Ultrasonic movement detector

for the Car Burglar Alarm

Designed to mate with our new Car Burglar Alarm (May '84), this ultrasonic movement detector provides added protection against illegal entry. It will trigger the alarm if a window is broken or if there is any movement inside the vehicle.

by JOHN CLARKE

Judging by the interest shown in the Car Burglar Alarm, this ultrasonic movement detector is sure to be popular. While the alarm, in its original form, will guard against entry via a door or interference to the ignition, it cannot protect against entry through a broken window.

It is thus possible for a thief to enter your car through a broken window and to abscond with your expensive sound system without triggering the alarm. Alternatively, having gained access, the thief could possibly disable the alarm and disappear with the vehicle. This circuit overcomes those problems.

In fact, when you think about it, an ultrasonic movement detector is an ideal add-on for a car burglar alarm. The metal and glass construction of a car means that the ultrasound is kept within the confines of the vehicle. The detector is thus unaffected by external movements and sounds.

Reference to the May '84 circuit will show that we made provision for this latest unit by including a second delayed entry (the first monitors the doors). This means that the alarm will not sound until 10s after movement has been detected, a necessary feature to allow for authorised entry to the vehicle.

A feature of the circuit is that it is very easy to build. Apart from two ultrasonic transducers, the circuit uses just two ICs, three transistors and a handful of other parts. These are mounted on a small printed circuit board (PCB) and accommodated in a plastic zippy case which mounts out of sight under the dash.

A small red LED on the front of the plastic case flashes on and off when movement is detected. This is used during the setting up procedure and allows the circuit to be adjusted for correct operation without actually setting off the alarm (which makes an unholy ruckus).

How it works

The basic concept is really very simple. Essentially, we have two ultrasonic transducers, a receiver and a transmitter. The latter emits a continuous 40kHz signal which is reflected from surfaces inside the car and picked up by the receiver.

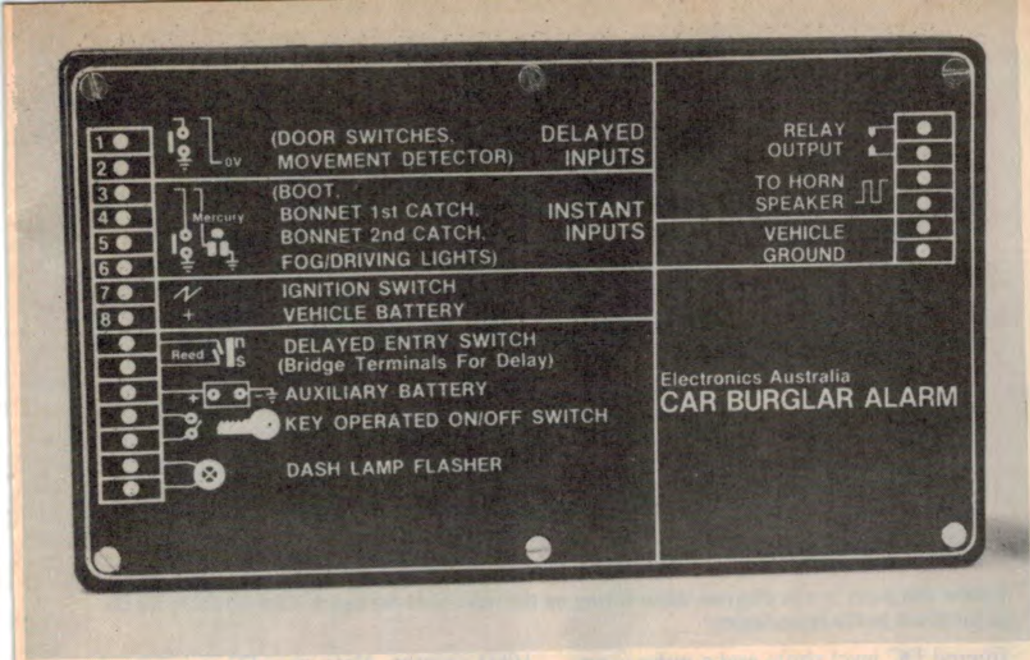
Provided all reflecting surfaces are stationary, the phase of the received signal will remain constant with respect to the transmitted signal. However, as soon as one of the reflecting surfaces moves, or a new surface is introduced, the phase of the received signal will change. This phase change is detected by the circuit and used to trigger the main alarm.

