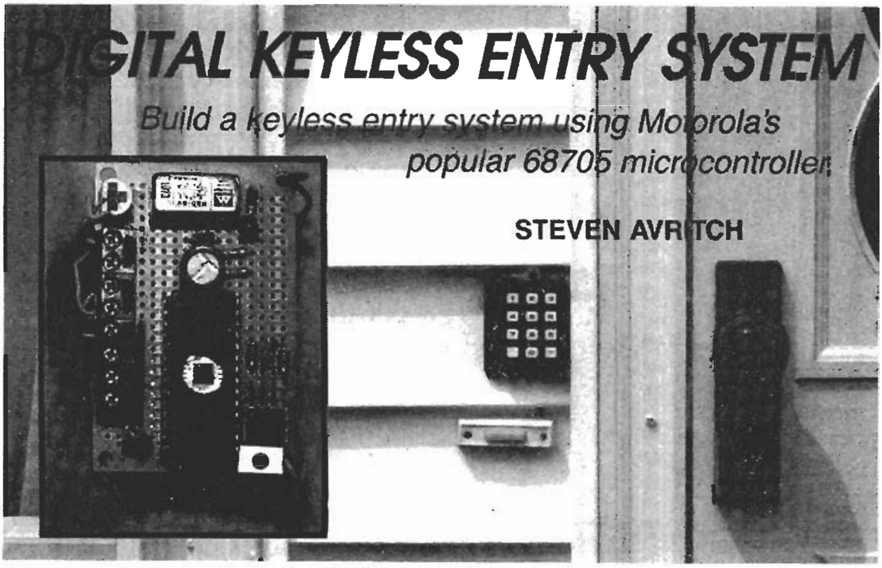
DIGITAL KEYLESS ENTRY SYSTEM

Build a keyless entry system using Motorola's popular 68705 microcontroller

STEVEN AVRITCH



Keyless entry systems have long been commercially available, but the costs associated with the systems usually preclude their use in homes and small businesses. However, by using a readily available and inexpensive microcontroller, a full-featured digital keyless entry system can be built from just a handful of components at a fraction of the cost of commercial units.

The digital keyless entry system presented in this article is a simple yet highly flexible design requiring approximately a dozen components. It costs less than $75, most of which (about $45, depending on where you get it) goes for the electromechanical door latch.

How it works

The digital keyless entry system consists of three major components: the microcontroller, a keypad, and the electromechanical door latch (see the block diagram in Fig. 1).

To unlock the door, the user simply punches a three-digit entry code on the keypad. The microcontroller compares that code with the valid codes stored in its battery-backed RAM. If it matches, the latch is energized, and the door may be opened. In a power failure, the user can bypass the code-entry scheme and open the door with a key.

The keyless entry system may be programmed to recognize three distinct entry codes, each

continued on page 74

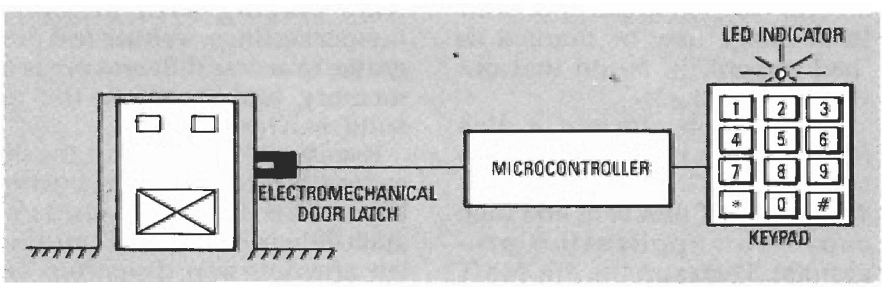


***Fig. 1.** A 68705 MICROCONTROLLER accepts keypad input and then energizes an electromechanical door latch after the proper entry code has been entered.*

KEYLESS ENTRY

continued from page 71

of which consists of three digits. You change the entry codes from the keypad by entering a special three-digit "function" code, discussed in detail later. An LED indicates system status.

It should be noted that the digital keyless entry system is not a complete security system in and of itself; however, it can function as an integral component of a complete security system.

Circuit description

The heart of the system is the Motorola MC68705P3 microcontroller discussed in detail in the September 1989 **Radio-Electronics** (page 82). To summarize its features, the microcontroller has 64 bytes of RAM, 2K of EPROM, a built-in clock oscillator, and 20 I/O ports.

You can program the 68705 with some off-the-shelf EPROM programmers; you may also want to consider building the programmer described in the earlier article.

The keypad used in this design is a standard four-row by three-column keypad with a common ground, as shown in Fig. 2. Each of the seven keypad outputs is pulled up by a resistor (R1–R7) and is connected to ports A0–A6 of the microcontroller, as shown in Fig. 3. The microcontroller uses a software scanning routine to determine when a key is pressed.

When the microcontroller has recognized a valid entry code, it sends port PB0 high, which turns on power MOSFET Q1, which in turn enables relay RY1. Current for the door latch then flows through the relay contacts. Diode D1 is wired across the coil of the relay to prevent voltage spikes caused by the instantaneous change in current through the relay coil.

Port B7 of the microcontroller drives LED1 (STATUS) directly. A logic low on port B7 completes the circuit to ground and lights the LED.

When the EXTAL and XTAL inputs (pins 4 and 5) are connected to-

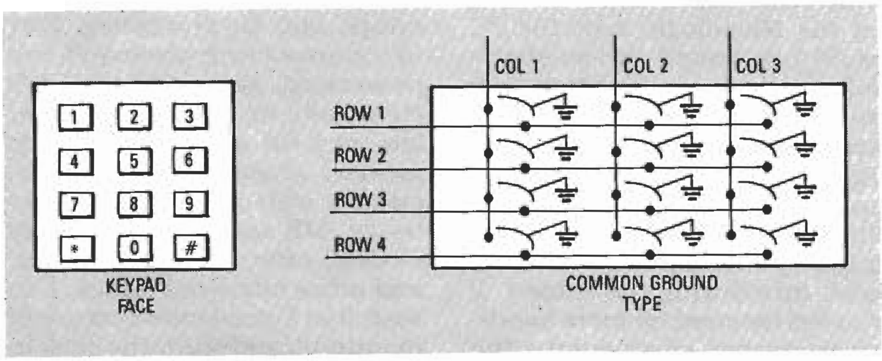


Fig. 2. THE KEYPAD consists of four rows by three columns. Pressing a key grounds the intersection of the corresponding row and column.

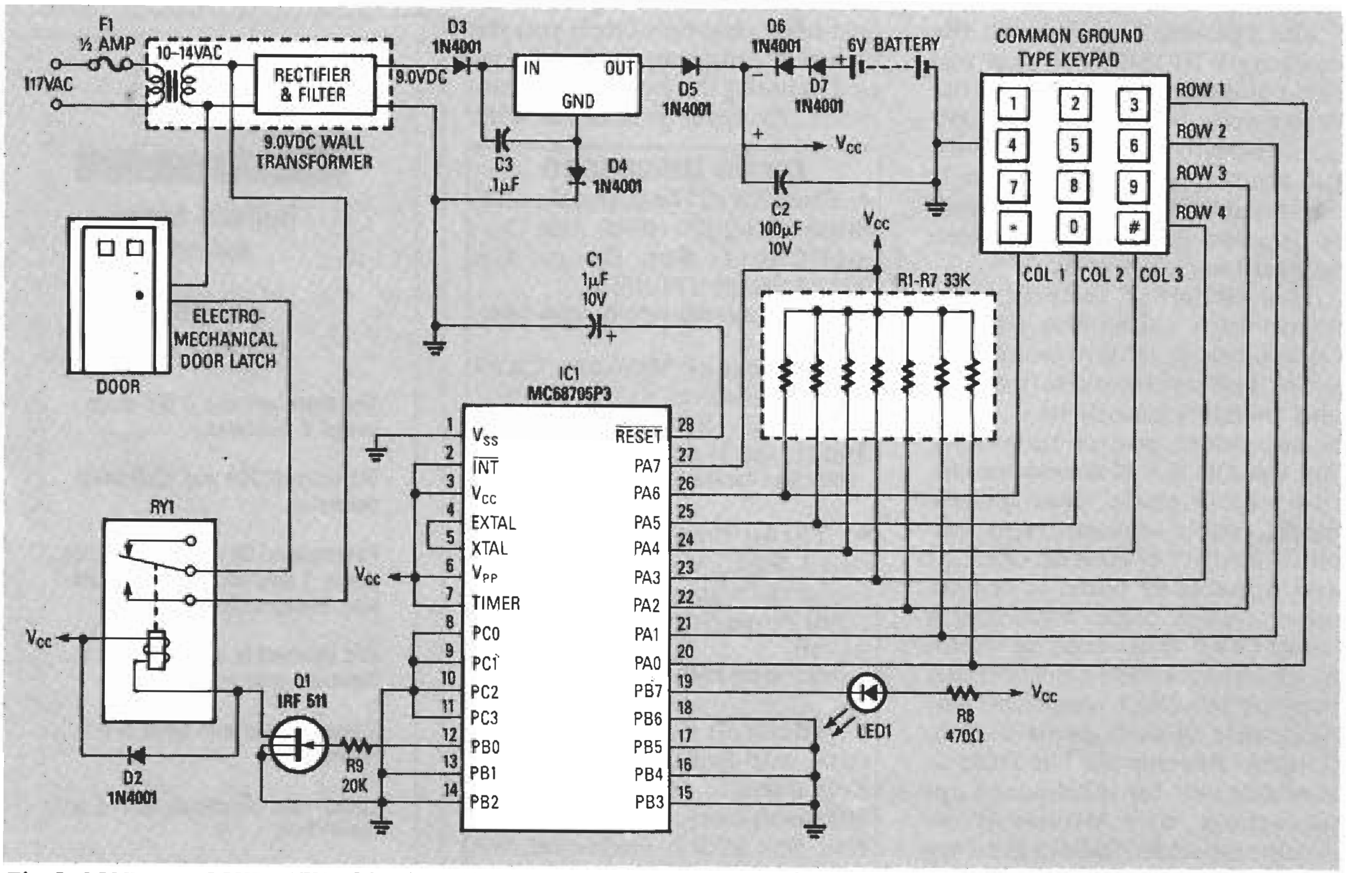


Fig. 3. COMPLETE SCHEMATIC of the digital keyless entry system. You can eliminate diode D4–D7 if you don't want battery backup. However, you'll be limited to the access codes burned into the microcontroller's EPROM.

Parts List

Resistors

All resistors are ¼-watt, 5%, unless otherwise noted.

R1–R7	*33,000 ohms*
R8	*470 ohms*
R9	*20,000 ohms*

Capacitors

C1	*1 µF, 10 volts, electrolytic*
C2	*100 µf, 10 volts, electrolytic*
C3	*0.1 µF, ceramic disc*

Semiconductors

IC1	*MC68705P3 microcontroller*
IC2	*7805, 5-volt DC regulator*
Q1	*IRF511, power MOSFET*
LED1	*standard red*
D2–D7	*1N4001, 100 volts, 1 amp*

Miscellaneous

Keypad	*common ground*
Door latch	*(see text)*
Relay	*SPST, 5-volt coil, 50 ohms, 100 mA*
Fuse	*1/2 amp (and holder)*
Transformer	*9-volt DC, wall-mount*
Batteries	*4 AA cells (and holder)*

Ordering Information

The following are available from Simple Design Implementations (SDI)
P.O. Box 9303
Forestville, CT. 06010

Preprogrammed & tested MC68705 .... $25 + $2.50 S/H

Electromechanical door Latch .... $45 + $4 S/H)

Complete kit of parts as shown in Parts List .... ($75 + $6 S/H)

Software on 5.25" disk ... $25 + $3 S/H)

gether as shown in Fig. 3, the microcontroller's internal oscillator circuit runs at about 800 kHz, providing a cycle time of about 1.25 µs. The accuracy of a crystal oscillator is not important for this project.

The microcontroller pulls up the $\overline{\text{RESET}}$ input (pin 28), thereby eliminating the need for an external resistor. The 1-µF capacitor (C1) connected from that pin to ground gives the power supply time to stabilize before allowing the microcontroller to start up.

The external-interrupt input ($\overline{\text{INT}}$, pin 2) is tied high because interrupts are not required for this project. V_{PP} (pin 6) is also tied high per the manufacturer's specifications.

Power considerations

The power supply bears some explanation; it provides an optional battery-backup system. If you want, you can hard-code the desired entry codes into EPROM. That way, you won't need to provide battery backup. But you won't be able to change codes without changing the contents of the EPROM.

The 7805 voltage regulator (IC2) maintains the supply at five volts, and filter-capacitor C2 removes any noise from the DC supply voltage. A reversed-polarity protection diode (D3) is included to protect against misapplication of power. Diode D4 serves to "lift" the 7805's output voltage by about 0.7 volts to provide an output of 5.7 volts, which is then dropped by D5 back to 5.0 volts. Diodes D5, D6, and D7 isolate the battery and the power supply from one another, preventing current from flowing from whichever source happens to be active into the other. The batteries supply about $6.0 - 0.7 - 0.7 = 4.6$ volts. Four AA batteries supply plenty of power to keep the micro-

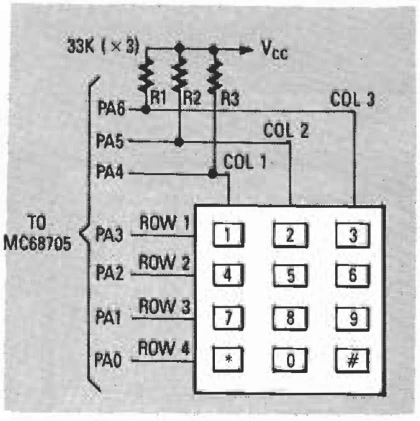


Fig. 4. *AN UNGROUNDED KEYPAD may be used, but you'll have to change the keypad scan routine. An excellent opportunity to get started in 68705 programming!*

controller's memory active (and your entry codes intact), but they can't operate the door latch, so in case of a power failure, you will have to use a key to open the door.

If the system encountered a battery failure and a main power failure simultaneously, the microcontroller's memory would be lost. When power was restored, the entry codes would be initialized to the default values stored in EPROM. Diodes D4–D7 may be removed if the battery-backup option is not used.

Software design

The following describes the software running on the microcontroller; with the information provided, it should be easy to customize operation to your liking. Complete source and object code have been posted on the RE-BBS (516-293-2283, 300/1200 baud, 8N1) in the file DIGKEY.EXE, a self-extracting compressed file. The compressed file consists of about 20K; run it on a disk with at least 50K of free disk space.

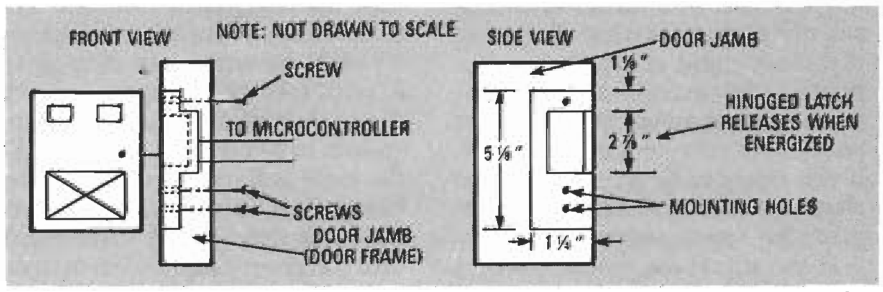


Fig. 5. *MOUNTING DIMENSIONS for the prototype door latch. This is only a guide: measure your own unit carefully.*

The system can recognize as many as three distinct entry codes. Each entry code is three digits long. The three entry codes can be independently changed and independently enabled or disabled. The system also recognizes a fourth three-digit code that puts the system into the "function" mode mentioned earlier; the function mode allows the user to change the entry codes or enable/disable the entry codes.

The three entry codes and their functional status are initialized on power up to default values stored in the EPROM. The function code, on the other hand, always starts up enabled, because if it started up disabled, the user would never be able to get into the function mode to enable it!

During normal operation, the LED flashes to indicate that the microcontroller is active and ready for input. The microcontroller stores the incoming keypad data in a buffer and constantly compares that buffer to the three valid entry codes. If a match is found, the microcontroller checks to see if that particular entry code is enabled. If the entry code is enabled, the electromechanical latch is energized for seven seconds.

If the microcontroller detects too many digits before a valid match is detected, the system enters a security mode prohibiting further input until the "*" key is pressed. While in security mode, the LED stops flashing, and remains off, indicating an improper access attempt.

The microcontroller purges the input buffer three seconds after the last key was pressed. Therefore, if the user enters one, two, or three incorrect digits, he must wait at least three seconds from the last entry before reentering the correct code. If the user does not wait three seconds, the incorrect digits remain in the buffer, a correct match cannot be made, and the system will enter security mode on the fourth digit.

The microcontroller enters the function mode when the correct three-digit function code is entered. Upon entering the function mode, the LED will turn on for 1.5 seconds, turn off for 1.5 seconds, and then remain on. The microcontroller will now accept an entry-code change. The user enters the number of the entry code he wishes to change (1, 2, or 3) followed by the three new digits, followed by a zero (0) if the code is to be enabled or a one (1) if the code is to entered but not yet enabled. If an entry code already contains the desired three digits and the user simply wishes to activate or deactivate the code, then he must hit "*" (deactivate) or "#" (activate), following the function code and the entry code number. The user is not required to enter the three digits of the entry code when enabling or disabling it.

Construction/installation

The prototype was built on a small piece of perfboard using point-to-point techniques. Be sure to observe the polarity of all polarized ports.

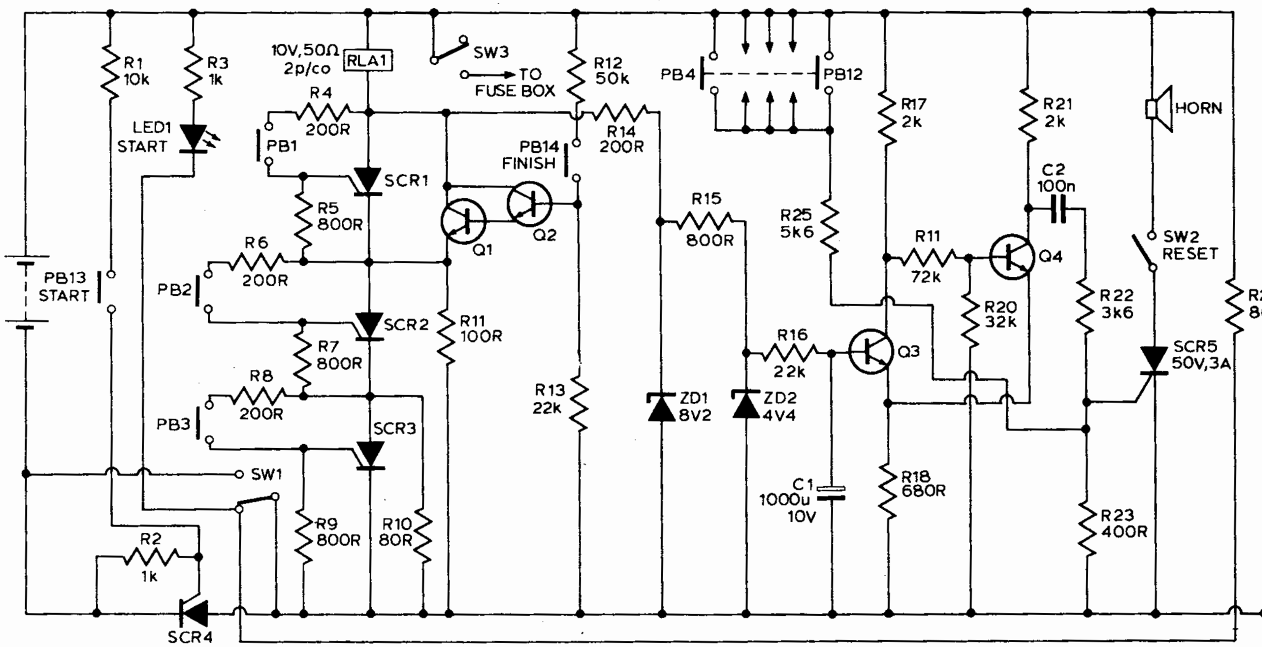
You could use a standard row/column connect type of keyboard; doing so would allow you to eliminate four of the seven keypad pullup resistors. Figure 4 shows the basic idea. However, you'd have to implement a different keyboard scan routine.

The only change to the existing lock assembly involves removing the latch receptacle in the door jamb and replacing it with the electromechanical latch.

The latch in the prototype was obtained at a local safe and lock store. Although the physical dimensions of the latches were fairly uniform (as shown in Fig. 5), drive potential varied from three to twenty-eight volts, either AC or DC. The author recommends driving the latch with an AC voltage because the latch will buzz when energized. DC drive voltages work just as well, but the latch will make only one faint click when energized. ◆CD◆

Electronic Ignition Switch

K. A. Last



NOTE

Q1 is BFY50
Q2,4 are BC108
Q3 are BC108C
SCR1–4 50V,1A TYPES
SCR5 50V,3A
LED1 is TIL 209
RLA1 is 10V,50R COIL WITH 2p/co CONTACTS

When used with a calculator type keyboard, this circuit provides a 'combination lock' ignition switch which only activates if the correct sequence of three numbers is keyed in. The keyboard has 14 keys numbered 1 to 12, 'START' and 'FINISH'. To start the car, the 'start' key is pressed and the start LED will light. The correct sequence of 3 numbers is then keyed in. If the sequence is wrong, the cars horn will be sounded. If the right sequence is entered, the 'START' LED will extinguish and the ignition will be energised. The correct sequence will be PB1, PB2, PB3, but these can be arranged amongst the other keys in the keyboard, and given any numbers.

Logical Lock Project

An electronic method of operating a security lock.

By Phil Walker

THIS lock will not make your house burglar-proof; however, it should do away with the need to hide keys. All you need to persuade your family to do is to remember a five-figure number. All the digits in the number must be different; for example, you couldn't use the code 9999, but they can be in any order, and the code can be changed if your number should get a little too widely known.

Although both the system diagram, **Figure 1**, and the circuit diagram are relatively large, the unit uses comparatively few components, just six integrated circuits and a handful of other components to do all the clever stuff. We expect that the actual control unit itself will be relatively cheap to build; however, the solenoid-operated lock will probably be the main expense, although there may be ways around this, as we shall see.

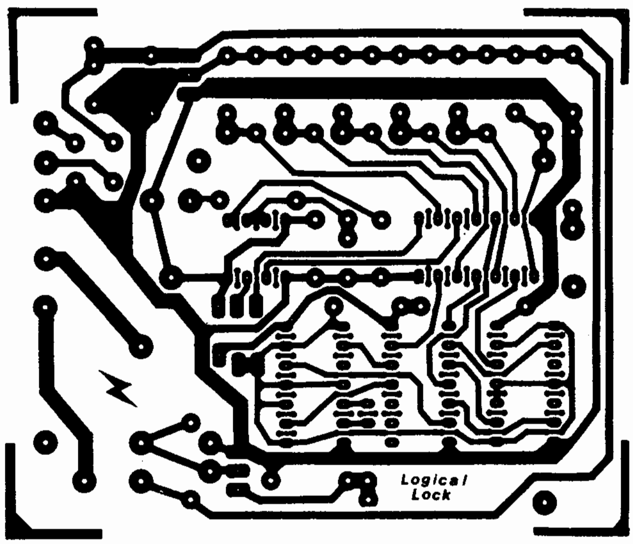


Fig. 1 The printed circuit.

How It Works

Switches SW1 to 10 make up the keypad. Of these, SW1 to 5 are all connected in parallel; these are the "wrong digits". Pushing any of these switches makes current flow through R1, down through the switch and then through R2 (a little current flows out of the input to IC1a, but this is small enough not to take account of). Capacitor C1 is present to ensure that the rise in voltage across R2 is smooth. When fairly inexpensive switches close, they don't just close cleanly, but make and break their contacts (bounce) several times before finally making firm contact; C1 prevents the fluctuations that occur from reaching IC1a's input.

IC1a is a Schmitt trigger with an inverted output. What this means is that it has a very precisely defined voltage at which it will turn on, and once it has turned on, the voltage at its input must be reduced to a much lower level than that which turned it on to get it to turn off. Because the output is inverted, the output voltage is actually a logic low when the input is turned on. Schmitt triggers are often used to clean up logic signals, and that is exactly what these are being used for here.

Resistors R1 and R2 form a potential divider while one of switches SW1 to 5 is

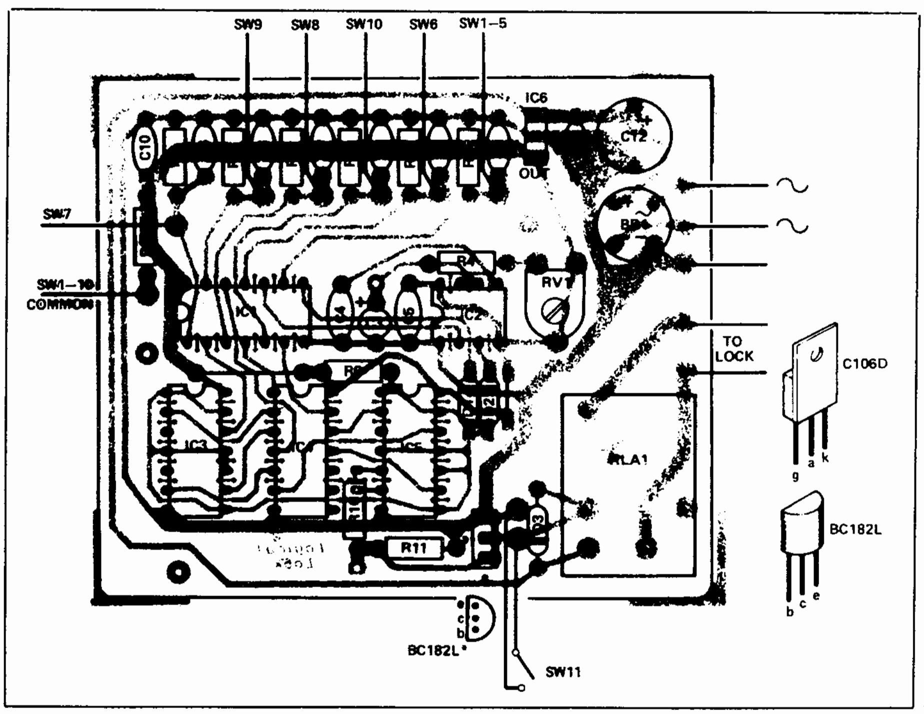


Fig. 2 The parts overlay.

Fig. 1 The printed circuit.

