PROXIMITY DETECTION

BY THE PROF

GREET YOUR INTRUDERS WITH A WAVE

Emissary emanations of etherical electromagnetism emit information about uninvited interlopers – usually in the form of a loud audible alarm. Select from rf, radar, ultrasonic or infra-red for starters.

A great many applications require that the presence of something, or more usually someone, must be detected. Typical applications are burglar alarms, automatic lighting, and automatic cutouts that operate if (say) someone gets too close to a dangerous piece of machinery while it is operating. Circuits of this type come under the general heading of "proximity detectors", or "presence detectors" as they are alternatively known these days. There must be almost countless ways of detecting the presence of someone by electronic means, but some of these are rather out-of-date now, or at the other extreme require advanced electronics that takes them beyond the scope of most amateur electronics enthusiasts. This still leaves a substantial number of systems that are of interest to the electronics hobbyist, and in this article we will consider three of these.

GOING TO GROUND

One of the earliest systems of proximity detection (possibly the earliest) is the type which uses an arrangement of the type shown in the block diagram of Fig.1. Although this is not exactly the most modern approach, it still represents one of the more interesting methods.

The l-c oscillator is at the heart of the unit, and this must have a feedback control that permits very accurate control of the positive feedback level. The degree of feedback used must be such that the circuit is only just able to sustain oscillation. One end of the l-c tuned circuit must be connected to earth (or "ground" if you prefer the Americanism). By this I do not just mean that it must be connected to the earth rail of the detector circuit — it must be literally connected to earth. If the unit is mains powered then the mains earth connection should suffice. If not, then a short wave radio style earth connection with a rod or pipe buried in the ground is needed. Failing this, a "dummy" earth might suffice, as described later in this article. The sensing element is an antenna connected to the non-earth end of the tuned circuit. This can be a length of wire, but in my experience a metal plate seems to offer far better sensitivity.

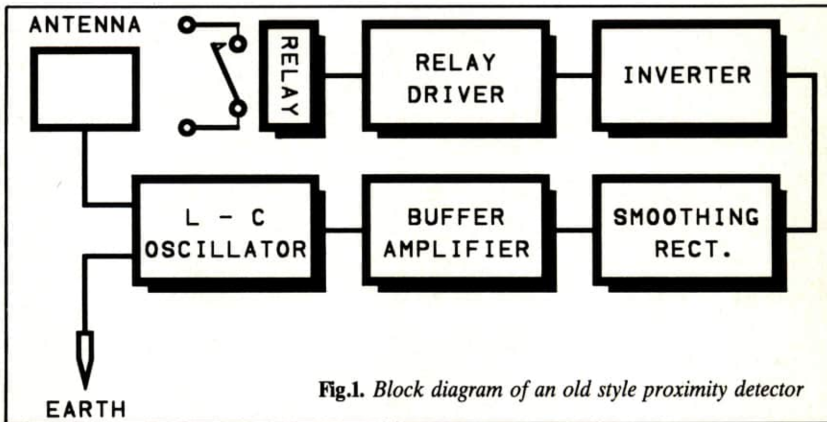

Fig.1. *Block diagram of an old style proximity detector*

This setup may not seem to offer any obvious means of presence detection other than a bit of esp, but it will in fact work quite well, albeit with rather limited operating range. I suppose that there is more than one way of looking at what happens when someone comes close to the antenna, but the generally accepted explanation is that someone close to or actually touching the antenna increases the capacitance from the antenna to earth. This happens due to your body either being earthed, or acting rather like a mini-earth. The effect on the circuit is to slightly damp the tuned circuit so that the level of feedback is no longer able to sustain oscillation. The rest of the circuit must change this lack of oscillation into a switching action that will drive a relay.

The output of the oscillator first feeds into a buffer amplifier. It seems to be very important to have a low level of loading on the oscillator if a reasonable degree of sensitivity is to be obtained. The output from the buffer amplifier drives a rectifier and smoothing circuit, and this normally provides a strong positive dc output signal. However, when oscillation ceases, the output from this circuit quickly drops to zero volts.

Next an inverter/amplifier stage is used to give an output signal that is normally low, but which goes high when the unit is activated. This stage operates the relay via a simple driver stage, and a pair of relay contacts control the load. Normally open contacts are used if the load must be switched on when the unit is activated — normally closed contacts are required if the load must be disabled when the unit is activated.

