PROJECT

Breaking Glass Alarm

Added protection for your home. Senses ultrasonic sounds generated by broken glass.

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As most readers will be fully aware, the human senses are not without their limitations. In particular, the eye only responds to a very small part of the range of frequencies generally accepted as being forms of light, and the ear can detect sound waves over a relatively small range of frequencies. Although you cannot see infra-red or hear ultrasonic sounds, they are both present as part of our natural surroundings.

Electronics seems to be increasingly involved with these unseen and unheard parts of the electromagnetic and sound spectrums. They find use in such things as remote control systems, automatic light switches, and intruder alarms.

Ultrasonics

The unit featured here is a form of intruder alarm, and it makes use of ultrasonic sound. However, it is not of the usual "Doppler Shift" movement detector or broken beam varieties. It is designed to pick up the ultrasonic sound waves produced when an intruder tries to break into premises by breaking a window.

On the face of it, the use of ultrasonics in this application is unnecessary, since breaking glass produces strong sound waves in audio spectrum, and a normal sound activated switch should do the job equally well. In fact there would seem to be advantages to an ordinary sound switch in that it would probably give greater range and a less restricted angle of "view". Ultrasonic sound waves tend to be highly directional, and to be more readily absorbed by air than audio frequency sounds.

There are in fact advantages in using an ultrasonic system. With most types of burglar alarm, there is no real difficulty in obtaining good sensitivity. The main difficulty is in avoiding false alarms.

False Triggering

A unit which responds only to ultrasonic sound is likely to be less prone to false alarms as there are fewer sources of strong ultrasonic sounds in most environments. The directivity of ultrasonic systems is helpful in cutting out possible causes of spurious triggering.

The same is true of the high absorption of high frequency sound waves in air. The chances of loud but distant sounds activating the unit are quite remote. For example, something like a low flying aircraft would be quite likely to activate an ordinary sound triggered switch, but would be very unlikely to trigger an ultrasonic type.

An aircraft probably produces some ultrasonic sound, but very little of what is produced is likely to reach the ground. The same is also true of thunder, with its predominantly low frequency content. Another advantage of ultrasonics is that, unlike low frequency sounds, they are largely blocked by windows and walls.

Alarms of this type are not totally immune to false alarms, but they are generally accepted as being less prone to problems in this respect than many other types of alarm. The most likely cause of a false alarm is when strong audio sound waves vibrate something in the vicinity of the alarm and cause it to produce ultrasonic sound waves.

Apparently it is important that all the broken glass should be removed when a smashed window is repaired, including any tiny chips, as these can be stimulated into producing ultrasonic sound waves by strong audio frequency sounds. Breaking glass alarms have been known to operate when a window in another building some distance away has been broken. This is almost certainly due to this phenomena of audio to ultrasonic conversion, rather than direct pick up of the ultrasonic sound over a long distance.

As described here the alarm is a self contained battery powered unit having a built-in two tone alarm generator circuit. It is intended to act as a simply stand-alone burglar deterrent, but the unit could probably be incorporated into a comprehensive alarm system without too much difficulty by someone with a reasonable knowledge of electronics.

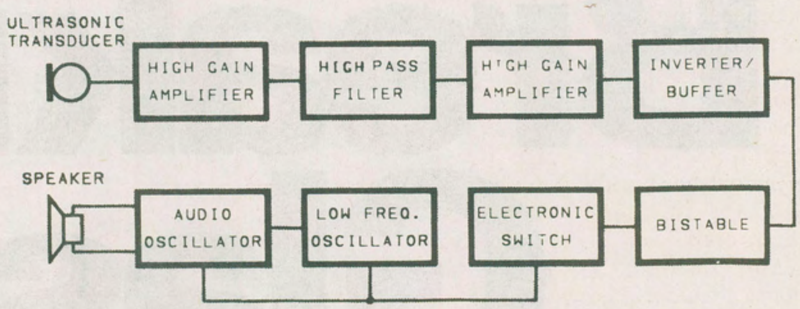


Fig. 1 Block diagram of the Broken Glass Alarm system.

