A 4-digit combination lock

This electronic combination lock has a four digit security code which is entered using a single pushbutton switch. For added security, each number of the code must be entered within certain time restraints. Once the correct code has been entered, the circuit triggers a solenoid operated door catch to unlock the door.

by IAN M. PAGE

Combination locks have the advantage over standard keyed locks in that access through a locked doorway can be made without the use of a key. Therefore it is not necessary to carry a key, which reduces the number of keys on your keyring. A further advantage is that the combination for the lock can be easily changed without cost, in contrast to keyed locks which require fitting new lock barrels and replacement of keys.

With these advantages it is perhaps difficult to understand why combination locks are not more common. One of the reasons could be that the keypad used to enter the code is usually obtrusive, and not as visually appealing compared to a keyed lock. This combination lock overcomes the problem by only using a single, easily concealed pushbutton switch for code entry.

An important feature is that the unit can be operated from batteries rather than from a mains supply. There is no power drawn during standby.

Operation

Operation of the combination lock involves pressing the code entering pushbutton to correspond to the 4-digit code. Each digit of the code is entered separately by pressing the button the appropriate number of times, with no more than a one second interval between pressings. The interval between digits must be at least one second, but no more than three seconds, before entering the next number.

If the switch is not pressed within three seconds since the last switch pressing, the circuit will be deactivated. Entering the wrong code will cancel the code entering operation.

A correctly entered code will activate the latch solenoid so that the door lock is released. Note that the device used to release the door lock is actually an electrically operated door striker plate. This mounts on the door jamb and is used in conjunction with the original door mounted lock. When power is applied to the electric strike, the strike opens, allowing the tongue of the door lock to pass the strike and release the door.

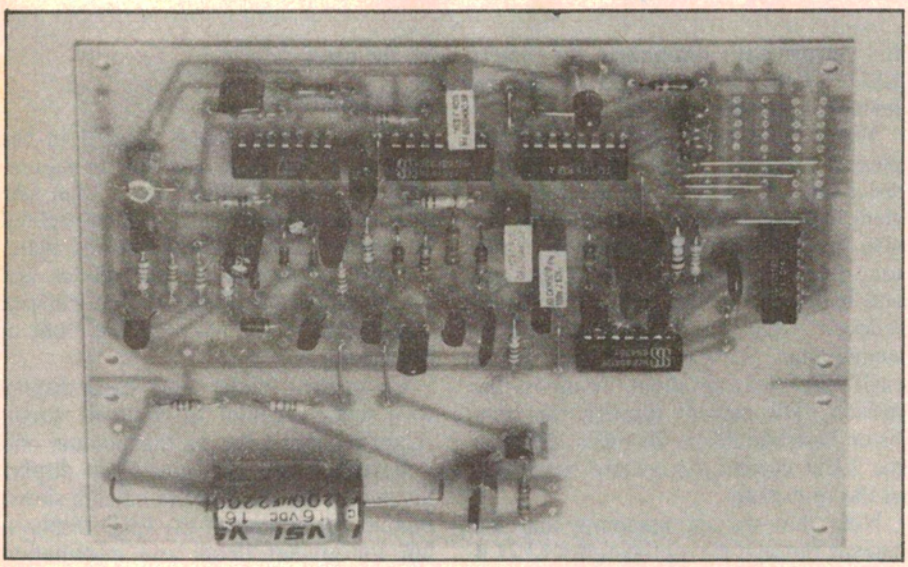
Electric striker plates are available from security companies specialising in locks.