At the heart of the circuit is IC1 which is a 4046 phase lock loop (or PLL for short). Among other things, this IC contains a voltage controlled oscillator (VCO) and a phase comparator. The phase comparator compares the incoming signal frequency (on pin 14) with the VCO signals and produces a square wave output at pin 1, the duty cycle of which is dependent upon the degree of phase mismatch.

When the signals are in phase, the output of pin 1 is permanently low (ie, zero duty cycle). When the signals are 180° out of phase the output is high. If the signals are 90° or 270° out of phase, the duty cycle is 50%.

VR1 and the .001μF capacitor on pins 6 and 7 set the internal VCO to 40kHz. Note that the VCO input is permanently tied low so that it operates simply as a fixed oscillator. The output appears at pin 4 and drives the ultrasonic transmitter via inverters IC2f and IC2e.

The two inverters provide complementary outputs to the transmitter. This technique ensures that the transmitter is driven by the full supply voltage during each half cycle of the 40kHz signal and



The Ultrasonic Movement Detector mates with the EA Car Burglar Alarm at left. It can also be used with some commercial alarms.

thus increases the output power. The 1.2kΩ resistor limits the surge current through the transmitter when the inverter outputs change state.

Note that the VCO output of IC1 is also connected to the pin 3 comparator input. This enables the phase comparator to compare the VCO signal with the received (reflected) signal.