System Operation

The block diagram of the overall make-up of the Breaking Glass Alarm is shown in Fig. 1, and helps to explain the way in which it functions. Ordinary microphones are very inefficient at ultrasonic frequencies, and so an ultrasonic transducer (of the type designed for remote control applications etc.) is used at the input of the unit.

Although ultrasonic transducers have a sharp peak of sensitivity centred on a certain frequency (usually 40kHz), they offer quite good sensitivity over a much wider frequency range. I tried out several different types of transducer, including 25kHz, 32kHz, and standard 40kHz components, but it was a 40kHz transducer that gave the best results.

The output level from the transducer is not likely to be very high, and so this signal is boosted by a high gain amplifier. The next stage is an active high-pass filter which severely attenuates any audio frequency signals produced by the transducer.

The sensitivity of an ultrasonic transducer is very low indeed over most of the audio frequency range, but a significant output signal can be produced over the upper part of the audio spectrum. This filter greatly reduces the risk of audio frequency signals spuriously activating the alarm. The filter is followed by a second high gain amplifier stage.

This gives quite a strong output signal when breaking glass is detected. The function of the rest of the circuit is to convert the strong ultrasonic sounds into a switching action that operates an alarm generator circuit, and keeps it switched on indefinitely.

The latching action is provided by a bistable circuit that is driven from the output of the amplifier via an inverter/buffer stage. An electronic switch is driven from the output of the bistable, and at switch-on the bistable is provided with a "reset" pulse that places its output low and turns off the switch.

Normally the output voltage from the amplifier is too high to "set" the bistable, but when an ultrasonic sound is detected the bistable is "set" on the first negative half cycle, at the output of the amplifier. Once "set" the bistable remains in this state until it is manually "reset".

The alarm generator is controlled by the electronic switch, and it is therefore activated when the switch is turned on. The alarm is a form of two-tone type, where the pitch of the audio frequency oscillator is swept up and down between two pitches by a low frequency oscillator. This gives a sort of warbling sound that is quite penetrating and effective as an alarm sound.

Circuit Operation

The full circuit diagram for the Breaking Glass Alarm appears in Fig. 2.

MIC. 1 is the ultrasonic transducer and the first amplifier is a common emitter type built around transistor TR1. This stage runs at a fairly low collector current of well under 1 milliamp, but it still provides a high level of gain over the ultrasonic range of about 20kHz to 80kHz. Transistor TR2 is an emitter follower buffer stage, and this is needed in order to give a low output impedance to drive the next stage.

This is conventional active high-pass filter having transistor TR3 as the buffer stage. The filter is a "four-pole" (24dB per octave) type having a cutoff frequency of slightly over 20kHz. The output of the filter is coupled by capacitor C6 to the input of the second amplifier stage, which is another common emitter type.

Preset control VR1 enables the quiescent output voltage of the amplifier to be adjusted. This permits the output voltage to be set high enough to ensure that the unit is not simply activated at switch-on, but low enough to give good sensitivity.

The inverter/buffer stages uses a CMOS quad 2-input NOR gate, IC1a, wired as a simple inverter, and two of the other gates of IC1 are cross-coupled so that they act as a basic bistable circuit. Capacitor C7 and resistor R11 provide the positive reset pulse to the bistable at switch-on. One gate of IC1 is left unused, and its inputs are tied to the positive supply rail to protect them against static damage.

The electronic switch has the common emitter stage based on transistor TR6 driving a second common emitter switch (TR5). This combination gives very high gain, and can easily handle the fairly high output currents involved when the alarm is activated.

Alarm Generator

Both the oscillators in the alarm generator are standard 555 astable circuit. IC2 provides the low frequency modulation while IC3 operates as the tone generator. The modulation is applied to pin 5 of IC3, and it has the effect of varying the charge and discharge thresholds of IC3. This gives frequency modulation, and with capacitor C9 omitted the operating frequency of IC3 is simply switched between two frequencies. Capacitor C9, in conjunction with resistor R14, provides lowpass filtering that produces a smoother transition from one frequency to the other, and a somewhat more effective alarm signal.

