Security Electronics

SYSTEMS AND CIRCUITS

PART 3

Ray Marston looks at contact-operated security circuits in the third episode of this new series.

Contact-operated security circuits are units that are activated by the opening or closing of a set of electrical contacts. These contacts may take the form of a simple push-button switch, a pressure-pad switch, or a magnetically activated reed switch, etc. The security circuit's output may take the form of some type of alarm-sound generator, or may take the form of a relay that can activate any external electrical device, and may be designed to give non-latching, self-latching, or one-shot output operation.

Contact-operated security systems have many practical applications in the home, in commercial buildings, and in industry. They can be used to attract attention when someone operates a push switch, or to give a warning when someone opens a door or treads on a pressure pad or tries to steal an item that is wired into a security loop, or to give some type of alarm or safety action when a piece of machinery moves beyond a preset limit and activates a microswitch, etc. A wide range of practical contact-operated security circuits are described in this article.

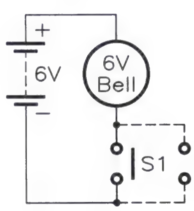
Bell and Relay-output Circuits

Close-to-Operate Circuits

The simplest type of contact-operated security circuit consists of an alarm bell (or a buzzer or electronic 'siren-sound' generator, etc.) wired in series with a normally-open (n.o.) close-to-operate switch, the combination being wired across a suitable battery supply, as shown in the basic 'doorbell' alarm circuit of Figure 1. Note that any desired number of n.o. switches can be wired in parallel, so that the alarm operates when any of these switches are closed. This type of circuit gives an inherently non-latching type of operation, and has the great advantage of drawing zero standby current from its supply battery.

A disadvantage of the basic Figure 1 circuit is that it passes the full 'alarm' current through the n.o. operating switches and their wiring, so the switches must be fairly robust types, and the wiring must be kept fairly short if excessive wiring voltage drops are to be avoided. This latter point is of particular importance in security applications in which the circuit is used with several widely separated n.o. switches. The solution to this problem is to activate the bell via a 'slave' device (which is fitted close to the bell but requires a fairly low input current), and to activate this slave device (and thus the bell) via the security switches. Figures 2 to 6 show a variety of such circuits, in which the slave device takes the form of a relay, a power transistor, or an SCR.

Figure 1. Simple doorbell type close-to-operate alarm circuit.



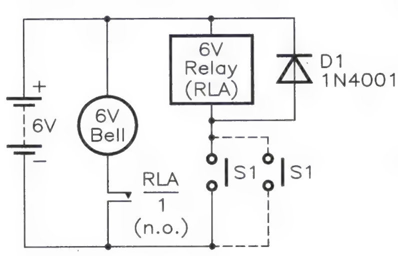


Figure 2. Relay-aided non-latching close-to-operate alarm.

Figure 3. Relay-aided self-latching close-to-operate security alarm.

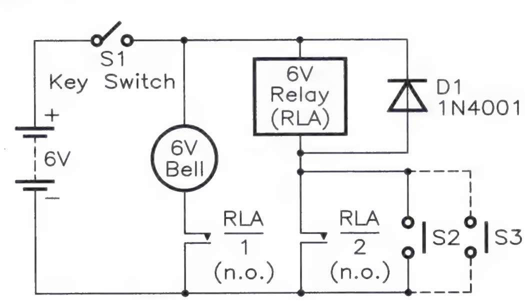


Figure 2 shows a relay-aided version of the close-to-operate alarm circuit. Here, the parallel-connected n.o. switches are wired in series with the coil of a 6V relay (which typically draws an operating current of less than 100mA), and the relay contacts (which can typically switch currents of several amps) are wired in series with the alarm bell, and both combinations are wired across the same 6V supply. Thus, when the switches are open, the relay is off and its contacts are open, so the bell is off, but when any one or more of the switches is closed, the relay is driven on and its contacts close and activate the alarm bell. Note in the latter case, that the switches a their wiring pass a current equal to that of the relay coil; the switches can thus be fai delicate ones, such as sensitive reed types, and the wiring can be reasonably long. Silicon diode D1 is wired across the relay's coil to protect the switches against damag from the coil's switch-off back emf.

The Figure 2 circuit gives a non-latching form of operation, in which the alarm operates only while one or more of the operating switches is closed. In most high-security applications, the circuit should be self-latching type in which the relay and alarm automatically lock on as soon as any one of the n.o. switches is closed, and can only be deactivated via a security key. Figu 3 shows the above circuit modified to give this type of operation. Here, the relay has two sets of n.o. contacts, and one of these wired in parallel with the n.o. switches so that the relay self-latches as soon as it is operated, and the entire circuit can be enabled or disabled/de-activated via key switch S1, which is wired in series with the battery supply line.

Circuits of this basic type are usually use in low-cost 'zone protection' applications, i which the 'zone' is a large room or shop floor, the S1 key switch is located outside o

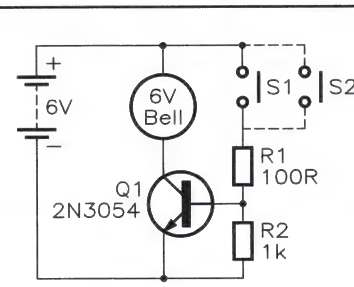


Figure 4. Transistor-aided non-latching close-to-operate alarm.

he zone, and the n.o. trigger switches are idden pressure-mat switches or door- or indow-operated microswitches fitted ithin the protected zone.

