An electronic combination lock

Give your home, flat or office increased security with this space-age electronic combination lock. Low in price and easy to build, it can be programmed to respond to any desired seven-digit code. This means that an intruder or other unauthorised person has only one chance in 10,000,000 of finding the correct code!

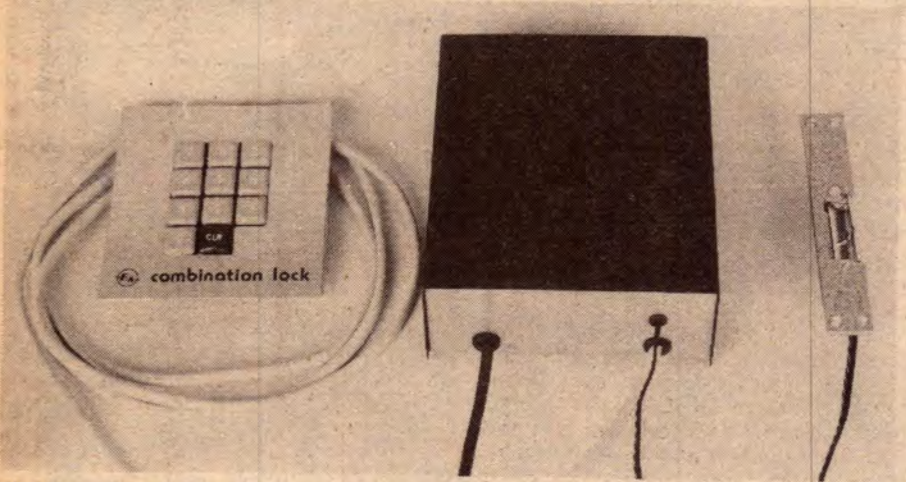
by RON DE JONG

Here is a new electronic combination lock design which we think should become very popular. It offers the security of more complex designs with the simplicity and low cost of simpler and less secure circuits. You can fit it fairly easily to almost any home, flat or office front door, and it can even be fitted with multiple input keyboards if you wish.

The actual code combination to which the lock responds is set by seven wire programming links inside the lock case — which is separate from the entry keyboard, for both convenience and security. While not normally accessible, the links can be changed at any time if desired, if you suspect that the code has become known to any unauthorised person. The code may be set to any desired combination of seven decimal digits — giving a total of 10,000,000 possibilities to choose from!

In use, the lock is triggered by entering in the code digits via a small keyboard whose keys are labelled 0-9. This provides elegant and fast entry, at the same time leaving no indication of what the code may be. The lock circuit is arranged so that the only way to release the door latch is to enter the correct code digits in the correct order, and with no false digits between them. Any false digits will immediately cause the circuit to reset, even if some correct digits were keyed in.

Like most electronic combination locks, the unit is designed to activate an electric latch release mechanism of the type commonly used in flats and home units. This type of latch release can be used in conjunction with an ordinary key-activated door latch, in place of the usual fixed striker plate. If this is done, you can gain entry by using either the combination lock or the normal key.



The completed unit together with the keypad and the door latch mechanism.

You can of course use the combination lock and release mechanism quite separately from the normal key-operated latch, to provide additional security. In this case it would probably be used with an "exit latch" door bolt, which can otherwise only be opened from the inside by a turn unit. Or you can use the latter arrangement by itself, so that the combination lock provides the sole means of gaining entry from the outside. The only problem with both of these arrangements is that in the event of a power failure, it can be very difficult to gain entry!

Assuming mains failure is not regarded as a problem, you could also use this combination lock with two keyboards — one on the inside and one on the outside of the door. This will give a "deadlock" effect, so that even if illegal entry is made via a window or other means, stolen items cannot be moved out by opening the door from the inside.