DETECTOR CIRCUIT

Fig.2 shows the circuit diagram for a proximity detector of this type. As will be apparent from Fig.2, this form of detector can be remarkably simple, and requires no particularly expensive components.

The oscillator has L1 plus the series capacitance of C3 and C4 as the tuned circuit, with the two capacitors providing a centre-tap on the tuned circuit. TR1 operates in the emitter follower mode, and the tuned circuit is coupled to its input by C2. The output of the amplifier is coupled to the centre-tap by C5. An emitter follower only has about unity voltage gain, and generally has a voltage gain of slightly less than unity. However, there is a small voltage step-up through the tuned circuit, and an emitter follower provides plenty of current gain. This enables the circuit to oscillate quite strongly, but VR1 acts as a variable attenuator at the output of the amplifier. In practice this is backed-off to the point where oscillation is only just sustained.

TR2 is the buffer stage, and is another emitter follower. C6 couples the output of TR2 to a standard rectifier and smoothing circuit based on D1 and D2. The oscillator operates at a frequency of a few hundred kilohertz and the relatively low values for C6 and C7 are more

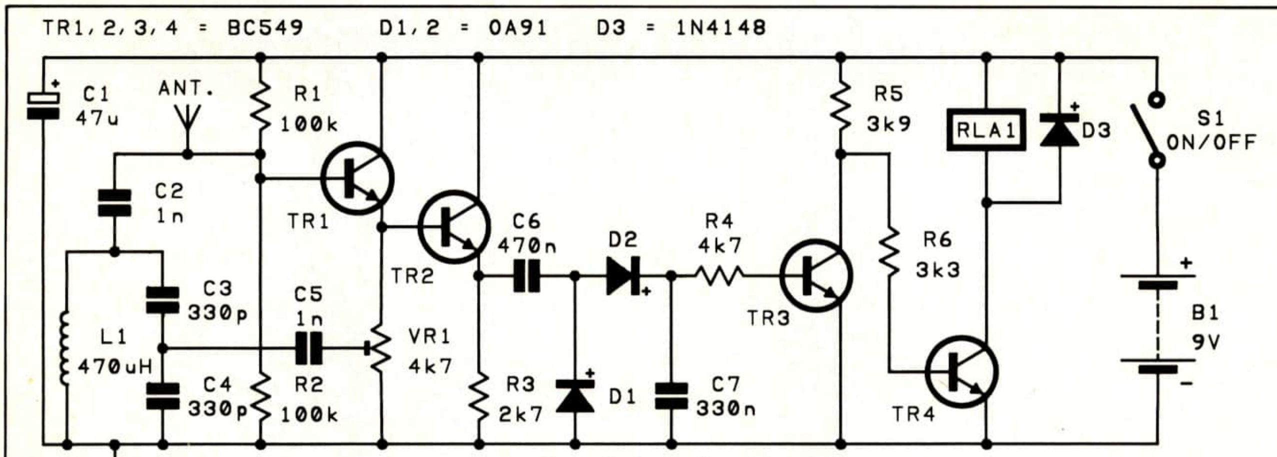

Fig.2. *Proximity detector circuit diagram*

than adequate. TR3 is the basis of the inverter/amplifier stage, which is a simple common emitter switch. This is turned on under normal conditions, but it switches off when oscillation ceases. Its collector voltage then goes to virtually the full positive supply potential. TR4 is the relay driver, and is a second common emitter switch. This is turned on when TR3 switches off, as is the relay that forms its collector load. D3 is the usual protection diode which suppresses the high reverse voltage spike that would otherwise be generated across the relay coil as it was deactivated.

PRACTICAL RESULTS

Although L2 has been specified as having a value of 470μH, any value from about 220μH to 2.2mH seems to give good results. This inductor does not need to be a high Q type, and any rf choke within the specified range should work perfectly well. VR1 needs to be adjusted very accurately if the unit is to achieve good results, and the use of a multi-turn trimpot here is virtually mandatory. An ordinary preset potentiometer might not have sufficient resolution to give satisfactory performance. The relay can be any type which can operate on a 6 volt supply, has a coil resistance of about 200 ohms or more, and which has suitable contacts for your intended application. I used an open construction printed circuit mounting type having a coil resistance of 410 ohms.