An alternative solution to the Figure 1 witch-and-wiring 'current' problem – but hich can only be used in non-latching pplications – is shown in Figure 4, in which pn power transistor Q1 is used as the slave evice. Resistor R1 ensured that – when any f the activating switches are closed – Q1's rive current is limited to less than 60mA, hich (assuming that Q1 has a nominal urrent gain of at least ×25) enables the ansistor to switch at least 1·5A through the larm bell.

Another solution to the 'current' problem to use an SCR (Silicon Controlled ectifier) as the slave device, as shown in igures 5 and 6. These circuits rely on the act that ordinary electromagnetic alarm ells are self-interrupting solenoid devices hat incorporate a self-activating on/off witch in series with the solenoid's supply ne. This switch is normally closed, allowing urrent to reach the solenoid and throw out striker that hits the bell dome and imultaneously opens the switch, thus reaking the current feed and causing the triker to fall back again until the switch loses again, at which point, the whole rocess starts to repeat, and so on; the ell's operating current is thus drawn in ulsed form.

In the Figure 5 circuit, the alarm bell is ired in series with an SCR that has its gate urrent derived from the positive supply ne via current-limiting resistor R1 and via he parallel-connected n.o. security witches, which (when R1 has a value of kΩ) pass operating currents of only a few nilliamps. When all the switches are open, he SCR and alarm bell are off, but when any one of the switches is closed, it feeds gate current to the SCR via R1, so the SCR turns on and activates the bell. Note in this design, that since the bell is a self-interrupting device, the circuit effectively gives a non-latching type of operation in which the SCR and bell only operate while one or more of the switches are closed.

Figure 6 shows how the above circuit can be modified to give self-latching operation. SCRs are inherently self-latching devices that, once they have been initially turned on, remain on until their anode current falls below a 'minimum holding' value, at which point, the SCR unlatches and turns off. In the Figure 5 circuit, the SCR thus automatically unlatches each time the alarm bell self-interrupts, but in the modified Figure 6 design, the bell is shunted via R3, which is wired in series with n.c. switch S4, which ensure that the SCR's anode current does not fall below the C106's minimum holding current value when the bell self-interrupts, thus providing the circuit with a self-latching action.

Note that the C106 SCR used in the Figure 5 and 6 circuits has an anode current rating of only 2A, so the alarm bell must be selected with this point in mind. Alternatively, SCRs with higher current ratings can be used in place of the C106, but this modification will probably necessitate changes in the R1 & R3 values of the circuits. Also, note in these SCR circuits that – to compensate for the SCR's typical 1V anode-to-cathode volt drop – the supply voltage must be at least 1V greater than the nominal operating voltage of the alarm bell.

Open-to-operate Circuits

A major weakness of the Figure 1 to 6 circuits is that they do not give a 'failsafe' form of operation, and give no indication of a fault condition if a break occurs in the contact-switch wiring. This snag is overcome in circuits that are designed to be activated via normally-closed (n.c.) switches, and a basic circuit of this type is shown in Figure 7.

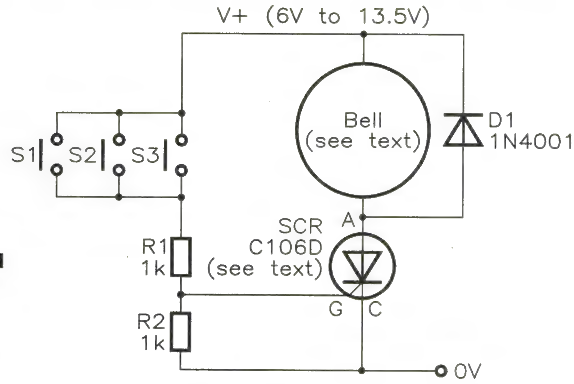


Figure 5. SCR-aided non-latching close-to-operate alarm.

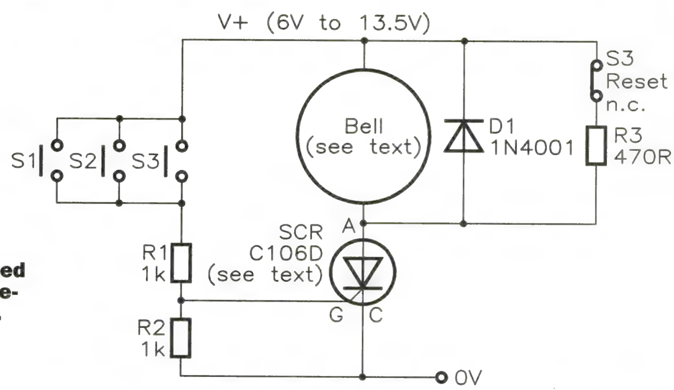


Figure 6. SCR-aided self-latching close-to-operate alarm.

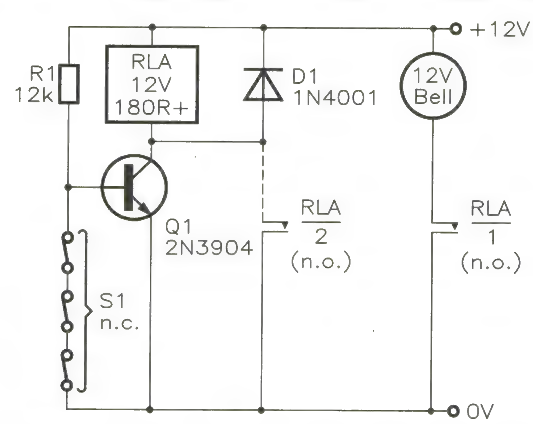


Figure 7. Simple open-to-operate alarm draws a 1mA standby current.

