Low-cost circuit uses a single IC!

Build this simple fridge door alarm

Do you have household members who hold the refrigerator door open longer than they should? It's always a temptation — especially for children — to hold the door open whilst deliberating over chocolate cake, ice cream, soft drink or various other non-nutritional products.

By COLIN DAWSON

When the refrigerator door has been left open for about 20 seconds – or, more correctly, when the light has been on for 20 seconds – this EA Fridge Alarm will emit a series of reminder beeps until the culprit closes the door.

A major advantage of making the device light-activated is that it is therefore completely self-contained; it does not need to be connected to the electrical wiring of the refrigerator. Another advantage is that it makes it difficult for the "smartie" to circumvent the alarm. There is no on-off switch and the natural impulse to snatch the alarm out of the refrigerator achieves nothing; it will remain triggered by the ambient light.

(If the door has to be held open legitimately for a long period, as when cleaning the refrigerator, the simplest approach is to pop the alarm into a drawer.)

Mind you, we would assume that any economy-minded EA reader will have already tilted the fridge back slightly so that the door closes automatically once it is left. This avoids the necessity of yelling at wife and kids to "close the blankety-blank fridge door."

The sound is actually provided by a piezoelectric transducer which is quite compact and remarkably efficient. The whole circuit has a quiescent current of only 4μA and even when sounding the alarm draws less than 400μA.

The transducer first came to our attention as part of the Voyager car computer, where it is used for a number of aural warnings. Similar devices are used in electronic clocks and watches.

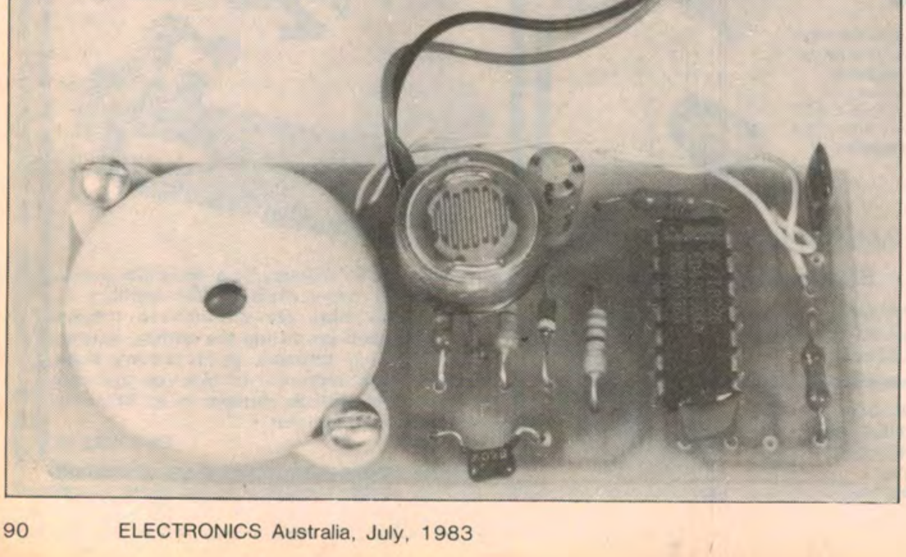
The plastic encapsulation of the transducer has two integral mounting lugs and the whole package is about the size of a 50 cent coin. It is manufactured by Toko and should be available through major kitset suppliers at about the time this issue goes on sale.

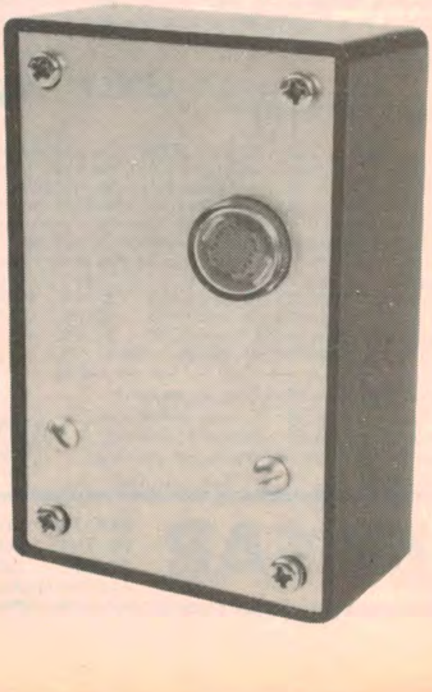
In the Voyager car computer, the transducer has a quite pleasant chime sound. Controlled by the microprocessor, the waveform has a rapidly decaying amplitude after an initial high level. Because we wanted to design the circuit with only one IC, it was not possible to duplicate this effect.