I operated the circuit from a 9 volt battery, but anyone using the circuit in earnest would be well advised to use a good quality stabilised mains power supply unit. Any significant variations in the supply voltage are likely to either render the unit insensitive or to produce false alarms. The current consumption under stand-by conditions is only about 5 milliamps or so, but this increases by around 30 milliamps when the relay is activated. The exact increase depends on the coil resistance of the relay, and a high coil resistance is advantageous in keeping down the current drain.

If the unit is powered from a mains power supply, then presumably the mains earth will be connected to the negative supply rail, and will act as the earth for the tuned circuit. You can operate the circuit without an earth, but results then become a little unpredictable, and in general, sensitivity will be reduced. A "dummy" or "artificial" earth will often give good results, and this can just consist of a metal plate beneath the unit, with the antenna above the unit.

The antenna can be a short length of wire, but even with VR1 very carefully adjusted, it is then unlikely that a range of more than a few millimetres will be obtained. Much better results are obtained using a metal plate, such as a sheet of aluminium or a sheet of copper laminate board (as used for printed circuit boards). A plate about 300 by 150 millimetres or larger should give good results. Of course, the antenna must be well insulated from earth if good sensitivity is to be achieved.

Adjusting VR1 is a matter of starting with it set for maximum feedback, and then slowly backing it off until the relay switches on. Then advance VR1 just far enough to cause the relay to switch off again.

This type of proximity detector is strictly a short range device. The best range I could obtain was about 400 millimetres or so. Even this sort of range requires a fairly large antenna plate and careful adjustment of VR1. Obviously some applications do not require very much in the way of operating range. This type of detector could, for instance, be used to detect someone on the other side of a door or window, attempting forced entry. Whereas most systems detect an intruder after entry has been achieved, or during the course of entry, this type of sensor can potentially detect someone as soon as they arrive on the scene. The circuit seems to be perfectly capable of operating through a door or window, incidentally. This type of proximity detector certainly represents an interesting line of investigation for the electronics experimenter, and the cost is extremely low.

ON REFLECTION

Ultrasonics are much used in presence detector type burglar alarms, and these mostly operate on the Doppler shift principle. There are other ways of using ultrasonics for proximity detection, such as broken beam and "radar" style detectors. The latter represents an interesting approach for short and medium range applications. Although it generally offers lower range than a Doppler shift type detector, it has one or two potential advantages for certain applications.

Probably the biggest drawback of an ultrasonic Doppler shift detector is that it is in many ways too sensitive. What is actually detected is not the presence or otherwise of an object, but movement of an object. These alarms seem well able to detect quite small objects, including such things as moths and other insects which may fly into their area of coverage! A radar type detector operates by detecting waves that are reflected back to the receiver, and small objects will simply not reflect back enough signal to be detected, especially at longer ranges. This potentially offers much better reliability at the cost of reduced range and area of coverage.

Where an ultrasonic radar type detector offers the biggest advantage over a Doppler shift type is probably for outdoors use. Anyone who has tried to use a Doppler shift type detector outdoors will be only too familiar with the problems that arise. Problems with insects etc causing false alarms are that much greater, and there are additional problems with the wind causing turbulence that generates false alarms. Even hail, rain, and snow can trigger a Doppler shift detector, as can something like leaves blowing around in the system's field of "view". While a "radar" type detector is not totally immune to these problems, they generally seem to be somewhat less troublesome.

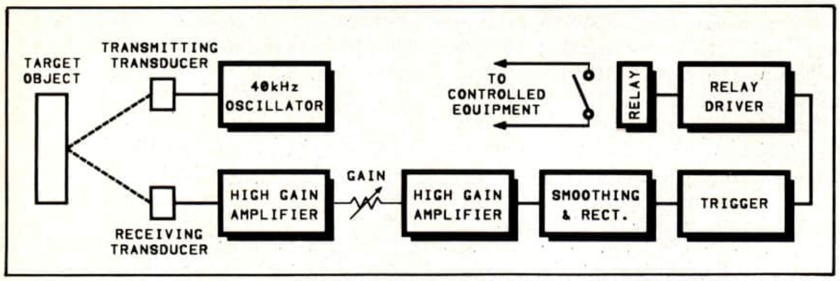

Fig.3. *Block diagram for a "radar" style ultrasonic detector*

A "radar" type system probably works best out of doors where there will normally be a lack of objects to reflect back the ultrasonic sound waves under stand-by conditions. Indoors there will often be a number of objects to produce reflections (such as items of furniture), as well as walls, the ceiling, etc. It is not that a unit of this type will not operate at all indoors, it is more a case of the range often being rather limited. The sensitivity of the system must be kept down to a level that prevents it from being held in the activated state.