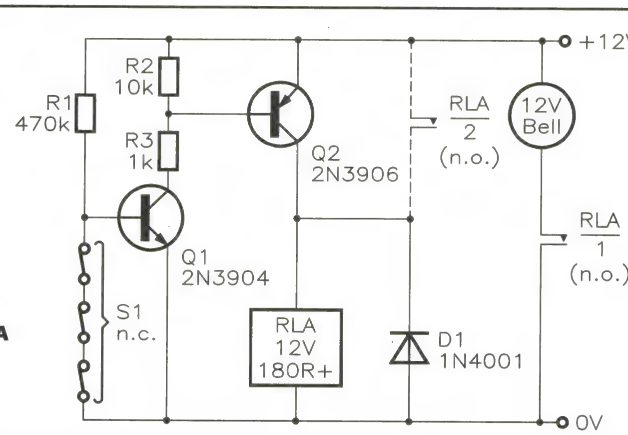
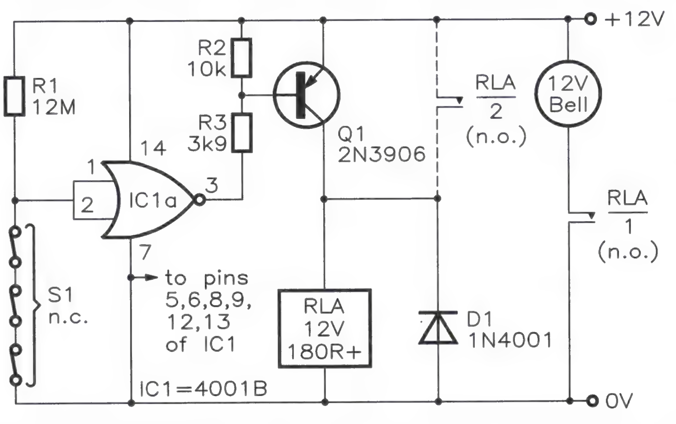


Figure 8. Improved open-to-operate alarm draws a 25μA standby current.

Figure 9. CMOS-aided open-to-operate alarm draws a 1μA standby current.



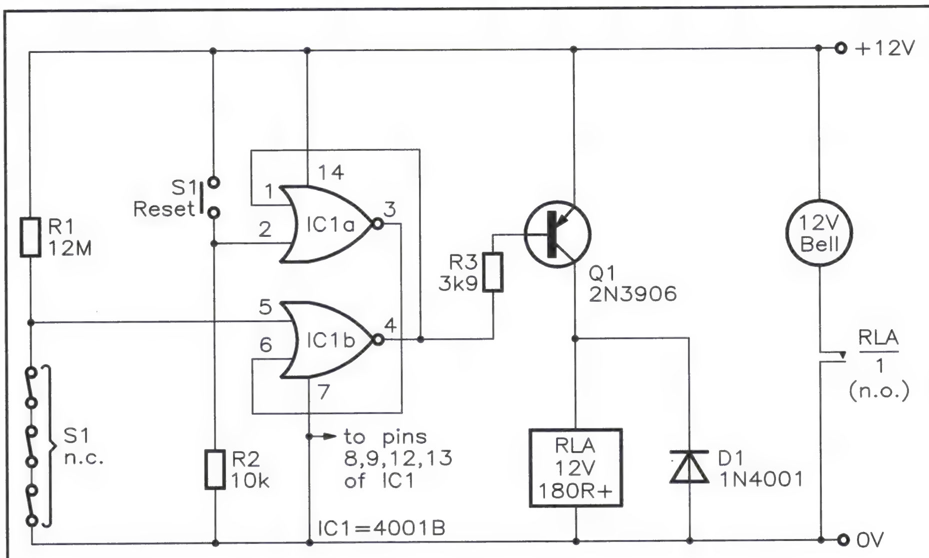


Figure 10. Self-latching CMOS-aided alarm draws a 1μA standby current.

In Figure 7, the coil of a 12V relay is wired in series with the collector of transistor Q1, and bias resistor R1 is wired between the positive supply line and Q1 base. The alarm bell is wired across the supply lines via n.o. relay contacts RLA/1, and n.c. operating switch S1 (which may consist of any desired number of n.c. switches wired in series) is wired between the base and emitter of the transistor. Thus, when S1 is closed, it shorts the base and emitter of Q1 together, so Q1 is cut off and the relay and the bell are inoperative. Under this condition, the circuit draws a quiescent current of 1mA via R1. When S1 opens or a break occurs in its wiring, Q1's base-to-emitter short is removed and the transistor is driven to saturation via R1, thus turning the relay on and activating the alarm bell via relay contacts RLA/1. This basic circuit gives a non-latching type of alarm operation, but can be made to give self-latching operation by wiring a spare set of n.o. relay contacts (RLA/2) between the collector and emitter of Q1, as shown dotted in the diagram.

Thus, the Figure 7 circuit gives fail-safe operation, but draws a quiescent or standby current of 1mA. This standby current can be reduced to a mere 25μA by modifying the circuit in the way shown in Figure 8. Here, the value of R1 is increased to 470kΩ, and Q1 is used to activate the relay via pnp transistor Q2, and the circuit's action is such that Q1-Q2 and the relay and bell are all off when S1 is closed, but turn on when S1 is open. The basic circuit gives a non-latching form of operation, but can be made self-latching by wiring a spare set of n.o. relay contacts (RLA/2) between the collector and emitter of Q2, as shown dotted in the diagram.

