Novel circuit uses a piezoelectric tweeter

Super Siren: an ear-splitting alarm

Ever wanted to build an ear-splitting alarm which would be compact and not draw much current? This is just the circuit for you. It uses a piezoelectric tweeter in a pulsed mode to form an arresting and very efficient alarm.

design by COLIN DAWSON

Piezoelectric tweeters have been around for a long time but they have never really caught as a medium for high fidelity sound reproduction, probably because they are difficult to manufacture to the requisite smoothness of frequency response.

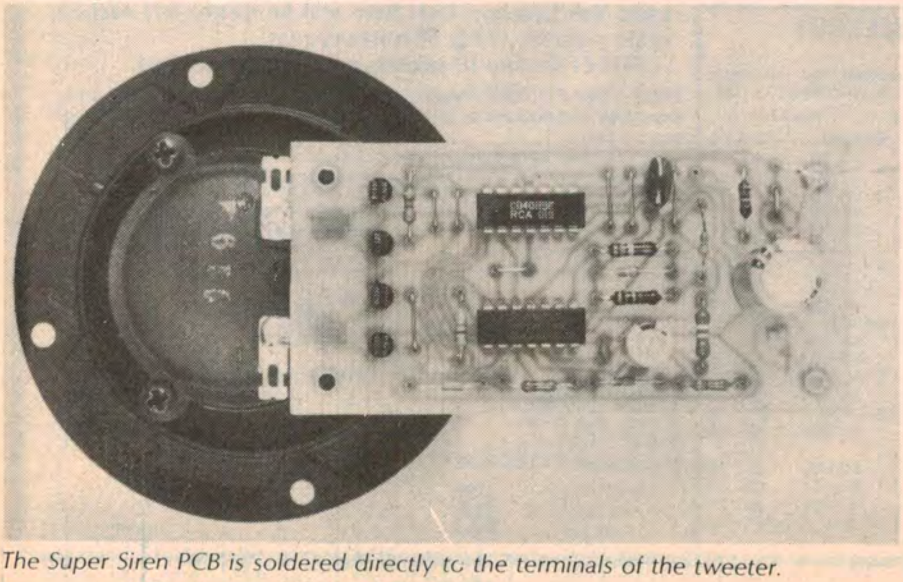
Be that as it may, piezo tweeters have a number of characteristics which make them highly suitable for use in alarms. In this respect, they are identical in principle to the small, highly efficient alarms used in many computers and digital watches.

The equivalent circuit of a typical piezo tweeter is a capacitor of about 0.1μF. Because of this, a piezo tweeter connected across an AC signal source draws very little current. This is important for our application because we wanted to operate the alarm from a small 9V battery. At this voltage the circuit draws less than 10mA when it is sounding.

The sound output of this alarm is a series of four short pips in a one-second period, followed by a half-second break, then another burst of pips and so on. The resulting sound effectively conveys a sense of urgency and is more likely to be acted upon than one of the more common transistor powered alarm circuits which sound like a half-strangled cat!

We will leave it to the reader to think of applications for this alarm. We are sure that there will be many. It could be used as an equipment malfunction alarm, intruder alarm or car alarm (separately powered and not dependent on the car battery).

Fig. 1 gives a picture of what the sound output of the alarm looks like on an oscilloscope. Each pip is actually a burst of 5kHz signal lasting for about 60 milliseconds and there are four pips in each 400ms burst. The frequency of 5kHz was settled upon as being the most earsplitting. At frequencies below 5kHz, piezo tweeters do not have much output.



The Super Siren PCB is soldered directly to the terminals of the tweeter.

The waveform of Fig. 1 could easily have been produced by conventional logic circuitry using counters and gates plus an oscillator to drive it all. But we elected to take a different approach and ended up with a circuit that uses no counters at all. The circuit uses just two CMOS ICs plus four transistors to buffer the piezo tweeter.

The two ICs are a 74C14 hex Schmitt trigger and a 4011 quad 2-input NAND gate.