Nothing very complex is required for an ultrasonic radar type detector, and the block diagram of Fig.3 shows the basic requirements. A 40kHz oscillator drives the transmitting transducer, which is a standard 40kHz piezo ceramic type, as used in ultrasonic remote control systems. This gives a continuous ultrasonic tone from the transmitter, and if a suitable target object is present, a significant amount of this signal will be reflected back to the receiving transducer. This is again a standard 40kHz ultrasonic transducer of the type intended for remote control applications.

Ultrasonic remote control systems will normally operate at a range of 12 to 15 metres, but such a long range is not practical in this application. The salient point is that in a remote control system the signal only has to go from point A to point B, whereas in a system of this type it also has to make the trip back to point A again. Even with the signal being reflected with 100% efficiency this gives a halving of the range, and in practice a substantial proportion of the signal is likely to be absorbed by the target object. The maximum range is likely to be no more than about four or five metres with co-operative target objects, and much less for small objects or those which have high absorption of ultrasonic waves.

This is sufficient for many applications, but a large amount of gain is needed at the receiver in order to obtain this kind of operating range. In the design featured here around 90dB of voltage gain is provided by a two-stage amplifier. A gain control is included between these two stages, and this is an essential feature. The gain must be as high as possible in order to obtain good range, but must be kept below the point at which the normal level of pick up holds the unit in the activated state.

The output of the second amplifier is fed to a rectifier and smoothing circuit. The positive dc signal this produces is fed to a trigger circuit that provides a high output level if the voltage from the smoothing circuit is above a certain threshold level. The output of the trigger circuit operates a relay via a simple relay driver circuit.

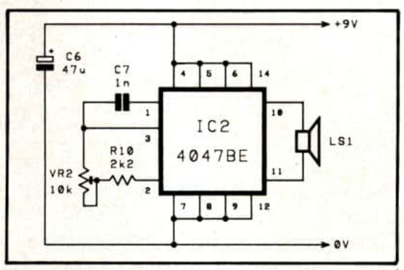

Fig.4. *Ultrasonic transmitter circuit*

CIRCUITS

The transmitter and receiver circuits are shown in Figs.4 and 5 respectively. The transmitter is basically just a cmos 4047BE astable/monostable which is used here in the free running astable mode. Its Q and not-Q outputs drive the transducer (LS1) with anti-phase signals, giving a large peak to peak output voltage. VR2 enables the output frequency to be trimmed to the one at which the two transducers give optimum efficiency.

Two common emitter amplifiers are used at the input of the receiver, with volume control style gain control VR1 being used between these two stages. The output of TR2 feeds into a conventional rectifier and smoothing circuit. The trigger circuit is operational amplifier IC1 connected as a voltage comparator. R7 and R8 provide a reference voltage to the inverting input of a little over 2 volts, and the output goes high when the voltage from the smoothing circuit exceeds this voltage. Common emitter switch TR3 is then turned on, and it in turn activates the relay.

IN USE

Due care needs to be taken with the component layout of this project due to its high level of voltage gain at the receiver and its quite large bandwidth. Also, the input and output of the amplifier are in-phase. The layout must be designed to ensure that there is no obvious path for stray feedback from the input to the output of the amplifier. Consult the retailer's literature to ascertain whether the transmitting and receiving transducers are identical, or there are different components for each circuit. If there are separate receiving and transmitting transducers, make sure you use them the right way round (not that I have ever found an error here to have much effect on performance!). If the receiving transducer has one of its terminals connected to its metal case, make sure that this is the terminal which connects to the negative supply rail so