If desired, the standby current of the Figure 8 circuit can be reduced to a mere 1μA or so by using an inverter-connected CMOS gate in place of Q1, as shown in Figure 9. The gate used here is taken from a 4001B quad 2-input NOR gate IC, and the three unused gates are disabled by shorting their inputs to the 0V line, as shown in the diagram. The used gate has a near-infinite input impedance, and the standby curren of the circuit is determined mainly by the value and by the leakage current of Q1. Th basic circuit gives a non-latching form of operation, but can be made self-latching b wiring a spare set of n.o. relay contacts (RLA/2) between the collector and emitte of Q1, as shown dotted in the diagram.

Figure 10 shows an alternative way of making the basic Figure 8 circuit give self-latching operation, without resorting to th use of a spare set of n.o. relay contacts. In this case, the relay-driving transistor (Q1) driven by a pair of 4001B CMOS NOR gate that are configured as a bistable multivibrat and has an output that goes low and self-latches if S1 is briefly opened or its leads a broken. As the bistable output goes low, it turns Q1 on, thus activating the relay and alarm bell. Once the bistable has latched t bell into the 'on' state, it can be reset into the standby or 'off' mode by closing S1 an momentarily operating RESET switch S2, a which point, the bistable's output latches back into the high state and turns off Q1 and the relay and bell. The circuit draws a quiescent current of about 1μA.

'Loop' Alarm Circuits

One type of contact-operated alarm circuit that is widely used in large shops and store (and also in domestic garages and garden sheds) is the so-called 'loop' alarm, in whic a long length of wire is run out from the alarm unit, is looped through a whole strin of 'to be protected' items in such a way tha none of them can be removed without cutting or removing the wire, and is then looped back to the alarm unit again, to complete a closed electrical circuit. The alarm sounds instantly if an attempt is mad to steal any of the protected items by cutting the wire loop, i.e., by effectively opening its 'contacts'. Figure 11 shows the circuit of a simple battery-powered unit of this type.

The simple Figure 11 loop alarm circuit i a modified version of the self-latching CMOS-aided Figure 9 circuit, with its series-connected S1 security switches replaced by a number of series-connected wire 'loops' that – when key-operated switch S1 is

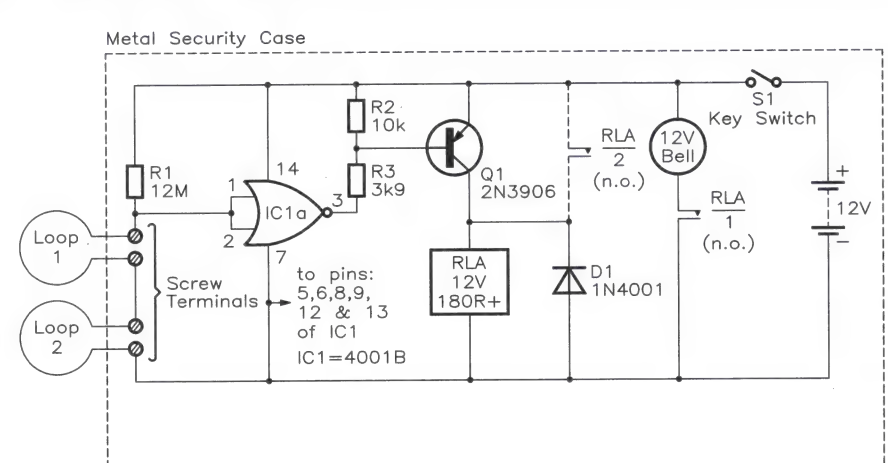


Figure 11. Simple self-latching loop alarm circuit.

sed – activate the self-latching alarm if / part of the loop wiring becomes open cuit. In the diagram, only two loops are own, but in practice, any desired number loops can be used. The entire circuit cept the loops) is housed inside a metal curity case, and the loops are connected screw terminals on the main circuit board grommet holes in the side of the case; wanted loops can be replaced by short cuits connected between the appropriate ew terminals. The entire circuit can be ned on and off via key switch, S1.

Figure 12 shows an improved version of Figure 11 self-latching loop alarm circuit. e first points to note about this version of circuit are that an LED is connected oss the relay coil via R4 and thus uminates and gives a visual indication enever the relay is turned on, and that circuit's +12V power feed is controlled 4-way key switch S1 and diodes D2 & . When S1 is in position '1', the entire cuit is turned off. When S1 is in position , the main part of the circuit (including LED indicator) is active but the alarm ll and self-latching facility are disabled; is TEST (non-latch) position is meant to used when testing the loop wiring. When is in the position '3' TEST (latching) sition, all of the circuit except the bell is abled. When S1 is in the position '4' ON sition, the entire circuit (including the arm bell) is enabled, and the circuit gives ormal 'security' operation.

The final point to note about the Figure circuit is that n.c. anti-tamper switch S2 is ired in series with the loop network and hen S1 is set to the ON position) activates e self-latching alarm if it (S2) takes up an pen' state. S2 is actually an ordinary n.o. ctile 'keypad' switch with a short coil-ring bonded vertically to its touch-pad, nd is fixed to the main circuit board in ich a way that the switch is held in the osed n.c. position (via the spring) when e circuit's security case is closed, but pens (thus sounding the alarm) if the case opened while the alarm system is still rned on. Anti-tamper switches of this asic type are quite easy to make from adily available components; Figure 13 lustrates the basic method of construction.