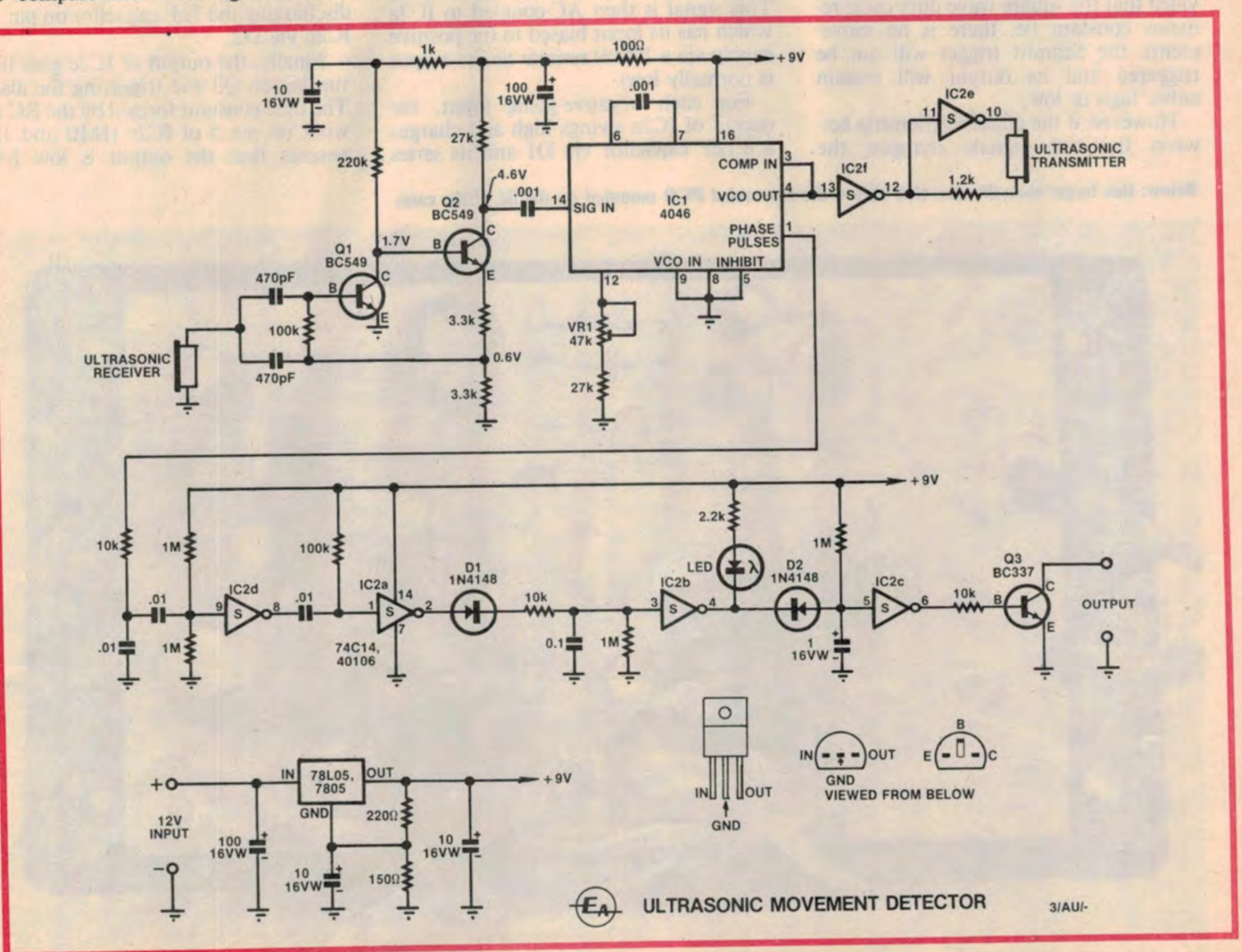
The receiver

The reflected signal is picked up by the ultrasonic receiver and fed via a 470pF capacitor to a two-stage amplifier consisting of transistors Q1 and Q2. These transistors operate as common emitter amplifiers and provide an overall gain of 100. The output is taken from the collector of Q2 and AC-coupled to the PLL via a $.001\mu F$ capacitor.

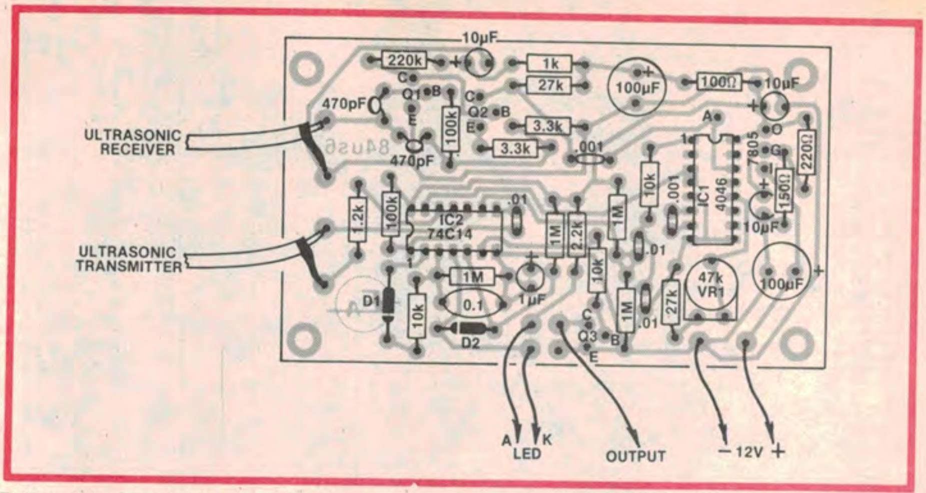
As well as providing signal gain, Q1 and Q2 also function as a bandpass filter. If you look closely at the circuit, you will notice that DC bias for Q1 is derived from a voltage divider network (2 x 3.3kΩ) at the emitter of Q2. At the same time, part of Q2's emitter signal is fed back to the input via a second 470pF capacitor.

So the circuit has two feedback paths: a DC feedback path which provides bias for Q1, and an AC negative feedback path which feeds part of Q2's emitter signal back to the input.