Circuitry

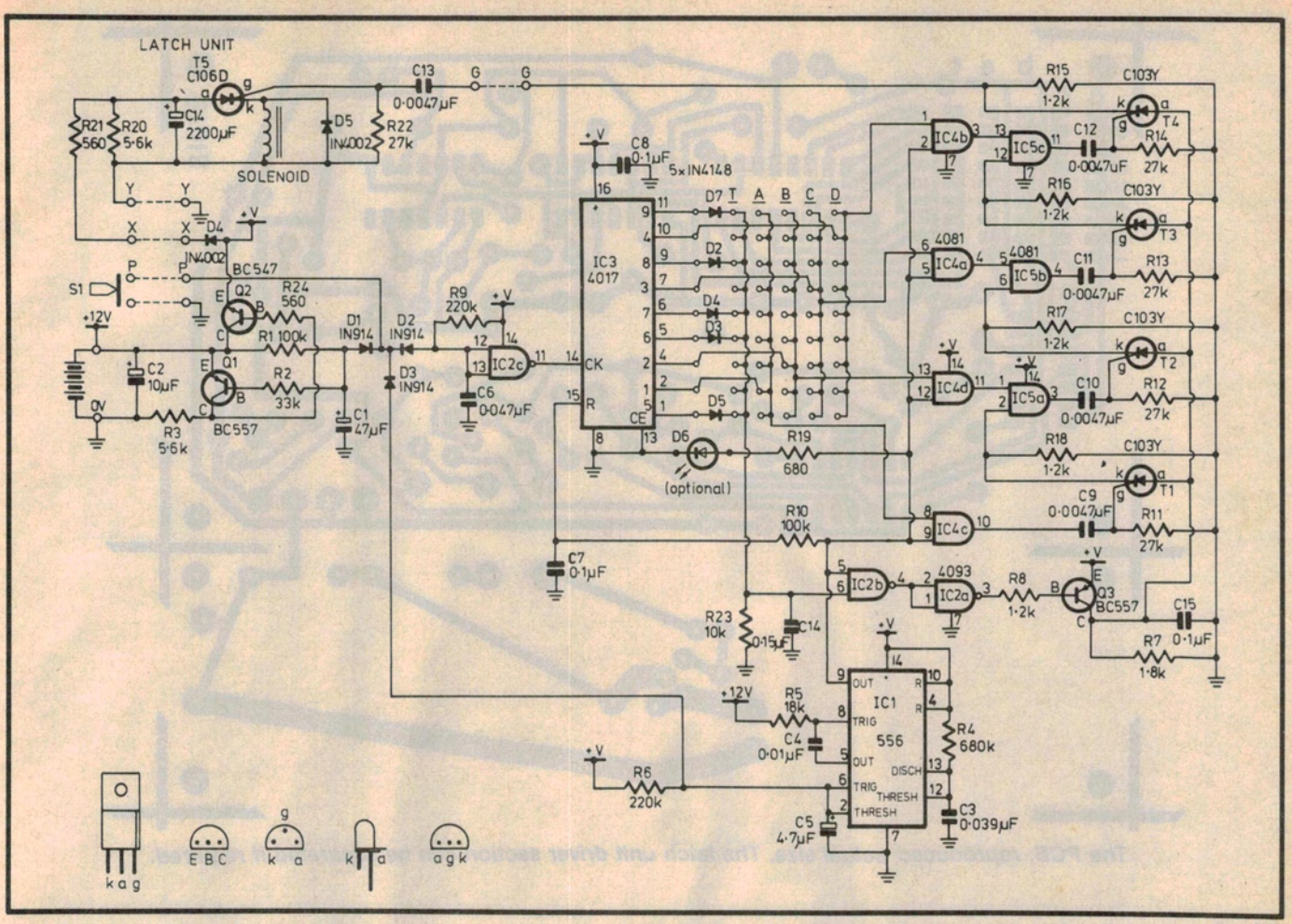
The circuit for the combination lock comprises several timers, a decade counter, latches and a solenoid driver. The decade counter is used to count the input pulses from the switch and produce an output at one of its ten pins corresponding to the number of pulses received. When a correct code number is entered, an SCR switches on preparing the circuit for the next number in the code. As each number is correctly entered, the corresponding SCR triggers on. Finally, on the last entered code the solenoid SCR fires to power the door lock solenoid.

An incorrect number or wrong timing will cause all the SCRs to drop out of the circuit, cancelling the counting operation.

Let's take a look at the circuit in more detail. Initially, capacitor C1 is charged to the supply voltage via R1. When S1 is first closed, C1 is discharged via D1 and turns on Q1 due to the base current through R2. Q1 switches on Q2, which supplies power to the remainder of the circuit.