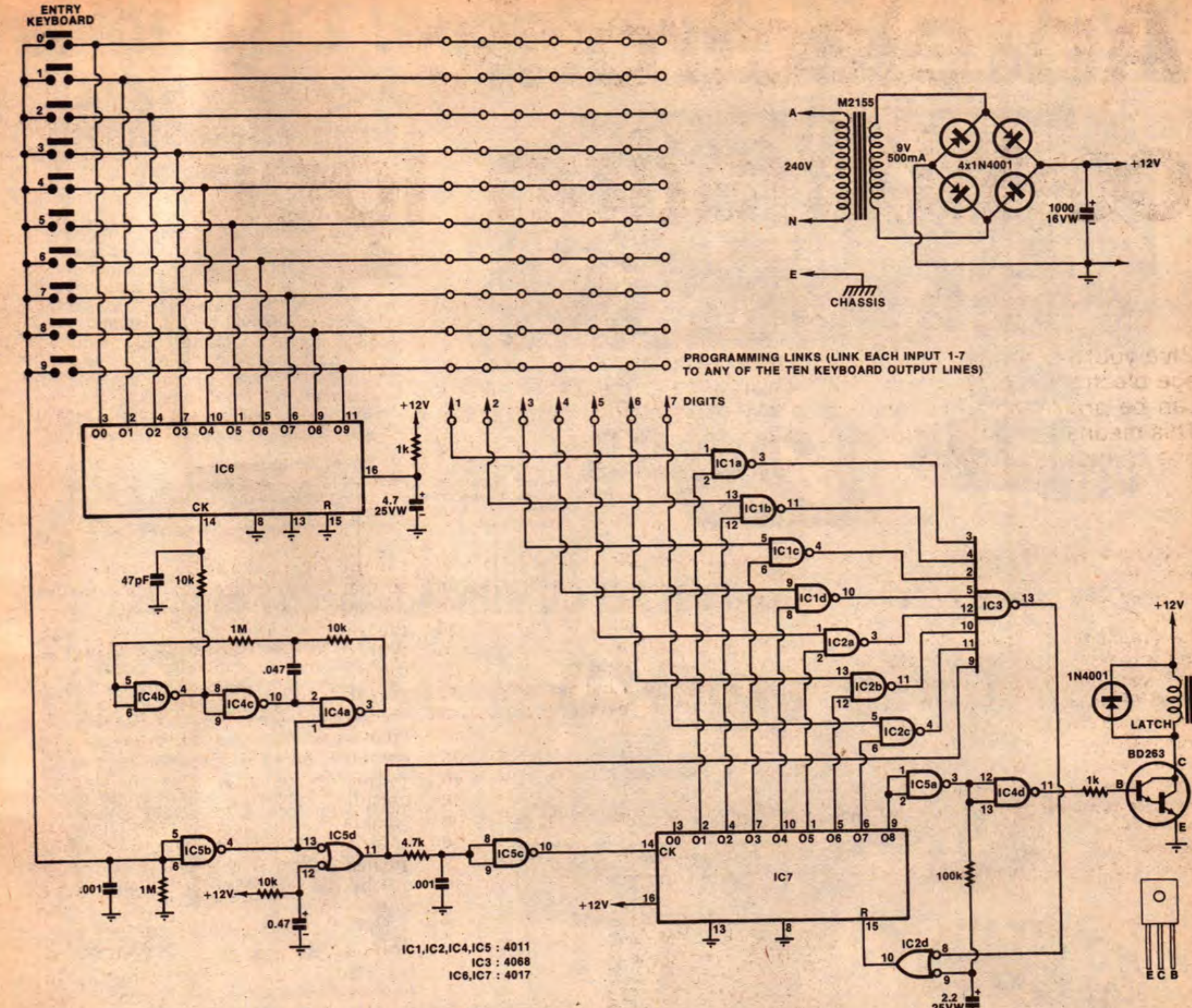
The electronic part of the lock uses only seven inexpensive CMOS integrated circuits and a transistor, all powered from a simple 12V supply. But the simplicity of the circuit belies its performance.

The easiest way of following circuit operation is to divide it into two distinct functional parts: the keyboard scanner and the code verification circuits.

At the centre of the keyboard scanner section is IC6, a 4017 decade counter with internally decoded outputs. This is driven by a clock oscillator formed by gates IC4b, IC4c and IC4a, and the oscillator is normally free-running at about 1kHz.

Each of the ten output lines of the counter is connected via the keyboard switches to the input of gate IC5b. This in turn is used to control the clock oscillator. As a result if any of the keys is pressed, the clock oscillator is disabled by IC5b as soon as the corresponding output of the counter goes high — which will happen within ten milliseconds. The counter will thus stop with the output line which corresponds to the pressed key held in the high state.

As well as being used to stop the keyboard scanning clock, the output from IC5b is also processed by IC5d and



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Seven low-cost ICs make up the circuit; programming links are added to make up the desired 7-digit code.