In greater detail, the upper 470pF capacitor on Q1's input functions as a high pass filter which progressively attenuates all signals below 40kHz. Signals above 40kHz are similarly attenuated by reason of the AC-feedback path via the lower 470pF capacitor, the amount of



Ultrasonic movement detector



Follow this parts layout diagram when wiring up the unit. Note the use of shielded cable for the connections to the transducers.

feedback increasing with rising frequency.

Because of the high sensitivity of the amplifier, it is necessary to decouple the power supply to each transistor. A 10µF capacitor and 1kΩ resistor decouple Q1, while a 100µF capacitor and 100Ω resistor decouple Q2.

The amplified signal at Q2's collector is AC-coupled to pin 14 of the PLL and compared with the VCO signal. As previously mentioned, this comparison results in a square wave signal output from pin 1, the duty cycle depending upon the degree of phase mismatch. These phase pulses are then filtered to a DC level and AC-coupled to the input of Schmitt trigger IC2d.

In this case, the input of IC2d is biased to half supply by two 1MΩ resistors. Provided that the square wave duty cycle remains constant (ie, there is no movement), the Schmitt trigger will not be triggered and its output will remain either high or low.

However, if the phase relationship between the two signals changes, the filtered DC level shifts and a pulse is applied to the input of IC2d. The greater the phase change, the greater the voltage pulse applied to the Schmitt trigger.

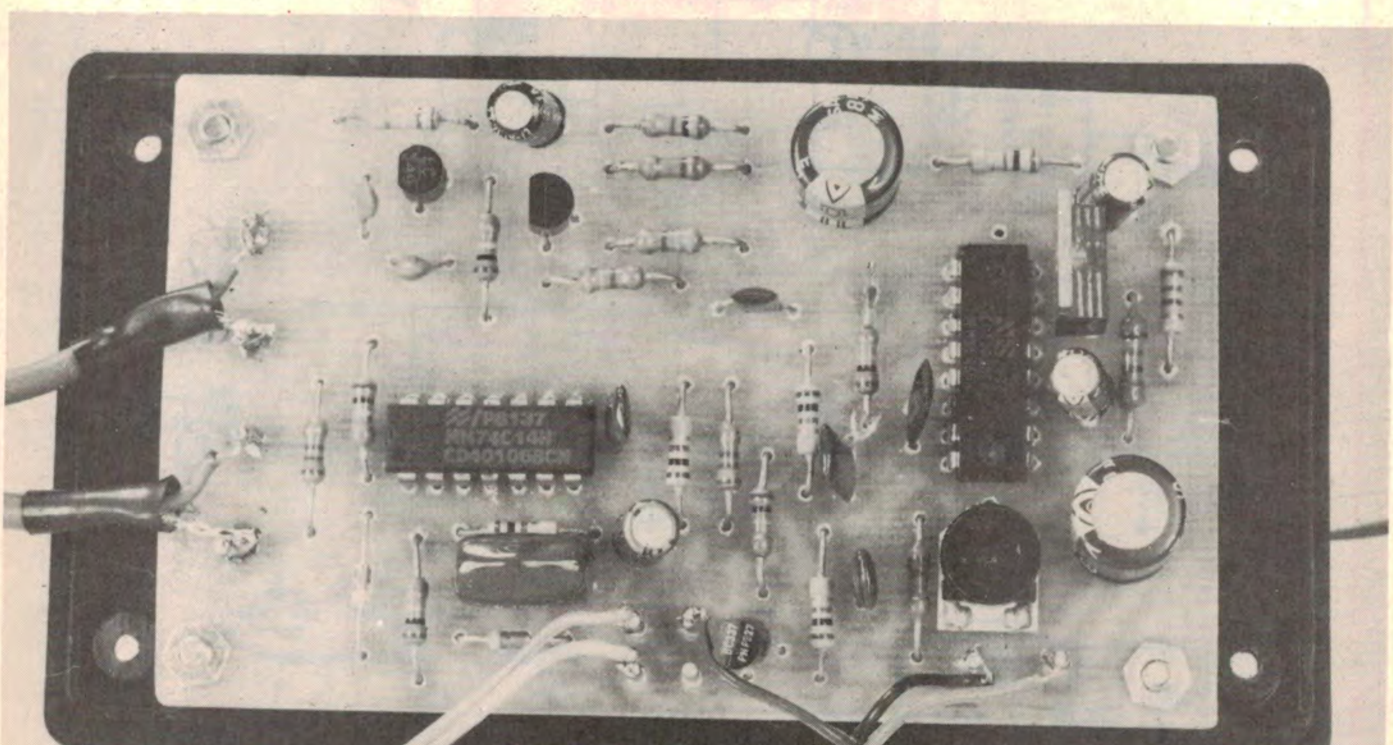
When this pulse exceeds the hysteresis level of the Schmitt trigger its output will change state. Note that if a continuous movement is detected, the output of IC2d will be a continuous pulse train. This signal is then AC-coupled to IC2a which has its input biased to the positive supply via a 100kΩ resistor (ie, its output is normally low).