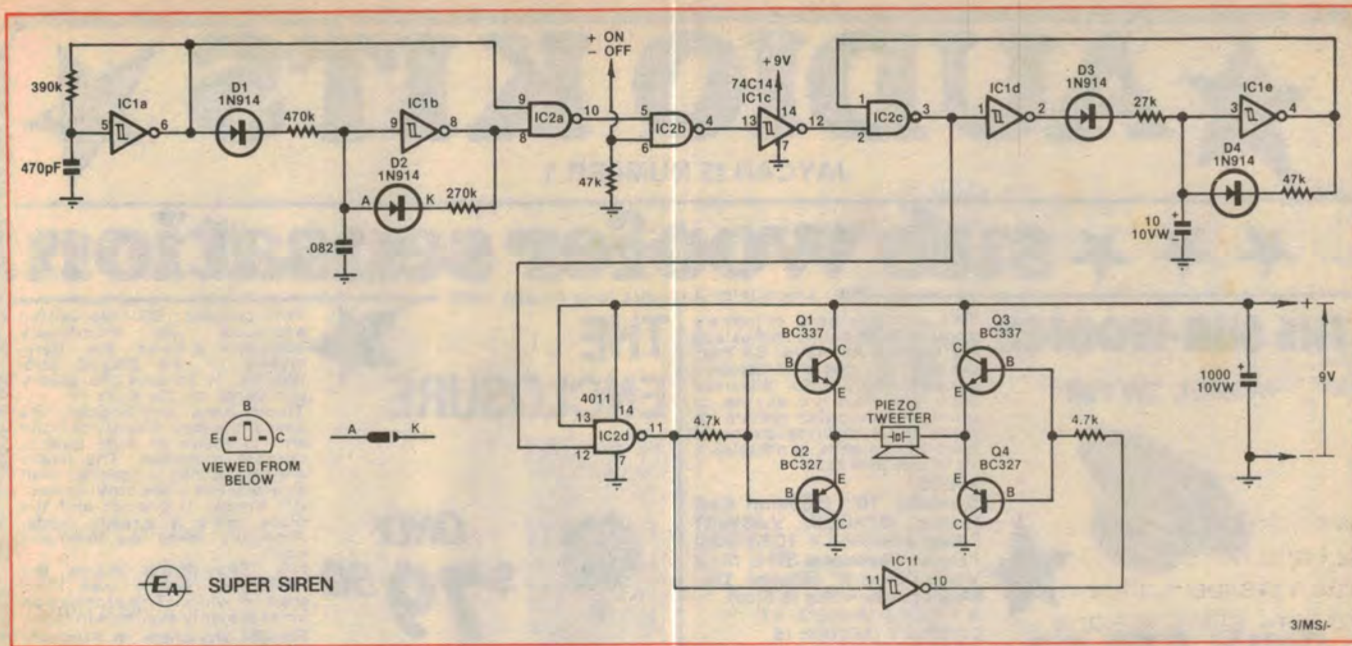
How it works

IC1a is the free-running oscillator in the circuit with its 5kHz frequency determined by the 390kΩ resistor and 470pF capacitor. This is one of the simplest oscillators possible and makes use of the hysteresis characteristic of a Schmitt trigger inverter. It works as follows:

Consider that power is applied and the 470pF capacitor is discharged. This means that pin 5 of IC1a is low and (because it is an inverter) pin 6 will be high. The capacitor is then charged from pin 6 via the 390kΩ resistor until the voltage across it rises to the upper threshold of the Schmitt trigger. At this point the voltage at pin 6 abruptly goes low and so the capacitor begins to discharge via the 390kΩ resistor.

It continues to discharge until it reaches the lower threshold of IC1a whereupon the voltage at pin 6 abruptly goes high again. This sequence continues while ever the power is applied. Thus the output waveform at pin 6 is a square wave of 50% duty cycle while the waveform at pin 5 is a sawtooth.

So IC1a provides the basic 5kHz tone which then needs to be frequency divided to derive the "pip" waveform. IC1b in conjunction with D1 and D2 form the first frequency divider. If you ignore the diodes for the moment the configuration of IC1b is similar to IC1a just described



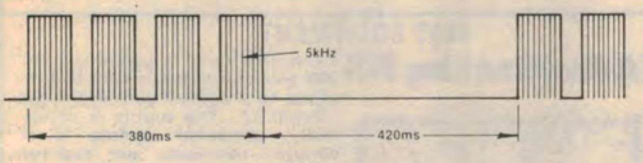
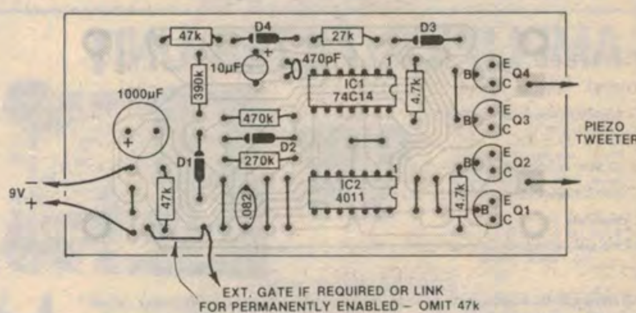


Fig. 1

This diagram shows the waveform across the tweeter.