The basic frequency of the alarm is easily changed if desired, and it is inversely proportional to the value of capacitor C10. Similarly the modulation frequency is inversely proportional to the value of capacitor C8.

The modulation depth is controlled by resistor R14 (lower values giving greater modulation), while the values of both R14 and capacitor C9 control the smoothness of the modulation. By making changes to the values of these components a considerable repertoire of alarm sounds is available.

Output currents of well over 100 milliamps are available from a standard 555 timer, and using an eight ohm loudspeaker quite high volume levels are achieved. The unit is certainly adequate in this respect for a simple burglar deterrent for use indoors.

A load impedance as low as eight ohms can tend to "pull" a 555 oscillator off its natural operating frequency, but a good alarm sound should still be obtained even if this should happen. A higher impedance loudspeaker can be used, but these seem to give significantly lower volume levels. The use of an "improved" version of the 555 for IC3 is not recommended, as many of these devices are low power types which have much lower maximum output currents than the standard device.

Burglar alarms often incorporate a timer that automatically shuts off the alarm a few minutes after it has been activated, so as to prevent the alarm from causing a public nuisance. This feature has not been incorporated in the present design, and it would be of limited value in a low power unit for indoor use.

S1 is the on/off switch, and the alarm is reset by switching off, waiting a second or so, and then switching on again. It is advisable to use a key-switch for S1 so that there is no quick and easy way for an intruder to silence the alarm once it has been activated.

The stand-by-current consumption of the unit is only about 1 milliamp. This is low enough to permit economic battery operation, and six good quality size cells fitted in a plastic holder are sufficient to power the unit for well over 2000 hours of operation, which equates to around 3 to 4 months of continuous operation. Assuming the unit is used intermittently, the batteries will have something not far short in their "shelf" life.

Note that once the unit is activated the current consumption increases to something in the region of 80 to 90 milliamps. A fairly high capacity battery must be used in order to allow this fairly high current drain to be met, as well as to give good battery life.

Construction

The printed circuit board accommodates all the components apart from the loudspeaker, battery on/off switch and microphone. The component layout and full size copper foil master pattern is shown in Fig. 3.

Construction of the board presents little that is out of the ordinary, but bear in mind that IC1 is a CMOS device and that it consequently requires the usual antistatic handling precautions. Also, do not overlook the single link-wire just to the right of resistor R19. Pins are fitted to the board at the points where connections to off-board components will be made.

A plastic case having an aluminum front panel is used as the housing for the prototype, this has approximate outside dimensions of 161mm by 96mm, but a somewhat smaller case should be capable of accommodating everything. For any security application it is advisable to use a reasonably tough case, but in this application it is not essential to use something as