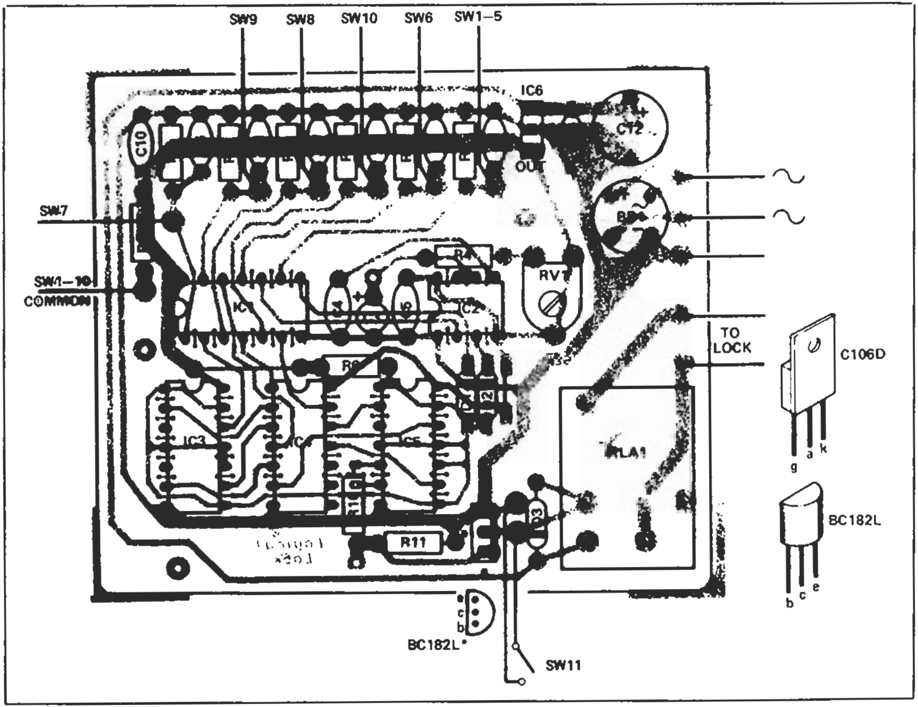


Fig. 2 The parts overlay.

Assembly

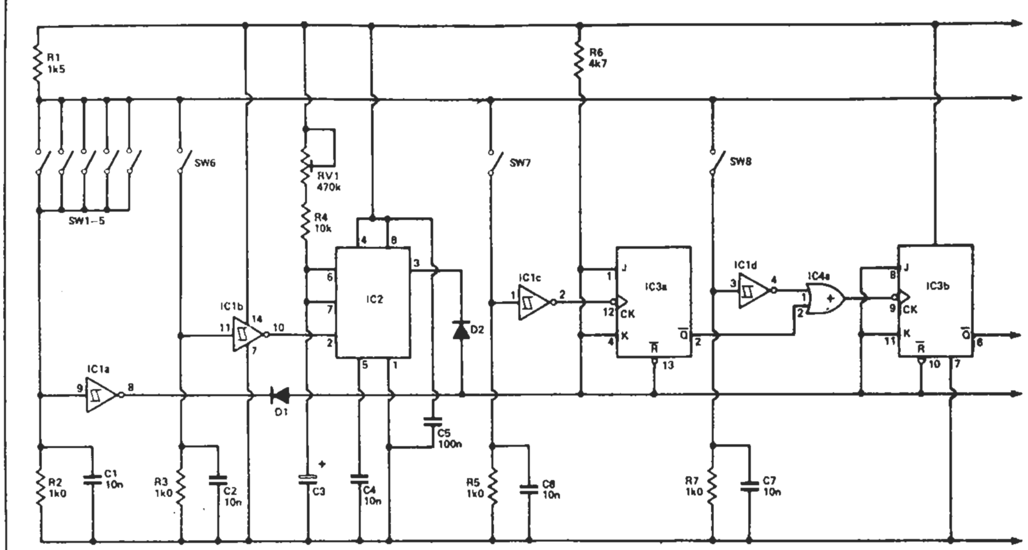
All the components for the project, except the keypad, transformer and fuse are mounted on a PCB. The prototype was built using Veroboard; however, there were so many links that we were easily convinced that a PCB would make life very much easier.

We did find it necessary to use one or two links on the PCB, so the first task in assembly should be to insert all the links. One hint: all the links run parallel to the edge of the board. If you have one which doesn't, you've got it wrong.

closed. The voltage at their junction point (via the closed switch) at the input of IC1a is just enough to trigger the input of the IC, as already discussed. If any of the switches SW6 to SW10 are closed, then R2 will be effectively in parallel with the resistors attached to the lower ends of the (other) switch which is closed (R3 or R5 or R6 or R7 or R8), so the voltage at the input to IC1a or any of the Schmitt triggers (the other sections of the IC discussed later) cannot reach the voltage needed to turn on the Schmitt triggers. This prevents our prospective intruder from trying to cheat by pressing more than one key at a time, as this will have no effect.

The output from IC1a will, therefore, go low if any of switches SW1 to 5 are pressed. This low signal is passed via D2 to the reset line to the ICs in the decoder section; these will be discussed quite soon.

SW6 is the first of the "right" switches that has to be pressed. As with IC1a, pressing SW6 takes the input of IC1b high and its output low. This low signal is fed to IC2, which is a 555 timer IC. The 555 timer is very useful, and for this reason is a very common integrated circuit that can do a great variety of timing jobs in electronic circuits. We won't go into the details of its operations here, except to say that it is wired as a monostable. What this means is that the circuit has only one



stable state (as opposed to the flip-flops that we shall meet shortly). A trigger pulse, such as it will receive from SW6 via IC1b, will make it go into its second, unstable state for a period of time which is controlled by capacitor C3 and potentiometer RV1, after which it will revert to its first, stable state.

In its unstable state, the output from the 555 timer IC, which is pin 3, is taken high. When it returns to its stable, first state, the output is taken low, which takes the reset line to the decoder via D2.

One incidental point to note here is that D1 and D2 are both germanium diodes. Germanium diodes have a lower voltage drop across themselves when they are conducting, so they are less likely to let a low logic signal get too high in voltage and fail to be recognized as a low.

Decoder

The next section of the circuit is the decoder, which is based on IC3 and 5 a and b, with associated ancillary logic

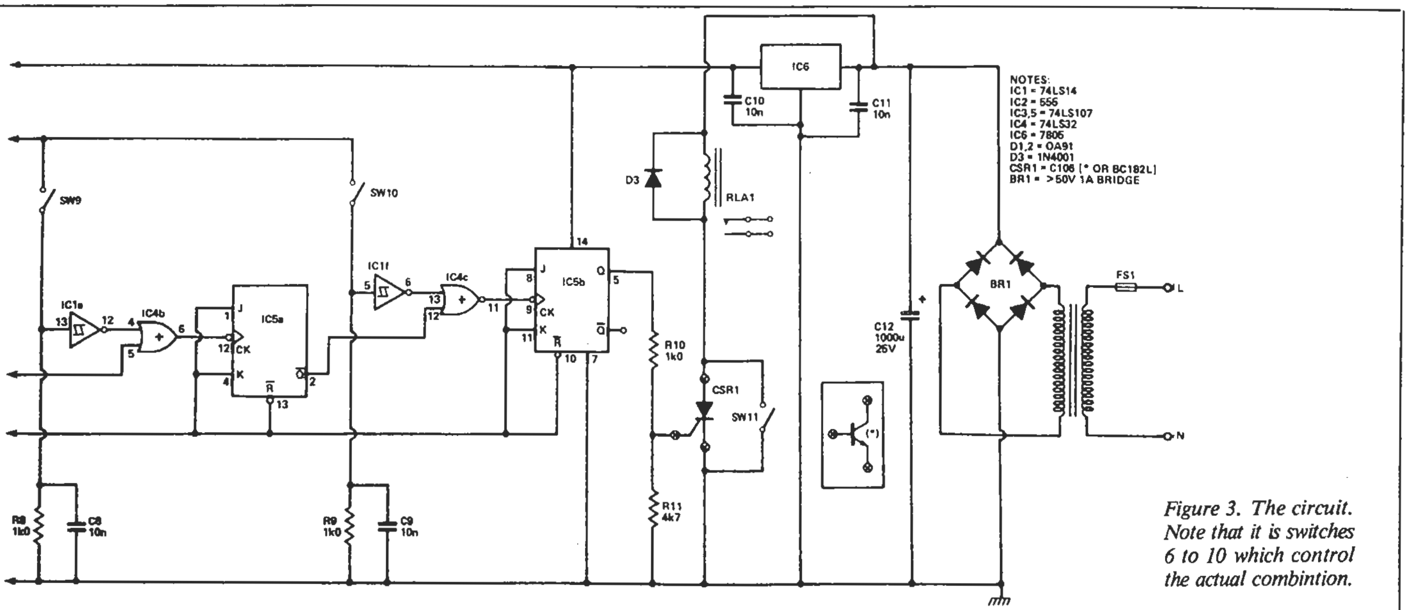


Figure 3. The circuit. Note that it is switches 6 to 10 which control the actual combintion.

gates. The first switch which must be pressed is SW7 (this is after SW6 has been pressed). This takes the output of IC1c low. This output is fed to the clock input of IC3a. IC3a and 3b, 4a and 4c, are flip-flops. These are devices which have two stable states: when they are put into one or other of their stable states, they will stay there until caused to "flip" to the other state, and they can then be made, by another stimulus, to "flop" into the first state.

There are many different types of flip-flops, and we could (and will, one day) spend an entire article talking about them. So let us just say that the type here is a J-K flip flop which is negative edge triggered. In English, this means that with the two inputs J and K wired to logic high, as they are here, the outputs will flip from low to high or vice-versa) depending on which stable state the flip-flop was in) as the clock input goes from positive to negative.

In practical terms, that means that as the output of IC1s goes from high to low, the output Q will change from either low to high or from high to low, depending on which state it was in just before IC1a's output changed. However, we know that state the output was in, because before SW6 was pressed, the reset line was low. This has, curiously enough, the effect of resetting all the flip-flops in the decoder, output Q will be high (incidentally, the inverted output Q, not used here, will be high), so it will then have gone to low (Q will go to high). This takes one input to the OR gate, IC4a, to low.

Like all OR gates, IC4a will let its output go low when both its inputs are low. Before SW8 is pressed, IC1d's input will be held low by R5, and its output will be high, so one input to IC4a is still high and its own output is also high. However, as soon as SW8 is closed, IC1d's input is taken high and its output goes low, taking IC4d's output low with it. This positive-to-negative transition is exactly what the clock input of IC3b needs to make this IC flip its outputs taking the Q output from high to low which will in turn take the Q output of IC4b high (exactly as with IC4a).

Again, closing the switch (SW9, this time) takes the other input the OR gate (now IC4b) low (via IC1e), again giving the flip-flop (IC5a here) the positive-to-negative transition, again the Q output goes from high to low, etc.

Let it suffice to say that if the switches are all pressed in the correct order, the Q output of IC5b will eventually go high; this will last for only a short space of time, because by this time, the timer will probably be near to the end of its period, and it will then take the reset line low, turning off all the flip-flops.

However, this is where the latch part of the circuit comes in. This makes use of a very useful component indeed, a silicon controlled rectifier (sometimes called a thyristor). In the normal reverse direction, the direction in which no diode will conduct, the SCR will not conduct either. However, in the other direction, the forward direction, the SCR will conduct only after a suitable voltage pulse has been applied to the gate terminal. After this pulse has been applied, the SCR will continue to conduct, whatever happens at the gate terminal, so long as the current flowing through the main terminals of the SCR remains above a certain, holding value.

In this circuit, the SCR makes a very good choice for the latch, because, besides latching on and staying on, the SCR also can pass relatively high currents with very little voltage drop and so relatively small heat dissipation. The only way to turn off SCR1 is by shorting it out briefly, so removing all the current through it; this can be done using SW11.

The SCR is used to provide power to the relay RLA1, which has contacts which are capable of taking the mains, at low current. More about this in the wiring-up section.

The final section of the circuit is the power supply, which is absolutely standard. T1 takes the line voltage and transforms it down to a much lower one; BR1 rectifies this and C12 smooths out the voltage; IC6 regulates this down to a steady 5 volts; C10 and C11 protect against high frequency instability causing problems in the regulator IC6.

Parts List

Resistors (All ¼W 5% carbon)	
R1	1k5
R2, 3, 5, 7, 8, 9, 10	1k0
R4	10k
R6, 11	4k7
Capacitors	
C1, 2, 4, 6-11	10n ceramic
C3	axial electro
C5	100n ceramic
C12	1000u
Semiconductors	
IC1	74LS14
IC2	555
IC3, 5	74LS107
IC4	74LS32
IC6	7805 regulator
D1, 2	1N34
D3	1N4001
SCR1	C106
BR1	any 1A 200V bridge.
Miscellaneous	
SW1-11	any suitable arrangement of panel-mounting single-pole push-to-make momentary switches or keypad
RLA1	12VDC relay
T1	9V miniature transformer, 3VA (minimum)
FS1	1A fuse and panel-mounting holder

PCB; cases for keypad and main unit; ribbon cable; wire solder, etc.

The keypad is assembled in its own case, and how you do this is very much a matter of personal choice, as is the keypad itself. For a ten-digit keypad you need eleven wires in total (ten digits and common). The reset switch must be inside the protected building as it will open the door when operated. You may find it useful to have more than one keypad; there is no problem provided the switches are wired in parallel, and also provided that only one pad is operated at a time.

Using a solenoid-operated door catch which uses 115VAC (not all do), the contact on RLA1 will have to be wired appropriately. You will have to work out the exact details for yourself according to the lock you are using; if you are not confident, don't use a line-operated lock.

Installation

The keypad has to be installed outside the door, with the rest of the installation on the inside. It is convenient to mount the reset button near the door, either with the main box or separately, but make sure that the reset (and the rest of the works) are more than an arm's length away from any breakable window, and preferably that the reset button is protected with a cover when not in use. If the reset button is away from the mains box, the wires should not be either too long or too thin. The action of the switch depends on the current path through it being at a lower resistance than the path through the SCR. If the wires are too long or thin, a sizeable current will continue to flow through the SCR, holding it on. Better to mount the whole assembly away from the lock in this case.

Most electronically-operated locks operate from the keeper (doorpost) side. Some specifically combine electrical operation with an ordinary night-latch lock so that they can be operated either electrically or with a key. ■

STATE OF SOLID STATE

ROBERT F. SCOTT,
SEMICONDUCTOR EDITOR

Electronic locks

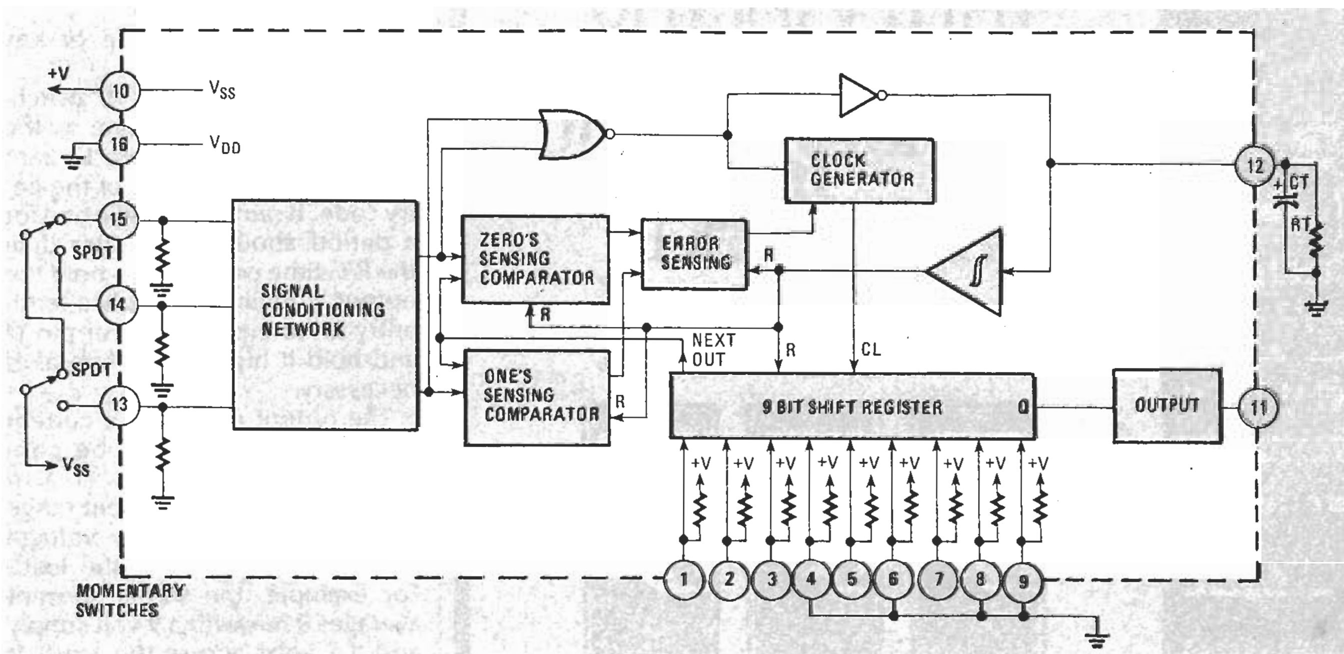


FIG. 1

THE RAPIDLY RISING CRIME RATE HAS forced us to go to the extremes to protect our valuables. For instance, it is not uncommon to see two and three locks on a single door.

If you use conventional locks to secure your home or valuables, you could find yourself carrying large numbers of keys. That means everytime you want to open a door or gain access to your property, you'll be saddled with the task of sorting through several keys to find the one you need at that particular moment. However, there is another way to get the needed security—replace some of those conventional locks with coded electronic types.

Two electronic locks worth your consideration are the LS7228 and LS7229 from LSI. Figure 1 is a block diagram of the innards of the LS7229 (the LS7228 is similar). Both units are ion-implanted, PMOS encoder circuits that include all the necessary logic to interpret the entry code and develop a momentary lock-control output. The LS7228 address decoder is keyed by two pulse trains of logic one's and zero's applied to the correct terminals. The LS7229 is keyed by two double-throw momentary pushbutton switches (which are used to enter one's and zero's).

Both units (housed in 16-pin DIP's) feature stand-alone lock logic, out-of-sequence disabling circuits, current-source lock-control outputs, externally controlled delay to set maximum time between pulses, and a 9-bit entry code determined by 9 parallel inputs. Each IC is powered from a single-ended 2.5- to 15-volt supply. Maximum standby current is 15 μA.

The locks are controlled by a 9-bit binary code that has 512 possible combinations. The leading or most significant bit is set by pin 1 and the end (least significant) bit is set using pin 9. Code terminals 1 through 9 control a 9-bit shift register. The entry code is programmed into the lock by either jumpering or floating (leaving open) certain pins. Refer to Fig. 2, a practical circuit for the LS7229.

To program any given input to accept a logic 1, the pin corresponding to that input is left open. Jumpering a pin to ground programs a zero into the device at the corresponding position in the entry code. For example, if pins 3, 4, 5, 6, and 9 are grounded and the others left open, the binary access-code would be 110000110.

The device is unlocked by entering the code (one's and zero's) in the correct sequence through switches S1 and S2. The zeros' and ones' entry ports are initially at logic zero (ground). As each key is pressed, its entry port goes to logic one and then returns to zero. When the first correct bit of the code is keyed in via S1 and S2, the external capacitor is discharged and an internal inhibit is removed so the circuit will be receptive to the second bit, and so on.

If all nine bits are in the correct sequence, a logic one passes through the shift register to the lock output at pin 11. An out-of-sequence entry or incorrect bit at any point in the entry code inhibits any further entry. After a delay period (determined by the time constant of an external R/C network) a new sequence of key pulses may be applied.

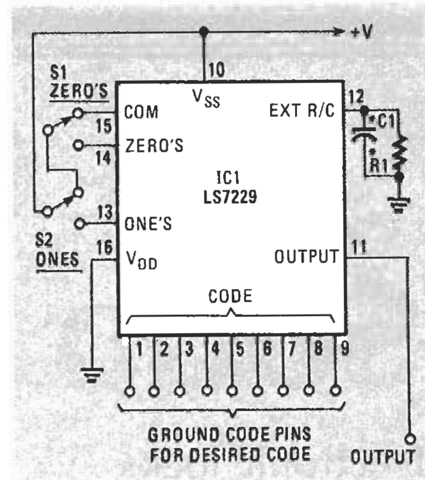


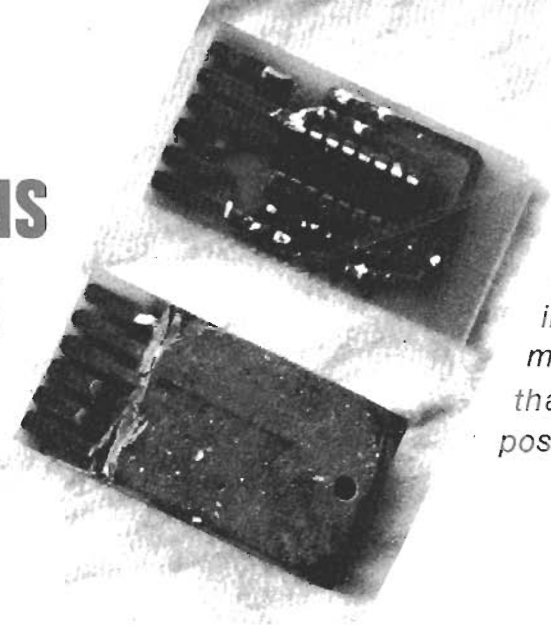
FIG. 2

The lock-output (pin 11) switches from zero to logic one as the voltage on pin 9 returns to zero following the last pulse of the entry code. It remains at logic one for a period about 30% longer than the R/C time constant. To hold the output at logic one, apply a tenth entry bit to either pin 13 or pin 14 and hold it high for as long as is necessary.

The output control is a current source so a load must be connected between pin 11 and ground. The source-current range depends on the supply voltage and the voltage across the load. For example, the source current averages 9 mA with a 9-volt supply and 8.5 volts across the load. It sources 26 mA with 7.5 volts across the load.

The time constant of the external R-C network at pin 12 determines the duration of the output pulse and the maximum permissible interval between valid entry-code bits. The time constant in seconds is the product of the resistance of R1 in megohms and the capacitance of C1 in microfarads. When using a 9-volt supply, the minimum suggested value for R1 is 2200 ohms and the maximum value is 3.3 megohms.

The LS7228 and LS7229 binary-lock circuits are available from **LSI Computer Systems, Inc.**, 1235 Walt Whitman Road, Melville, NY 11747 at $2.70 each for 1 to 24 pieces. Include $5.00 for shipping and handling. New York State residents add sales tax. Data sheets are available on request. **R-E**



IC KEY OPENS ELECTRONIC DOOR LOCK

Pickproof lock can only be opened by an integrated circuit that makes an active key that is just about impossible to duplicate.

by J.B. WICKLUND

THE RAPID INCREASE IN CASES OF theft and burglary in this country indicates the need for a lock that cannot be "picked." Modern electronics can provide such a lock. One form of electronic lock would use a "key" capable of storing a binary code, and a lock that could be programmed to read and recognize the correct code.

A binary code is nothing more than a series of 1's and 0's called bits. If two bits are used, there are four possible codes (00, 01, 10 and 11). With sixteen bits, there are 65,536 possible combinations. Availability of low-cost digital computer type IC's makes a digital lock practical.

The feasibility of such a lock can be demonstrated by the construction of an eight-bit lock and key set. The lock is built with inexpensive TTL logic modules and is battery powered.

Principles of operation

The key is very simple and consists of a small eight-bit code stored in its memory. When inserted into the lock, its code is read and the lock responds with a positive output signal when the key has the correct code. *The eight-bit code is chosen at the time of construction and wired into the lock and key.*

The key is constructed with an eight-bit data selector that has eight inputs and one output, with three control lines to control its operation. The data selector acts like an eight-position switch, with the output connected to one of the inputs, where the three control lines electronically operate the switch. The eight-bit code can be stored by wiring the eight inputs to ground or +5 volts for zero and one respectively.

A schematic diagram of the lock and key is shown in Figs. 3 and 4, respectively, on the next page.

A square-wave oscillator is built with IC9 and drives IC8 which is a decade counter. The decade counter counts these pulses from zero through nine and then starts over. The counter output is connected to the three control lines of the key, and as the counter goes from zero through seven, the eight bits of data stored in the *key* are read by the *lock*. The eight bits are stored in a shift-register memory made up of IC2, IC3, IC4 and IC5. After the eighth bit is read and stored, the eight-bit code is decoded by IC1 and if the correct code is present, the output flip-flop (IC6) will be set. When the key is removed or an incorrect code is read, the flip-flop is reset again.