At right is the parts overlay diagram. The 47kΩ resistor on pin 6 of IC2 can be omitted if the alarm is to be permanently enabled.



and that will give a clue to its operation.

Now consider that the .082µF capacitor associated with IC1b is discharged and, as a consequence, pin 8 is high. This reverse-biases D2 and effectively removes it and the 270kΩ series resistor from the circuit, for the moment. Each time pin 6 of IC1a goes high, D1 is forward biased and feeds a small amount of charge into the .082µF capacitor via the series 470kΩ resistor.

This continues until the voltage across the .082µF capacitor rises to the upper threshold of IC1b whereupon the voltage at pin 8 goes low. This then discharges the .082µF capacitor via D2 and the 270kΩ resistor until the voltage at pin 9 drops to the lower threshold of IC1b. The voltage at pin 8 then goes high again, reverse-biasing D2 and allowing the capacitor to charge via D1.

The result of this charge and discharge cycle is a square wave at the output of IC1b which is high for approximately 65 milliseconds and low for 30 milliseconds. This is then used to gate the 5kHz waveform on and off, using NAND gate IC2a.

IC2b is used to provide an enable control for the whole siren circuit. If pin 6 of IC2b is held high, the signal from IC2a will be gated through and the circuit will operate. If pin 6 is low, IC2b is disabled. The gated signal from IC2b is inverted by IC1c to provide the correct pulse polarity to enable the following frequency divider, comprised of IC2c, 1d and 1e, to work.

IC2b allows the circuit to be switched on in a "standby" mode without the siren actually sounding. When the external gate is taken high, the siren is instantly enabled. This avoids the inevitable distortion of the siren tone which occurs briefly while the supply bypass capacitor charges. Also, because the circuit uses such a small amount of power, the siren is audible for a number of cycles after power is switched off. If either of these characteristics is considered a disadvantage, then the external enable is the solution. Where not required, it is simply tied high by an optional link on the board.

> We estimate that the current cost of components for this project is approximately
>
> **$21**
>
> This includes sales tax, but not the cost of a battery.

IC1e plus diodes D3 and D4 function in exactly the same way as IC1b, with the 10µF capacitor charging via D3 and discharging via D4. The difference with this circuit is that while the capacitor is being discharged by D4 the signal to D3 via IC1d is disabled by means of NAND gate IC2c. IC2c, and thus IC2d, is gated on when the output of IC1e (pin 4) is high. IC2d functions merely as an inverting buffer for the output of IC2c.

By using IC2c and IC1d (to invert the signal), the duty cycle of the output waveform from IC1e can be controlled over a wide range by suitable selection of the associated 27kΩ and 47kΩ resistors.

To sum up the circuit description thus far: We have a free-running oscillator at 5kHz, IC1a; a frequency-divider with an output at about 10Hz (IC1b) which gates the 5kHz signal on and off via IC2a; and a further frequency divider, IC1e and associated components, with an output at about 1.25Hz which also gates on and off the pulse-modulated 5kHz signal from IC2a, using gate IC2c.

Two variables will affect the oscillator frequency and the timing of the pips. The first variable is the supply voltage and the second is the hysteresis of each Schmitt trigger in IC1, ie, the difference between the upper and lower voltage thresholds.

Because of the effect of these variables it may prove desirable, in some cases, to alter some resistor values to obtain a preferred sound from the circuit. The important point to note is that, if alterations are made to the first frequency divider, IC1b, the 270kΩ resistor cannot be increased appreciably, with respect to the 470kΩ resistor, otherwise the circuit will cease to divide.

The pulse-modulated signal from IC2d cannot be used to drive the piezo tweeter directly because of the relatively high output impedance of CMOS devices. One side of the tweeter is driven by Q1 and Q2 which function as complementary emitter-followers and thus as a buffer stage for IC2d.

