

The usual warning regarding this pc.b. therefore has to be given. Unlike a normal custom printed circuit board, the multi-project board has numerous holes and pads that are left unused. In order to avoid placement errors it is therefore essential to take slightly more care than normal when fitting the components, and to thoroughly check the finished board for errors.

Construction of the board follows along the normal lines with resistors and capacitors being added first, taking care to fit the electrolytic capacitors with the correct polarity. There is a single link-wire towards the top right hand corner of the board, which should also be fitted at this stage. This link can be made from a piece of wire trimmed from a resistor leadout.

Single-sided solder pins are fitted to the board at the points where connections to switch S1, socket SK1, the battery, and the sensor plate will be made. "Tin" the tops of the pins with a generous coating of solder.

Finally, add IC1, being careful to fit it the right way round. This device is not static-sensitive, but it is still a good idea to fit it in a holder.



Components mounted on the Multi-project printed circuit board. Note the single link wire, top right.

MAKING SENSE

Practically any small to medium size plastic case should accommodate this project. It is best ***not to use*** a metal case, as this would make it difficult to get the sensor plate working effectively.

The general layout of the unit is not too

COMPONENTS

Resistors

R1 to R4	10M (4 off)	
R5	39k	
R6	10k	
R7	1M	

All 0·25W 5% carbon film

See SHOP TALK page

Capacitors

C1	100μ radial elect. 10V
C2	2μ2 radial elect. 50V
C3	1n Mylar
C4	100n ceramic

Semiconductors

IC1	LF351N bifet op.amp

Miscellaneous

S1	s.p.s.t. min toggle switch
SK1	3·5mm jack socket
B1	9V battery (PP3)

Small plastic case, size to choice; multi-project printed circuit board available from the *EPE PCB Service*, code 932; copper clad board or aluminium plate for sensor, size 50mm x 50mm approx; crystal earphone; 8-pin d.i.l. holder; battery connector; wire; solder pins; solder, etc.