Two oscillators

On the other hand, a single tone is not as attention-getting as might be desirable, so we provided for a more complex sound by feeding the transducer with signals from two oscillators operating at different frequencies. This sound is then switched on and off by means of a third, low frequency, oscillator, giving a succession of beeps.

Below is a view of the assembled PCB while at right is the prototype housed in the optional plastic zippy case. Power is supplied by a 9V battery.





Although the project has been designed to fit into the smallest size "zippy" box, a box is not at all essential. In fact, we simply put the project in a sealable plastic "zipper" bag. This prevents condensation from interfering with the operation of the circuit, without diminishing the effect of the buzzer.

Depending on the frequencies chosen for the first two (signal) oscillators, the alarm can be given a simple digital clock style beep, or a somewhat more dramatic "emergency" style warning.

In normal circumstances putting a battery power supply in a refrigerator would be a questionable practice – the performance of the battery might be reduced to such an extent that circuit operation might be prejudiced. However, tests have confirmed that no problems will arise with this circuit, since it has such a low power consumption. In fact, the battery can be expected to last for at least its shelf life, depending on how often the alarm is triggered. This should give a service life measured in years.

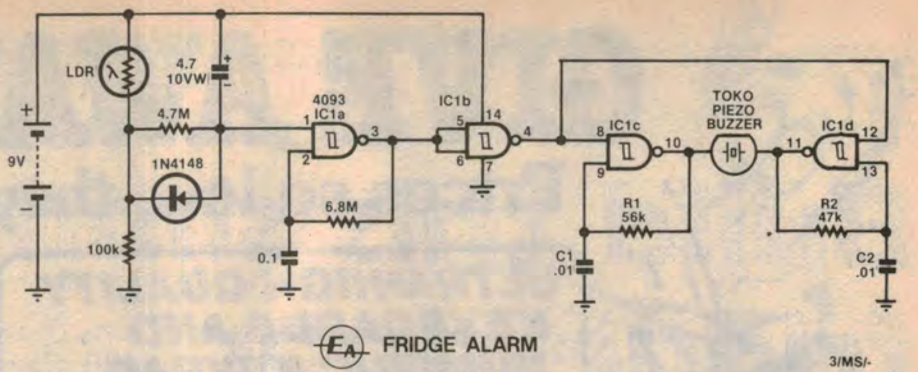
Most refrigerators have an internal light which is activated when the door is opened. This is used to trigger the circuit by means of an LDR (light dependent resistor). In cases where no such light is fitted, the ambient light will usually be sufficient to trigger the alarm.

We have used a 20 second delay between the light coming on and the alarm sounding and this is probably a realistic period. However, it can easily be altered to any period between zero and a few minutes. In fact, this aspect of the circuit's operation gives it the potential to be adapted to "egg timer" applications.

By replacing the LDR with a switch, the alarm would wait for the predetermined period after switch on and then sound the reminder until switched off.

The Toko transducer appears to be most efficient at about 1.5kHz, suggesting that this would be the ideal operating frequency. Since it has more than sufficient volume for the application, however, some may prefer to sacrifice some efficiency in favour of a more pleasant tone.

While there are several ways in which the output of the two signal oscillators could be mixed and applied to the transducer, we found the simplest arrangement was to connect the transducer between the two oscillators.

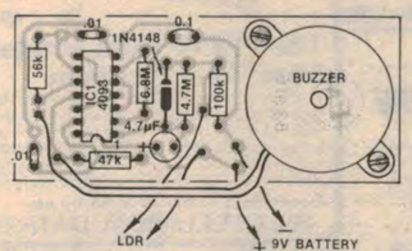


The circuit is triggered by the LDR while IC1c and IC1d drive the buzzer.