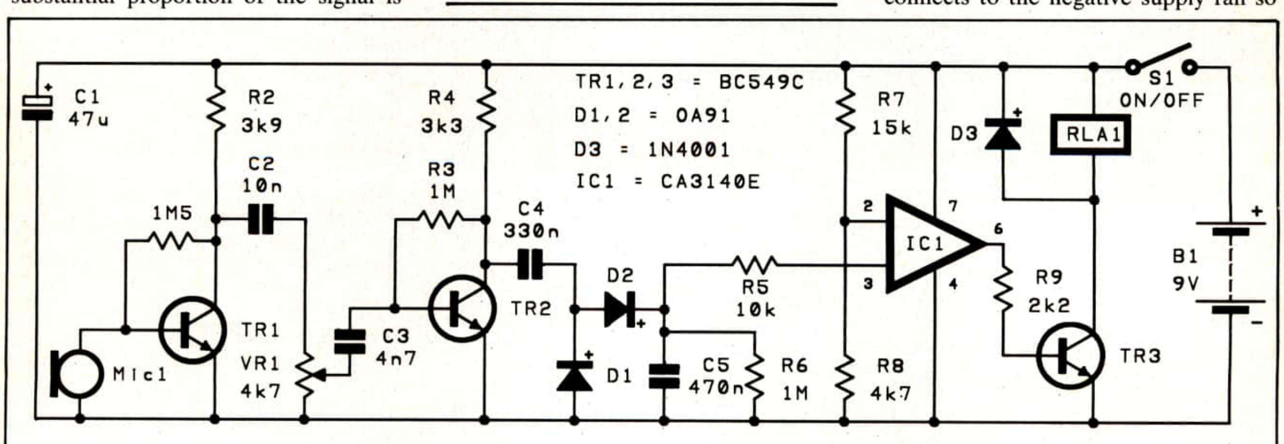

Fig.5. *The ultrasonic receiver circuit*

that stray pick up in the input wiring is minimised.

Direct pick up of the transmitted signal is nothing like as troublesome as you might expect. This is due to the highly directional nature of ultrasonic sound waves. Reasonably low direct pick up should be obtained provided the two transducers are not mounted very close together. I found that about 75 to 100 millimetres of separation was quite adequate.

VR2 must be adjusted for good efficiency from the system, and measuring the voltage across C5 is a simple but effective way of obtaining a relative indication of the received signal strength. It is then just a matter of adjusting VR2 for maximum voltage, with VR1 being adjusted to keep voltage readings within reasonable bounds (between about 0.5 and 3 volts should be satisfactory).

Obviously the unit must be sited where it is "looking" into a reasonably open area. With the unit mounted a metre or more from the floor and aimed into a totally vacant area, an average size person can normally be detected at a range of a few metres. With a lot of objects giving reflections under quiescent conditions the unit will probably give much less impressive results. For optimum results VR1 should be advanced as far as possible without the unit being activated. Keep well out of the unit's field of "view" when making this adjustment. The angle of "view" obtained with most ultrasonic transducers is quite narrow, and the unit will almost certainly only offer good range almost directly in front of the transducers.

Anyone wishing to experiment with more sophisticated ultrasonic detectors should consult the issues of PE dated February and March 1987. These dealt with circuits that provide ranging and not just presence detection, using a technique which is basically the same as a bat's "radar".

HOT STUFF

Most up-market presence detectors seem to rely on microwave radar devices or passive infra-red detectors. The former offer an interesting line of experiment, but the transmitter/receiver units they are based on are quite expensive (about £40.00) and to be strictly within the UK regulations the system as a whole must have type approval. The system of approval seems to operate in a similar manner to the old metal detector licenses, but as yet I do not have definitive information on what is involved in obtaining type approval. This is a subject to which we might return at a latter date.

Passive infra-red detectors are much cheaper, and are free of any licensing requirements. They are very interesting devices for experimentation purposes, as well as having many practical applications. They are something that no self-respecting electronics experimenter can afford to leave untried!

These devices are made from a slice of a special ceramic material which has electrodes on opposite faces. The effect they rely on is reminiscent of the piezo electric effect used for crystal microphones etc, but the charge across the electrodes is produced by heat rather than twisting of the material. The slice of ceramic material is made very thin in order to give a reasonably fast response time, but we are still only talking in terms of an upper −6dB point at something in the region of 3Hz! The output impedance is very high, and practical devices normally come complete with a built-in source follower buffer stage. The input bias resistor of this amplifier leaks away the charges generated on the sensing element, and this limits the low frequency response (typically to a −6dB point at about 0.2Hz). Due to their very restricted bandwidth these "pyro" sensors can not reliably detect a static infra-red source, and must be used in some form of movement detector.