Before leaving this section of the article, ote that the various relay-output circuits nown in Figures 2, 3, and 7 to 11 can, if esired, be used to activate any type of lectrical or electronic alarm or system via heir n.o. relay contacts when the relay is iggered in response to an input contact-witching action, and are thus not restricted o use with alarm bells only.

iren-sound Security Circuits

ontact-operated security circuits can easily e designed to produce electronically enerated 'siren' alarm sounds in iezoelectric 'sounders' or in lectromagnetic loudspeakers. Such systems an be made to produce a variety of sounds, t a variety of power levels, and may be lesigned around various types of emiconductor device. All siren-sound enerators take the basic form shown in igure 14, and consist of a siren waveform enerator, an output driver, and an electro-coustic transducer.

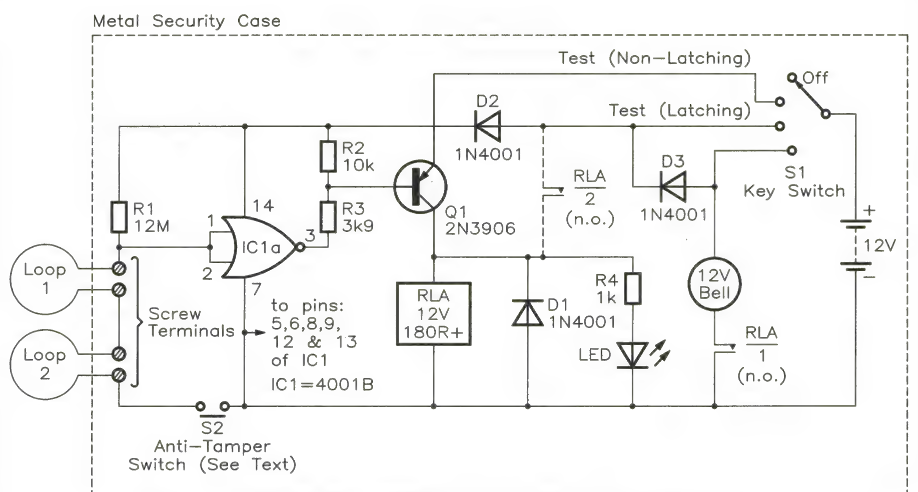


Figure 12. Improved version of the self-latching loop alarm.

Figure 14. Basic elements of a siren-sound generator.

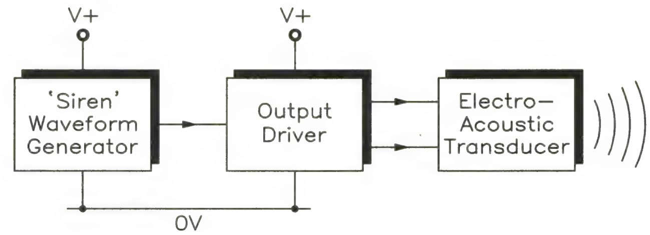
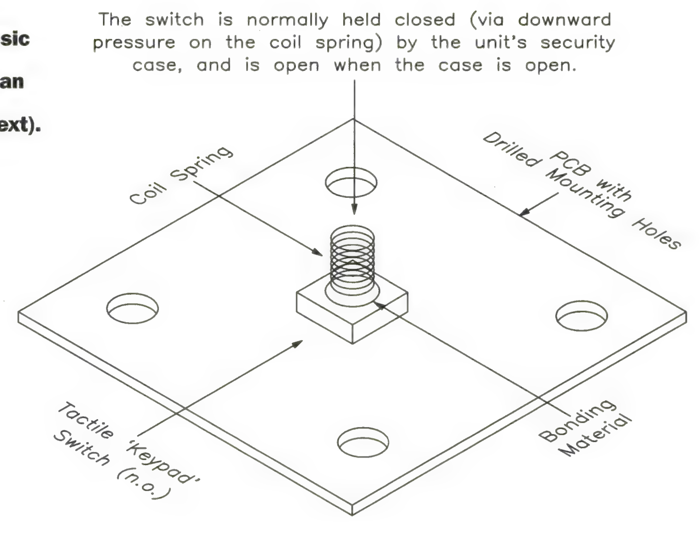


Figure 13. Basic way of constructing an anti-tamper switch (see text).



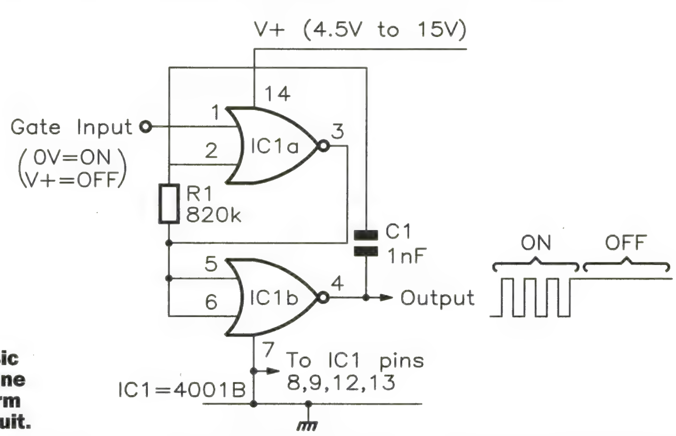


Figure 15. Basic 800Hz monotone 'siren' waveform generator circuit.