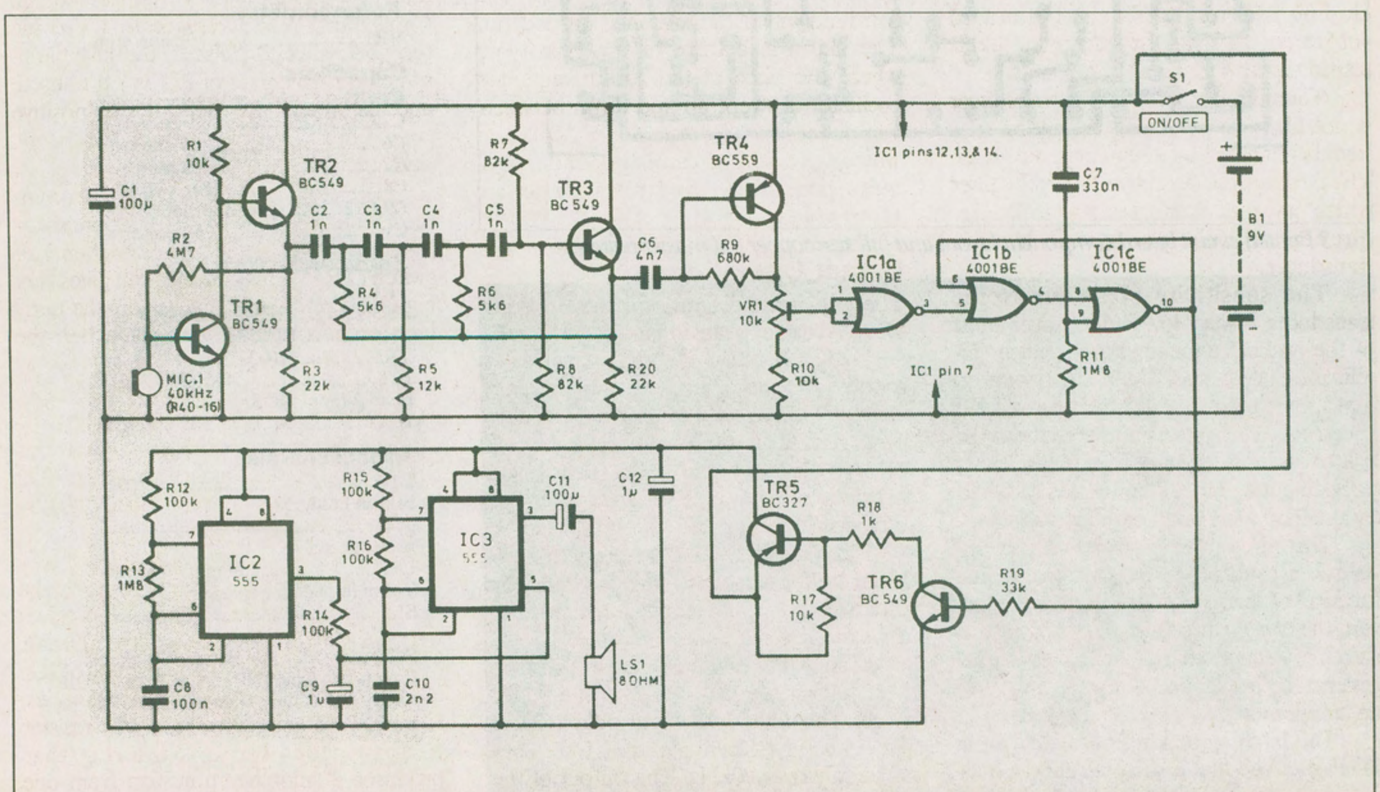


Fig. 2 Complete circuit diagram for the Breaking Glass Alarm.