The output flip-flop drives Q2 and Q3 which can be used to drive a relay or solenoid or door opener. The TTL in-

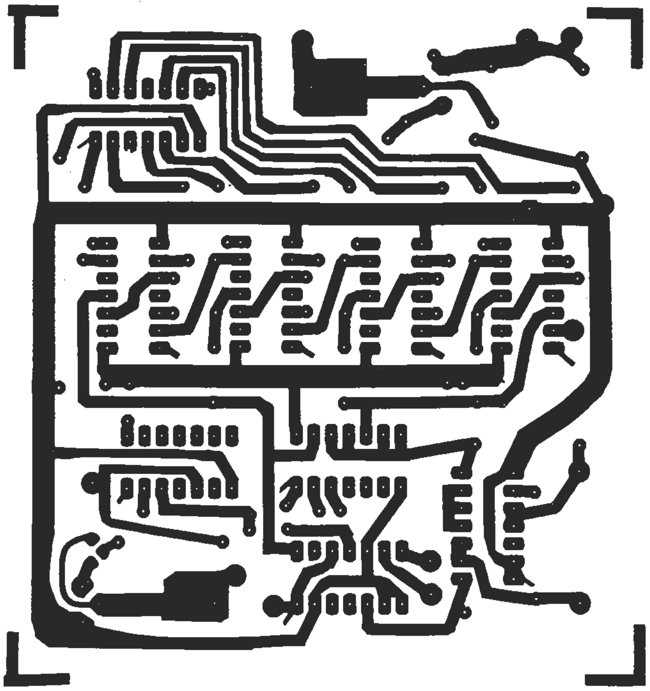


FIG. 1—FOIL PATTERN for the electronic lock. The board measures 3½ x 3¾ inches. Parts are positioned and mounted as in Fig. 2

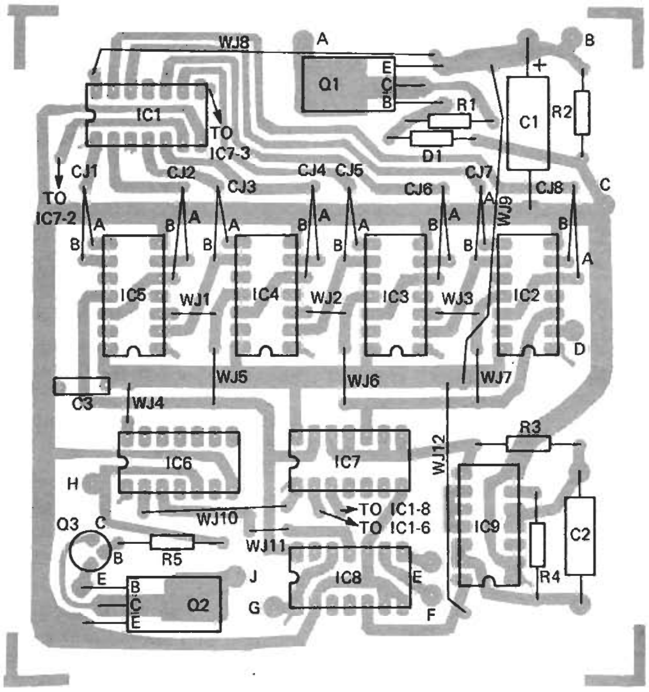
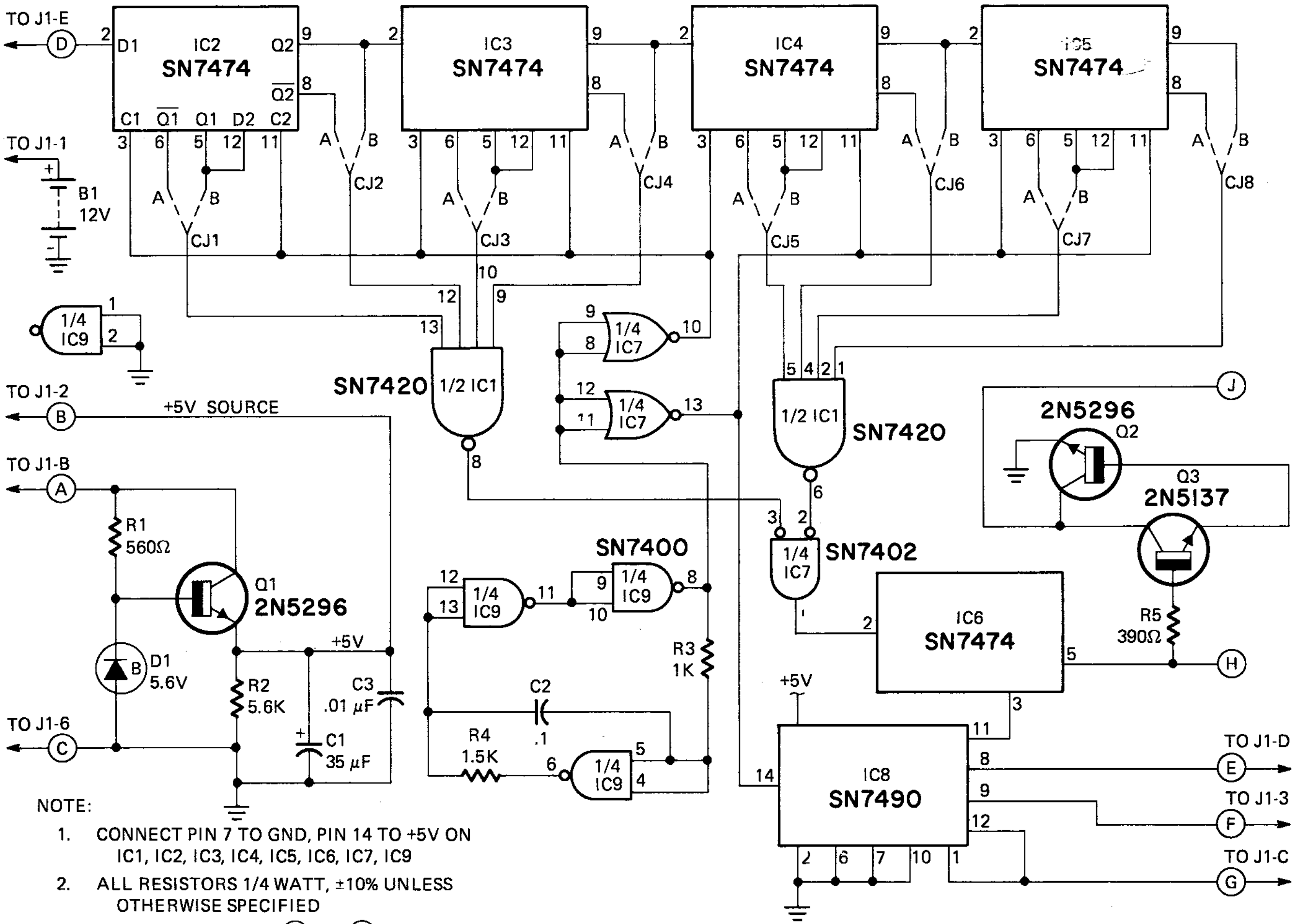


FIG. 2—WHERE LOCK PARTS ARE LOCATED. Jumpers CJ2-A, CJ2-B, etc) set digital code used to insure secrecy and fool-proof operation.



NOTE:

1. CONNECT PIN 7 TO GND, PIN 14 TO +5V ON IC1, IC2, IC3, IC4, IC5, IC6, IC7, IC9
2. ALL RESISTORS 1/4 WATT, ±10% UNLESS OTHERWISE SPECIFIED
3. CIRCLED LETTERS (Ⓐ, Ⓑ etc.) CORRESPOND TO POINTS ON P-C BOARD.

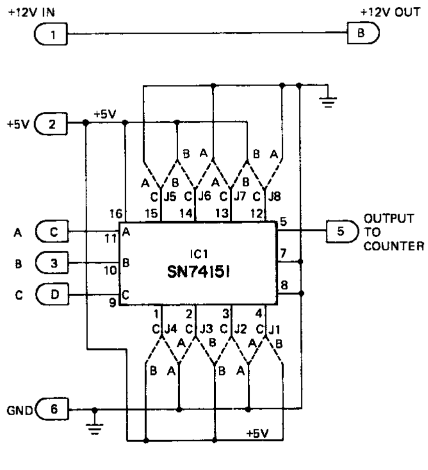
FIG. 3—THE ELECTRONIC LOCK uses digital logic circuitry and digital IC's for its foolproof operation. Digital code wired into key is read by the lock and must be correct before the circuit will operate and release the mechanism.

PARTS LIST

R1—560 ohms, ¼ watt
R2—5,600 ohms, ¼ watt
R3—1000 ohms ¼ watt
R4—1500 ohms ¼ watt
R5—390 ohms ¼ watt
IC1—SN7420N
IC2, IC3, IC4, IC5, IC6—SN7474N
IC7—SN7402N
IC8—SN7490N
IC9—SN7400N
D1—5.6V ±5% Zener diode 1N752A
D2—1A, 1N4003 (see Fig. 7)
Q1, Q2—2N5296
Q3—2N5137
C1—35μF/6 Vdc (Sprague TE-1093 or equal)
C2—.1μF Mylar (Sprague 225P10491 or equal)
C3—.01μF disc ceramic
J1—Connector (Elco 00-6007-012-980-00 or equal)
B1—12V (2 Eveready 510S or equal)
FOR KEY:
IC1—SN74151N

The following parts are available from Northwest Engineering; PO Box 5426; Seattle, Wash. 98107

DL-100—All parts & printed circuit cards.$26.00 (excluding batteries & door opener)
DL-101—Integrated circuits only..............$12.50
DL-102—PC boards & connector only..........8.75
DL-103—Extra key 6.25
DL-200—Edwards model 154 door opener.13.25
Postpaid in US.



2/B = TERMINALS ON KEY BOARD, LETTERS ON TOP SIDE, NUMBERS ON BOTTOM

tegrated circuits used in this lock are designed to operate from 5.0 volts and should never have more than 5.5 volts applied to any terminal. The circuit (Fig. 3) provides a 5.0 V voltage regulator (Q1, D1) which allows for any input voltage between 8 and 14 volts to operate the lock.

Construction

Printed-circuit construction is used to insure accuracy and a compact installation. The pattern for the lock is in Fig.

FIG. 4—DIAGRAM OF THE KEY. The IC is mounted on a small 2-sided PC board with contacts to match a PC card-edge connector.

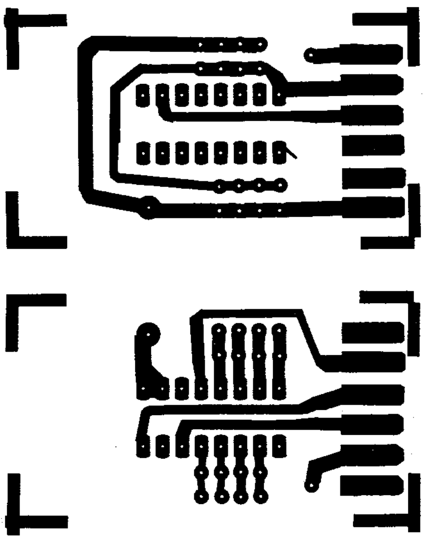


FIG. 5—TWO-SIDED BOARD USED FOR KEY requires careful alignment of both foil patterns so all drilled holes coincide. Patterns full size.

1 and the pattern for the double-sided key board is shown in Fig. 5.

To prev[illegible] a possible wiring error in the voltage regulator from damaging the integrated circuits, the regulator (Q1, R1, R2, C1 and D1 in Fig. 3) should be built and checked out prior to wiring the rest of the circuit. With 12 volts applied to the input of the regulator, the output voltage should be between 4.5 and 5.5 volts.

The remainder of the circuit board can now be assembled, with the exception of the code jumpers (CJ1-CJ8) which are used to select the desired binary code. The location of all wire jumpers are shown in Fig. 6. The next step is to wire the board to the connector (J1), which is used as the "key slot." The connector can be located several feet from the lock circuit if desired.

After selecting an eight-bit code, refer to Table 1 for a listing of which of the 16 jumpers should be installed to implement that code. Eight of the jumpers will be used, the other eight being left open. For example, if the code 10101010 is selected, jumpers CJ1B, CJ2A, CJ3B, CJ4A, CJ5B, CJ6A, CJ7B and CJ8A will be used. The table also lists the jumpers necessary to implement the same code on the key.

TABLE I

CODE JUMPERS TO IMPLEMENT EIGHT BIT CODE ABCDEFGH

	A	B	C	D
0	CJ1A	CJ2A	CJ3A	CJ4A
1	CJ1B	CJ2B	CJ3B	CJ4B

	E	F	G	H
0	CJ5A	CJ6A	CJ7A	CJ8A
1	CJ5B	CJ6B	CJ7B	CJ8B

The key can now be assembled as shown in Fig. 6. The jumper wires as listed in Table 1 should be installed. On the key, the jumper wires only connect the top foil to the bottom foil on the PC board and should only be long enough to go through one hole and be soldered on top and bottom. The key should not be potted until everything is completely tested and is working correctly.

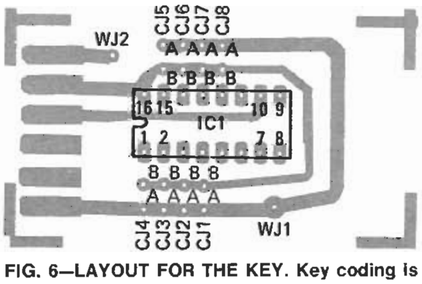


FIG. 6—LAYOUT FOR THE KEY. Key coding is provided by eight jumpers—each with two possible connections—to ground or to =5 volts. Jumpers extend through board from foil to foil.

Connect a 12-volt battery to the power terminals and a dc voltmeter to pin H of the PC card. The voltmeter should read 0 volts. Now plug the key into the socket: the voltmeter should change to 5 volts. If the voltmeter does not change, check to be sure the key is not upside-down in the socket.

If the key/lock does not operate correctly, disconnect the power and check the wiring and assembly of the PC cards and the connector socket. Check that all the necessary jumpers are in place on both cards and that the same code is wired onto both the key and the lock. The oscillator can be checked with an oscilloscope at pins 10 and 13 of IC-2 when power is applied and the key is inserted in the lock.

After the key has been checked out, it can be potted to protect the circuitry and to hide the code jumpers. Epoxy cement or Silicone Rubber can be used if a regular potting compound is not available. The epoxy cement provides a good hard compound that can be filed to shape.

Application

When used as a door lock, the output transistor, Q2, is used to drive a door opener to activate the latch. The door opener can be operated from the same battery that operates the lock or from a separate source as shown in Fig. 7. The diode D2 protects Q2 from reverse voltage breakdown due to counter emf when the solenoid or door opener is released.

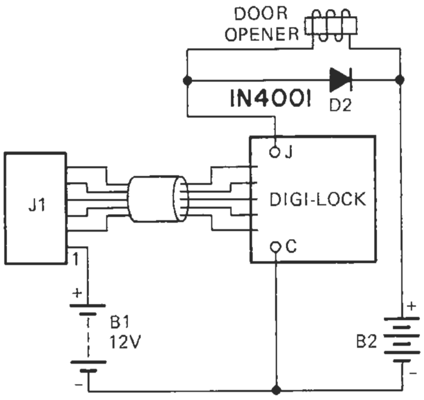


FIG. 7—THE DIGI-LOCK drives door opener. A 1N4003 diode is preferred for D2.

The lock can also be used to prevent unauthorized people (or children) from operating power tools or other pieces of electrical equipment. For this application, the lock is used to drive a relay as shown in Fig. 8. If the lock is to be used for long periods of time (turned on with the key inserted) in this application, the power supply shown in Fig. 9 can be built to power the lock.

Under normal operation, the lock only draws power from the battery when the key is inserted in the lock. Therefore, when used for short periods of time, as in the case of a door lock, the battery life will be nearly equal to the shelf life of the battery. **R-E**

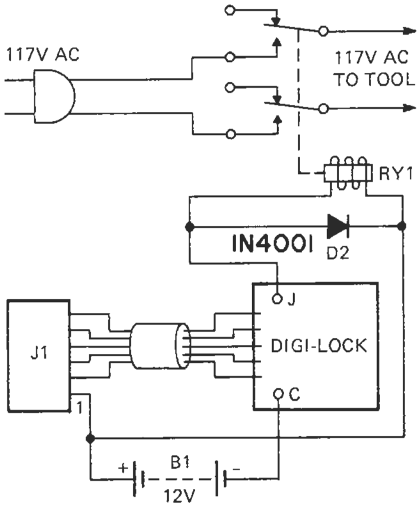


FIG. 8—TO LOCK TOOLS, use Digi-Lock to operate relay with contacts between line and load.

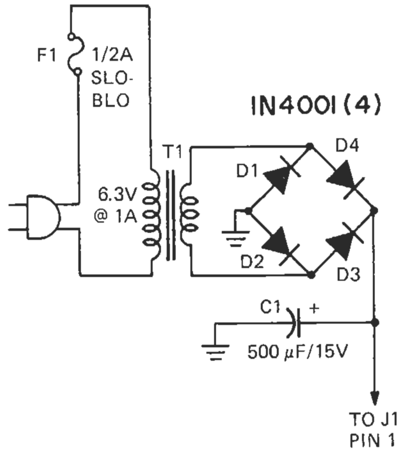
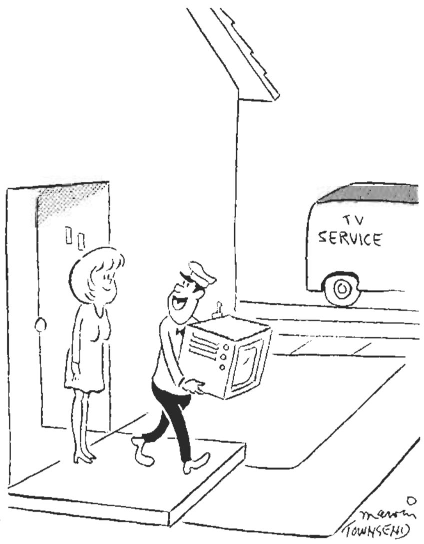


FIG. 9—SIMPLE POWER SUPPLY replaces batteries when Digi-Lock is used on power tools.



For a small extra fee I can manage to keep it until after baseball season is over.

ELECTRONIC COMBINATION LOCK

UP TO 1 MILLION COMBINATIONS CAN BE CREATED

BY J. A. NUNLEY

ELECTRONIC COMBINATION locks are not what you would call earth-shaking novelties these days. But many of them leave something to be desired when it comes to flexibility of combinations and selfprotection against being opened accidentally. The solid-state lock (patent pending) described here is capable of having 10,000 different combinations and, with slight modifications, can have a million or more. The basic circuit can be programmed to accept any four-digit combination—even four of the same number—while the simple encoding process permits changing the code within a few seconds if it is suspected that the code has been detected.

The circuit is self-protecting in that the combination cannot be entered too rapidly and if an incorrect combination is entered, a wait of about four seconds is required before a second try can be made. Trials of various combinations in an attempt to break the code take about six seconds each.

Any wrong digit, even if preceded by correct ones, cancels the stored information so that, even if the first three digits are guessed correctly, a wrong fourth one negates the attempt. Pressing several buttons at once is also useless since only the lowest number registers and is effective only if correct.

The power supply for the lock can be 117-volt line power or a 12-volt battery such as those found in cars, boats, and trailers.

Construction. The circuit of the lock (see Fig. 1) is divided into two sections. One part is the pushbutton keyboard and the other is the de-ciphering circuit. The two can be located as near or as far from each other as necessary. Any type of packaging can be used though the circuits should be enclosed so that they can't be tampered with. The mounting of the keyboard depends upon the application. The 14 gate diodes, *D1* through *D14*, can be of any type as long as they have a reverse breakdown of at least 12 volts.

The connections between the electronic circuit (terminals 1 to 4) and the keyboard (terminals 0 to 9) determine the combination. In the prototype, simple spring-loaded wire clips were used for these connections. This does not provide an ideal low-resistance circuit but will suffice. If desired, four independent,

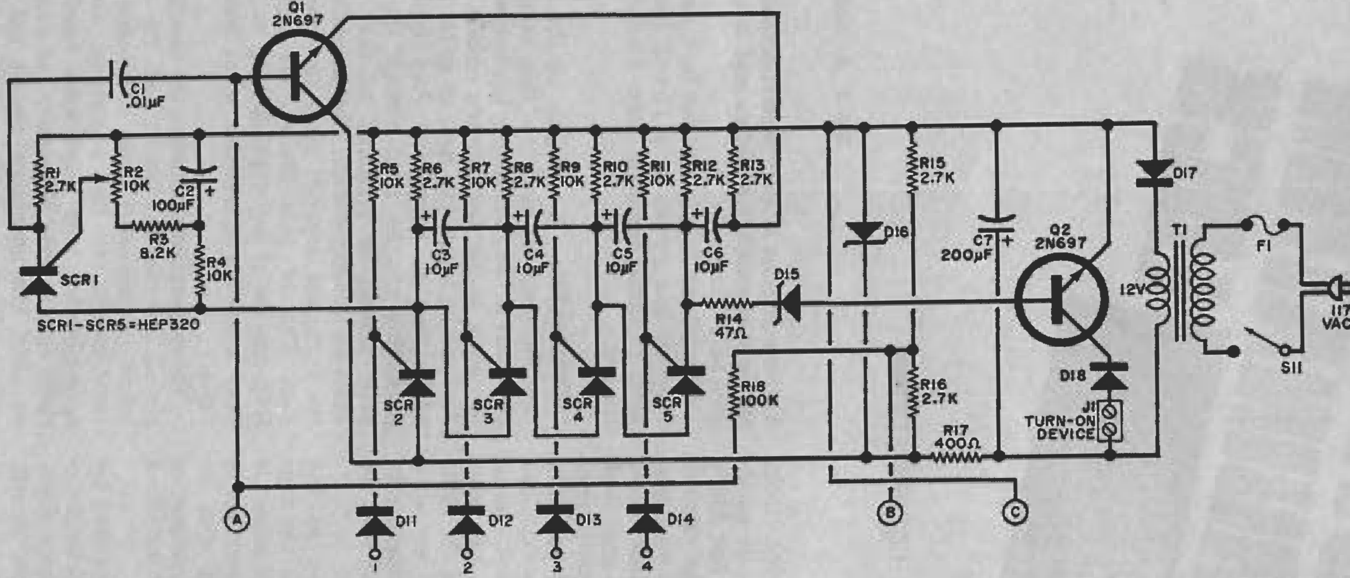
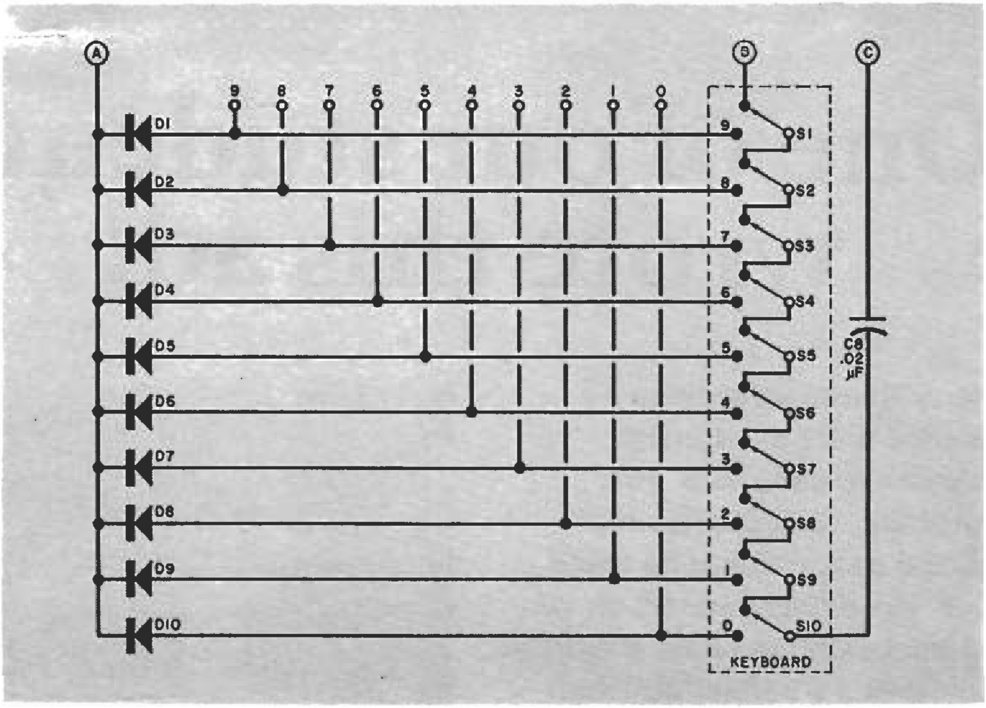


Fig. 1. Terminals 1 through 4 (below) represent the four sequential inputs. These are connected to any four of the 0 through 9 terminals (right). When the correct pushbuttons (S1-S10) are depressed in right order, Q2 turns on. SCR1 is the timing generator.

PARTS LIST

C1—0.01-µF capacitor
C2—100-µF, 15-volt electrolytic capacitor
C3-C6—10-µF, 15-volt electrolytic capacitor
C7—200-µF, 35-volt electrolytic capacitor
C8—0.02-µF capacitor
D1-D14—Diode with 12-volt PIV
D15—6-to-8-volt, 1-watt zener diode
D16—12-volt, 10-watt zener diode
D17—35PIV, 0.5A silicon rectifier diode
D18—200PIV, 0.5A silicon diode
F1—1A fuse and holder
J1—Two-pin connector
Q1,Q2—2N697, HEP53 (or similar) transistor
R1,R6,R8,R10,R12,R13,R15,R16—2700-ohm, ¼-watt resistor
R2—10,000-ohm subminiature potentiometer
R3—8200-ohm, ¼-watt resistor
R4,R5,R7,R9,R11—10,000-ohm, ¼-watt resistor
R14—47-ohm, ½-watt resistor
R17—400-ohm, 5-watt resistor
R18—100,000-ohm, ¼-watt resistor
S1-S10—Spdt pushbutton switch
S11—Spst slide or toggle switch
SCR1-SCR5—HEP320 silicon controlled rectifier
Misc.—Suitable enclosure, multi-conductor cable, spring-loaded clips (10), line cord, solenoid, press-on type, etc.



single-circuit, 10-position rotary switches can be used. At any rate, diodes *D11* through *D14* must be connected to four of the leads from the keyboard matrix. To change any digit at any time, one of the four is moved to another location.

Theory of Circuit Design. The keyboard has 10 (or more) spdt pushbutton switches in series. One end of the series is connected to a source of approximately 6 volts dc and the other end to a higher voltage through capcitor *C8*. When all switches are in the off position, *C8* is charged up to the voltage difference. If one of the pushbuttons is depressed, the charge on *C8* is applied to one of the silicon controlled rectifiers *SCR2* through *SCR5* through one of the diodes *D11* through *D14*. Simultaneously, it is connected to the timing circuit (*SCR1*) through one of diodes *D1* through *D10*. When a pushbutton is depressed, all pushbuttons of a higher number are disconnected and have no effect until *C8* is recharged.

Consider the operation in the most difficult case—when all numbers are the same. Assume the combination is 4444. All four digit register stages are connected to terminal 4 on the keyboard. When *S6* is depressed (to apply the 4), the charge on *C8* is applied to *SCR2* through *SCR5* simultaneously. However, only *SCR2* turns on since they are connected together by coupling capacitors. The latter appear as low impedances across the SCR's during their charging period and prevent the establishment of a minimum holding current. The discharge pulse from *C8* is much shorter than the charging pulse across *C3* through *C5* so by the time the latter are charged up, the gate current available from *C8* is gone. Pushbutton *S6* is then released and *C8* is allowed to recharge. When *S6* is again depressed, the second digit register comes on but the rest are still inhibited by the coupling capacitors. Each subsequent operation of *S6* turns on another stage until the complete code has been entered. For other, non-similar combinations, the inhibition principle of the coupling capacitors is not used but their charging rate determines the fastest rate at which discrete digits can be entered.

Once turned on, the SCR's remain in the conducting state as long as they have the minimum holding current. When cancellation stage *Q1* is turned on, a voltage pulse is applied to capacitors *C3* through *C6* and the SCR's (*SCR1* through *SCR5*)

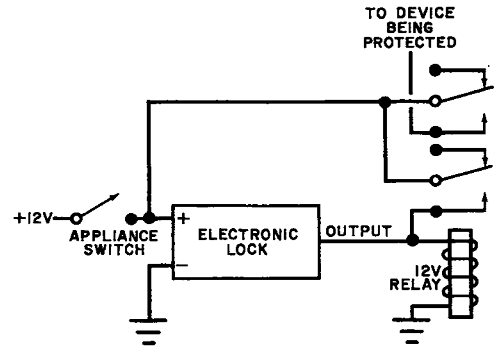


Fig. 2. This circuit is for use with a heavy load. It is also suitable for car or boat use.

are turned off. This occurs when any pushbutton is depressed. However, when the correct pushbutton is depressed *Q1* is inhibited by the charging of one of the capacitors through an SCR. Thus, "good" numbers do not cause cancellation, but any false number cancels everything. Also, if only four numbers are being used, and a fifth number is selected, the register is cancelled.