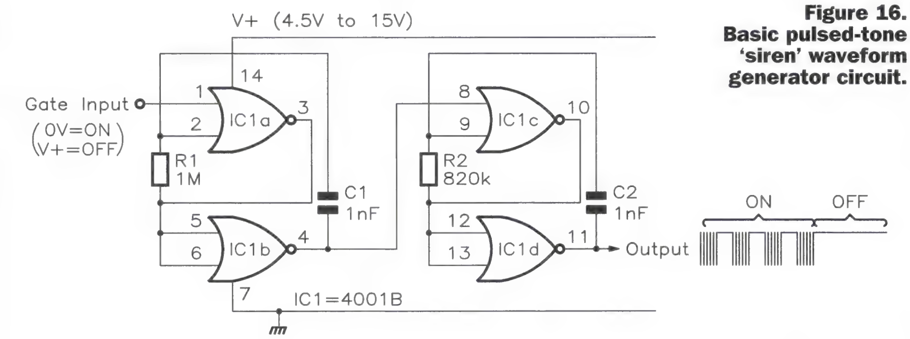


Figure 16. Basic pulsed-tone 'siren' waveform generator circuit.

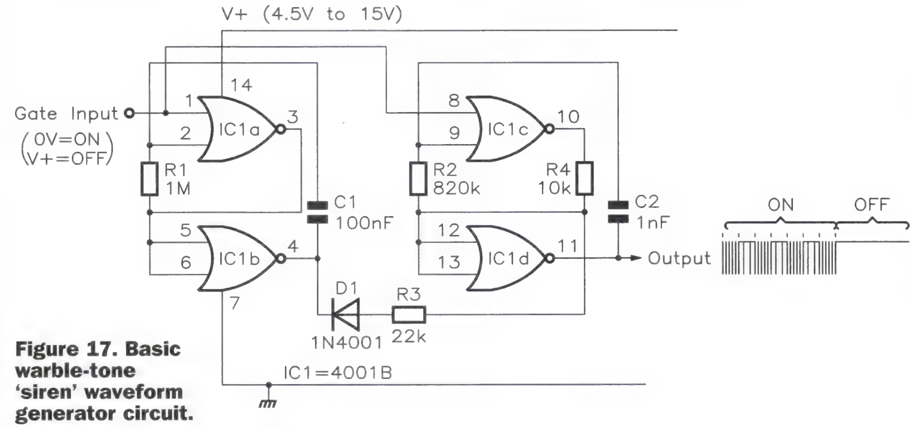


Figure 17. Basic warble-tone 'siren' waveform generator circuit.

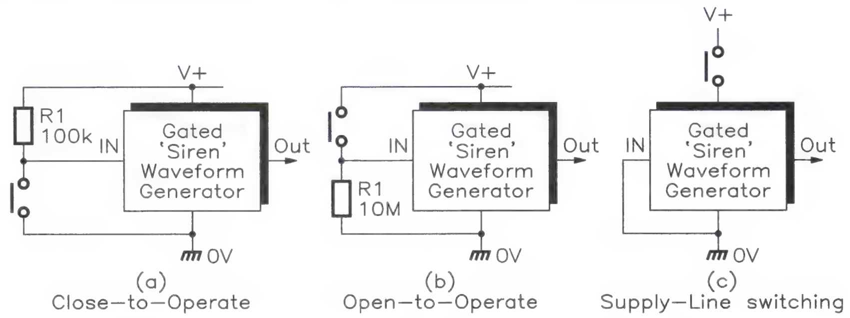


Figure 18. Alternative ways of gating the Figure 15 to 17 'siren' waveform generator circuits.

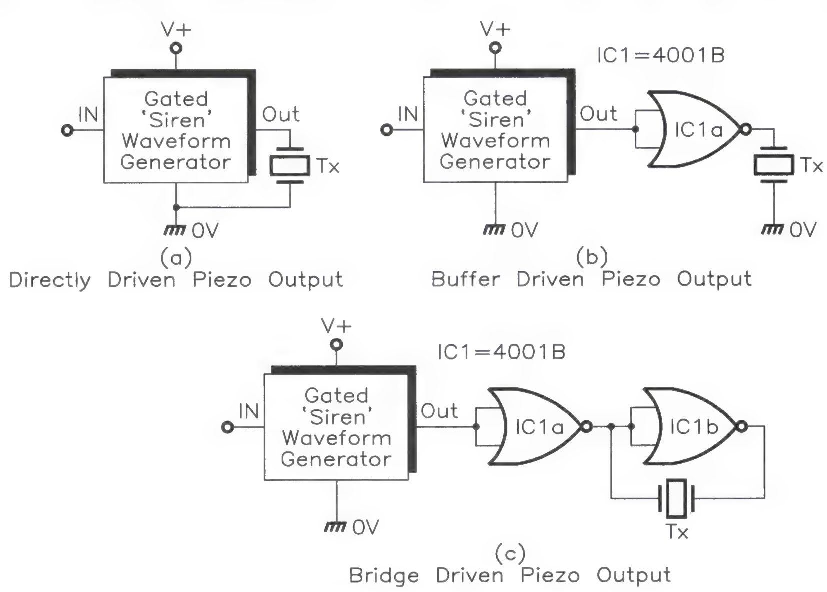


Figure 19. Alternative ways of driving a piezoelectric 'sounder' from the outputs of the Figure 15 to 17 'siren' waveform generator circuits.