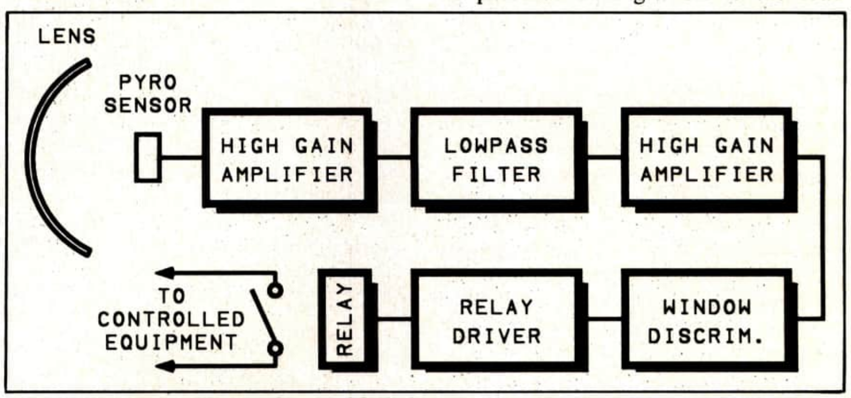

Fig.6. *Basic passive infra-red detector block diagram*

The usual arrangement is something along the lines shown in Fig.6. The pyro sensor is used in conjunction with some form of lens, which is normally a fresnel type that divides the monitored area into alternate zones of high sensitivity and "blind" spots. Anyone moving from one zone to another produces a varying output from the sensor and activates the unit. Alternatively, a convex lens can be used to give a narrow corridor of high sensitivity.

A third, and very effective type of lens, is the so-called "curtain" type. This is a form of fresnel lens, but it gives only two closely spaced zones of high sensitivity. It gives an effect like an invisible curtain which can be used to divide a room in two. Anyone crossing through the "curtain" triggers the unit. It differs from the response obtained using a convex lens in that it has a narrow horizontal coverage but a large vertical angle of "view". With beam type sensors you have to use several vertically stacked beams in order to make it impossible for someone to jump over or duck under the beam. A curtain lens gives excellent reliability with full floor to ceiling coverage (except quite close to the lens of course).

Quite simple electronics are involved, with the low level output from the pyro sensor being fed to a two stage high gain amplifier. Lowpass filtering minimises problems with noise, but it is still noise from the pyro sensor that imposes the upper limit on performance. Some sensors use twin elements connected in anti-phase so that any background noise they pick up tends to be cancelled out. In contrast, as the infra-red signal is swept across the sensing elements it gives a signal of first one polarity and then the other, resulting in a doubling of the peak to peak output voltage.

The output from the amplifier is fed to a window discriminator. Normally the output voltage of the amplifier will stay within the 'window', but when triggered it will stray outside the normal limits. This sends the output of the window discriminator high, and activates the relay via a simple driver stage.

A practical circuit using a pyro sensor is provided in Fig.7. R1 is the load resistor for the source follower in pyro sensor IC1. IC2 and IC3 form what is virtually a high gain, two stage, audio amplifier circuit, but the capacitor values have been made high in value so as to give a suitably extended low frequency response. C5 provides the lowpass filtering. IC4 is the window discriminator, and VR1 is used to "open" and "close" the window. A narrow window gives high sensitivity, a wider window gives lower sensitivity. However, making the window too narrow will make the unit vulnerable to false alarms. VR1 must provide the narrowest window that provides reliable results, which involves a certain amount of trial and error.

DOUBLE VISION

The SBA02 pyro sensor is contained in a three lead TO-99 style case. It is a twin element type, and in normal use is mounted so that the rectangular window is horizontal. I would strongly recommend the use of lenses specially designed