The PC board for the combination lock. Programming for the code digits is carried out using the diodes and links in the top right hand corner.

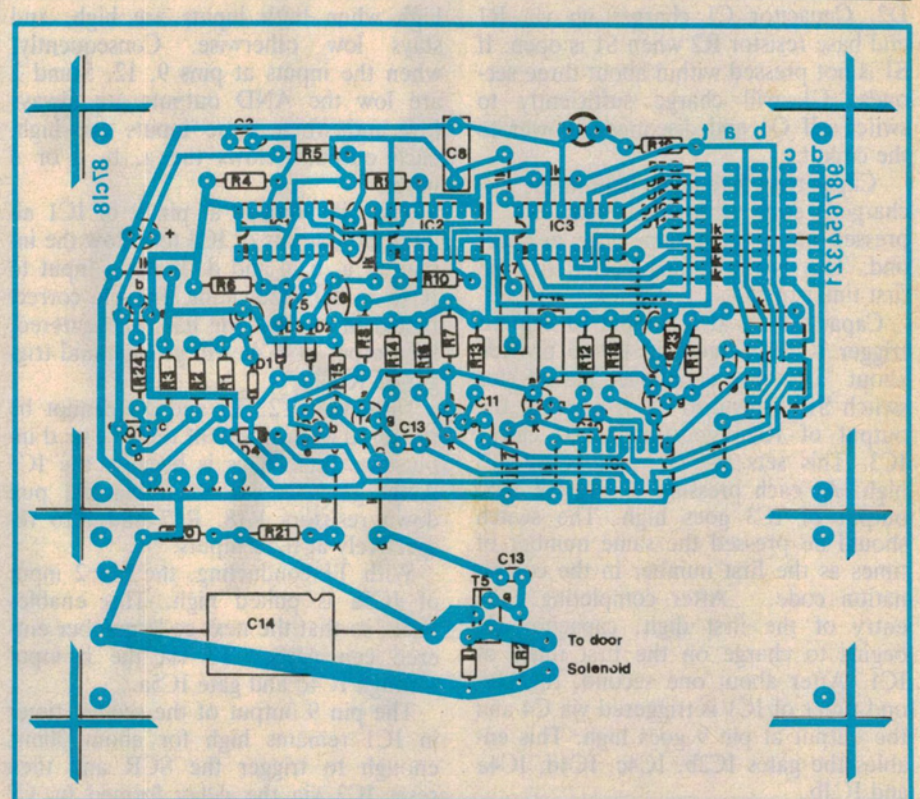


IC1 is a dual 555 timer (556). When power is first applied via Q2, the output of the first timer at pin 5 is high. The timing capacitor C5 and R6 at pins 2 and 6 respectively set the time constant to about 1 second. After this time the output at pin 5 goes low to trigger the second timer at pin 8 via capacitor, C4. The time period for which the output at pin 9 is high is set by C3 and R4 to about 30ms.