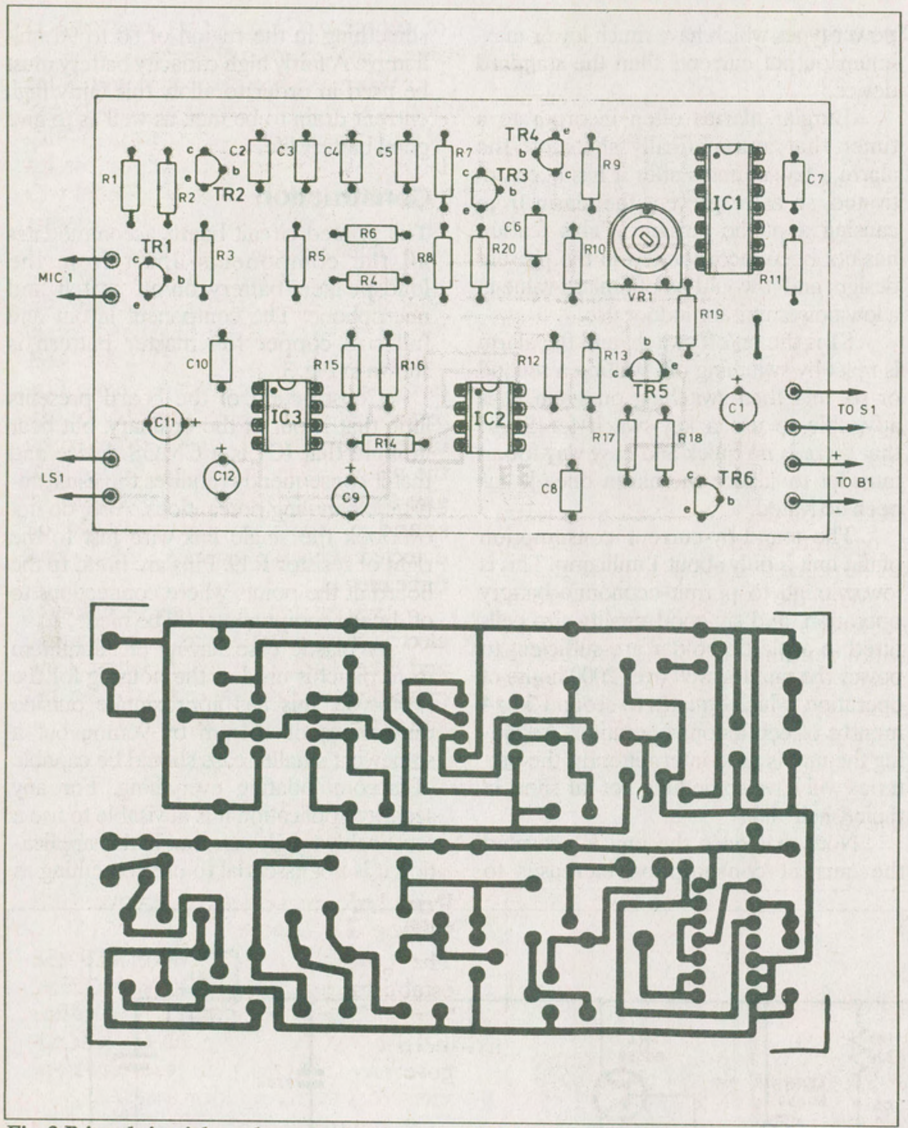
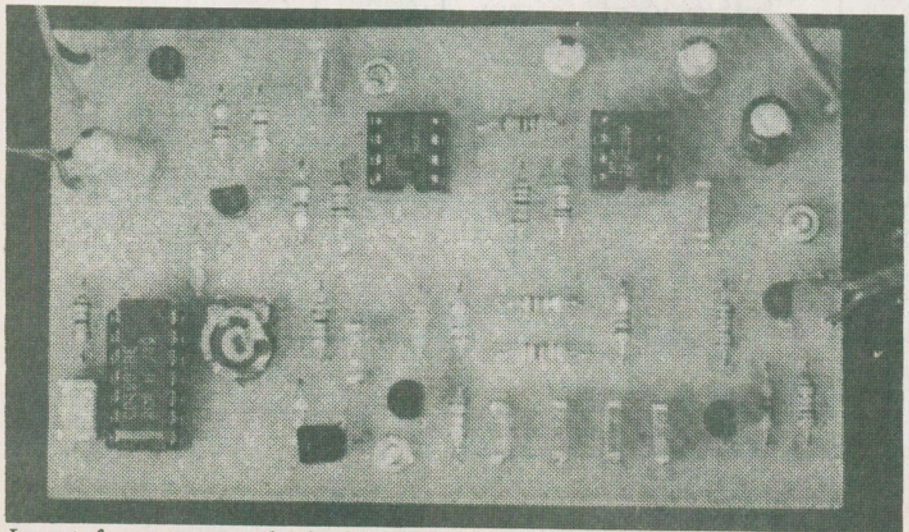


Fig. 3 Printed circuit board component layout and full size copper foil master pattern.



Layout of components on the circuit board.

hardy as a diecast aluminium or heavy gauge steel type.

Switch S1 is mounted on the right hand section of the front panel, and the component used required a 20mm diameter mounting hole which was made with a chassis punch. This seems to be typical of the mounting requirements for key switches. The loudspeaker is mounted to the left of S1, leaving space for the batteries to fit between these two components.