The timing circuit *(SCR1)* operates on the basis of the time constant of the combination of *R4* and *C2*. When the first correct digit is entered (*SCR2* is turned on), a positive voltage is applied to the anode of *SCR1* and to *R4*. This puts a charge on *C2* so that when the voltage at the junction of *R4* and *C2* reaches the correct potential, *SCR1* is turned on. The timing can be adjusted by potentiometer *R2* to vary between 5 to 15 seconds after *SCR2* is turned on. Capacitor *C6* and resistor *R13* are an extension of the timing chain to permit proper operation of the cancellation stage.

The solenoid driver stage *(Q2)* is a simple transistor switch that is turned on by the final register stage *(SCR5)*. Zener diode *D15* prevents the short pulses that result from the turning on of previous stages from actuating *Q2*. Diode *D18* protects the transistor from damaging back emf from an inductive load.

Applications. If the power requirements of the solenoid that operates the door exceed 24 volts at 300 mA, then a power relay must be used as the turn-on device.

If it is desired to use the lock in a 12-volt application (car, boat, etc.) eliminate *T1* and *D17* and reduce the value of *R16* to about 25 ohms. Remove the lead from the 12-volt supply to the device to be protected, and add the circuit shown in Fig. 2. When the normally used appliance switch is turned on, only the combination lock is energized. The correct combination must be entered to activate the external latching relay. The latter, in turn, applies 12 volts to the device being protected. In an ignition system, for example, substitute the ignition switch for the appliance switch so that the relay applies power to the ignition coil. Be sure the relay is wired to latch in. Otherwise, it will reopen in a few seconds.

Increasing Combinations. To increase the number of possible combinations, increase the number of keyboard pushbuttons or the number of digit register stages. The latter procedure is more effective. If the number of digit register stages is n and the number of pushbuttons is p, the total number of possible combination is p^n. It might be argued that the number of combinations is (p^n—1) but the combination 0000 is acceptable.

For 10 pushbuttons and four register stages, the number of possible combination is 10^4 or 10,000. With one more register stage, the number is 100,000, etc. By contrast, if two pushbuttons alone are added, there are 20,736 combinations.

One interesting possibility is to use 26 pushbuttons labelled A through Z. The number of combinations is then 456,976 and a four-letter word can be used as the code. At six seconds per try, it would take 761 hours to try all possible combinations.

Digit register stages identical to stages *SCR3* and *SCR4* can be added easily. The circuit shown in Fig. 1 can take only two more register stages without some circuit modifications to provide reliable operation. ◈

SCR COMBINATION LOCK

SIMPLE CIRCUIT OPERATES ON 12 VOLTS

BY DAVID E. FAHNSTOCK

LOCK THE DOOR and throw away the key! With an electronic combination lock, you never have to worry about losing the keys or locking them inside. All you have to do is remember a five-number combination. What's more the combination lock described here needs only a 12-volt supply so it can be used on your car or boat with no attachments or problems. The circuit of the lock is unusually simple and uses silicon controlled rectifiers for trouble-free operation.

The basic system, whose schematic is shown in Fig. 1, uses only five pushbutton switches for 120 combinations. However, you can easily add to the circuit to provide for more combinations (720 for six pushbuttons, 5040 for seven, etc.). The combination can be changed easily and quickly if you think someone has learned what it is.

In addition, the system is timed so that, even if the first number is chosen correctly, the rest of them must be chosen within 3 seconds (which can be adjusted) or the process must be started over again.

Theory of Circuit Design. The circuit of the combination lock is essentially five SCR's in series, with the last SCR in the chain controlling a relay. The chain is controlled by a UJT timing circuit and "feedback" from the relay.

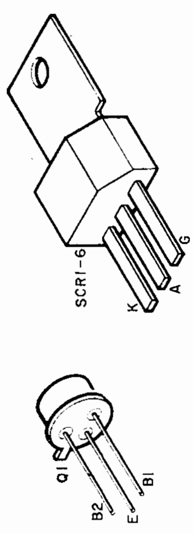
When switch *S1* is operated, its normally open section turns on *SCR2* and it latches in. With *SCR2* on, there is a potential of about 12 volts across *R7*, with the junction of *R7*, *C3* and *SCR2* negative. This voltage is applied to the timer circuit, charging *C2* through *R4* and *C3* through *R5*. Capacitor *C1* also starts to receive a charge through *R1*, and when this charge is sufficient, *Q1* starts to conduct, producing a positive going spike across *R2*. If the relay is de-energized, its normally closed contacts are in series with *SCR1*. Thus, the positive spike from *Q1* causes *SCR1* to turn on. The resistance of *R4* is too high to permit enough current to flow through *SCR1* to latch it in. However, sufficient current is supplied by the charge on *C2* to maintain the latch until C2 is discharged.

While *C2* is discharging, a voltage is developed across *R5* which is added to that across *C3*. This causes the anode of *SCR2* to be at the same potential as its cathode, turning it off. Since *SCR2* is the first in the SCR chain, which it turns off, the complete chain is disabled.

When the various switches are operated before the *Q1* circuit runs out of time, the relay is energized. This simultaneously applies power to the external circuit and opens the cathode circuit of *SCR1*. Thus, as long as the relay is energized, *SCR1* cannot turn off the chain

PARTS LIST

C1—15-µF, 25-volt electrolytic capacitor
C2—10-µF, 25-volt electrolytic capacitor
C3—6-µF, 25-volt electrolytic capacitor
K1—12-volt dpdt dc relay
Q1—2N2646 or HEP310 unijunction transistor
R1—150,000-ohm, ½-watt resistor
R2,R5—270-ohm, ½-watt resistor
R3—470-ohm, ½-watt resistor
R4—100,000-ohm, ½-watt resistor
R6,R8,R10,R12,R14—1000-ohm, ½-watt resistor
R7,R9,R11,R13—10,000-ohm, ½-watt resistor
S1-S5—Spdt pushbutton switch
SCR1-SCR6—Silicon controlled rectifier (GE C106Y2 or C106Y1, or Motorola HEP320)
Misc.—14-conductor cable (may be made from individual wires), suitable mounting plate for switches, mounting for PC board, power relay (optional)



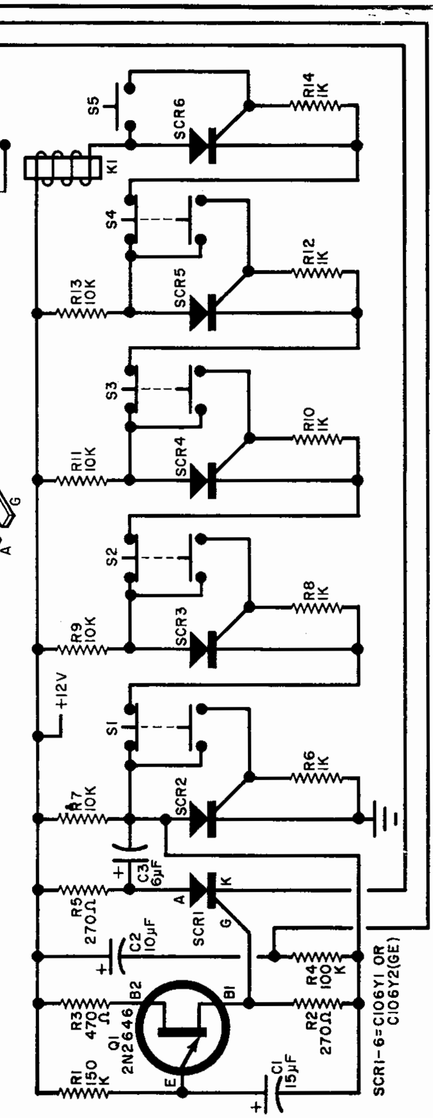


Fig. 1. The pushbuttons of the series SCR circuit must be operated in the correct sequence before timing of Q1 is complete.

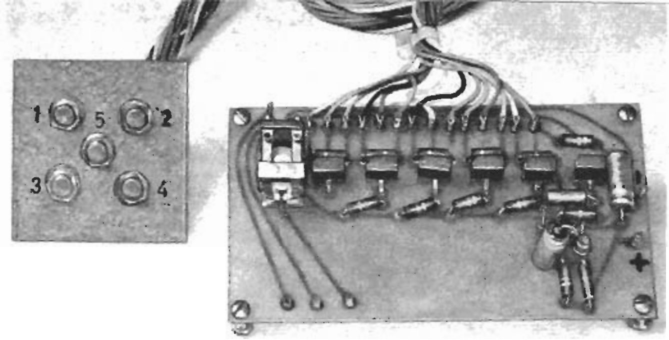
even though *Q1* keeps generating pulses.

To reset the alarm, any switch other than *S5* is operated. For example, if *S3* is depressed, the series circuit is broken and *SCR5* and *SCR6* are turned off, de-energizing *K1*. This enables *SCR1* to operate at the next UJT pulse.

Construction. The circuit is assembled on a printed circuit board whose foil pattern is shown in Fig. 2, which also shows component layout. Install the semiconductors carefully and observe the polarities of the electrolytic capacitors. Use a heat sink (such as long nose pliers) on the leads of the semiconductors when soldering and use a low-power (35 watts) soldering iron.

In the prototype, the printed circuit board and the switch plate were built as two separate units, interconnected by a length of multi-conductor cable. In this way, the electronics board can be hidden, with only the pushbuttons available for use. The pushbuttons can be arranged in any configuration—as long as you know which is which. The combination can be changed by changing the positions of the switches. The combination shown in the prototype is 1-4-3-2-5.

Although the pushbutton panel is mounted in the open, the actual control board should be hidden from view. If higher control power is needed, the output relay can be used to operate a power relay.



If you want to decrease the 3-second timing for completion of the combination, reduce the value of *R1* or *C1*. To make the time longer, increase the value of either of the two components.

The relay used can be any 12-volt type requiring low coil current. If the existing contacts will not carry sufficient current for your needs, use an external relay activated through the contacts of the relay on the board.

The lock described here was designed for use with a 12-volt battery. However, if you want to use it on the 117-volt commercial power line, a simple 12-volt dc supply can be added. ◈

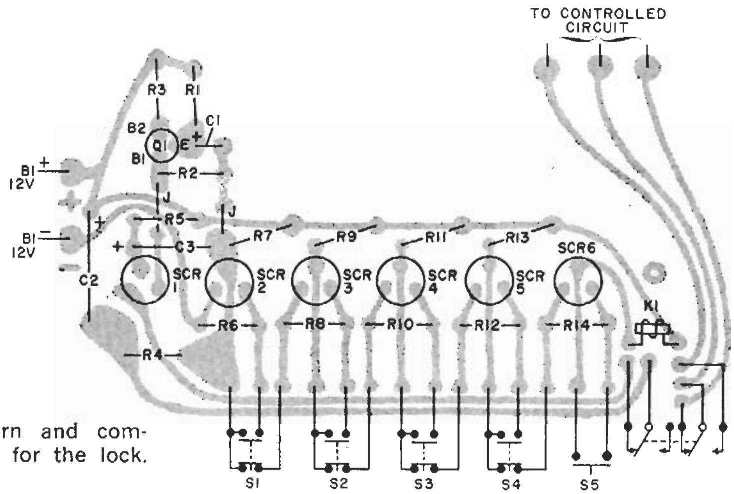


Fig. 2. Foil pattern and component installation for the lock.

Digital combination lock is virtually crackproof

by Dale Platteter
Naval Weapons Support Center, Crane, Ind.

All the sandpaper in the world wouldn't help a safe-cracker open a 15-digit combination lock with the electronic "tumblers" described here. In fact, it could take more than a million and a half years to generate the correct code, if combinations were tried at the rate of one every 10 seconds.

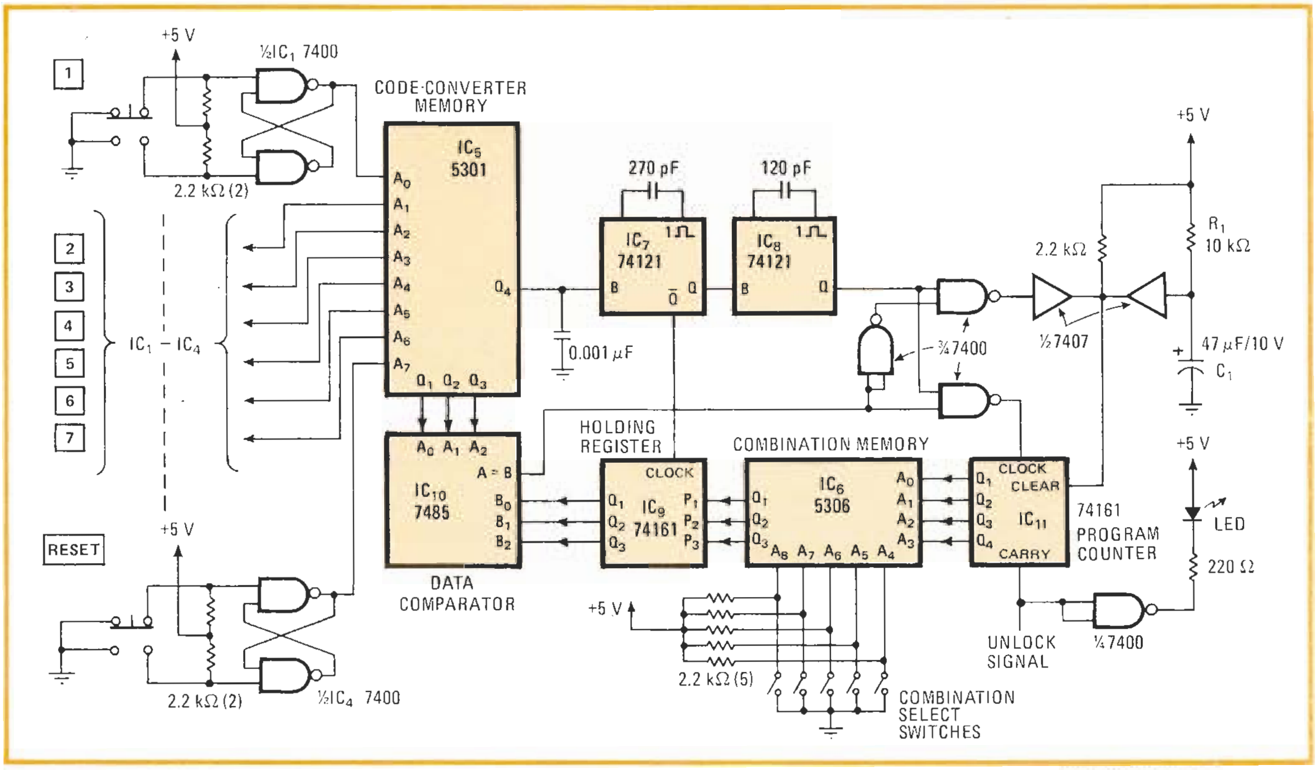
Would-be thieves are further discouraged by the automatic reset of the circuit on entry of any incorrect number—which requires that the entire sequence be re-entered and thus disrupts any orderly trial-and-error approach. In addition, the 512-by-4 bit programable read-only memory that stores the correct combination has room for as many as 32 easily selectable combinations, enabling the code to be changed periodically.

The circuit compares the combination entered with one stored in memory, a digit at a time, and latches a transistor-transistor-logic output high after the entire code is correctly entered. The reset button is pushed before the combination is entered to ensure that the lock is ready for entry of the first digit. The operator also presses it to start over after he thinks he may have made a sequence error.

Only eight possible inputs—the reset and seven numbers—may be encoded, because the binary words representing each are 3 bits long. But it's a good idea to use a standard 0–9 push-button array and allow one, two, or all three of the spare buttons (0, 8, and 9 in this example) to serve as reset. This increases security of the lock, since no unauthorized person will know which button to push for reset.

Integrated circuits $IC_1 - IC_4$ in the figure are quad NAND gates connected as R-S flip-flops to debounce the single-pole, double-throw push buttons. The entered numbers are encoded by IC_5, a Monolithic Memories Inc. type 5301 256-by-4-bit PROM programed according to the truth table in Table 1. This chip was selected to simplify programing, because its background is initialized to logic 1 and the reset code of 111 means most of the addresses will be logic 1s. The unlocking codes are programed into the combination memory, IC_6, an MMI type 5306 512-by-4 bit PROM.

Shown in the figure are code-selecting switches that determine the 5 most-significant bits of the address-data inputs (A_4 through A_8) and hence, which of the possible 32 combinations is selected. The five data lines may be programed from a remote location for the temporary exclusion of particular "key holders," or just to change



Maximum security. A total of 13 integrated circuits is used in this digital combination lock, which requires a sequence of 15 digits to open. The design permits easy changing of sequence length and number of possible digits, and the memory stores up to 32 combinations.

PROM PATTERN FOR CODE-CONVERTER MEMORY (IC 5)

Address									Output				Comments
Binary								Decimal					
A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0		Q_4	Q_3	Q_2	Q_1	
1	1	1	1	1	1	1	1	255	0	1	1	1	No inputs
1	1	1	1	1	1	1	0	254	1	0	0	1	Enter 1
1	1	1	1	1	1	0	1	253	1	0	1	0	Enter 2
1	1	1	1	1	0	1	1	251	1	0	1	1	Enter 3
1	1	1	1	0	1	1	1	247	1	1	0	0	Enter 4
1	1	1	0	1	1	1	1	239	1	1	0	1	Enter 5
1	1	0	1	1	1	1	1	223	1	1	1	0	Enter 6
1	0	1	1	1	1	1	1	191	1	0	0	0	Enter 7
0	1	1	1	1	1	1	1	127	1	1	1	1	Reset
—All remaining addresses—									1	1	1	1	Error input—reset

PROM PATTERN EXAMPLE FOR COMBINATION MEMORY (IC 6)

Address										Output				Digit
Binary									Decimal					
A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0		Q_4	Q_3	Q_2	Q_1	
1	1	1	1	1	0	0	0	0	496	x	0	0	1	1
1	1	1	1	1	0	0	0	1	497	x	0	0	0	7
1	1	1	1	1	0	0	1	0	498	x	1	0	0	4
1	1	1	1	1	0	0	1	1	499	x	0	1	0	2
1	1	1	1	1	0	1	0	0	500	x	1	1	0	6
1	1	1	1	1	0	1	0	1	501	x	1	0	1	5
1	1	1	1	1	0	1	1	0	502	x	1	0	1	5
1	1	1	1	1	0	1	1	1	503	x	0	1	1	3
1	1	1	1	1	1	0	0	0	504	x	0	0	0	7
1	1	1	1	1	1	0	0	1	505	x	0	0	1	1
1	1	1	1	1	1	0	1	0	506	x	0	0	0	7
1	1	1	1	1	1	0	1	1	507	x	0	1	0	2
1	1	1	1	1	1	1	0	0	508	x	1	0	0	4
1	1	1	1	1	1	1	0	1	509	x	1	0	0	4
1	1	1	1	1	1	1	1	0	510	x	0	1	1	3
1	1	1	1	1	1	1	1	1	511	x	1	1	1	Reset

Remainder of memory is used to store 31 additional combinations
x = not used

the combination in the interest of security.

Timing of the circuit is controlled by two monostable multivibrators. When any button or combination of buttons is pressed, the MSB output (Q_4) of the code-converter memory, IC_5, goes high and triggers the first monostable, IC_7. The rising edge of its Q output latches the binary word at the output of the combination memory, IC_6, into the holding register, IC_9, a 4-bit programable binary counter. After 375 nanoseconds, the rising edge of the $\overline{Q}$ output of IC_7 triggers the second monostable, IC_8.

While the Q output of IC_8 is high, which occurs for 165 ns, a 4-bit magnitude comparator IC_{10}, compares the entered and stored words. If the words of IC_5 and IC_6 are identical, the A = B output of the comparator will go high, incrementing the program counter, IC_{11}, another 4-bit binary counter, through the NAND-gates. If the words differ, the program counter is reset, and the entire combination must be entered again.

Upon entry of the correct combination, the program counter advances 15 counts, and the carry output goes high. This is the unlock signal, indicated by a light-emitting diode. It can drive external TTL circuits, or may be buffered to control a solenoid-operated lock.

The program counter could assume any initial state when power is applied. To prevent opening of the lock when power is periodically interrupted, a power-on reset circuit made up of the R_1-C_1 charging network and a buffer clears the program counter for the first few milliseconds.

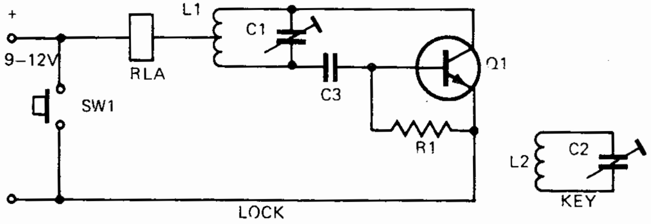
If less security is permissible, the circuit may be simplified to keep down the component count and cost. A priority encoder such as the 74147 may be used in place of IC_5, sacrificing the automatic reset effected when two or more buttons are simultaneously pressed. A smaller memory may be used if 32 different combinations are not needed, and the power-on reset circuit may be eliminated.

A 2-bit word length might even be used, greatly reducing circuit complexity. It still could require as much as 4½ years to crack at the rate of one 15-digit combination every 10 seconds—and burying those three possible input numbers in a complete 0–9 push-button array would increase security many times over. The system is completely expandable—word length (hence number of inputs) and sequence length are easily adjusted to suit one's needs.

A PROM sample programing pattern for the combination 174265537172443 is shown in Table 2. Each of the 15-digit combinations is allocated 16 bits of memory, leaving the last bit unused. It is beneficial, as shown, to program 111 into these locations (since the first address is 0, the 16th bits are in every 2^n-1 address, where n is greater than 3—for example, 15, 31, 63, etc.). Reset will then occur automatically when any digit is pressed after the lock has been opened. □

Designer's casebook is a regular feature in Electronics. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.

SIMPLE ELECTRONIC LOCK



Operation is very simple, when the key is brought near the lock, providing L1–C1 have the same resonant frequency as L2–C2, the reed relay will open as the key absorbs energy from the lock. After each operation of the lock, it should be reset by a short press on the reset button.

Setting up is best done with a resistor in place of the relay with a voltmeter across it, making the operating range of the circuit more apparent.

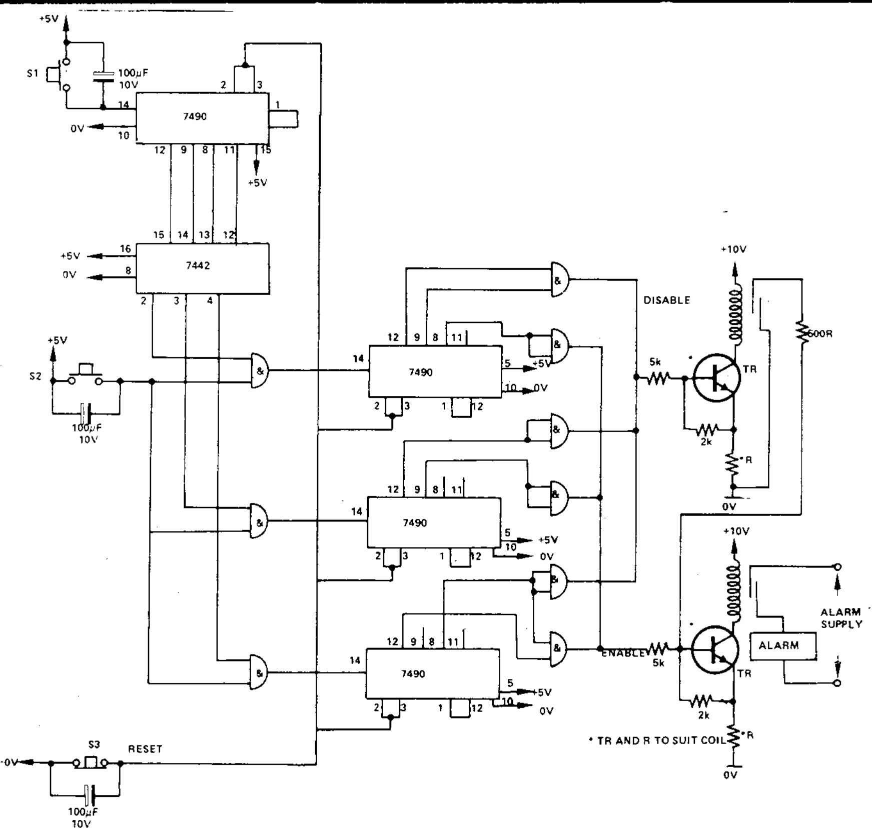
PARTS LIST

Q1	**BC108**
C1/C2	**250pF trimmers**
C3	**1000pF ceramic**
L1/L2	**80 turns 34swg on 3/8" diameter ferrite (L1 is tapped at 40 turns)**
R1	**27k**
RLA	**Reed relay resistance around 5k**
SW1	**Push-to-make switch**

P.S. Found that ETI's TIC-TAC radio could be used as key!

Electronics Today International, 36 Ebury Street, London SW1W 0LW.

COMBINATION LOCK



The circuit and switching system is simplified by the use of a multiplex system. S1 inputs pulses to the decade counter 7490. The resulting BCD is decoded by the 7442. It is the decimal output of this which carries out the multiplexing via the AND-gates.

S2 inputs pulses which are transferred to the other 7490 decade counters by the AND-gate multiplex system. The BCD output from the 7490's is taken to the AND-gates whose outputs control the Alarm 'Disable' and 'Enable' switch system.

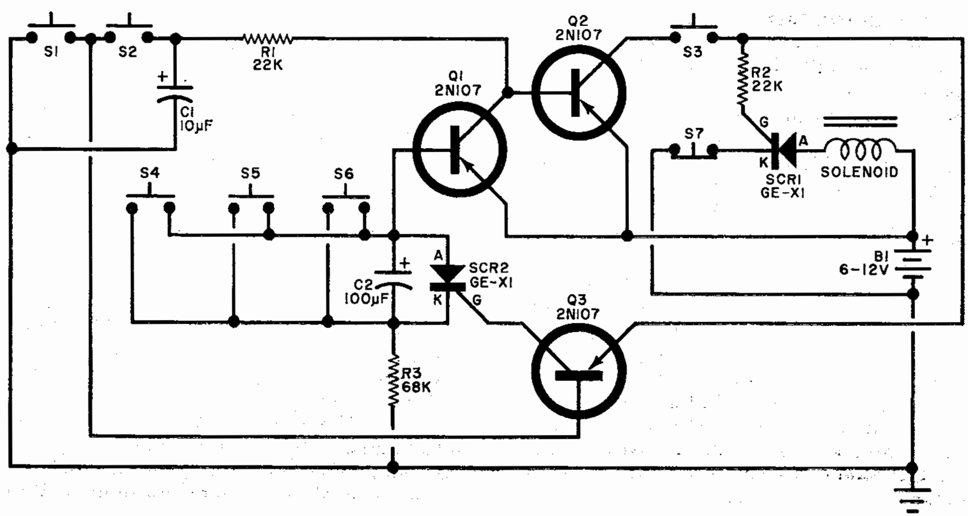
The 'Disable' function effectively prevents TR2 from being biased on and hence prevents the 'Enable' Reed relay from working.