For each negative-going input, the output of IC2a swings high and charges a 0.1µF capacitor via D1 and its series 10kΩ resistor. Note that D1 is reversed biased when the output of IC2a is low; the only discharge path for the capacitor is via the parallel 1MΩ resistor.

Provided it receives sufficient pulses from IC2a, the 0.1µF capacitor quickly charges to the upper trigger voltage of IC2b. The output of IC2b then switches low, lighting the indicator LED and discharging the 1µF capacitor on pin 5 of IC2c via D2.

Finally, the output of IC2c goes high, turning on Q3 and triggering the alarm. The time constant formed by the RC network on pin 5 of IC2c (1MΩ and 1µF) ensures that the output is low for a

Below: this larger-than-life-size view shows the assembled PCB mounted on the lid of the case.



minimum 1s period.

Power for the circuit is derived from the vehicle battery (see construction) and regulated to +9V using a 5V 3-terminal regulator. That's not quite as silly as it sounds.

In this circuit, the GND terminal of the regulator is connected to a voltage multiplier network consisting of 220Ω and 150Ω resistors. Because the regulator produces 5V between its OUT and GND terminals, it follows that the current through the 220Ω resistor will be 23mA or thereabouts. Both this current and a 6mA current from the GND terminal flow through the 150Ω resistor which "jacks up" the GND terminal by about 4V.

Thus, the output voltage is set to around 9V. The 100μF capacitor filters the supply line while the 10μF capacitors provide decoupling to improve the transient response of the regulator.

Construction

The Ultrasonic Movement Detector is housed in a plastic case measuring 120 x 65 x 39mm, while most of the components are mounted on a PCB coded 84us6 and measuring 97 x 57mm.

Begin construction by installing the parts on the PCB according to the overlay diagram. Take extra care with the semiconductors and the electrolytic capacitors since these must be fitted with due regard to polarity. We used PC stakes to facilitate the external connections.

Once the PCB had been completed, it can be mounted on the lid of the case on 6mm spacers. The hole for the indicating LED is centrally located on one side of the case, while the external wiring passes through a grommeted hole in the opposite side of the case.

Rainbow cable can be used for the connections to the LED, while the power supply and output connections should be run using light duty hook-up wire. Connections to the ultrasonic transducers must be run in shielded cable.

The two ultrasonic transducers are housed in rightangle sparkplug covers. Feed the connecting cable through the cover first, then solder the leads to the transducer with the shield connected to the earth pin. The transducer can then be pushed into the cover to provide a neat assembly.

The ultrasonic transducers are positioned above the front windscreen, one on each side of the vehicle. Each transducer is supported by a nylon cable clamp which is wrapped around the lead exit of the sparkplug cover, which in turn is held by one of the screws that locate the sun visor.

Be careful not to get the two transducers mixed up. The transmitter is labelled SCS401A while the receiver is labelled SCM401A. The two should be mounted as far apart as possible (to avoid interference) and pointed towards the rear of the vehicle.

The ground wire for the circuit can terminate at a convenient chassis point while the positive supply lead goes to the switched side of the key operated on/off switch. The output lead goes to the spare delayed entry input, but don't make this connection until after the setting up procedure has been carried out.