A loudspeaker grille can be made by drilling a matrix of holes about 5mm in

PARTS LIST

Resistors

R1,R10,R17 .... 10k(3)
R2...4M7
R3,R20.................................. 22k(2)
R4,R6.................................... 5k6(2)
R5..12k
R7,R8.................................... 82k(2)
R9...680k
R11,R13............................1M8(2)
R12,R14,R15,R16.............. 100k(4)
R18..1k
R19..33k
All resistors 0.25W 5% carbon

Potentiometer

VR1..............................10k hor. trim

Capacitors

C1,C11........100u radial elec.10V(2)
C2,C3,C4,C5 .... 1n polyester(4)
C6..............................4n7 polyester
C7..............................330n polyester
C8.............................. 100n polyester
C9,C12...........1u radial elec.63V(2)
C10..............................2n2 polyester

Semiconductors

TR1,TR2,
TR3,TR6...... BC549 or 2N3904 npn
TR4............. BC559 or 2N3906 pnp
TR5............... BC327 or 2N5819pnp
IC1 ....4001BE CMOS
quad 2-input NOR
IC2,IC3.........................555 timer(2)

Miscellaneous

B1...9V(six cells in holder)
Mic.1......................40kHz ultrasonic transducer
LS1 .... 80mm diameter 8 ohm impedance speaker
S1 ....Keyswitch

PCB; case (161 x 96 x 59mm) with aluminum front panel; 8-pin DIP socket(2); 14 pin DIP socket; 9V battery connector. TR5 can be any PNP capable of 800mA or more.

diameter. Be very careful with the positioning of the holes as it is a lot more difficult to make a really neat job of this than you would imagine.

With miniature loudspeakers there is usually no obvious means of fixing them in place, and it is generally a matter of carefully gluing them in place using a good quality adhesive such as an epoxy type. Try to avoid smearing adhesive onto the diaphragm.

The situation is similar for the ultrasonic transducer (MIC. 1), which is mounted on the left hand end panel for the case, and which will almost certainly have to be glued in place. The unit will probably work quite well with any 40kHz ultrasonic transducer. To complete the unit the small amount of point-to-point style wiring is added. The connections to the battery holder are made via an ordinary PP3 type battery connector.

Many ultrasonic transducers have one terminal connected to their metal case. With such transducers this terminal should be the one which connects to the negative supply rail.

Testing and Use

After giving the wiring a thorough final check, set preset VR1 at a mid-setting and switch-on the unit. The alarm will probably not be activated, but if it is, switch off again and set VR1 fully clockwise. The alarm should then fail to activate when the unit is switched on again.

It is not necessary to smash glass to test the unit, and any ultrasonic sound in front of the transducer should activate it. Rubbing your fingers together in front of the unit should be sufficient.

By adjusting VR1 in an anticlockwise direction it will probably be possible to gain some increase in sensitivity. However, it is probably best to adjust VR1 well off the point at which the alarm is triggered, as otherwise the unit may well be prone to spurious triggering.

With the prototype there were no problems, with vibration from the on/off switch tending to trigger the unit at switch-on. However, if this should prove to be problematical making the initial reset pulse longer by increasing the values of capacitor C7 and (or) resistor R11 should eliminate the problem.

When deciding where to install the unit, bear in mind that the angle of "view" of the transducers is fairly narrow. With a large window, or several windows side-by-side, coverage will probably be better with the unit angled across the window rather than aimed perpendicular to it.

During experiments, using two transducers connected in series, with the two of them aimed in slightly different directions, seemed to work quite well, giving a wider acceptance angle. Optimum reliability would probably be obtained with the transducer mounted on the window, but this would be likely to give away the presence of the alarm. The sound of breaking glass should be detected reliably at a range of at least three metres.

Avoid mounting the unit very close to electric fires, refrigerators, mains wiring, and other likely sources of electrical impulses that could be picked up by the unit and cause false alarms. ■