This circuit has several advantages over conventional electronuc combination locks as only two switches need be installed on the object to be guarded, regardless of the number of figures in the combination. The value of the example combination is 314. The alarm is triggered if any of these digits is exceeded in value. While the circuit is capable of directly driving an actuator it is recommended that it is only used to disable an alarm system — conventional locks doing the actual locking. (To operate the example the switch sequence would be: S1, S2, S2, S2, S1, S2, S1, S2, S2, S2, S2.)

Useful Circuits. Fascinated by Busse's electronic combination lock (see "Build A Cryptolock" by James G. Busse, POPULAR ELECTRONICS, January 1971), reader Walt Isengard (Box 511, Grove City College, Grove City, PA 16127), an electrical engineering student, studied the circuit in some detail. Walt finally concluded that the lock would operate if the proper three combination switches were depressed simultaneously. If a potential thief had read the magazine article, then, he would be able to operate the lock in less than ten minutes, assuming that he tried all possible combinations and allowed for the maximum penalty delay after each wrong combination. With only average luck, a thief would be able to "break" the combination in half that time.

Undeterred, Walt decided to modify Busse's original circuit to reduce its vulnerability, while still retaining its basic operational characteristics, minimal switch requirements, and overall simplicity of design. His circuit is shown in Fig. 1.

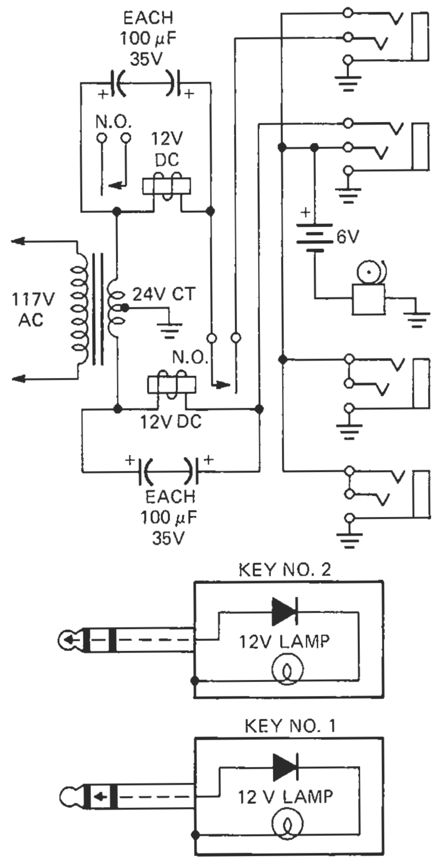
Fig. 1. Based on a circuit originally appearing in January, 1971, this variation carries the electronic lock one step further and makes it even more burglar-proof.



letters

DIODE LOCK

I found Matt Mandl's article on "Switching Tricks With Silicon Diodes", **Radio-Electronics,** May 1972 very interesting; especially the electronic keys. Here is a combination lock that has two electronic keys. A stereo phone plug for each key, and four stereo jacks for keyholes were used. Key number one has its diode connected to the center of the plug, and key number two has its diode connected to the tip of the plug. With the keys constructed this way, the right key must be inserted in the right keyhole. An alarm



will sound if either key is inserted in any keyhole other than the right one. Also if a false key or a shorting wire is used the alarm will sound. Either key can be inserted first, but both keys must be in the lock at the same time. Of course any number of keyholes can be added.

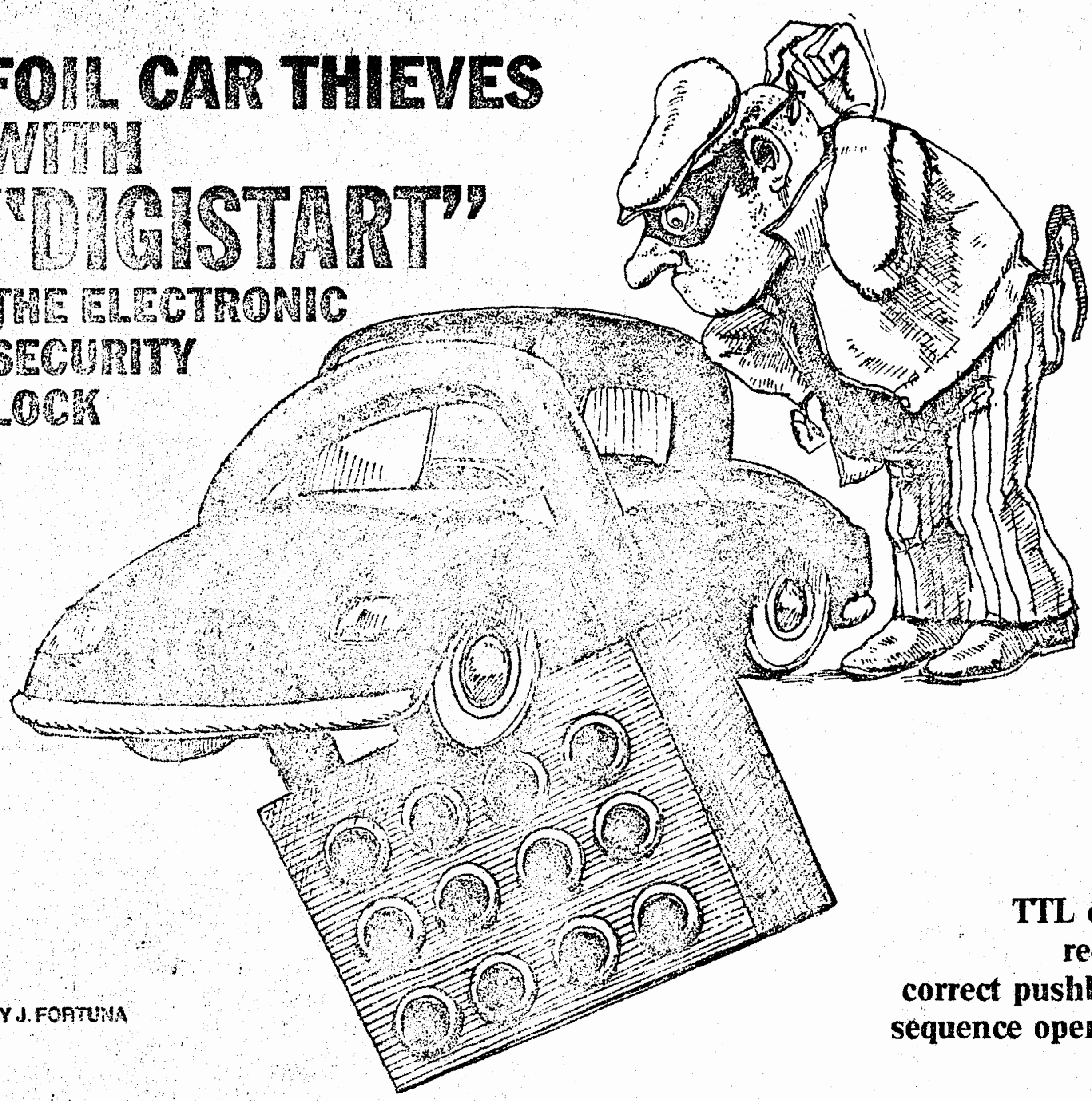
The lamps in the keys have two functions, they work as a fuse and as a reminder not to leave them in the lock.

THOMAS E. SHAFFER
Dwight, Ill.

(continued on page 22)

FOIL CAR THIEVES WITH "DIGISTART"

THE ELECTRONIC SECURITY LOCK



TTL circuit requires correct pushbutton sequence operation.

BY J. FORTUNA

DIGISTART can be used as a "keyless" security system for a vehicle or boat starter system, an electrically operated door, or any system that requires an electrical signal to activate.

This new digital security system uses a series of pushbutton switches that must be operated in a particular sequence, otherwise it will not operate. Even when the correct combination is inserted, the user must operate still another switch, and then he gets only between 5 and 6 seconds (adjustable by the installer) to activate the circuit.

Although this article uses a vehicle starter solenoid as the external electrical system being controlled, any type of 6-volt door solenoid can be activated. It can even be used to control a garage-door lifting motor, if the low-power contact relay within this circuit is used to operate a power relay whose contacts can take the current requirements of the door lifting motor.

How It Works. As shown in Fig. 1, the Digistart consists of five conventional JK flip-flops (*IC1,IC2,IC3*), whose Q-outputs are fed to 8-input NAND gate *IC4* with the three unused inputs connected in parallel with one of the used inputs. (This allows for further expansion if desired.) The output of *IC4* triggers a one-shot (*IC5*) whose on time is determined by *R6-C1*. The positive-going output from *IC5* turns on transistor *Q1* to energize *K1* in its collector circuit. When relay *K1* is energized, it completes the circuit between the system 12-volt bus, and the vehicle ignition key so that the starter solenoid can be operated.

However, for the Digistart to operate, each of the flip-flops must be "clocked" in order—left to right in the schematic, and this is done by operating the normally open pushbutton switches *S1* through *S5*. Each of these switches is connected to the clock (C) input of its associated flip-flop, and governs the flip-flop operation in accordance with the 74107 truth table shown in Fig. 2.

Initially, the system must be manually cleared by depressing one of the *S6* through *S11* "clear" pushbuttons. Once this is done, the Digistart will clear itself after each operation since the clear line is connected to the output of *IC5*, not-Q, which goes to ground after each operation. Once cleared, all the not-Q outputs will be high, and all the Q outputs will be low.

A clock pulse applied to the C input of *IC1A* (via *S1* closure and release) will cause its Q-output to go high since its unterminated J-input is high. Since the *IC1A* Q-output is connected to the *IC1B* J-input, the *IC1B* Q-output will go high when its C-input is clocked. This sequence continues down the line to *IC3*.

When all the Q-outputs are high, NAND gate *IC4* is enabled. When *IC5* gets toggled, the Q-output goes high, and the not-Q output low. This clears the

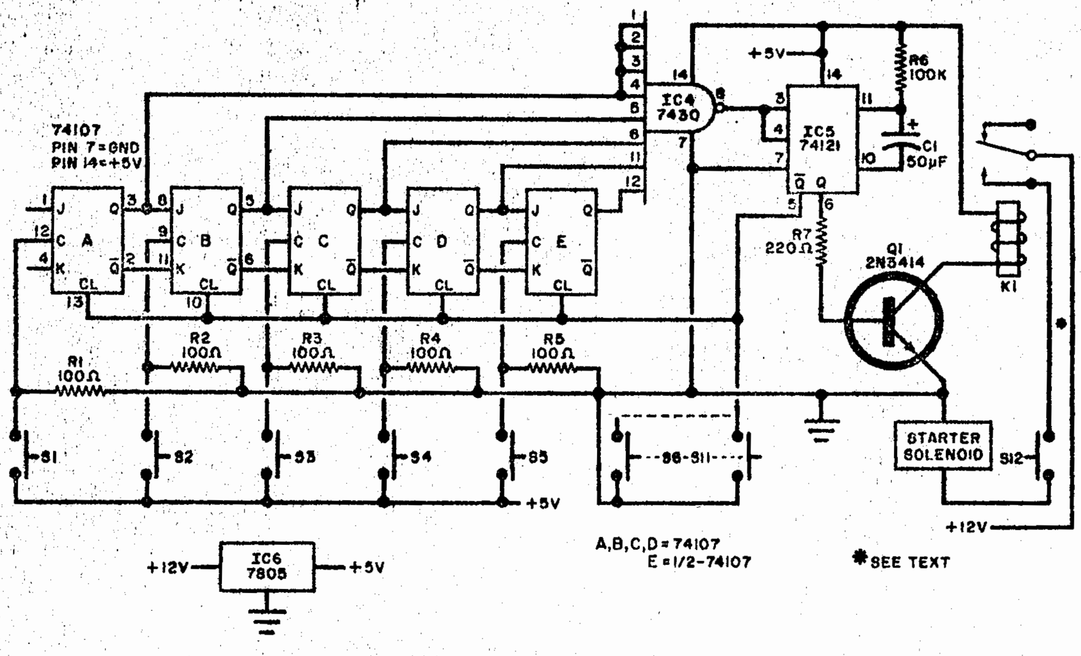


Fig. 1. Switches S1 through S5 sequentially "clock" the flip-flops and operation of S6 through S11 will shut the system down. Once activated, 5 seconds remain to start the controlled system.

PARTS LIST

C1—50-µF, 20-V electrolytic capacitor (see text)
IC1,IC2,IC3—74107 dual JK flip-flop
IC4—7430 8-input NAND gate
IC5—74121 one-shot multivibrator
IC6—5-volt regulator (7805 or similar).
K1—5-volt dc relay, spst (see text)
Q1—2N3414 transistor
R1 through R5—100-ohm, ¼-W resistor
R6—100,000-ohm, ¼-W resistor
R7—220-ohm, ¼-W resistor
S1 through S11—Normally open, momentary-contact pushbutton switch (Grayhill miniature, or similar)
S12—Spst slide or toggle switch
Misc.—Suitable enclosure, panel for switches, mounting hardware, etc.

flip-flops by the clear bus. The Q-output of *IC5* remains high for the duration of the time constant determined by *R6-C1* (which can be altered as desired). In the schematic, the time interval will be about 5 seconds. During this time interval, transistor *Q1* is saturated, and energizes *K1*. This completes the circuit to the starter solenoid—and if *S12* is held closed—the starter can be operated. When the timing interval has elapsed, the Q-output of *IC5* goes low, transistor *Q1* cuts off, the relay opens, and the circuit to the starter solenoid is open, thus the starter will not operate.

INPUTS				OUTPUTS	
CLEAR	CLOCK	J	K	Q	$\bar{Q}$
L	✱	✱	✱	L	H
H	⎍	L	L	Q_0	$\bar{Q}_0$
H	⎍	H	L	H	L
H	⎍	L	H	L	H
H	⎍	H	H	TOGGLE	

✱DON'T CARE

Fig. 2. Truth table for the 74107 flip-flop.

Note that besides the five "clock" pushbutton switches, there are six (more or less as desired) pushbutton switches that when operated, only serve to reset the Digistart and thus disable it. If all 11 switches (unmarked of course) are mounted on a small panel, the user must know which switch to operate, in what order, and if he "misses" any part of the sequence, or hits a reset switch, the Digistart will shut down.

Construction. The circuit can be assembled on a small piece of perforated board using sockets for the IC's and transistor, and small pins to support the six resistors and one capacitor.

Relay *K1* should be selected so that its contacts can handle the vehicle starter solenoid current. The wiring between the relay contacts and the starter solenoid should also be capable of handling this current. The five-volt regulator can be attached to the metal chassis for use as a heat sink.

The pushbuttons are mounted as a group on a small panel using any arrangement desired (such as that used for the prototype as shown is Fig. 3).

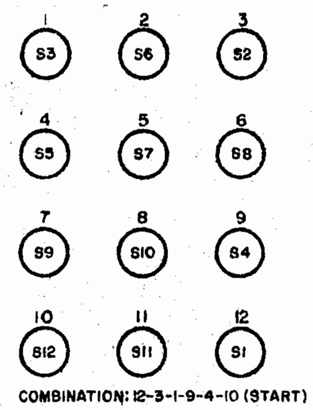


Fig. 3. Typical layout for a Digistart switch panel.

If desired, up to three more flip-flops can be added (along with their "clock" pushbuttons, 100-ohm clear resistors, using the extra inputs of *IC4*), and *S12* can be omitted. You can also elect to use two pushbuttons in series for *S12*. If you want to change the timing interval, select values for *R6-C1* in accordance with T=*RC* where T is in seconds, *R* is in ohms, and *C* is in microfarads. ◇

Electronic combination lock offers double protection

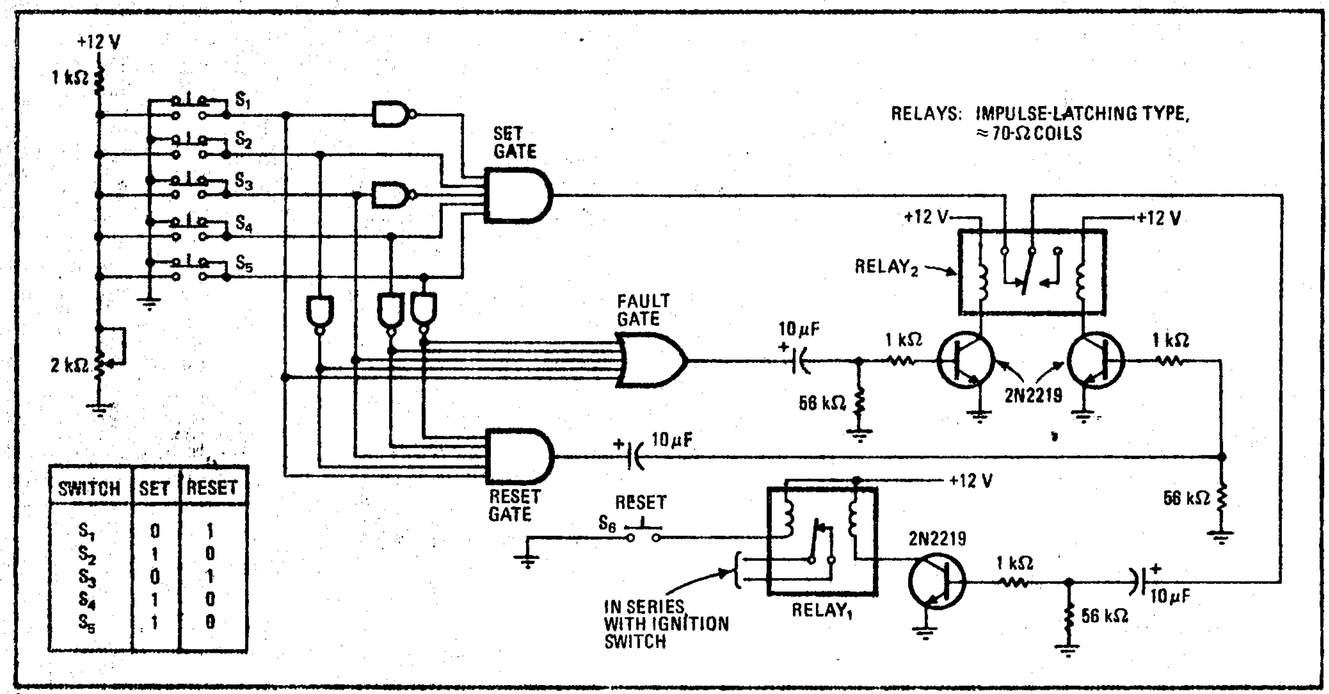
by Louis F. Caso
Bethpage, N.Y.

If you need a doubly safe lock, try the electronic combination lock shown here. It will not unlock unless the correct combination of switches is depressed, and if the wrong combination is chosen, the lock will not open until it is reset with another combination.

The circuit in the figure is intended for installation in an automobile, but it can be easily modified for other applications. When the correct combination of switches S_1 through S_5 is depressed, the output of the SET gate goes to logic 1, closing the contacts of $RELAY_1$. When the car's ignition is turned off, this relay should be reset (contacts opened) by using switch S_6.

To open (set) the lock, switches S_2, S_4, and S_5 are depressed simultaneously. If an error is made, the output of the FAULT gate goes to logic 1, and the contacts of $RELAY_2$ will open. When this happens, the lock must be reset before the opening combination can be used again. Switches S_1 and S_3 are depressed simultaneously to reset the lock.

Any secret combination of push buttons can be selected by arranging the switches as desired. For most applications, the multiple-input logic gates can be obtained by interconnecting standard dual-input gates. □



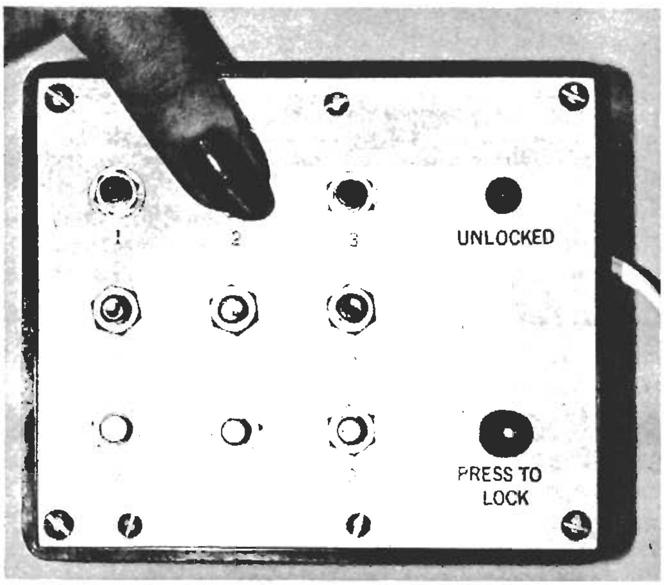
SWITCH	SET	RESET
S_1	0	1
S_2	1	0
S_3	0	1
S_4	1	0
S_5	1	0

Safe and sound. To open this electronic combination lock, depress the correct combination of switches S_1 through S_5. But if an error is made, the lock must be reset with another switch combination before it can be opened again (The switches are depressed simultaneously.) The circuit shown here is for locking an automobile ignition, but it can be readily adapted for other uses.

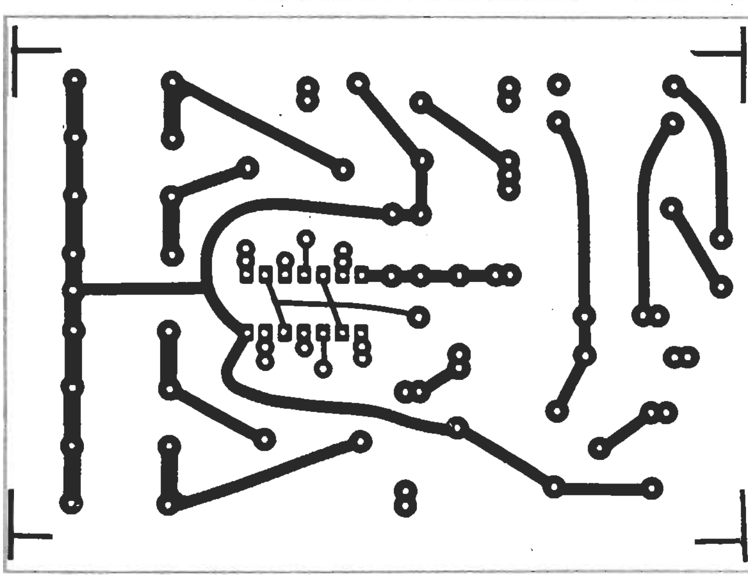
ELECTROLOK

HAVE YOU EVER stopped to consider just how many locks there are in the average house? Take a census in your own home; the number will probably surprise you. Most of the locks you find—in fact, probably all of them—will be mechanical. While such devices are fine for the majority of household applications, sometimes what you really need is an *electronic* lock. For example, suppose you have a favorite piece of electronic equipment; something that's expensive and delicate. To make sure that no one else can meddle with it—whether it be a photographic enlarger, an amateur transceiver, a stereo system or a computer—you need to prevent the power from being turned on. Although you might lock things up mechanically, an electronic lock is the easier, more effective solution.

Features. Presented here is a simple, inexpensive, electronic combination lock that's really tough to crack. To open the lock and turn on the protected apparatus, you must enter a 5-digit numerical code by means of pushbutton switches. If you enter the wrong code, the system will disable itself for about 15 seconds, during which time the lock cannot be opened even if the correct combination is entered. Furthermore, the code must be entered quickly; if someone dawdles more than a second or so between entries, the lock won't open, even with the right code. All these features add up to a system that is both convenient (no key) and difficult to beat.



Electrolok may be assembled in any convenient cabinet, or combined with an easily available surplus telephone-type touch-pad to give a real finished look. Make sure that the touch-pad you get has discrete-wired switches. Other types (matrix) might not be compatible with Electrolok's wiring arrangement.



This is the full-scale template for Electrolok's PC board. Using the PC board will allow more compact project.

Circuit Function. Let's see how the lock works by taking a look at the schematic diagram. A half-wave-rectifier system consisting of T1, D1, and C1, supplies power to the lock. Resistor R1 and zener diode D2 do not regulate the supply voltage. Instead, they just clip any voltage spikes generated on the power line, thus protecting U1. You'll note that there is no power switch on the primary (117 VAC) side of T1. That's because standby power consumption is so minute, that a power switch was deemed unnecessary. (However, you might wish to include one. In that case, the primary power switch would have to be turned on before the 5-digit combination could be entered.)

Capacitor C3 is charged up by supply current flowing through resistor R2. Let's assume that enough time has elapsed after the application of AC power for C3 to have become fully charged. In that case, a logic "1" input is seen by pins 2, 5, 9 and 12 of the four AND gates comprising U1. The result is that each AND gate behaves as a very-high-gain amplifier. Specifically, if the voltage presented to the one remaining input of any gate exceeds half the supply voltage (approximately), the gate's output will be high (at supply potential). With inputs of less than half the supply potential, the output remains low (grounded).

In this lock circuit, the four AND gates are arranged to form a sort of "bucket brigade"—only it's not water that's being transferred, it's an electrical charge instead. When S1 is pressed momentarily, capacitor C4 charges rapidly to supply potential through R5. Once S1 is released, C4 begins to discharge through R6, taking a second or so to discharge half way. Since AND gate A's input (pin 1) reads the voltage on C4 through R5, we know that the gate's output (pin 3) is going to be high for about a second, which is

This electronic combination lock keeps your equipment safe

by Walter Sikonowiz

the time it takes C4 to discharge half way. Therefore, if we press S2 before the one-second interval has elapsed, it is possible to charge capacitor C5 to supply potential. (If we dawdle more than a second, however, gate A's output will have dropped to ground potential, and no charging of C5 will be possible.)

Assuming that C5 has been charged, it is obvious that gate B's output (pin 4) will remain high for the second or so that it takes R8 to discharge C5 half way. Therefore, we can now charge C6 by pressing S3 before another second goes by. Applying the same reasoning, it should then be possible to charge C7 if S4 is pressed quickly enough. Finally, pressing S5 within a second of S4 will send a current from U1-D's output (pin 11) through R13 into the gate terminal of the SCR (Q1). This causes Q1 to latch in a conducting state, thereby allowing current to flow through relay K1 and light-emitting diode LED1. Once actuated, the relay's contacts close and supply power to whatever device you wish to control. The lighting of LED1 alerts you to the fact that the circuit is unlocked.