PARTS LIST

- *1 Printed circuit board, 32 x 75mm, code 83al6*
- *1 Light dependent resistor (LDR)*
- *1 Miniature piezoelectric transducer (Toko PB-2720 or equivalent)*
- *1 9V battery (Eveready 216 or equivalent)*
- *1 Battery snap connector to suit*
- *1 Plastic box 28mm × 54mm ×83mm (optional)*
- *1 4093 CMOS quad two input Schmitt NAND gate IC*
- *1 1N4148 diode*
- *1 4.7μF/10V electrolytic capacitor*
- *1 0.1μF monolithic capacitor (see text)*
- *2 .01μF greencaps (see text)*

RESISTORS (¼W, 10%)
1 × 6.8MΩ, 1 × 4.7MΩ, 1 × 100kΩ, 1 × 56kΩ, 1 × 47kΩ



Check the polarity of the IC, diode and electrolytic capacitor before soldering them into place.

Circuit details

Operation of the circuit is quite straightforward. The oscillators and trigger circuitry are provided by a 4093 CMOS quad NAND Schmitt trigger IC. Each NAND gate in the package has two Schmitt trigger inputs. This differs from the normal NAND gate in that there is defined hysteresis in the triggering levels, ie, triggering on an upwards transition occurs at a different level to triggering on a downward transition.

The difference in triggering levels is typically 2V with a 9V supply. Although the advantage of this hysteresis may not be immediately apparent, it enables a considerable saving in the number of gates required.

The logic conditions for any NAND gate are such that the output is low only when both inputs are high. For any other combination of inputs, the output will be high.

This allows us to use any one input pin as a control. Taking this pin low effectively inhibits the gate because the output will always be high regardless of what happens to the other input. In fact, IC1a is used in exactly this way with pin 1 serving as the alarm control.

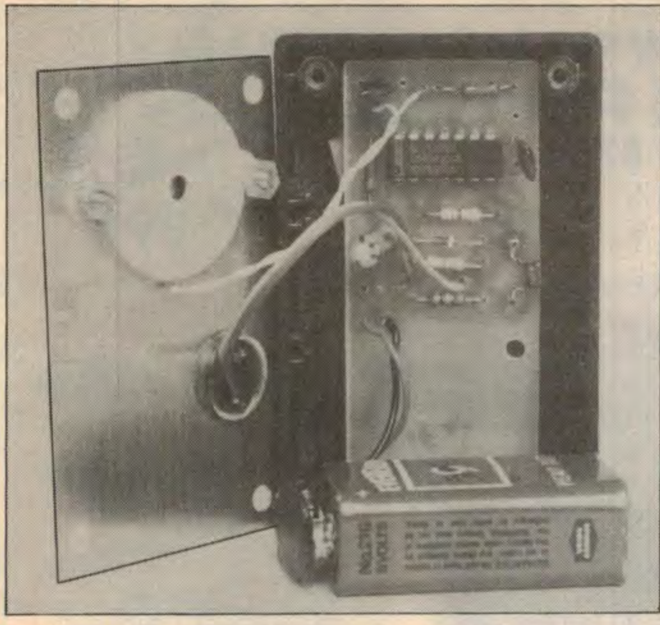
The control voltage is actually derived from a voltage divider consisting of the LDR and a 100kΩ resistor. When little or no light falls on the LDR its resistance is high (hundreds of kilohms or even megohms). This means the voltage at the divider tap is low.

When the refrigerator door is opened and the LDR is subjected to a relatively high level of light, its resistance will fall to a few hundred ohms. Consequently, the control voltage will rise and eventually exceed the gate threshold of IC1a.

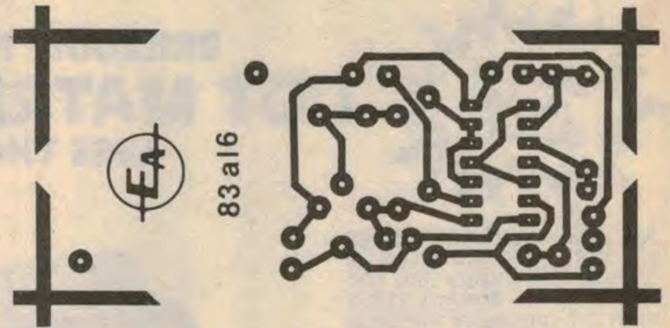
Rather than couple the control voltage directly to pin 1, it is first passed through a delay network consisting of a 4.7MΩ resistor and a 4.7μF capacitor. About 20 seconds after the light is switched on, the voltage on pin 1 will exceed its positive threshold and IC1a will be gated on.