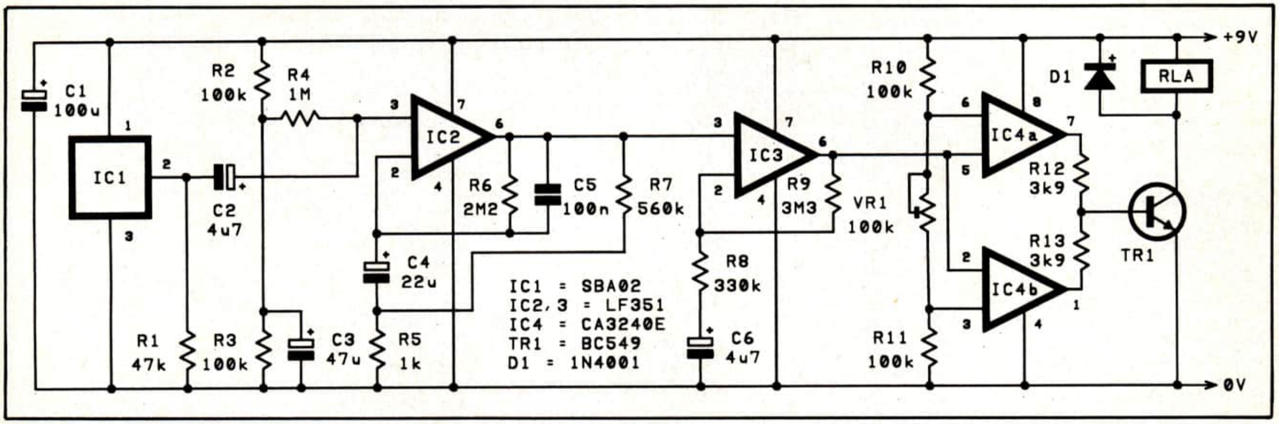

Fig.7. *Passive infra-red detector unit*

for this type of application as normal lenses seem to be completely useless. We are dealing with very long wavelengths of about 7 to 12 microns, and at these wavelengths ordinary lenses either seem to be opaque or simply let the infra-red pass through without any significant refraction! Two inexpensive fresnel lenses for use with pyro sensors are available, and these are the CE24 and CE26. The former gives a wide angle of coverage while the latter is a curtain type lens. A range of up to about 10 metres can be achieved with the CE24, but the CE26 should give at least three times the range. It has 100 degree field of coverage, but horizontally its two lobes of sensitivity are just 2 degrees wide and separated by two degrees. In an application where this type of response is appropriate it offers an amazing level of performance.

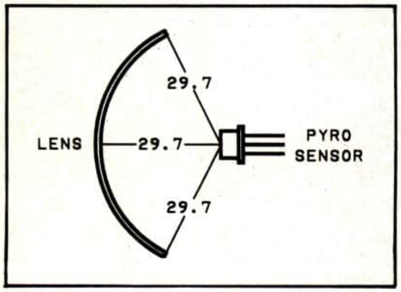

Fig.8. *Required lens curvature*

These lenses are supplied as what are virtually flat pieces of plastic, and their mountings provide them with the correct curvature (see Fig.8). This requires a little ingenuity, but is not too difficult. A slight lack of accuracy only seems to marginally reduce performance. Ideally the lens mounting should be airtight. Passive infra-red sensors are reasonably free from problems with spurious triggering, but turbulence close to the pyro sensor can cause difficulties. An important point to note is that the CE24 is used horizontally, but the CE26 must be mounted vertically (or "landscape" and "portrait" formats as photographers would have it).

Passive infra-red detectors offer excellent performance, but remember that, unlike the other detectors described in this article, they are movement detectors. They are only sensitive to someone moving across their field of "view". Also, they are heat detectors, and will not detect an object that does not radiate a reasonable amount of heat. This is often an advantage, as it makes them pretty well moth-proof, etc.

The SBA02 pyro sensor, CE24 and CE26 lenses, plus white window material are available from Chartland Electronics Ltd., Twinoaks, Cobham, Surrey, KT11 2QW (Tel. 037284 2553).

PE

CLOSE ENCOUNTERS

An acquaintance of mine has a burglar alarm that is activated by magnetic switches at strategic points and for a long time it gave him much peace of mind.

Until, that is, he was adopted by a cat. Being a kind hearted fellow he hated keeping Felix out in the cold while he was at work. Instead, he installed a cat door. It has a magnetically operated catch that only responds to a suitable collar around the cat's neck. It's meant to prevent hordes of marauding cats from around the neighbourhood enjoying his hospitality.

Well, this cat, inquisitive as the rest of its race, delighted in investigating around the house, particularly the human entry points it was also accustomed to use. The alarm contact on one of these doors was less precisely adjusted than it should have been, and yes, you've probably guessed it, moggy's magnet collar kept triggering it while Owner was out. It took Owner a long time, though, to realise the cause of the problem!

My window cleaner tells me that he has to be careful when passing parked cars with his metal ladders — it's embarrassing, he says, to explain to irate owners that their car's proximity alarms have not been maliciously set off.

Ed.