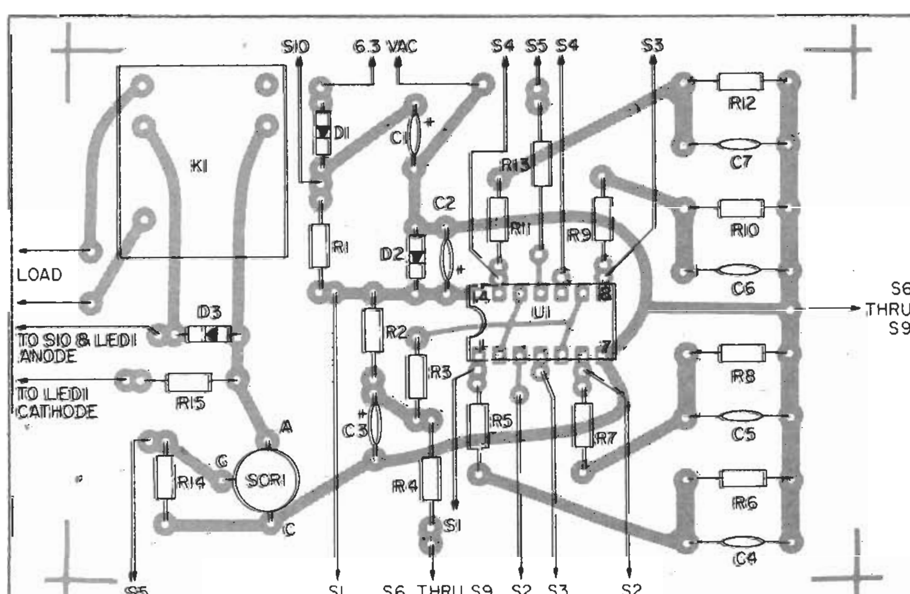
To lock the circuit once more, it's necessary to momentarily interrupt the flow of anode current through the SCR. This can be done by pressing S10. Once the anode current has been interrupted, Q1 will not conduct until the proper code has once again been entered.

From the schematic, you can see that besides the five pushbuttons required to open the lock, there are four extra dummy switches; S6 through S9. These serve the purpose of foiling any attempt to pick the lock. Whenever one of the four dummy switches is pressed, C3 gets discharged quickly through R4. While C3 is recharging through R2 to a potential greater than half the supply voltage—an interval of 15 to 20 seconds on the average—the bucket brigade remains disabled and all AND-gate outputs are locked at ground potential. Therefore, any code, even the correct one, entered while C3 is insufficiently charged, will have no effect. Once a would-be lock picker touches a dummy switch, it is very probable that he will press another dummy before C3 has been sufficiently recharged. This means that the bucket brigade remains inoperative for 15 seconds more. Consequently, the chances of cracking the code by punching in numbers at random are exceedingly slim.

Numbers may be assigned to S1 through S9 at will. Therefore, should someone break the code (an unlikely but still possible occurrance), you can easily change the combination by rewiring some of the switches.

Although the pushbuttons used in the prototype were small discrete units, you might wish to employ a calculator-type keyboard instead. If you do, make sure that the board you choose has individually accessible switch contacts. Some keyboards have switches wired in a matrix arrangement, which would be useless here.

Select a relay that can handle the maximum expected current drawn by the equipment you intend to control. The device used in the prototype is rated for an RMS current of one amp @ 117 VAC. For heavier loads, use the Circuit Specialists #D1-966, which can



Here's a top view of the PC board showing the component locations. All parts except F1, switches, LED 1, and power transformer mount here. We recommend use of an IC socket.

e/e ELECTROLOK

handle three times as much current. When using the latter relay, however, be sure to modify the circuit board, which was designed specifically to accommodate the pin arrangement of the prototype's Radio Shack device.

Construction. Construction of the lock should be simple; either perfboard or a printed circuit will do. For those who choose PC construction, suitable templates are featured elsewhere in this article.

Use a low-heat (25-watt or less) iron and resin-core solder for all the electrical connections. It is recommended that you *not* solder U1 directly into the circuit. Instead, use an IC socket, and install the integrated circuit into the socket only after all soldering and construction are completed. This will minimize the chances of accidentally damaging your IC.

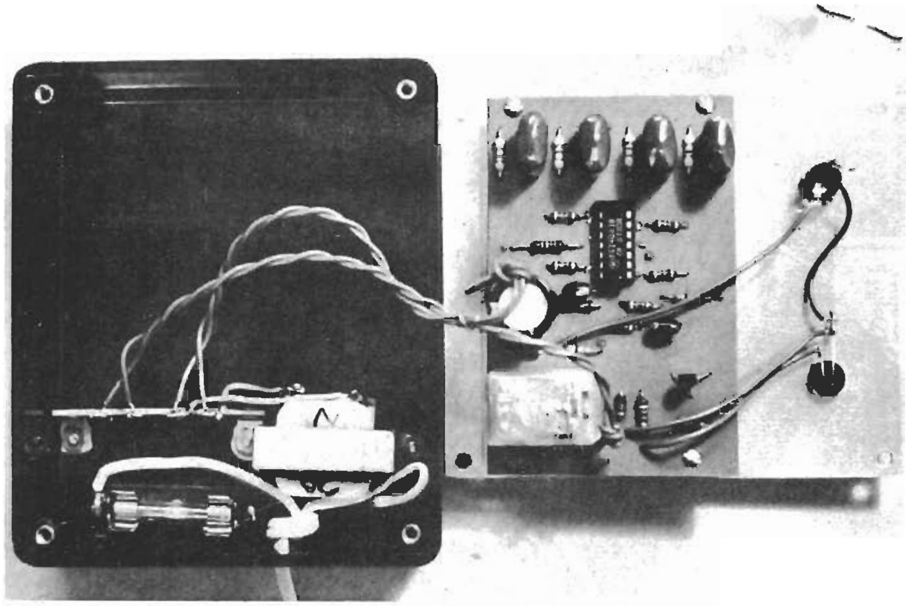
Be certain to observe proper polarities with all the diodes, Q1, U1, and all the capacitors.

Almost any small cabinet can be used to house the lock circuit. In the prototype, a 2 by 5 by 4-inch plastic cabinet was used, but if you lack experience in small-scale construction, you may be more comfortable with a larger box.

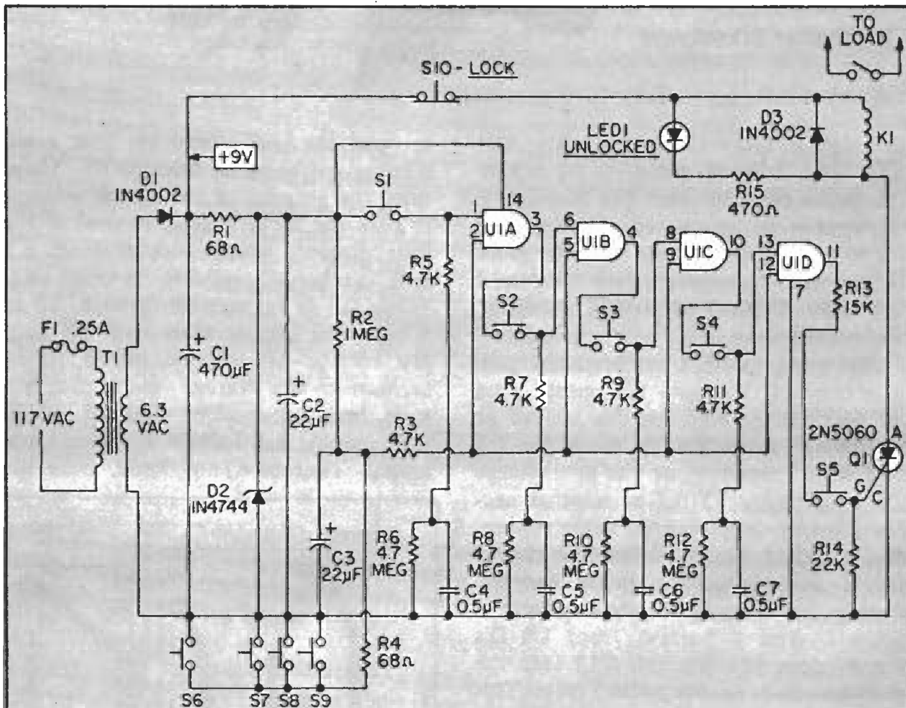
Operation. When construction is complete, you're ready to check out your work. In these initial stages of testing, do *not* connect any load to relay K1. Plug the circuit into the AC line, and wait one minute. This is more than enough time for C3 to charge up completely. Now, quickly punch in the correct combination (according to the way you've wired up the pushbuttons). After the entry of the last digit, LED1 should light up, and K1 should emit a faint "click" as it pulls in.

Once you have successfully unlocked the device, press switch S10. The circuit should return to its locked state, and LED1 should cease to glow. Next, hit one of the dummy switches, followed by the correct combination. Your circuit should be unaffected by the code and remain locked.

Final Touches. When proper operation of the lock has been verified, you can proceed to wire K1's contacts into the load circuit. In addition to the applications already suggested, you might consider using the lock to control an electronic garage-door opener or burglar-alarm system. In fact, there are so many ways to use the circuit, that you may wish to build several units—each with a different combination. ■



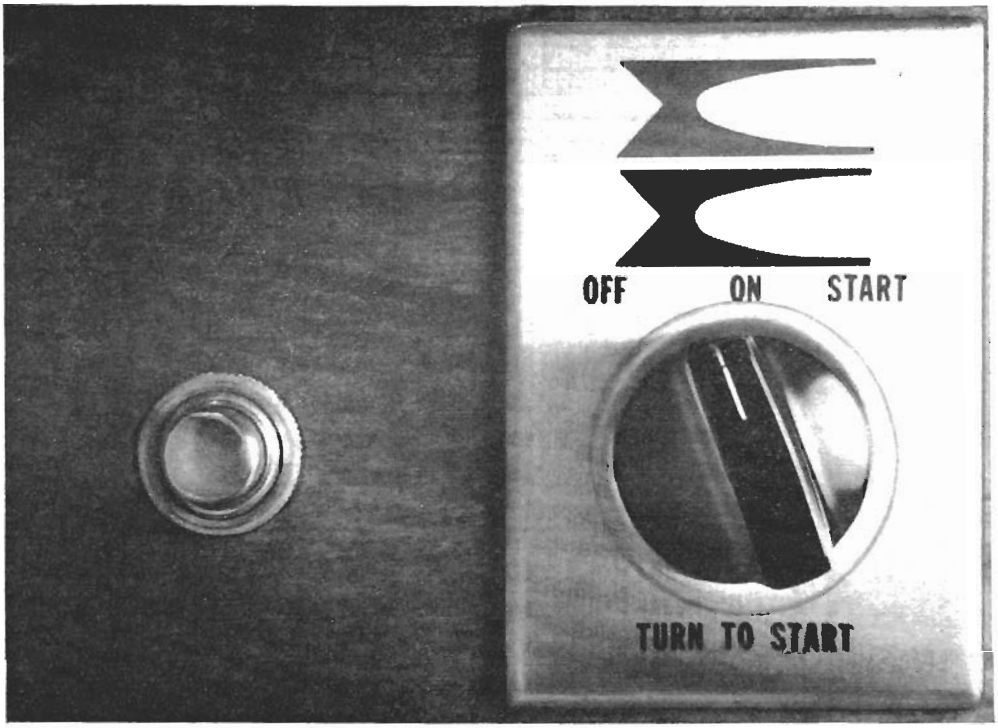
The prototype Electrolok with the cover removed, shows the placement of the PC board and off-board components. No power switch is used, as idle current is very low in the operating mode. You can add an SPST switch in series with a transformer primary lead.



PARTS LIST FOR ELECTROLOK

C1—470-uF electrolytic capacitor, 35-VDC
C2, C3—22-uF tantalum capacitor, 25-VDC
C4 to C7—0.5-uF mylar capacitor, 25-VDC
D1, D3—1N4002 diode
D2—1N4744 zener diode
F1—0.25-amp fuse (3AG type)
K1—relay with 6-VDC, 500-ohm coil (Radio Shack #275-004 or Circuit Specialists #DI-966—see text)
LED1—small LED rated 20-mA @ 1.75-VDC
R1, R4—68-ohm, ½-watt resistor, 10%
R2—1-megohm, ½-watt resistor, 10%
R3, R5, R7, R9, R11—4,700-ohm, ½-watt resistor, 10%
R6, R8, R10, R12—4.7-megohm, ½-watt resistor, 10%
R13—15,000-ohm, ½-watt resistor, 10%
R14—22,000-ohm, ½-watt resistor, 10%
R15—470-ohm, ½-watt resistor, 10%
SCR1—2N5060 silicon-controlled rectifier
S1 to S9—SPST normally open pushbutton switch
S10—SPST normally closed pushbutton switch
T1—power transformer; primary rated 117-VAC, secondary rated 6.3-VAC @ 100-mA
U1—Motorola MC14081B quad AND gate
MISC.—suitable enclosure, line cord, IC socket, hookup wire, solder, etc.

(Note: U1 is available from Circuit Specialists, Box 3047, Scottsdale, AZ 85257.)



ELECTRONIC COMBINATION IGNITION LOCK

SURE-FIRE PROTECTION FOR YOUR BOAT

BY JOHN BEISWENGER

DURING THE PAST FEW YEARS, there have appeared in print a wealth of anti-theft/anti-intruder lock projects for the home and automobile. But as one boat owner so aptly put it: "Doesn't anyone know or care that boats get stolen, too?" Well someone does know and has done something about curtailing boat thefts by designing an "Electronic Combination Ignition Switch" just for marine engines.

Aside from providing theft protection, the electronic combination switch saves a lot of frustration if you have a knack for forgetting rarely used boat keys or drop your keys into the drink. The reason is that there just aren't any keys to remember or guard. The lock works essentially like a mechanical combination lock.

Inexpensive and easy to build, the lock is designed to operate with any manual or electric start outboard motor that includes, as an accessory, the conventional off/on or off/on/start switch characteristic of most such systems. The lock is also designed to operate positive ignition engines, such as the inboard and inboard/outboard types.

About The Circuit. The Electronic Combination Ignition Lock is, as mentioned above, very similar in operation to its mechanical counterparts. Numbers must be "dialed in" in a set sequence to "open" the lock. (The lock does not actually open; instead, it actuates a battery of relay contacts.)

In the schematic diagram (Fig. 1), the combination for the prototype lock

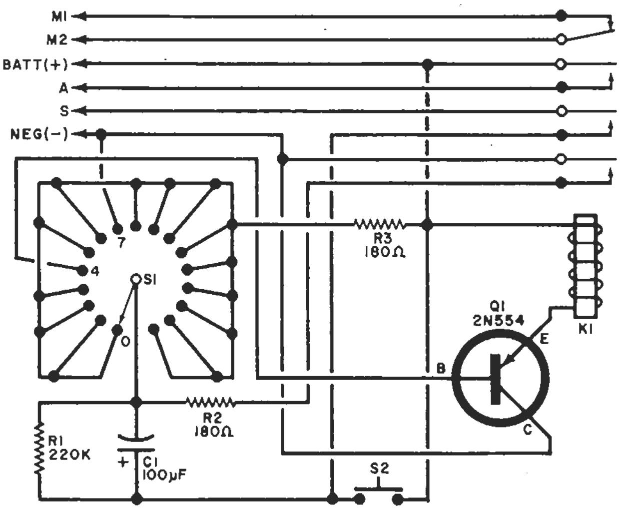


Fig. 1. Combination sequence is 7-4. Simple rewiring of S1 allows selection of any other two-digit combination desired.

PARTS LIST

C1—100-μF, 15-volt electrolytic capacitor
K1—4p.d.t. 12-volt d.c. relay with 5-ampere contacts (Potter & Brumfield No. GA17D or similar)
Q1—2N554 or HEP-230 transistor (Motorola)
R1—220,000-ohm, ½-watt resistor
R2,R3—180-ohm, ½-watt resistor
S1—17-position non-shorting rotary switch (Mallory No. 31117J or similar)
S2—S.p.s.t. momentary-action pushbutton switch
1—2¼" x 2¼" x 4" aluminum utility box
Misc.—Hardware, switch knob, hookup wire, solder, etc.

is 7-4, in that order. Any attempt to open the lock by feeding in a 4-7 combination will meet with frustration. Switch *S1* is the combination dial; with it, the operator enters his combination. After each number, in its proper sequence, is dialed, momentary-action pushbutton switch *S2* must be depressed to "program" the actuating circuit consisting of transistor *Q1* and relay *K1*.

When 7 is dialed into the lock and *S2* is momentarily closed, capacitor *C1* charges up to approximately the supply voltage level. Then, when *S1* is dialed to position 4 and *S2* is again depressed, the charge on *C1* is applied to the base of *Q1*, triggering into conduction the transistor, which energizes relay *K1*.

The operator has approximately ten seconds in which to dial in the second

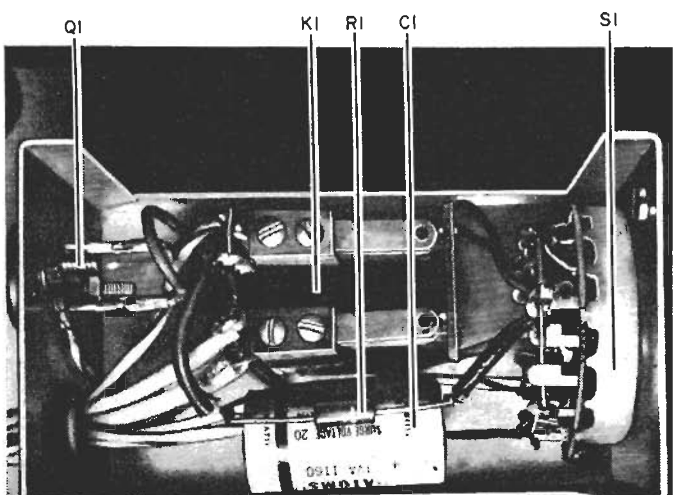


Fig. 2. After mounting components in small utility box or under dashboard, try to waterproof circuit to prevent relay and switch contact corrosion.

number after actuating the first to have the lock open. Any longer delay, including the depressing of *S2*, will allow the charge across *C1* to bleed off through *R1*, resulting in an insufficient potential to trigger on *Q1*.

As *Q1* conducts heavily and *K1* energizes, the top relay contacts open; the second, third, and fourth, in descending order, close to complete various functions. The lowest contacts supply a negative bias to the base of *Q1* via position 4 of *S1* continuously. The next set of contacts puts *S2* directly into the start solenoid circuit. The remaining set of closed contacts supplies power to the boat's accessories. The top contacts simply open the grounding circuit of the boat's motor magnetos. (Note: If the boat motor is an inboard or inboard/outboard type, eliminate the top contacts and let the second set of contacts supply power to the ignition and accessories.)

Now, to "close" the lock, all you need do is switch *S1* out of position 4. This will remove the bias from *Q1* and allow *K1* to deenergize immediately, shutting down all systems.

How To Install. Since the project is so simple, the only construction information necessary is shown in Fig. 2. This is only a suggested layout; if you wish, you can use your own ingenuity to house and mount the circuit. One thing, however, is worth pointing out: Do not put numerals at the knob pointer locations for *S1*'s positions. Plan to count the clicks instead. This will preserve the security of your lock combination if someone is watching you open it.

Now, referring to Fig. 1, connect the ground lead of your boat's magneto ground wire to the uppermost contacts of *K1* (if used). The remaining system wires connect to the other contacts on *K1* as indicated by the original key switch terminal markings. —30—

ELECTRONIC COMBINATION LOCK

There's only one chance with this unusual combination lock — any incorrect setting will sound an alarm!

THIS electronic combination lock is a simple device which may be used as a security device, or just for amusement. Very few parts are required and most of them will probably already be in the experimenter's junk box.

A total of 1000 combinations are provided by three, eleven-way switches, only one setting out of the possible 1000 will actuate the output relay (and hence any other device required to be operated). More combinations may be provided by simply wiring further switch banks in series with the existing three.

To prevent people from just rotating switches until the lock eventually opens, "lock" and "unlock" push buttons have been provided. Thus once a switch selection has been made the "unlock" button must be pressed to open the lock. Should *any* incorrect selection be made the alarm will sound. The lock push button must then be pressed to reset the alarm. There is therefore no way in which an intruder can test different combinations, without the alarm sounding, except in the 1 in 1000 chance of selecting the correct combination the first time.

CONSTRUCTION

Construction is very simple. We built our unit into a metal box, but if the unit is meant to prevent access to somewhere, or something, (such as the biscuit tin!) it could well be built directly into the lid or door etc.

Points to watch are the connections to the BC558 transistor, especially as there are two different base connections available, and that the alarm and relays have voltage ratings applicable to the selected supply voltage. The supply voltage may be anything convenient, up to a maximum of 30 volts, this being limited by the rating of the transistor specified. ●

PARTS LIST
ETI 233

R1	Resistor	10 k 20% ½W
Q1	transistor	BC178, BC558 or similar
D1	diode IN914 or similar	
PB1	push button switch (normally closed)	
PB2	push botton switch (normally open)	
RLA, RLB	relay double pole change-over, voltage to suit battery supply used.	
SW1 2, 3	Switches single pole 11 position rotary.	
Alarm	- buzzer etc. to suit battery supply used.	

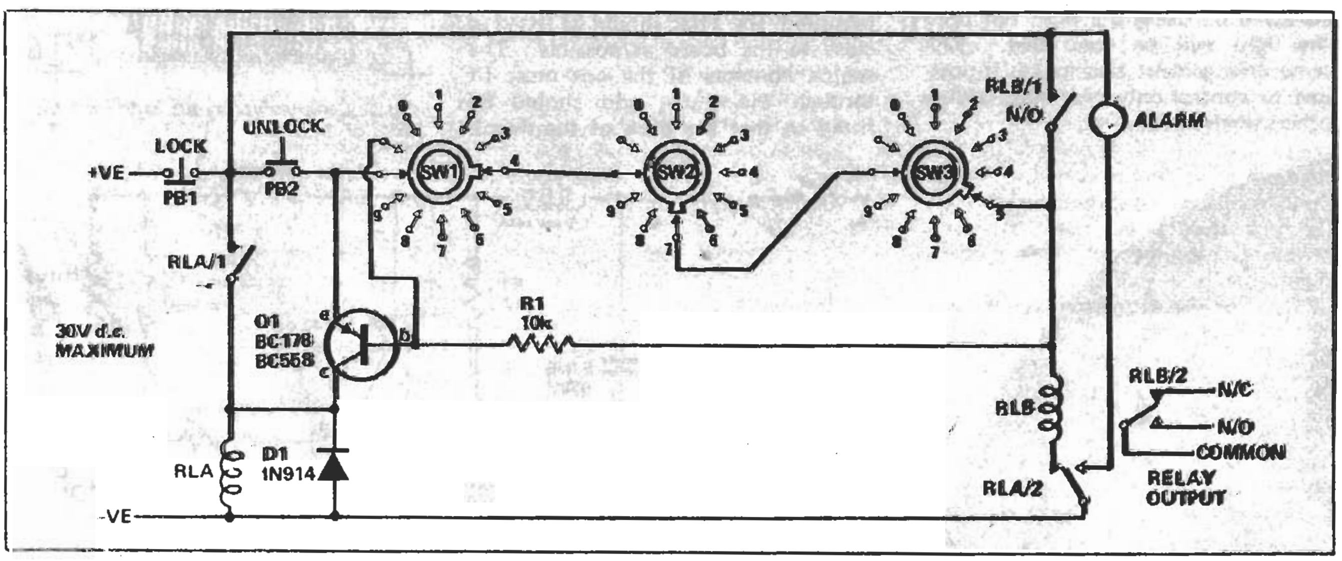
HOW IT WORKS

The three switches (SW1, 2 and 3) are prewired to some specific number. In our circuit diagram the switches are wired to unlock with 475 selected.

When the unlock push button is pressed, power is applied to Q1 and SW1. If the switches are set to the correct "UNLOCK" code, power is also applied to relay B causing it to close, RLB/1 contacts therefore close latching relay B on. The switches can now be altered without relay B opening.

If, however, when the "UNLOCK" pushbutton PB2, is pressed, the switches are not in the correct code position relay RLB is not actuated. Nevertheless, Q1 turns on due to base current flowing through the coil of RLB and R1, and RLA closes. Contacts RLA/1 therefore close, latching on RLA, and contacts RLA/2 change over disconnecting RLB and actuating the alarm. Only by pushing the "LOCK" button can the alarm be de-activated and a new combination tried. If desired the alarm could be connected across the coil of RLA rather than in the position shown.

The switches should normally be left in the number 11 (blank) position. If in this position the unlock button is pressed the alarm will not be actuated. This prevents accidentally raising the alarm.



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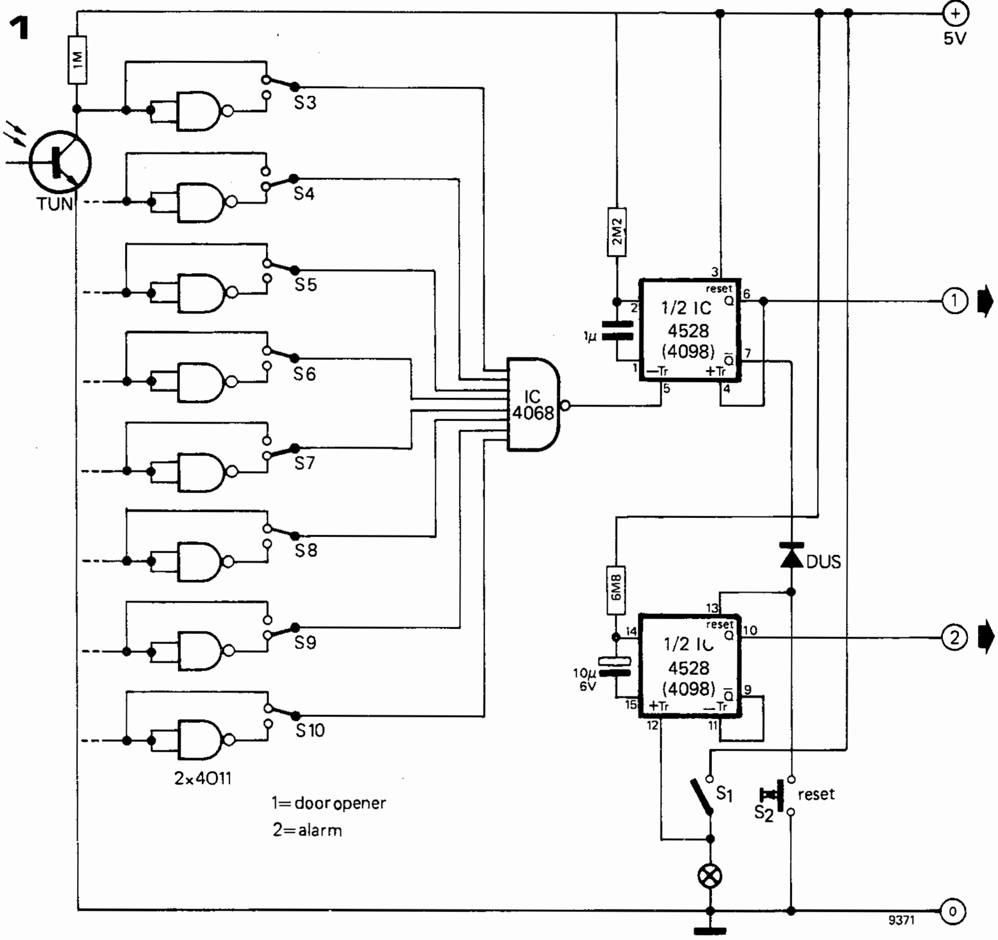


optical-lock

An electronic lock, which is opened using a binary encoded optical key can easily be constructed using 'home-made' phototransistors and CMOS logic ICs. The principle of operation is very simple. The lock consists of a row of phototransistors, which can be illuminated by a lamp. The key is a strip of transparent plastic with sections opaqued to form a binary code.