One of the cheapest and most useful semiconductor devices for use in this type of application is the CMOS 4001B quad 2-input NOR gate IC, which draws near-zero standby current, has an ultra-high input impedance, ca operate over a wide range of supply-rail voltages, and can be used in a variety of waveform generating applications. The rest of this article shows various ways of using one or two 4001B ICs and a few other components to make a variety of contact-operated siren-sound security circuits.

Figures 15 to 17 show three different ways of using 4001B ICs to make practical siren waveform generator circuits. Figure 15 shows the basic circuit of a simple gated 800Hz (monotone) siren waveform generator. Here, two of the gates of a 4001B IC are connected a a gated 800Hz astable multivibrator, and the IC's two remaining gates are disabled by wirin their inputs to ground. The action of this astable is such that it is inoperative, with its pin 4 output terminal locked high (at V+) when it pin-1 input terminal is high (at V+), but acts as a squarewave generator when its input pin is low (at 0V); the generator can thus be gated o and off via the pin-1 input terminal, and produces its output signal on pin-4. The astable's operating frequency is controlled by the R1 and C1 values.

Figure 16 shows a single 4001B IC used to make a gated pulsed-tone waveform generator. Here, the two left-hand gates of the IC are wired as a gated low-frequency (about 6Hz) astable squarewave generator, and the two right-hand gates are wired as a gated 800Hz astable that is gated via the 6Hz astable. The action of this circuit is such that it is inoperative with its pin-11 output terminal locked high (at the positive supply rail voltage) when its pin-1 input terminal is high, but becomes active and produces a pulsed-tone output on pin-11 when its input pin is low (at 0V). This generator can thus be gated on and off via the pin-1 input terminal, and when gated on, produces an 800Hz tone that is gated on and off at a 6Hz rate. The operating frequency of the 6Hz astable is controlled by R1-C1, and that of the 800Hz astable is controlled by R2-C2.

Figure 17 shows how the Figure 16 circuit can be modified so that it produces a warble-tone alarm signal. These two circuits are basically similar, but in the latter case, the 6Hz astable is used to modulate the frequency of the right-hand astable (rather than to simply pulse it on and off), thus causing the generated tone to switch alternately between 600Hz and 450Hz at a 6Hz rate. Note that the pin-1 and pin-8 gate terminals of the two astables are tied together, and both astables are thus activated by the pin-1 'gate' input signal; the circuit is inoperative, with its pin-11 output terminal locked high (at V+) when the pin-1 input terminal is high, but becomes active and produces a warble-tone output on pin-11 when the input pin is low (at 0V). The operating frequency of this circuit's 6Hz astable is controlled by R1-C1, the centre frequency of the right-hand astable is controlled by R2-C2, and the 'warble-tone' swing of the right-hand astable is controlled via D1-R3.

Note that each of the Figure 15 to 17 gated waveform generator circuits are inactive (with their output terminal locked high) when their pin-1 input terminal is high (at V+), but can be gated on by pulling pin-1 low (to 0V). Each of these circuits can thus be gated on and off by using any of the three input connections wn in Figure 18. Thus, they can be gated on losing an n.o. switch by using the input nections shown in (a), or by opening an switch by using the input connections wn in (b), or can be gated on or off by king or breaking the supply line connection using the input connections shown in (c). In es (a) and (b), the circuit draws a typical ndby current of only 1μA or so when in the ' state.

f the Figure 15 to 17 gated waveform erator circuits are to be used in alarm-sound plications where fairly low acoustic output wers are required, these can be obtained by ding the circuit's output to a low-cost piezo nder in any of the three basic ways shown in ure 19. Thus, in (a) the sounder is driven ectly from the generator's output, and in (b), driven via a 4001B gate that is used as a nple inverting buffer; in both cases, the rms rm' voltage applied across the piezo load uals 50% of the V+ value. In (c), the sounder driven in the 'bridge' mode via two series-nnected 4001B inverters that apply anti-phase nals to the two sides of the piezo load, using the piezo load to 'see' a squarewave ve voltage with a peak-to-peak value equal to uble the V+ value, and an rms 'alarm' signal ltage that equals the V+ value. The (c) circuit us gives four times more acoustic output wer than either of the (a) or (b) circuits.

If the Figures 15 to 17 gated waveform nerator circuits (which each have an output at is locked high when the generator is gated) are to be used in alarm-sound applications here fairly high acoustic output powers are quired, these can be obtained by feeding the table's output to inexpensive 'low-fi' or horn-pe loudspeakers (these have an electro-oustic power conversion efficiency that is pically some twenty to forty times greater an a normal Hi-Fi speaker) via one or other of e simple direct-coupled 'driver' circuits own in Figures 20 to 22.

Thus, the simple Figure 20 driver circuit is esigned to pump a maximum of only few undred milliwatts of audio power into a cheap Ω speaker. When the siren waveform enerator is gated off, its output is high and Q1 thus cut off, but when the generator is gated , its output drives Q1 on and off and causes to feed power to the 64Ω speaker. The tput power depends on the supply rail ltage, and has a value of about 520mW at 12V, 120mW at 6V, when feeding a 64Ω speaker ad. Note that, since Q1 is used as a simple wer switch in this application, very little wer is lost across the 2N3906 transistor, but current rating (200mA maximum) may be ceeded if the circuit is used with a supply lue greater than 12V.