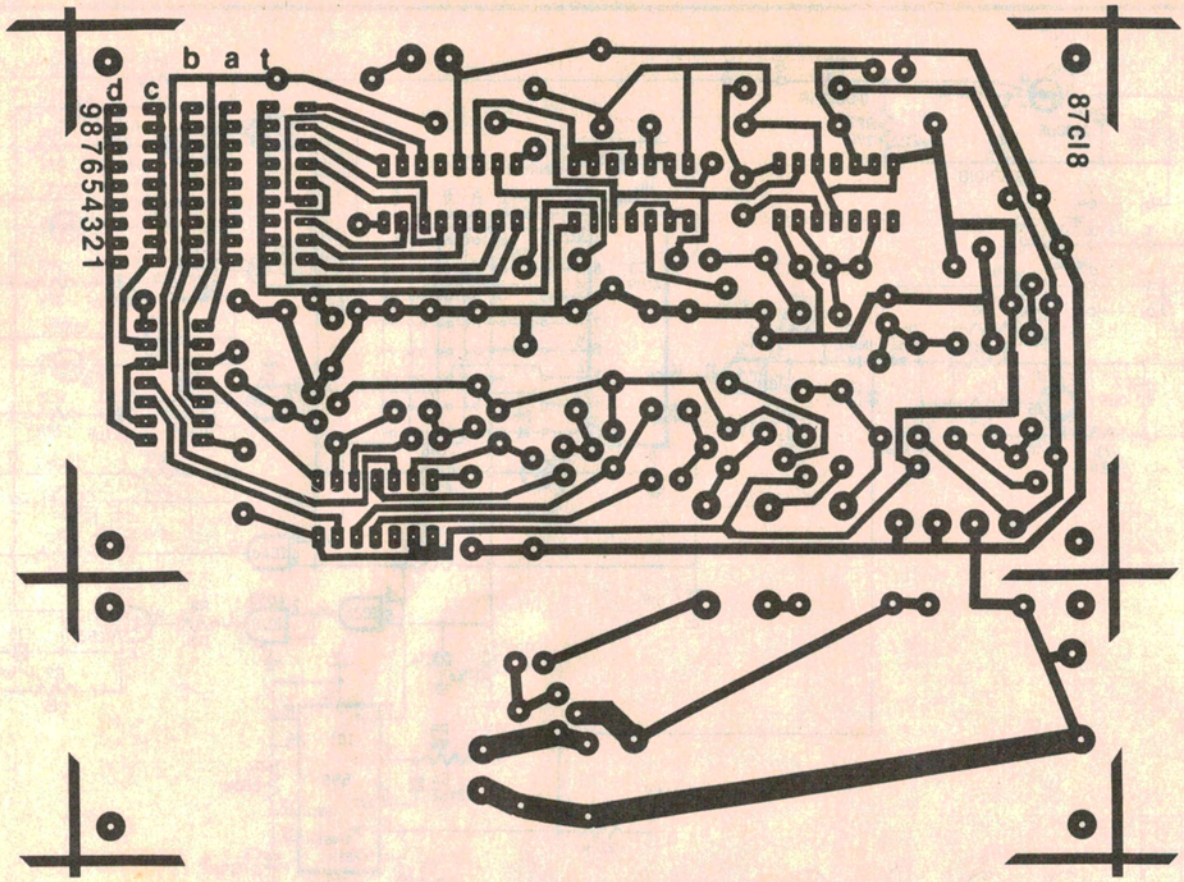
While the output at pin 9 is high, resistor R10 charges C7 at the reset pin (15), of IC3. This resets IC3 after about 10ms, setting low all the outputs of IC3 from 1 to 9.

Programming the code for the 4-digit combination lock is done by connecting the "a", "b", "c" and "d" inputs to outputs between 1 and 9 on IC3. For example, if "a" is connected to 1, "b" to 2, "c" to 3 and "d" to 4, the code becomes 1234. The remaining outputs of IC3 from 5 to 9 should be connected using diodes to the "t" input at pin 6 of IC2b.

Whenever switch S1 is pressed, three capacitors are independently discharged. Capacitor C1 is discharged via D1, capacitor C5 by D3 and capacitor C6 by



Here is the parts overlay for the combination lock PCB. Note that the latch unit driver section can be cut off and mounted separately.



The PCB, reproduced actual size. The latch unit driver section can be separated if required.

D2. Capacitor C1 charges up via R1 and base resistor R2 when S1 is open. If S1 is not pressed within about three seconds, C1 will charge sufficiently to switch off Q1 and disconnect power to the circuit.

Capacitor C5 remains held in the discharged state, provided that S1 is pressed more often than once per second. This is the timing period for the first timer of IC1.

Capacitor C6 at the input to Schmitt trigger IC2c charges via R9 to provide about a 10ms debounce period for switch S1. Whenever S1 is pressed, the output of IC2c goes high and clocks IC3. This sets the "1" output of IC3 high. At each pressing of S1, the next output of IC3 goes high. The switch should be pressed the same number of times as the first number in the combination code. After completing code entry of the first digit, capacitor C5 begins to charge on the first timer of IC1. After about one second, the second timer of IC1 is triggered via C4 and the output at pin 9 goes high. This enables the gates IC2b, IC4c, IC4d, IC4a and IC4b.