The circuit

Figure 1 shows the circuit of the optical lock. For simplicity only one phototransistor is shown, but there are 8, each connected to the input of a NAND-gate as is the own shown. Each phototransistor has a 1 M collector resistor. When a transistor is illuminated its leakage current increases and the collector voltage falls. When it is not illuminated the leakage current is very small and the collector voltage is almost equal to supply voltage. The illuminated and non-illuminated states therefore correspond to logic '0' and logic '1' respectively on the input of the NAND gates (connected as inverters).

When the key is inserted into the lock it depresses a microswitch (S1) so that the lamp lights (see figure 2). The opaque sections of the key correspond to logic '1', and the transparent sections to logic '0'. The outputs of the phototransistors thus assume the binary code. Switches S3 to S10, which are used to set up the coding of the lock, are so arranged that any '0' outputs are complemented by the inverters, while '1's are connected straight to the inputs of the 8-input NAND-gate.
Thus only when the correct key is inserted will all inputs to the NAND-gate be '1', so its output will go low. This triggers the monostable (½ 4528) producing an output pulse (1) which can be used to operate a solenoid bolt.

The $\overline{Q}$ output of this monostable also inhibits a second monostable. Depression of microswitch S1 by the key triggers the second monostable, whose output (2) is connected to an alarm circuit. Should an incorrect key be inserted then the output of the 8-input NAND-gate will not go low and the first monostable will not be triggered.

santatronics

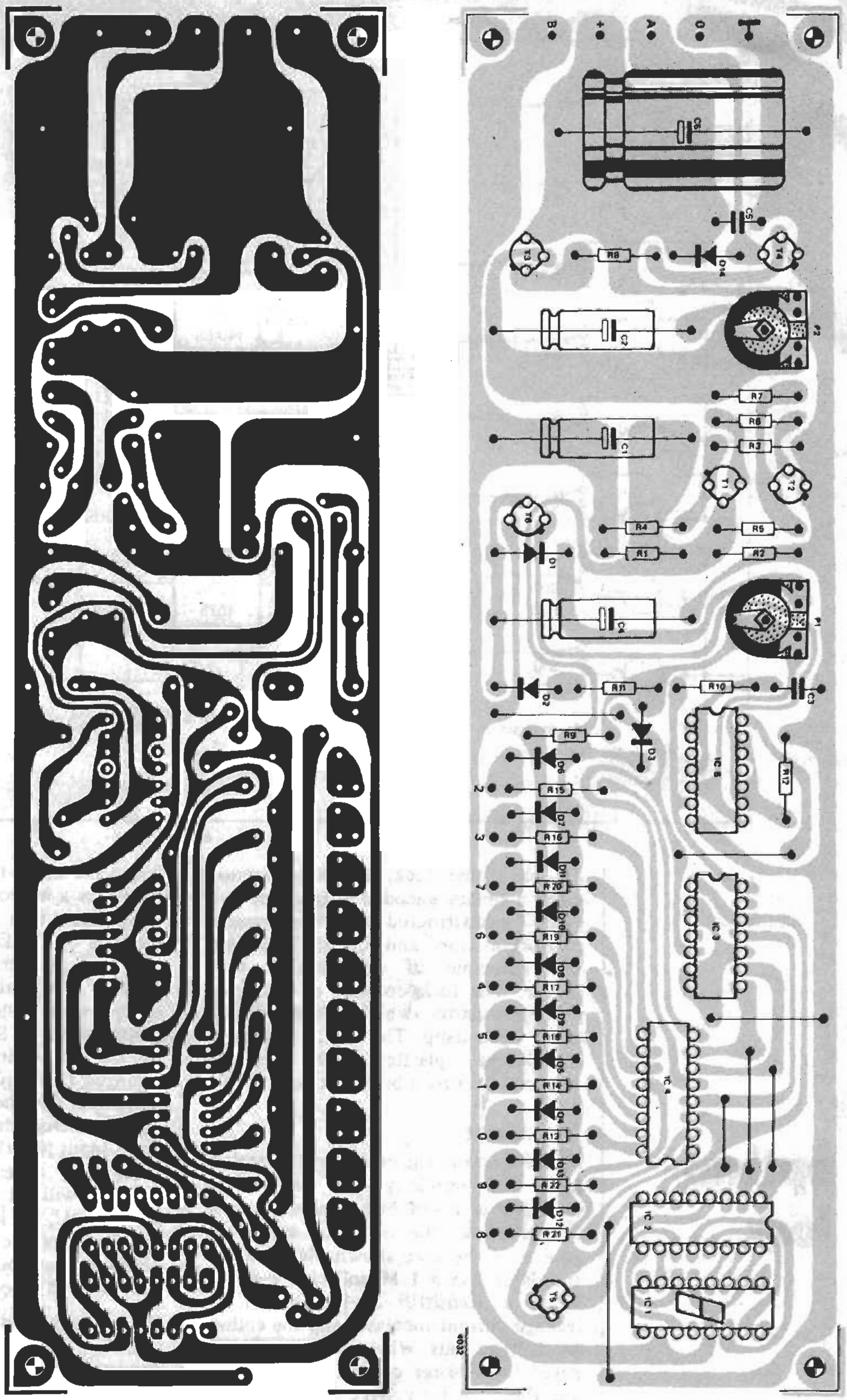
Components list:

Resistors:
R1 = 6k8
R2 = 39 k
R3,R4,R6 = 1 k
R5 = 8k2
R7,R13 . . . R22 = 470 Ω
R8 = 10 k
R9 = 100 k
R10,R12 = 330 Ω
R11 = 3k9
P1 = 47 k preset
P2 = 22 k preset

Capacitors:
C1,C2 = 1000 μ/10 V
C3 = 2n2
C4 = 470 μ/10 V
C5 = 100 n
C6 = 1000 μ/25 V

Semiconductors:
D1 . . . D14 = DUS
T1 = TUP
T2 . . . T6 = TUN
IC1 = 3015 F minitron
IC2 = 7447
IC3 = 7490
IC4 = 74141
IC5 = 7413

Miscellaneous:
Re = 6 V/250 Ω relay
(1 break, 3 make)
L1,L2 = 6 V/50 mA lamp
S0 . . . S9 = pushbuttons



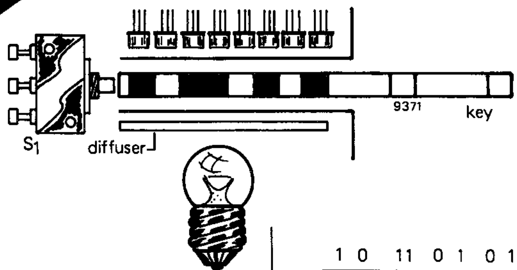
power was turned on. It consists of P2, C2, T3 and T4. The interval that must elapse before this time switch fires can be preset by P2. When the electrolytic is sufficiently charged, the current through T4 will cause the relay to attract. This relay will 'hold' via one of its contacts, so that it can only be released by interrupting the power supply. A second contact turns off the tester proper and replaces the 'no drive' indication by 'drive'. The remaining contacts (in parallel) are wired in series with the car's starter relay circuit, so that they enable the engine to be started.

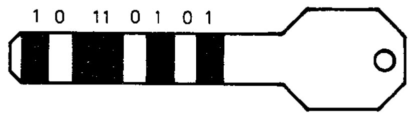
Whenever a too-long reaction time causes T1 and T2 to latch, the main timing capacitor (C2) will be discharged, essentially restarting the test period. It is only possible to obtain a 'drive' permit after a sufficient number of sufficiently quick reactions has been successively performed. As already noted above, the tester is cleared by a short interruption of the power supply. Bear in mind that the necessary 5 volt supply will have to be derived from a vehicle battery of which the voltage can drop quite far during starting!

One could spend hours discussing to what extent a piece of hardware can be expected to stand in for the failing sense of responsibility (or lack of self-discipline) of a human being. Perhaps the final remark could be this: use pushbuttons of a recessed type, to prevent the subject of the test from depressing them all simultaneously!

K

2





Thus the second monostable will not be reset by the $\overline{Q}$ output of the first, and the alarm will sound. The alarm may be reset manually by S2.

Practical notes

The coding of the lock is set up using switches S3 to S10. Where a particular bit of the code is to be a '1' then the relevant switch is left in the position where the inverter is bypassed. Where a bit is to be '0' the switch is placed in the position where the output is taken from the inverter, thus complementing the bit and producing a '1' at the input of the 4068 8-input NAND gate. If one does not wish to change the lock code frequently then the switches may be replaced by hardwired links.

The number of possible codes for the lock depends upon the number of bits used. In the circuit given 8 bits were used for convenience of the IC package count (2 x 4011 and 1 x 4068 required) but there is no reason why the number of bits cannot be extended. Using 8 bits gives 2^8 - 2 or 254 possible combinations. The code 00000000 is not used as this corresponds to total illumination, which could be accomplished by an intruder depressing the microswitch with a piece of stiff wire or transparent plastic. Similarly 11111111 is not used, as in the event of lamp failure this code would be registered whatever key was used.

Finally, excellent phototransistors can be made from BC 108s by (carefully) sawing off the top of the can and filling with transparent casting resin as sold in handicraft shops.

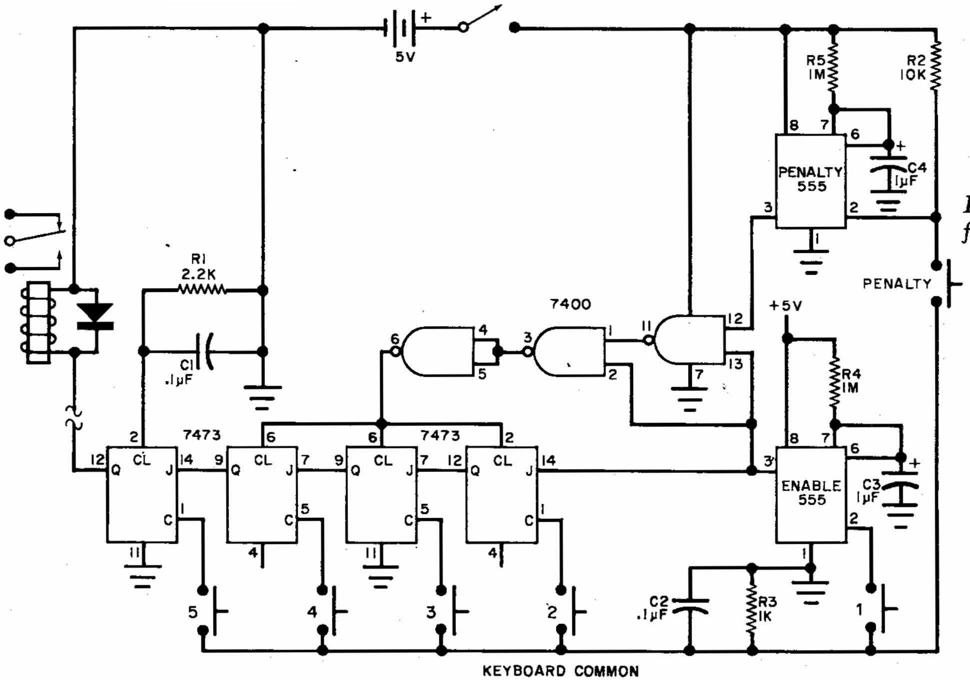


Fig. 4. Schematic diagram for an electronic lock.

Reader's Circuit. Submitted by a 17-year old reader, David Wang (1490 Waukazoo Drive, Holland, MI 49423), the digital electronic lock circuit illustrated in Fig. 4 features inexpensive 7400 series TTL IC's in conjunction with a pair of type 555 timers. David writes that he assembled his original model for under five dollars by using an inexpensive surplus "4-banger" calculator keyboard for his basic switch array. In operation, the lock is opened (i.e., the external sensitive relay is activated) when a five-number combination is entered within a specified time limit. No number may be entered twice or out of sequence. If any number not in the combination is entered, a "penalty" delay is activated which prevents circuit operation for, during the penalty period, the lock circuit is held in reset and not even the right sequence will activate it. The combination of a limited operational time once the initial key is pressed and an unknown penalty time if a wrong key is pressed makes the lock exceedingly difficult to defeat by "guess" and manipulation.

The basic circuit consists of four interconnected J-K flip-flips, with the Q terminal of the last one providing the circuit's output signal. Operation is initiated when the 555 "enable" timer is switched to a low state by depressing key 1. Thereafter, the flip-flips are clocked in turn by depressing keys 2, 3, 4 and 5 in order. After the preset time delay, the enable timer goes to a high state, triggering the flip-flop chain and providing an output signal. If any of the penalty keys is pressed accidentally, the penalty timer is activated, applying a signal through logic gates to hold the flip-flops in a reset state for a given time.

The initial (operational) time delay is established at about 3 seconds by a 1-megohm resistor in conjunction with the 1-µF capacitor, *R4* and *C3*, respectively, while the longer "penalty" delay is determined by *R5* and *C4*. Capacitor *C1*, shunted by *R1*, serves to reset the final flip-flop when the circuit is first switched on. In the power supply circuit, *R3* and *C2* form a simple keyboard debounce filter. Series resistor *R2* in the penalty timer circuit serves to stabilize the 555 against false triggering.

With neither parts placement nor wiring arrangement critical, the electronic lock circuit can be assembled on perf board using point-to-point wiring or on a suitable etched circuit board, as preferred. All the resistors are ½-watt types, while the capacitors can be either low-voltage ceramics or electrolytics, as appropriate to their values. The flip-flop IC's are type 7473, the logic gates type 7400, and the timers, as indicated previously, type 555. The combination switches are spst momentary-contact pushbutton types (as on a calculator keyboard), while the main power switch is a spst toggle, slide, or rotary type. The lock circuit's output can be used to activate a sensitive relay or as a control signal for other logic circuitry.

Until next year . . . Happy Holidays! ◇

SIMPLE ELECTRONIC COMBINATION LOCK

As an electronic lock, or as a game, this system is hard to beat

BY JOE A. ROLF

THIS space-age combination lock defies deception! Even the great escape artist Houdini, were he alive today, would probably back away from this lock before trying to open it. You can easily duplicate it for fun or practical use for less than $20.00.

The lock is opened by pushing a correct combination of five pushbuttons in the proper sequence. There are 30,240 possible combinations and the odds of randomly selecting the proper one are better than three million to one. The only key that will work is a five-digit code carried in the owner's head; and, unless this combination is completed in ten seconds, the lock forgets what it has been told. Power is required only after the first correct digit has been selected.

How It Works. The circuit of the lock is shown in Fig. 1. It consists of a two-transistor timer (*Q1,Q2*) and an SCR sequence detector. Five pushbuttons (*S6* through *S10*) are used for the combination and five more (*S1* through *S5*) defeat the circuit if they are operated.

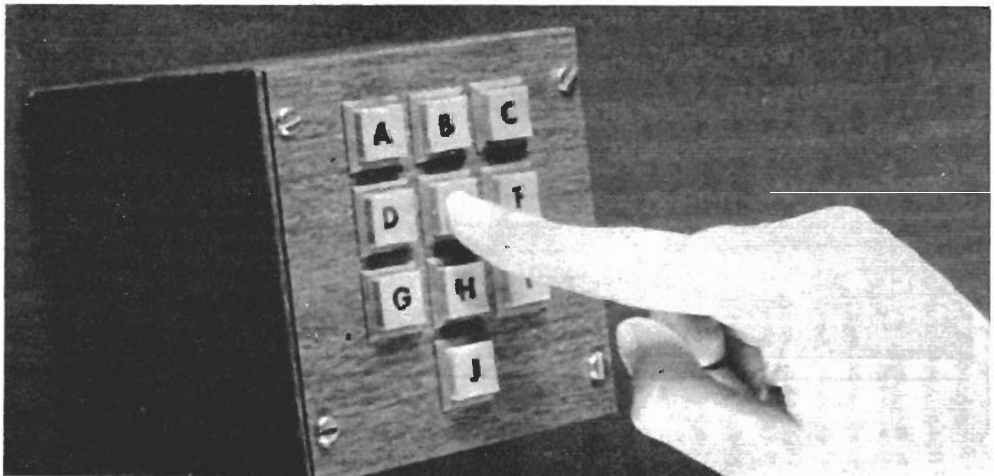
Switch *S6*, which can be any of the ten buttons on the panel, is the first digit of the combination. Depressing this switch momentarily charges capacitor *C1* and turns on *Q1* and *Q2* for approximately ten seconds.

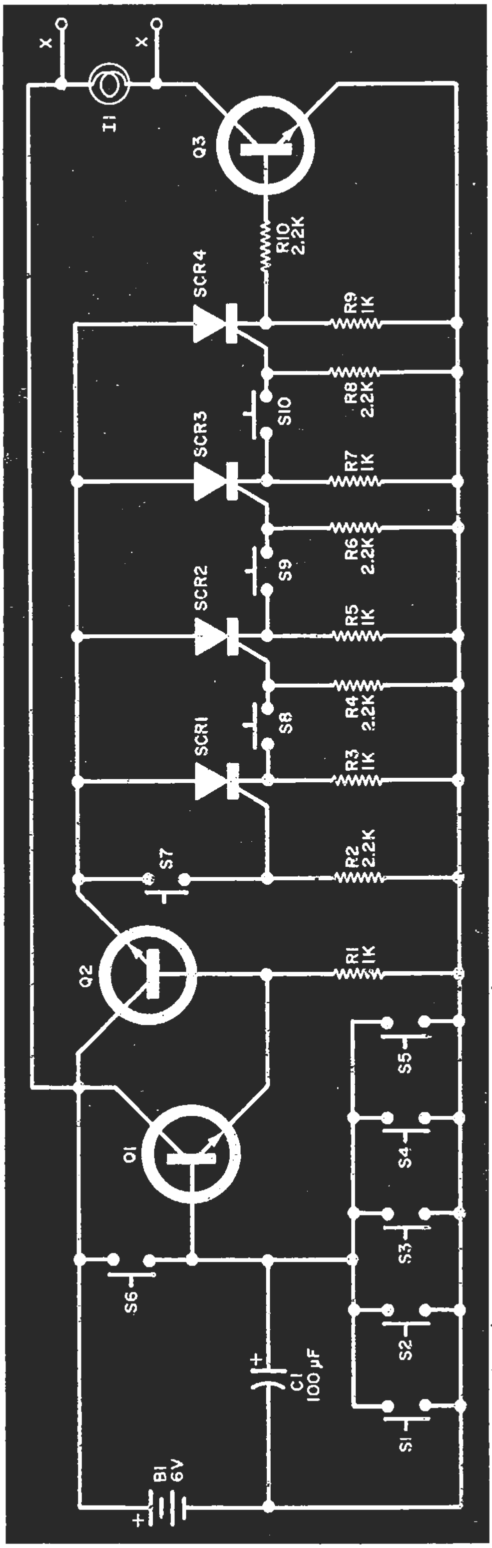
Switch *S7* is the second digit of the combination. When *S7* is depressed, *SCR1* fires and applies voltage to *R3*. This furnishes a triggering voltage to fire *SCR2* when *S8* is depressed. The sequence continues through *S9* and *S10* until the relay driver (*Q3*) is turned on.

An indicator lamp (*I1*) can be included to show that the correct combination has been selected. The entire combination must be completed in the proper sequence in about ten seconds or the circuit automatically turns off. Then the sequence must be started again.

If any of the pushbuttons that are not part of the combination (*S1-S5*) are operated, capacitor *C1* is discharged and the circuit it turned off. The combination can be changed at any time by changing the physical positions of the ten switches.

Of course, the design can be changed to use fewer than ten switches, with a consequent lowering of the total number of combinations. If you use only 4 buttons, for instance, with 2 digits in the combination, the total number of possible combinations is only 12. With 8 buttons and using 4 for





the combination, 1680 combinations are possible.

Construction. The circuit can be assembled on a PC board such as that shown in Fig. 2 or on a perf board. In the prototype, a 3-3-3-1 matrix of pushbuttons was mounted on the cover of a 4" by 4" by 2" aluminum box with the last switch (*S10*) containing a light. The PC board was bolted to the bottom cover of the box with a short cable connecting the board to the switches to permit easy service and change of combinations.

A second box of the same size was used to hold four series-connected alkaline penlite cells.

You may prefer to use smaller pushbutton switches which could be assembled to be mounted in a standard surface or wall junction box. This assembly could be located away from the PC board and battery with a 16-conductor 22-guage shielded cable con-

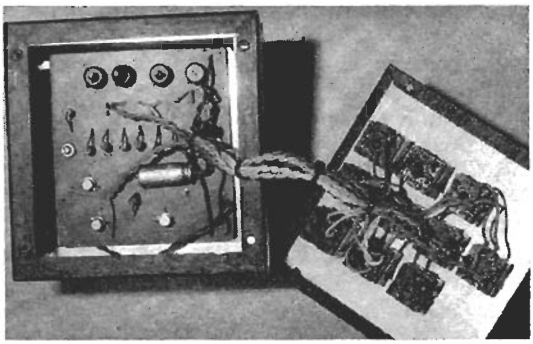
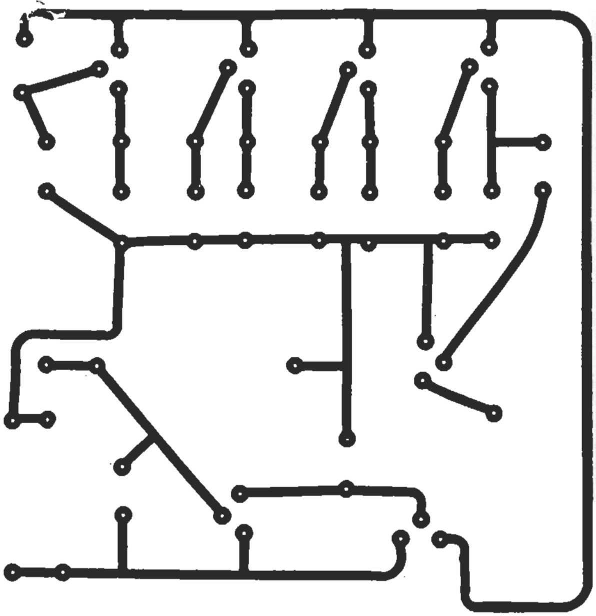


Photo shows how prototype of lock was wired.

PARTS LIST

B1—6-volt supply (see text)
C1—100-µF, 15-volt electrolytic capacitor
I1—6-volt, 75-mA lamp (optional)
Q1-Q3—Transistor (GE-20, HEP 53, or similar)
R1,R3,R5,R7,R9—1000-ohm resistor
R2,R4,R6,R8,R10—2200-ohm resistor
SCR1-SCR4—Silicon controlled rectifier (GE-C6U, HEP320, or similar)
S1-S10—Single-pole, normally open pushbutton switch (S10 can be illuminated)
Misc.—Aluminum utility box (BUD AU-1083 or similar), battery holders, mounting hardware, interconnecting cable, etc.
Note—Electrically operated locks are available for almost any application from most large building supply and hardware outlets. The exact model you choose will depend on the application. One major manufacturer is the Trine Co., which offers a variety of models at prices from $12.75 up.

Fig. 1. Five of ten switches make up combination. Others will open circuit.



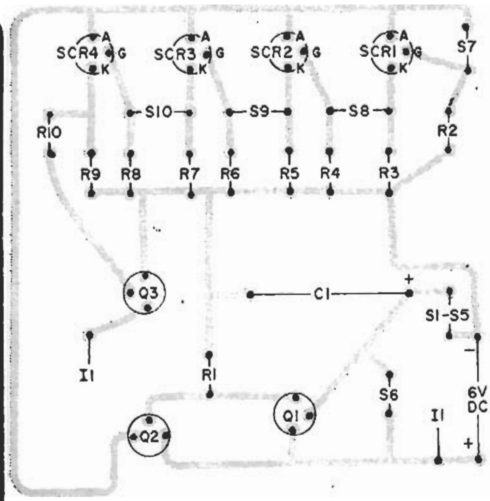


Fig. 2. You can use the foil pattern at left to make up a printed circuit or assemble components on perf board.

necting the components. The distance can be as much as 20 or 30 feet. Be sure to use shielded cable to prevent the lock from opening at odd times due to electrical noise pickup on the long cable run.

To operate a door lock, connect an external control relay across the points marked "X" in Fig. 1. Any single-pole, normally open, 6-volt dc relay can be used as long as it requires less than 0.2 amperes to energize the coil and the contacts can handle the lock current. For this purpose, the Potter & Brumfield KA5-DY or Guardian 200 relays are suitable.

Power Supply. One difficulty encountered when using an electronic lock is what to do about the power supply. If you use the ac power line, a power failure on the line can keep you locked out of the house. On the other hand, batteries go dead.

With the lock described here, since power is required only for short periods, a set of alkaline D cells will give satisfactory service if replaced frequently. Better yet, a 6-volt lantern battery can be used to provide service for several months of normal usage.

If you really want to be safe, you can build the simple float charger circuit shown in Fig. 3. This will keep the lantern battery well charged and will also provide power if the battery fails. If you use a 6-volt dc lock, you can also eliminate problems caused by ac outage.

Troubleshooting. To check out the timer, connect a voltmeter between the emitter of *Q2* and the negative battery terminal. Momentarily depressing *S6* should give a 6-volt indication for about ten seconds. Depressing one of *S1* through *S5* during this interval should cause the indication to go to zero.

Next measure the voltage across *R3* after depressing *S6* and *S7* in proper sequence.

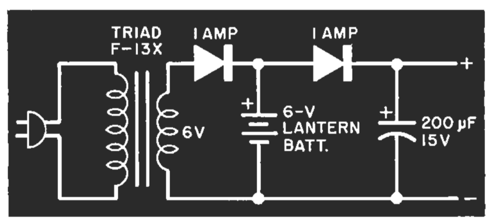


Fig. 3. Supply to protect against ac failure.