Approx. Cost Guidance Only **£9** ***excl. batt. & case***

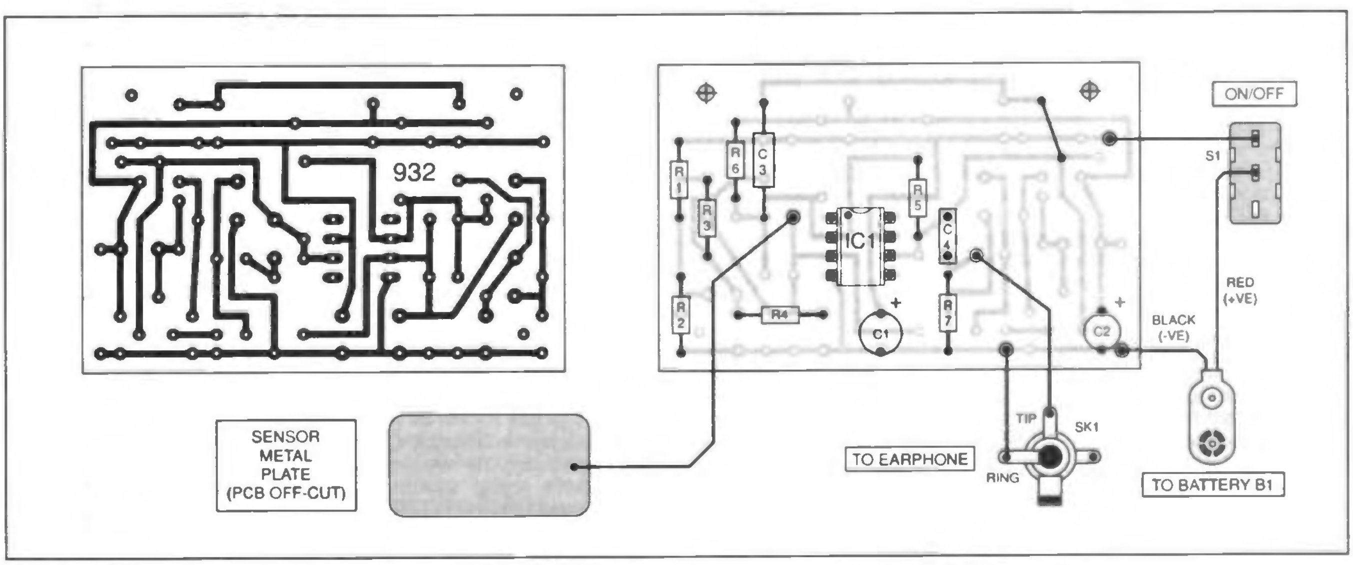
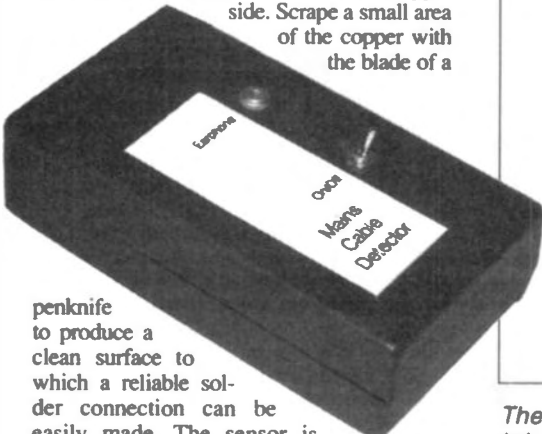
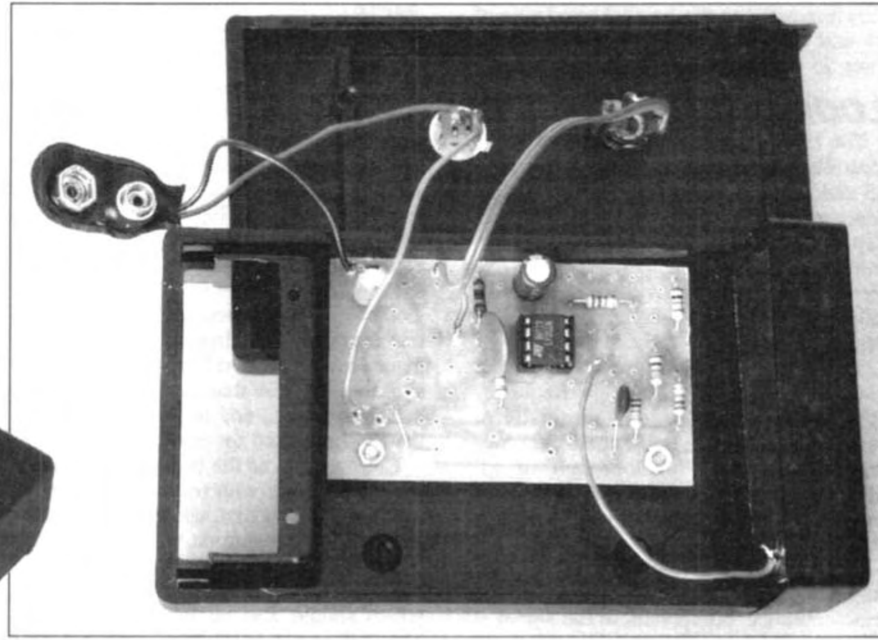


Fig.3. Multi-project printed circuit board component layout, underside full size copper foil master and wiring to off-board components. Not all holes/copper pads are used, so you must double-check component positioning before soldering in place.

important, but try to keep output socket SK1 and its wiring reasonably well separated from the sensor plate and the wire that connects it to the circuit board. The sensor plate can be a piece of copper laminate board (as used for do-it-yourself printed circuit boards) having an area of around five square centimetres or so.

As supplied, this type of board often has a rather dirty and corroded finish on the copper side. Scrape a small area of the copper with the blade of a penknife to produce a clean surface to which a reliable solder connection can be easily made. The sensor is glued in place at the front of the unit, inside the case.





The completed detector, above left, and layout of components inside the prototype case. The sensor plate is glued in place at the front of the unit, inside the case.

A small piece of aluminium can be used instead of copper laminate board, but soldering to aluminium can be difficult even if the special solder is used. It is easier to bolt a solder tag to the piece of aluminium and then make the connection to the tag.

IN USE

When first switched on there will almost certainly be some "hum" and general noise on the output of the unit even if it is not placed close to a mains lead. The output level should be quite low though. Placing the unit near to the mains lead of any appliance that is plugged into the mains supply should produce a loud 50Hz "hum" signal from the earphone.

In practice, there is a fair amount of noise on the "hum" signal, which will consequently produce more of a "buzzing" sound from the earphone. It seems to be possible to detect cables whether or not they are actually passing a current, but detection is certainly easier if there is a current flow.

Walls, floorboards, etc. do not significantly hinder signal pickup, but there can be a general spreading of the apparent signal source. Even so, it is not usually too difficult to follow the path of power or lighting cables. □