IC2 and IC4 are quad AND gates. These operate so that the output goes high when both inputs are high, and stays low otherwise. Consequently, when the inputs at pins 9, 12, 5 and 2 are low the AND outputs are always low and when these inputs are high, each output follows the a, b, c or d input.

The high output at pin 9 of IC1 allows the outputs of IC4 to follow the inputs at a, b, c and d. If the a input to IC4c is high, indicating that the correct first digit of the code has been entered, the output of IC4c will go high and trigger SCR T1.

Note that T2, T3 and T4 cannot be triggered even if one of the b, c or d inputs are high. This is because the IC5 AND gates are disabled via the pull down resistors R18, R17 and R16 respectively at their inputs.

With T1 conducting, the pin 2 input of IC5a is pulled high. This enables IC5a, so that the next code number entered can trigger T2 via the b input through IC4d and gate IC5a.

The pin 9 output of the second timer in IC1 remains high for about 30ms, enough to trigger the SCR and then reset IC3 via the delay formed by C7 and R10 at pin 15.

After the second digit is correctly entered, the b input to IC4d goes high at pin 13. SCR T2 is then triggered via IC5a and enables IC5b at pin 6. When the third digit is selected at c, SCR T3 is triggered enabling IC5c at pin 12. Similarly, entering the fourth digit brings the d input of IC4b high and triggers T4 via IC5c.

When T4 switches on, it supplies a positive pulse to the gate of T5 to switch it on. T5 powers the solenoid door latch mechanism. Note that the relatively heavy transient current required for the solenoid is drawn from a 2200μF capacitor, which is supplied via R21 and D4. Diode D5 removes the reverse voltage spike when the solenoid current is switched off.

To assist in data entry, LED D6 is lit briefly during resetting. This indicates that the next code can be entered.

If a digit that is not in the code is fed in, one of the diodes at D7 to D11 will go high and pull the pin 6 input of IC2b high. This sets the outputs of IC2b low and IC2a high respectively, to remove base bias to Q3. Q3 removes the positive power supply from the anodes of the SCRs and thus resets them. Note that C14 is used to remove glitches that can cause all the SCRs to latch on when

S1 is pressed. If code entry for each digit is entered before IC3 resets, any entered number will be added to the previous count, causing an incorrect code.

Construction

The circuitry for the 4-Digit Combination Lock is constructed on a PCB coded 87cl8 and measuring 137 x 110mm. Note that the PCB can be cut in two, so that the latch unit circuit on the PCB can be mounted close to the electric strike.

This has the advantage that the high transient current required for the solenoid can be supplied directly from the large storage capacitor C14, using short connecting leads. Alternatively, heavy duty wiring will be needed between the solenoid and latch unit PCB if this section of the PCB is located far from the solenoid.

Begin construction by deciding on the code required for the combination. Linking is required between the a, b, c and d inputs of IC4 and the outputs from IC3, while diodes (D7 — D11) are inserted between the unused outputs of IC3 and the "t" input to pin 6 of IC2b.

A special area at the top right side of the PCB has been reserved for combination coding and the overlay shows encoding for the example combination code of 1234. For this combination, the "1" output from IC3 is linked to the "a" bus, the "2" output to the "b" bus, the "3" output to the "c" bus and the "4" output to the "d" bus. The D7 to D11 diodes connect between the "t" bus and the "5, 6, 7, 8 and 9" outputs of IC3. These diodes will need to be mounted upright.

Note that it is also possible to duplicate a number in the code simply by linking between one output of IC3 and two of the a, b, c or d inputs. In this case an extra diode will be necessary for the free output from IC3.

Continue with construction by installing the low profile components such as the links, resistors, diodes and ICs. Take care with the orientation of the diodes and ICs. Now the transistors, SCRs and capacitors can be installed. Note that these with the exception of the non-electrolytic capacitors, must be orientated correctly as shown on the overlay diagram.