The Figure 21 driver circuit can pump a aximum of 6·6W of audio power into an 8Ω eaker load, or 3·3 watts into a 16Ω load. ere, both transistors are cut off when the aveform generator is gated off, but are witched on and off in sympathy with the siren aveform when the generator is gated on. ote in this circuit, that the positive power upply rail is fed directly to the output driver, ut is fed to the waveform generator via ecoupling network R1-C1, that voltage divider 2-R3 ensures that the output stages are not riven on until the generator's output voltage lls at least 1·9V below the supply rail value, nd that diode D1 is used to damp the eaker's back-emf when driver Q2 switches off.

Finally, the Figure 22 driver circuit can pump a maximum of 13·2W into a 4Ω speaker load when powered from a 15V supply. Here, all three transistors are cut off when the waveform generator is cut off, but are switched on and off in sympathy with the siren waveform when the generator is gated on.

Thus, Figures 15 to 17 show three alternative 'siren' waveform generator circuits that can – when used in practical contact-operated security circuits – each be gated in any of three basic ways and be used in conjunction with any of six basic types of acoustic output driver circuit, thus offering a total of 54 different circuit combinations. Figure 23, for example, shows how the Figure 17, 18(a) and 20 circuits can be combined to make a warble-tone alarm-call generator that can be activated by closing an n.o. switch and which can pump 520mW into a 64Ω speaker load when operated from a 12V supply. ELECTRONICS

Figure 20. Simple output driver circuit that can feed up to 520mW into a 64Ω speaker load.

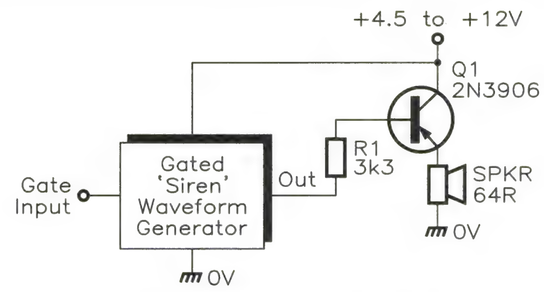
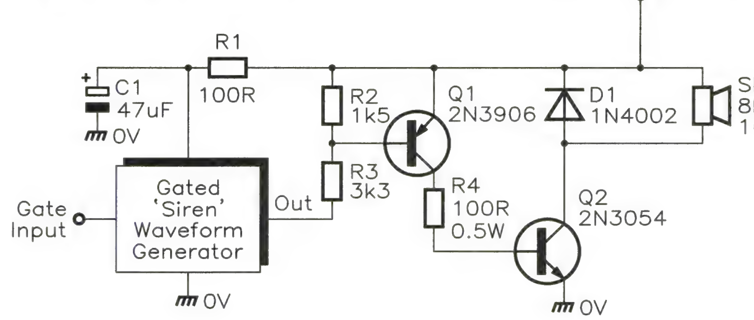


Figure 21. Medium power (up to 6·6W into 8Ω) output driver.



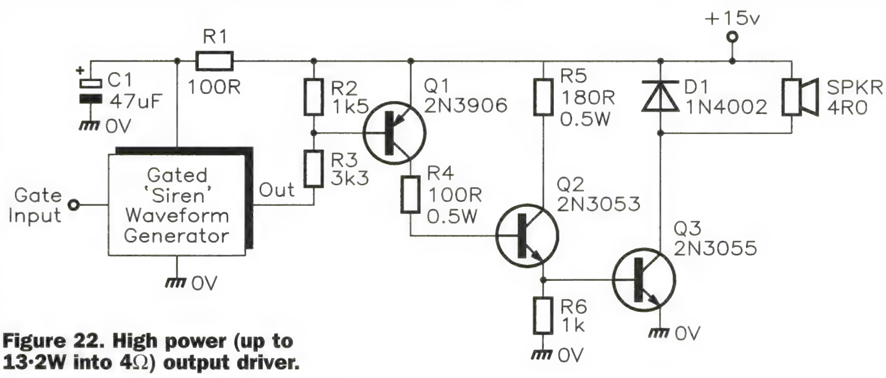


Figure 22. High power (up to 13·2W into 4Ω) output driver.

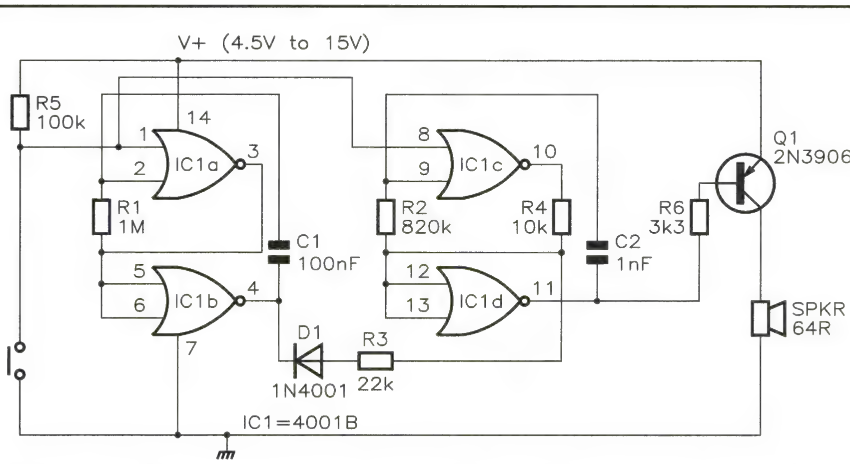


Figure 23. Low-power (up to 520mW) warble-tone alarm-call generator, activated by closing a n.o. switch.