Voltage should appear at this point for about ten seconds. Repeat measurements across *R5*, *R7*, and *R9*, after depressing the proper buttons in sequence. In this manner, you can quickly determine which portion of the circuit is not working. A malfunction can usually be traced to a wiring mistake or a bad solder joint.

One final point, write down the combination you choose and store it away somewhere —just in case you should forget. Otherwise, you will have a lock that will be very difficult to open. ◈

Electronic lock boasts low cost and low power

by B. J. Sokol
London, England

Three integrated circuits, two switches, and a few diodes are all that is really needed to build a very low-power programmable combination lock, the circuit for which is shown in the figure. The combination is entered by pressing two push-button switches or, alternatively, toggling a lever-action telephone-type switch in the correct sequence. If the switches are pressed in the wrong sequence or if the user hesitates for more than 200 milliseconds while entering the combination, the 4017 counter resets and the sequence must be reentered.

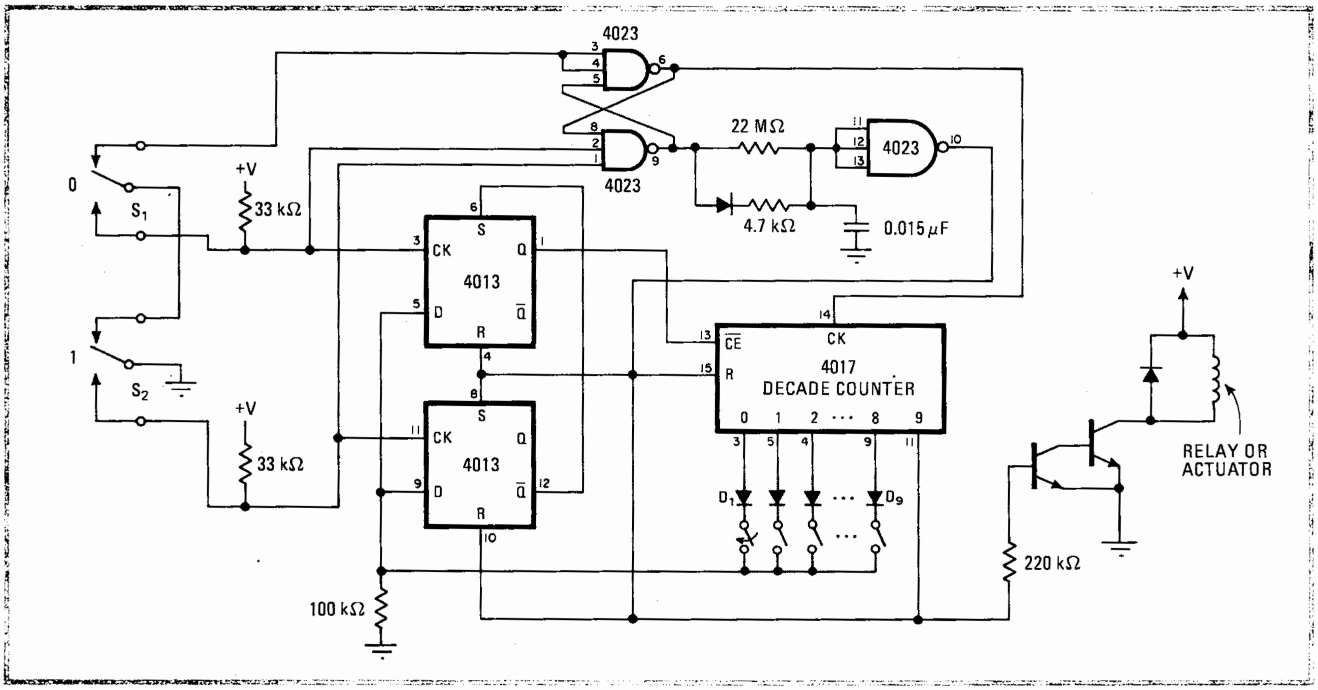
The sequence is programmed by switching a diode in or out between the 4017 count outputs and the 4013 dual flip-flop data inputs. For every diode placed at a counter output, a logic 1 is required at a corresponding point in the switching sequence. For example, if a diode is placed at the counter's 0 output but not at the others, the only combination enabling the relay or actuator to open the lock would be 1-0-0-0-0-0-0-0-0.

After the correct sequence is entered, further switch depressions are ignored because the 4017 $\overline{CE}$ inhibit line is forced high through the action on the reset and set pins of the 4013. However, after about a quarter second, the reset of the 4017 is actuated. This reset is inhibited if either push-button switch is held down—a feature allowing an extended pulse to be applied to an actuator, such as a solenoid-driven door latch.

When the switches are not operated, only a minute amount of power is drawn, most of it by the 100-kilohm pull-down resistor. As this lock will work with very little power, it is ideal for battery-powered applications.

For security, no connection of wires to the switches can trip the lock. Shorter combinations are possible if the connection to the counter's 9 output is moved instead to another output. More than 512 different combinations are possible so anyone attempting to try all combinations would require waiting for a reset in every wrong instance—a process requiring considerable time and trouble. This lock provides reasonable security and an easily remembered code, especially if the user knows octal or hexadecimal notation. □

Designer's casebook is a regular feature in *Electronics*. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $75 for each item published.



Secret. A few components is all that it takes to put together this low-power combination lock. A nine-number sequence of 1s and 0s is clocked by two switches, S_1 and S_2, and must correspond to the combination programmed by diodes D_1 to D_9, shown in the shaded area.

Electronic combination lock offers double protection

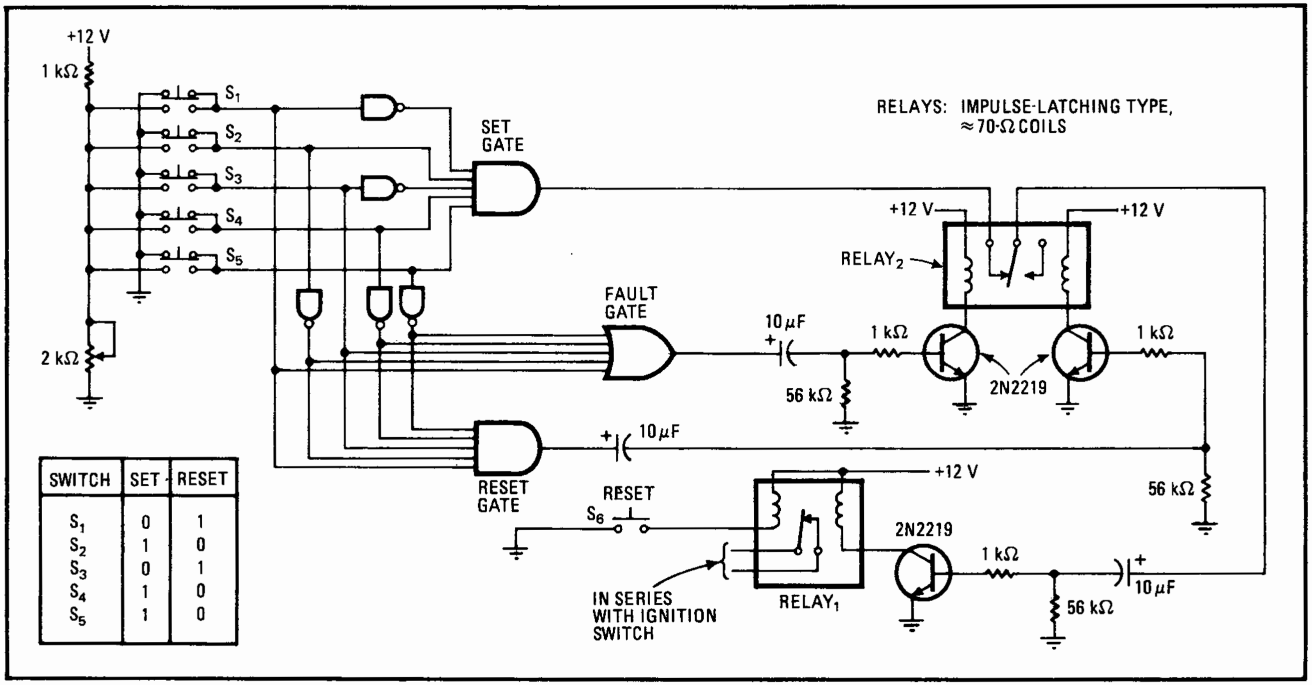
by Louis F. Caso
Bethpage, N.Y.

If you need a doubly safe lock, try the electronic combination lock shown here. It will not unlock unless the correct combination of switches is depressed, and if the wrong combination is chosen, the lock will not open until it is reset with another combination.

The circuit in the figure is intended for installation in an automobile, but it can be easily modified for other applications. When the correct combination of switches S_1 through S_5 is depressed, the output of the SET gate goes to logic 1, closing the contacts of $RELAY_1$. When the car's ignition is turned off, this relay should be reset (contacts opened) by using switch S_6.

To open (set) the lock, switches S_2, S_4, and S_5 are depressed simultaneously. If an error is made, the output of the FAULT gate goes to logic 1, and the contacts of $RELAY_2$ will open. When this happens, the lock must be reset before the opening combination can be used again. Switches S_1 and S_3 are depressed simultaneously to reset the lock.

Any secret combination of push buttons can be selected by arranging the switches as desired. For most applications, the multiple-input logic gates can be obtained by interconnecting standard dual-input gates. □

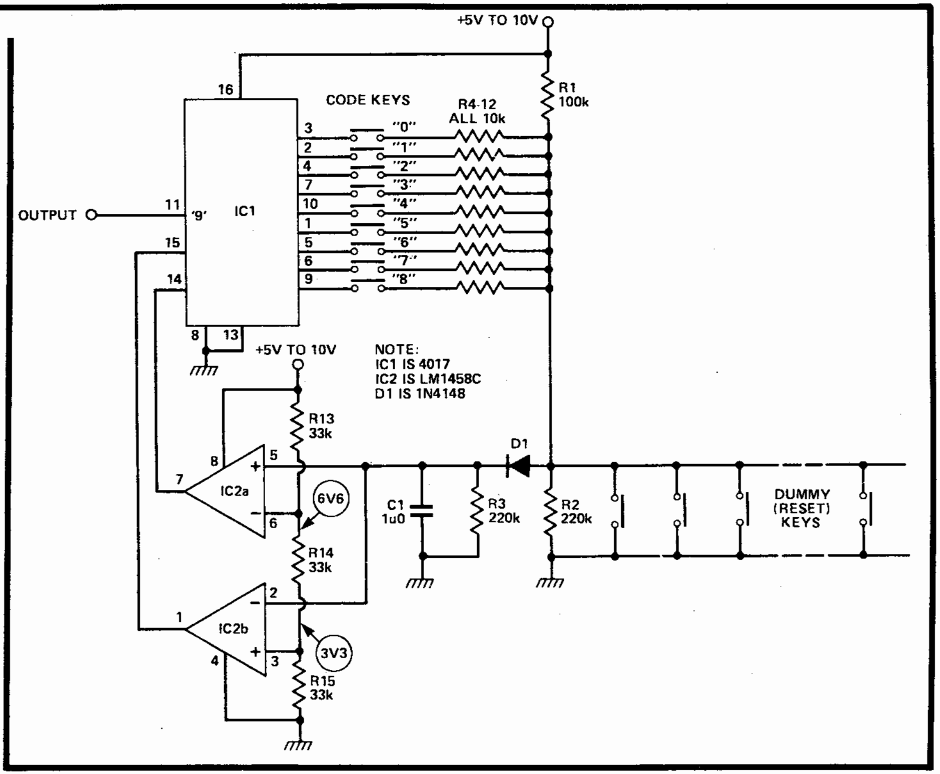


SWITCH	SET	RESET
S_1	0	1
S_2	1	0
S_3	0	1
S_4	1	0
S_5	1	0

Safe and sound. To open this electronic combination lock, depress the correct combination of switches S_1 through S_5. But if an error is made, the lock must be reset with another switch combination before it can be opened again (The switches are depressed simultaneously.) The circuit shown here is for locking an automobile ignition, but it can be readily adapted for other uses.

Foolproof Combination Lock

Ben S. Meyer



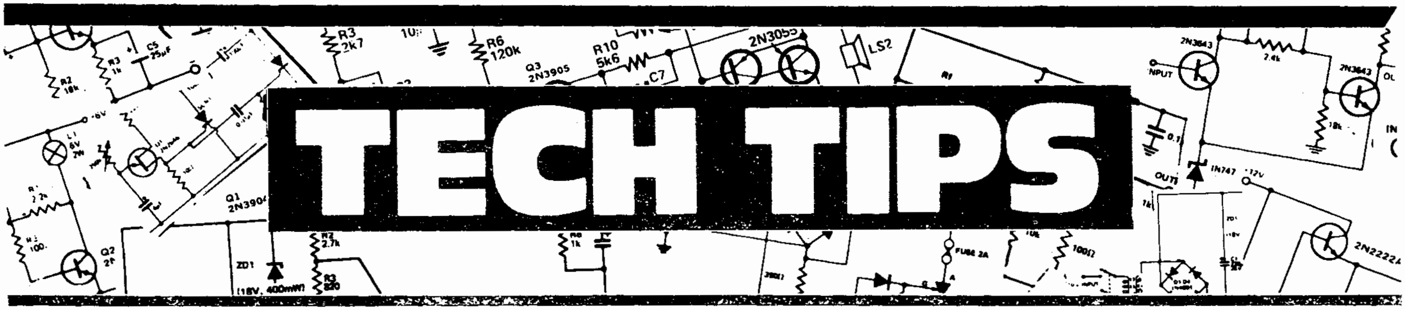
This lock really is foolproof, as all the keys except the correct one will cause a reset. The problem with other types of locks is that only the dummy keys will cause a reset. All voltages given are for a 10 V supply.

A power-on reset is provided by C1. When reset, pin 3 of IC1 is at 10 V. When code key '0' is pressed, the voltage across C1 rises to above 8 V. This triggers IC2a whose output clocks IC1. This causes pin 3 to return to 0 V, and pin 2 goes high. Pressing the other keys repeats this action until pin 11 goes high.

Pressing a dummy key will cause the voltage across R2 to fall to zero, while pressing a code key out of order will cause a drop to 1 V. C1 discharges via R3 and as soon as the voltage pin 2 falls below the 3V3 reference, IC1 is reset by a high at pin 15.

All the output pins except the one currently switched high by the count are held at ground by IC1. This causes a problem, as it would be impossible to advance the counter since the respective switch would be grounded before it could be released and so reset the count to zero. C1 holds the charge on it during clocking, long enough for the key to be released. The diode prevents any discharge through R2. R3 discharges C1 and provides a bias path for the diode. The value of the capacitor can be altered to suit your needs, but R3 is a part of the voltage divider R1,2,3 and its value cannot be changed.

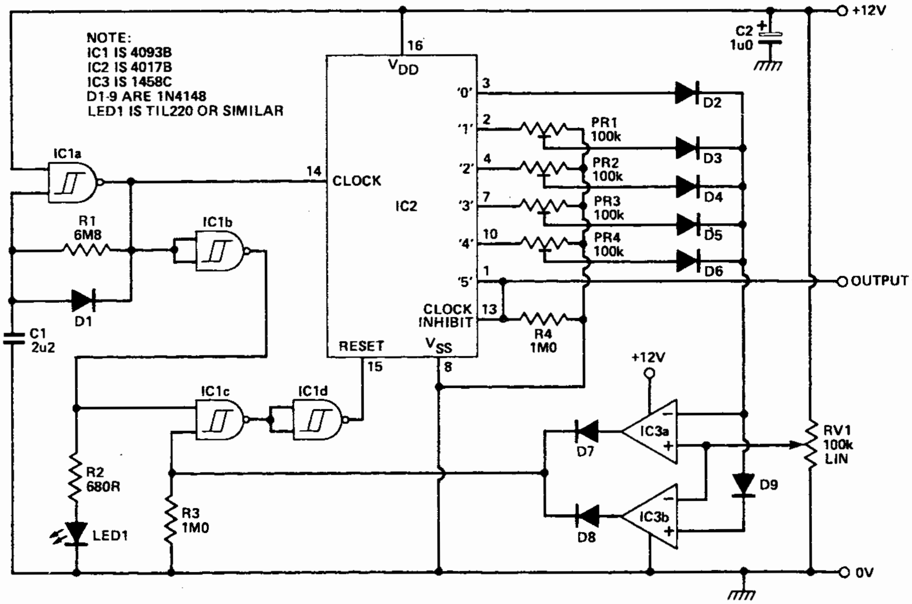
R4-12 are current limiters which prevent damage to IC1 if more than one key is pressed. To reset the system after the output has been enabled, just press any key.



TECH TIPS

Rotary Combination Lock

Chris Pearce



There are many circuits for push-button and rotary switch combination locks, but this circuit uses a potentiometer to enter the four-digit code (easily expanded to eight). LED1 flashes approximately every 2 seconds. To enter the code, the potentiometer must be turned to the first digit for the duration of one flash, then moved to the next digit, ready for the next flash, and so on until the code is entered. If a wrong number is entered at any time the lock will reset and the code must be re-entered.

RV1 should be set up so that it can point to a number between 1 and 10. As a 12 V supply was used, '1' corresponds to 2 V, '2 to 3 V, and so on. Circuit operation is as follows: IC1a and C1, R1, D1 form an oscillator which provides clock pulses for the circuit timing. This clock pulse drives IC2 and is also inverted to drive LED1 and the reset logic.

Assuming IC2 is reset and the code is '1234', a high will appear at IC2 pin 3, which corresponds to a count of '0'. On receiving the next clock pulse, the high will move to count '1' (pin 2). This will drive PR1, and thus feed a voltage to the window comparator IC3. D9 sets the window width at 0V6. As the first digit of the code is '1', which corresponds to 2V, PR1 will be set to 2V9, allowing for 0V6 dropped across D3, and thus settig the upper window limit to 2V3 and the lower to 1V7. If, when the LED flashes, the potentiometer is set to within the limits, the comparator output will be low and IC2 cannot be reset. On the next clock pulse IC2 will move to count '2' ready for the next digit and so on.

If the potentiometer is outside the limit ie the wrong number, the comparator output will be high and IC2 will be reset when the LED flashes. If the correct code is entered the clock of IC2 will be inhibited via pin 13 and the output will be high. To set the lock the potentiometer is moved off the last digit.

C1 should not be electrolytic. C2 provides decoupling and should be placed near IC3. The chance of breaking the four digit code in any one attempt is 1 in 10,000, and 1 in 100,000,000 for an eight digit code.

Combo Lock

A six-key electronic lock for security or other purposes.

CHUNG YIU KO

Neighbourhood Watch schemes cover the land. Security in the home has a higher profile today than ever before and a simple electronic locking device could be worth its weight in missing cufflinks.

The circuit detects correct sequence input and provides a relay output suitable to trigger an electronic lock. Its main beauty is that it uses no ICs and keeps things simple and cheap. The correct combination is hardwired rather than programmed and the lock could be used to protect door openers, burglar alarms, car ignitions — the applications are limited only by your imagination. The circuit diagram is shown in Fig. 1.

The heart of the circuit is the sequential detector which interprets the correct sequence inputs from the key switches, turns the output on and activates a relay. An indicator (LED1) indicates that the correct number sequence has been entered. If the right numbers are entered but in the wrong order than the sequence detector is reset and the entire sequence must be repeated.

Alarm circuitry is incorporated in the design and this is activated if the digits not appearing in the combination are pushed.

How It Works

The sequence sensing circuit is constructed around Q1 to Q6, the key switches and the relay.

Initially Q1 to Q6 are non-conducting. As soon as key 1 is keyed Q2 is forward biased, collector current flows through R4 and the base and emitter of Q1. Q1 charges via R3 and R4 which provides sufficient bias to turn Q1 on. The voltage drop developed across R2 (due to Q1 collector current) briefly holds Q2 on and a constant current source is now available at the emitter of Q1, forming the power source for the remaining stages of the emitter follower.

The functions of Q3 and Q4, Q5 and Q6 are a similar except that the loading of the final stage is a relay coil and LED indicator. Obviously the keys must be keyed in correct sequence (1, 6 then 8 as shown in Fig. 1), otherwise there will be no power source available from one stage to another and the relay will never energize.

The incorporation of the keypad or key board enables the user to select any three digits of any combination number he chooses while the remaining keys are connected the reset/alarm mode input.

Whenever the unselected keys are pressed the circuit is reset by pulling Q1 base to negative (via D1 in alarm mode) and at the same time discharging C1. Q1 is biased off turning off Q2. At this stage the entire sequence must be repeated. The second half of the circuit is alarm warning circuitry. Whenever a reset/alarm key is keyed (except the actual reset key Q) the alarm will sound for a short duration.

Q7 and Q8 form a basic astable multivibrator circuit. Initially the oscillator is inoperative, because Q8 is biased off via resistors R14 and R11 to the positive supply. As soon as a reset/alarm key is keyed, capacitors C4 charges via R16 with the polarity shown. Q8 becomes forward biased and the oscillation starts for a duration determined by the R11 and C-4 network.

Gradually C4 discharges across R11 to cut Q8 off and the oscillator stops.

Q9 is a simple direct-coupling emitter-output power amplifier. The circuit will operate well on 12V DC and draws a maximum standby current of 20mA. The maximum current is 400mA with the alarm and relay energized. This makes the device ideal for 12V car system or an AC derived supply.

Construction

Though stripboard could be used with care, the PCB is recommended and the overlay is shown in Fig. 2. The relay will fit directly onto the PCB. It is possible to use any relay having a 12V 300R or higher resistance coil, but it may be necessary to redesign the printed circuit layout or mount the relay off board.

The key switches are of push-to-make momentary action type and any switches of this type can be used. However a low profile keypad or keyboard is more desirable for ease of construction. After inspecting of the PCB for short circuits, broken tracks and any damage, the resistor should be soldered onto the board, followed by the capacitors, then the diode and transistors (care being taken with polarity of these components).

Once all the components are securely fitted onto the board, connect the corresponding wirings to the desired sequence and reset key switches.

In Fig. 1 the sequence number is shown as 1-6-8. Zero is for reset and the remaining unselected invalid keys are connected to parallel to the reset/alarm warning circuitry input. The PCB is purposely small so that it can be mated back-to-back with the key pad by two spacers, and tuck away in any suitable front panel. For door opener applications the unit can be fitted in a metal blanking plate (as used in house wiring) and mounted in the door frame, with the speaker wired remotely indoors. For automotive applications a small module case with metal front panel is most suitable. The base of the case can be secured onto the dashboard, with the metal front panel used to mount the complete unit.

The alarm in the circuit shown is not going to wake the street; in its present configuration it is more of a loud indication that the incorrect sequence has been entered. It would not be difficult to fit a second relay into the alarm section of the circuit which could trigger a bell alarm, or a flashing neon arrow with "Burglar" written on it, or even to release an enormous weight from the second floor onto the burglar... ■

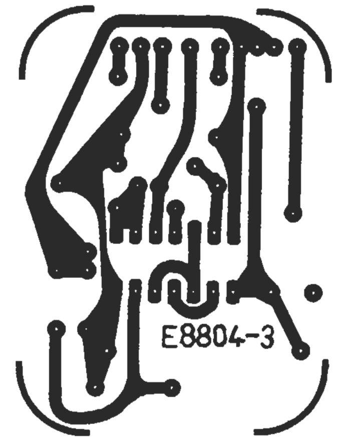


Fig. 3. The printed circuit board

PARTS LIST

Resistors (all 1/4W 5%)

R 1, 5, 8 ....470R
R2, 6, 9 ....150R
R3, 7, 15 ....1K0
R4 ....82R
R10, 12 ....51OR
R11, 13, 14 ....56K
R16 ....5K0

Capacitors

C1, 2, 3 ...... 3u3 12V electro.
C4 ...... 100u 12V electrolytic
C5, 6 ....20n ceramic

Semiconductors

Q1,3,5 MPS3904 (Radio Shack 276-2009)
Q2,4,6,7,8 MPS2907 (RS 276-2023)
Q9.... TIP3055 (RS 27-2020)
D1 1N4001
LED .... red LED

Miscellaneous

RLA1 12V relay 300R or higher
Keypad or push-to-make switches
PCB, PCB pins (16), wire, nuts and bolts.

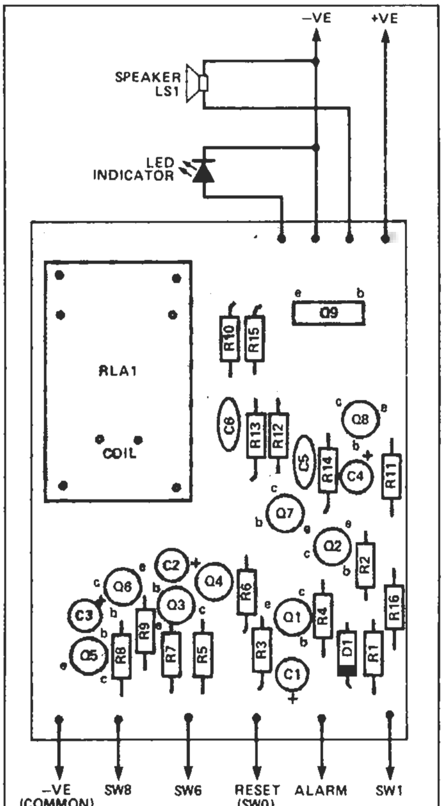


Fig. 2. The component overlay.

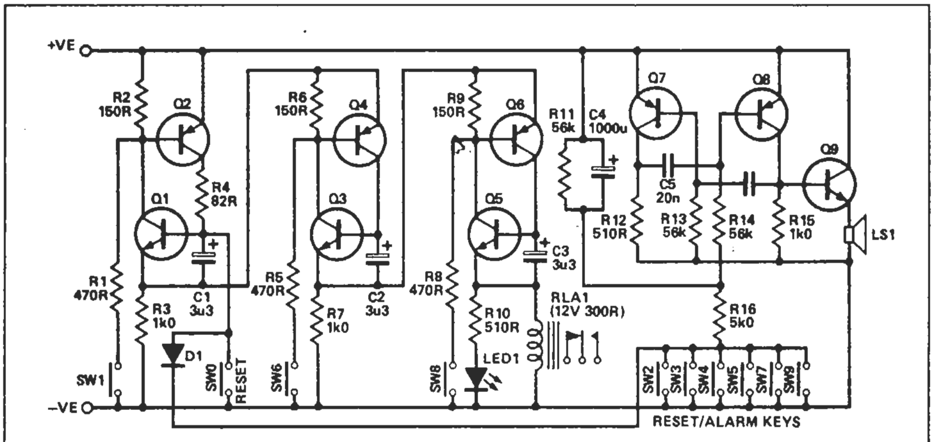


Fig. 1. The circuit diagram for the combination lock.