PARTS LIST

- *1 Printed circuit board, code 82al11, 49 x 101mm*
- *1 9V battery (Eveready 216 or equivalent)*
- *1 Battery clip to suit*
- *1 Piezo tweeter*

SEMICONDUCTORS

- *4 1N914, 1N4148 diodes*
- *2 BC337 NPN transistors*
- *2 BC327 PNP transistors*
- *1 4011 quad NAND gate*
- *1 74C14 hex Schmitt trigger*

CAPACITORS

- *1 1000μF/10VW electrolytic*
- *1 10μF/10VW electrolytic*
- *1 .082μF metallised polyester (greencap)*
- *1 470pF ceramic*

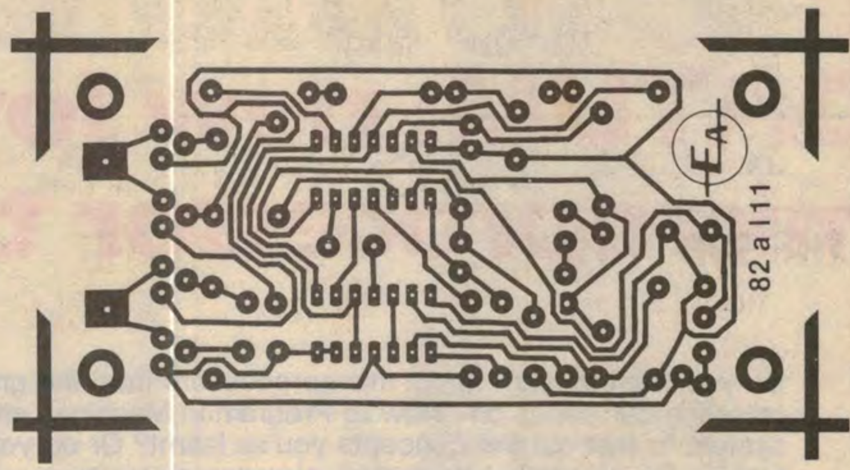
RESISTORS (¼W, 5%)

1 x 470kΩ, 1 x 390kΩ, 1 x 270kΩ, 2 x 47kΩ, 1 27kΩ, 2 x 4.7kΩ

If Q1 and Q2 were used alone to drive the tweeter, it would have a square wave of about 9 volts peak impressed across it. This is equivalent to a voltage of 4.5V RMS. By adding Q3 and Q4 to drive the other side of the tweeter with an antiphase signal from inverter IC1f, we double the drive voltage to 9V RMS and thus quadruple the power level.

The 1000μF electrolytic capacitor across the 9V battery allows the transistors to deliver the necessary high spike currents to the tweeter. These spike currents occur because we are essentially feeding a capacitor (the tweeter) with a square wave.

While the spike currents may be quite high, the average current when the alarm is sounding is low and typically of the order of only 10mA during actual sound pulses, or about 5mA overall. When the alarm is disabled, using pin 6 of IC2b, the standing current is about 0.4mA.



Above is an actual size reproduction of the PC board.

The circuit will work effectively, with some change in frequency and rate as mentioned before, over the range of supply voltages from 6 to 15 volts. For supply voltages above 10V, the rating on the two electrolytic capacitors in the circuit should be increased to 16VW.

Construction

Almost any piezoelectric tweeter may be used with the circuit. We used one made by Motorola and supplied by Jaycar. The printed circuit board, measuring 101 x 49mm and coded 82al11, was designed to mate with the solder lugs on the Motorola tweeter.

Mount the links first on the PC board and then the resistors and diodes. Take particular care to ensure that diode polarity is correct. The diodes we used had clear glass packages with a coating of grey paint over the cathode end.

Next, mount the capacitors, starting with the 470pF ceramic. The transistors can then be installed and, finally, the two CMOS ICs. With these you should solder the supply pins, 7 and 14, first and then solder the others but first connect the barrel of the soldering iron to the negative rail of the copper pattern using a jumper lead.

The piezo tweeter may be soldered directly to the PC board if its lugs are compatible with the spacing of the output pads. Alternatively, it may be wired into circuit.

When it comes to testing the siren, place the piezo tweeter face down on the bench and wear ear muffs. Do not direct the tweeter at yourself or anyone else as the sound level is painful at close quarters. It could do permanent damage, so do not play about!

If you are using the external enable option do not forget to tie it high for the test.

When finally installing the alarm, be aware that the piezo tweeter is fairly directional and should be aimed to cover the "target" area. Do not place it where someone may be blasted by it at close range.