Setting up

Before making any adjustments, first check that the transducers point towards the rear of the vehicle and are reasonably parallel. This done, set your multimeter to read low AC volts and connect it to the test point marked "A" on the parts layout diagram (pin 14 of IC1). Apply power and adjust VR1 for maximum reading (typically 0.5-0.6V).

There's just one hassle here — you will have to keep quite still while you make this adjustment, otherwise the reading will fluctuate.

This done, check that the LED flashes whenever there is movement in the vehicle. If the unit displays a tendency to false trigger, rotate the trimpot (either way will do) to reduce the sensitivity.

Finally, the output lead can be connected to the delayed entry input of the alarm and the unit mounted permanently under the dashboard. The leads from the transducers run down the windscreen pillars and can be fixed with contact adhesive.

That's it. If a thief can get past that lot, there's always the insurance!

We estimate the current cost of parts for this project to be approximately

$30

This includes sales tax.

PARTS LIST

- 1 PCB, 84us6, 97 x 57mm
- 1 plastic case, 120 x 65 x 39mm
- 1 ultrasonic transmitter, SCS401A (Dick Smith Electronics)
- 1 ultrasonic receiver, SCM401A (Dick Smith Electronics)
- 4 6mm standoffs
- 2 right angle spark plug covers (for lawnmowers and motor bikes)
- 1 5.5mm grommet
- 1 4-metre length of screened cable
- 2 cable clamps

Semiconductors

- 1 4046 phase lock loop
- 1 74C14/40106 hex Schmitt trigger
- 2 BC549 NPN transistors
- 1 BC337 NPN transistor
- 1 7805 5V 3-terminal regulator
- 2 1N4148/1N914 small signal diodes
- 1 3mm red LED

Capacitors

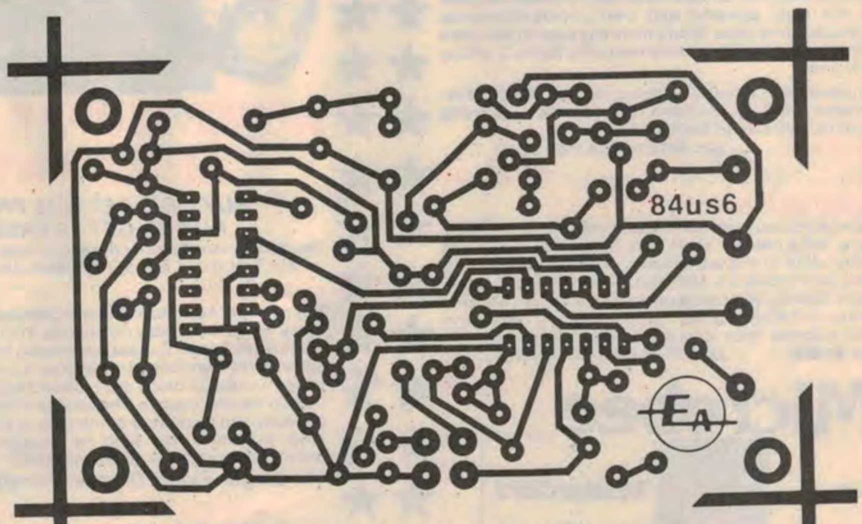
- 2 100μF/16VW PC electrolytic
- 3 10μF/16VW PC electrolytic
- 1 1μF/16VW PC electrolytic
- 1 0.1μF metallised polyester
- 3 .01μF metallised polyester
- 2 .001μF metallised polyester
- 2 470pF ceramic

Resistors (¼W, 5%)

4 x1MΩ, 1 x 220kΩ, 2 x 100kΩ, 2 x 27kΩ, 3 x 10kΩ, 2 x 3.3kΩ, 1 x 2.2kΩ, 1 x 1.2kΩ, 1 x 1kΩ, 1 x 220Ω, 1 x 150Ω, 1 x 100Ω, 1 x 47kΩ miniature horizontal trimpot.

Miscellaneous

Machine screws and nuts, rainbow cable, hook-up wire, PC stakes.



Here is an actual-size reproduction of the PC artwork.