After installation of the components, check your work for the correct placement of components, for dry solder joints and shorts. The circuit is now ready for testing.

Connect S1 between the "P" terminal and "0V" on the PCB and interconnect the latch unit PCB to the main PCB if the two have been separated. A 12V power supply or battery can be connected to the +12V and 0V terminals.

Use a multimeter to check that Q2 switches power to pins 14 of IC1, IC2, IC4 and IC5 and pin 16 of IC3 when switch S1 is pressed. After S1 is released, the power should remain on the ICs for about 3 seconds.

Press S1 again and check that LED D6 flashes for a very short time one second after S1 is released. After this time, S1 can be pressed again and the "1" output of IC3 should go high. Pressing S1 again should bring the "2" output high. The pressing of S1 can be continued to check that each output

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PARTS LIST

1 PCB coded 87cl8 measuring 137 x 110mm
8 AA size cells
1 8 x AA battery holder
1 momentary contact pushbutton switch
1 12V electrically operated striker plate

Semiconductors
1 556 dual timer
1 4093 quad NAND Schmitt
1 4017 decade counter
2 4081 quad AND gate
1 5mm LED
2 BC557 PNP transistors
1 BC547 NPN transistor
4 C103Y SCRs
1 C106D SCR
8 1N914 small signal diodes
2 1N4002 1A diodes

Capacitors
1 2200uF 16VW PC electrolytic
1 47uF 16VW PC electrolytic
1 10uF 16VW PC electrolytic
1 4.7uF 16VW PC electrolytic
1 0.15uF metallised polyester
3 0.1uF metallised polyester
1 0.047uF metallised polyester
1 0.039uF metallised polyester
1 0.01uF metallised polyester
5 0.0047uF metallised polyester

Resistors (0.25W, 5%)
1 x 680kΩ, 2 x 220kΩ, 2 x 100kΩ, 5 x 27kΩ, 1 x 18kΩ, 1 x 10kΩ, 1 x 5.6kΩ, 1 x 1.8kΩ, 5 x 1.2kΩ, 2 x 560Ω

Miscellaneous
Solder, tinned copper wire, hookup wire.

Combination Lock

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from IC3 goes high from 1 to 9 consecutively.

Allow more than 3 seconds to elapse, so that the power supply is disconnected from the ICs, and press S1 again. Wait for D6 to flash, and then press S1 the number of times equal to the first digit in the combination code. Check that after 1 second D6 flashes and T1 closes to pull pin 2 of IC5 high.

Press S1 again for the number of times equal to the second code in the combination. This time T2 should close, to bring pin 6 of IC5b high. Press S1 again for the number of times equal to the third number in the combination code. This time T3 should close to bring pin 12 of IC5c high. Press S1 again for the number of times equal to the fourth number in the combination code, and T4 should close to trigger T5 and the solenoid.

The solenoid can be held energised for as long as S1 is held closed. R21 may need to be reduced in value to suit the particular latch solenoid used for the striker.

Release S1 and wait 3 seconds for the power supply to be removed, then press S1. Wait for a second, and then press S1 a number of times equal to the first digit of the combination code. Wait for T1 to close. Now press S1 a number of times which is not equal to the next digit in the combination code. After D6 flashes, transistor Q3 should turn off, removing power to the anodes of the SCRs. This will release SCR, T1.

If everything has happened according to the above description, your combination lock should be working properly.

Installation

The electric striker plate will require installation into the door jamb. This normally will replace the original striker plate of a key operated lock, allowing use of the original lock to gain entry to the door when the combination lock is not activated.

Cut away sufficient material in the door jamb to accommodate the striker plate and temporarily locate the plate to check that the door will close satisfactorily. Once it is installed correctly, wiring can begin.

Wiring to the striker plate should be concealed within the door frame and run to the combination lock circuit which can be located in the ceiling or under the floor. Ideally, the latch unit part of the PCB should be located as close as possible to the striker plate, as noted earlier.

Further wiring is necessary between the combination lock PCB and the switch S1 and LED D6. These can be unobtrusively located near the door, with the wiring again run within the door frame if possible. EA