This condition represents the triggered state for the alarm. When the refrigerator door is closed and the alarm condition no longer exists, we want the alarm to cease immediately. This means defeating the 20-second delay, and this is achieved by the diode across the 4.7MΩ resistor.

A charge path exists through this diode



LEFT: *This view shows how the parts are mounted in a plastic zippy case.*



Above is an actual-size reproduction of the PCB artwork.

We estimate that the cost of parts for this project is approximately

$9

for the PCB version. This includes sales tax.

and the 100kΩ resistor which means that charging occurs much more rapidly than discharging. Due to residual charge of the 4.7μF capacitor, the delay period will be less than 20 seconds for some time after an alarm. For example, closing the refrigerator door during an alarm will silence the alarm immediately, but if the door is opened straight away, the delay may be only three or four seconds. The delay period will increase as long as the door is closed, reaching its full value after about one minute.

Pulse oscillator

The role of IC1a is as a modulation gate or pulse oscillator, which breaks up the tones of the signal oscillators into a series of beeps. When its pin 1 goes high, as just described, its output (pin 3) goes low (which turns on the signal oscillators) but it will remain low only briefly.

IC1a's other input (pin 2) is connected to ground via a 0.1μF capacitor and to a 6.8MΩ feedback resistor. When IC1a is gated off, these components have no effect on the circuit, but as soon as pin 3 goes low it begins to discharge the 0.1μF capacitor via the feedback resistor. After about 0.5s, the falling charge on the capacitor will take pin 2 below the lower threshold and the gate will toggle. (Remember only one input need be low to disable the gate.)

This means that the output goes high once again and therefore begins to charge the 0.1μF capacitor. Hence the cycle continues and IC1a oscillates at about 2Hz while ever it is "enabled".

The actual audio tones are generated by IC1c and IC1d. These gates function as oscillators in exactly the same way as IC1a except that their frequency of operation is higher (nominally, 1.5kHz and 2kHz).

Notice that IC1c and IC1d have a common input line (pins 8 and 12 respectively). This is the control line and functions in exactly the same way as pin 1 of IC1a. When the control line is low, the gates are disabled. The problem with this arrangement is that the output of IC1a goes low when it is triggered and is high at other times.

This has the opposite sense to our requirements, so we employ IC1b as an inverter. By connecting both inputs (pins 5 and 6) together, the output (pin 4) will always be in the opposite state to the inputs and, in this circuit, have the correct sense to control the audio oscillators.

As far as the resistor and capacitor values are concerned for IC1c and IC1d, it may be preferable to compare the results of several different combinations. In any case, 47kΩ and 56kΩ for the resistors and .01μF for the capacitors is a good starting point. Alternative pads are provided on the printed circuit board to fit larger capacitors if necessary.

Construction

Although the project can be built into a plastic utility box measuring 28mm × 54mm × 83mm, a sealable plastic bag is just as functional and will make construction that much simpler.

The printed circuit board (PCB) measures only 75mm × 32mm and is coded 83a16. If you do not intend to mount it in a box, the transducer can be fixed directly to the PCB. Space has been provided for this purpose although the transducer can also be screwed to the lid of the box (where applicable).

The 4.7μF electrolytic capacitor and the diode are both polarised and therefore need to be mounted exactly as shown on the overlay diagram. The LDR is not polarised but must be mounted proud of the PCB to clear the other components. If you do intend to put the project in a box, the LDR should be mounted on the lid with two wires connecting it to the mounting holes.

The 0.1μF capacitor is specified in the parts list as a monolithic type. This is necessary only if the project is fitted into the plastic "zippy" box where a normal 0.1μF greencap would be too large.

Put the 4093 in place only after all the other components have been installed and don't overdo the heat when soldering. Note that the IC is a CMOS device. Make sure that it is mounted the right way round and solder the supply pins (7 and 14) first.

The project is actually quite a tight fit in the "zippy" box so you'll need to take care with the installation. Use the accompanying photograph as a guide. The most likely cause of trouble is the battery – it will foul the transducer and LDR if they are not installed carefully.

We suggest that you wrap the battery in foam so that it does not short with components on the PCB.

As already intimated, we have not included a switch in the circuit – once the battery is connected the project will be operational. For testing, it is not necessary to actually put the alarm in the refrigerator. Covering the LDR with an opaque card will suffice for the "dark" condition and room light will trigger it when the card is removed.