IC5c to produce two "key pressed" strobe signals for the code verification circuitry. The 4.7k/.001uF combination between IC5d and IC5c ensures that the signal from IC5c is slightly delayed with respect to that from IC5d, as this is required by the verification circuit.

The main reason for using this keyboard scanning circuit is to ensure that only one output line goes high, no matter how many keys may be pressed simultaneously. This is because the 4017 can only have one of its outputs high at any particular time. As a result, it becomes impossible to "fool" the code verification circuit by pressing all keys down at once.

A further advantage of the scanning approach is that the .001uF capacitor and 1M resistor at the input of IC5b effectively debounce all of the keyswitches at once.

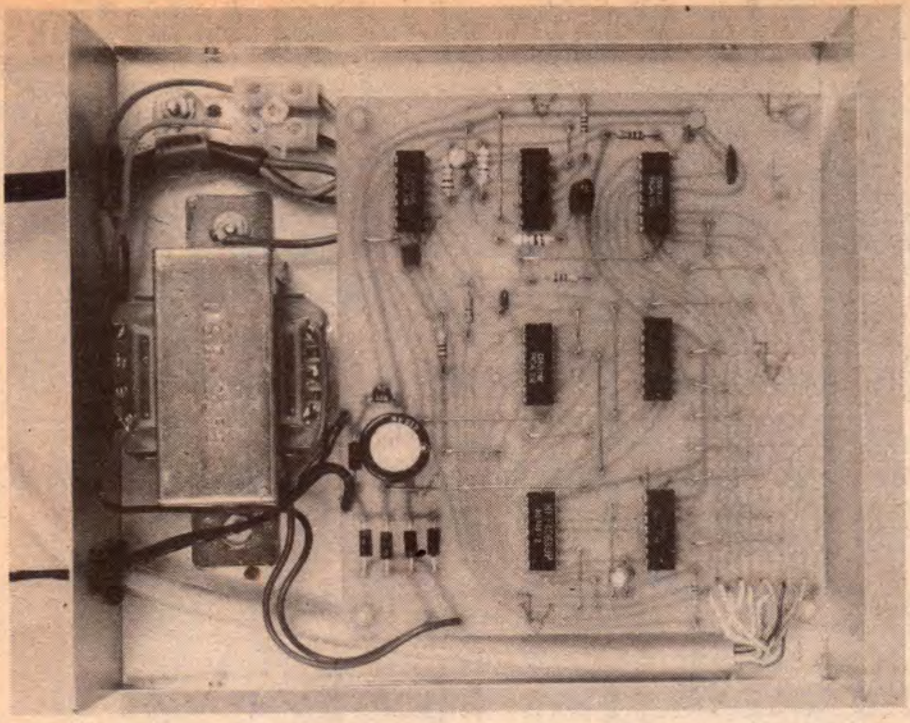
When the key which was pressed is finally released, IC6 does not immediately revert to scanning the keyboard again: there is a short delay. Partly this delay is due to the .001uF/1M combination at the input of IC5b, which produces a delay of around 1ms before the input of IC5b falls to logic low, its output rises to logic high and the clock oscillator is allowed to restart.

The remainder of the delay is produced because the input of IC6 is driven from the output of IC4b in the clock oscillator, rather than from the more usual point at the output of IC4a. As a result when the clock oscillator restarts there is a half-cycle delay before the input of IC6 receives its first positive-going clock transition. Since IC6 is triggered only by positive-going clock edges, this ensures that the output of IC6 remains "frozen" for approximately 1.5ms after the release of the keyswitch.

Note that in addition to producing the "key pressed" strobe signals, IC5d and IC5c are also used to generate a similar pair of pulses when power is first applied to the lock circuit. These pulses are generated by the 10k/4.7uF combination connected to the second input of IC5d, and are used to initialise the code verification circuitry.

The code verification section of the circuit takes the consecutive outputs from the keyboard scanning section, as a series of keys are pressed, and checks if the correct keys have been pressed in the programmed sequence. Only if the sequence is correct in all respects does it finally activate the latch release mechanism.

This section of the circuit is again based on a 4017 decoded decade counter device, IC7. In broad terms the circuit works by starting with the counter in the zero state, and incrementing it by one count for every correct digit entered in its correct position in the



Inside the completed electronic combination lock. Programming links have been added here to give a 0123456 demonstration code.

PARTS LIST

1 Instrument case, 184 x 70 x 160mm
1 Power transformer, 9V at 1A; A&R type 2155, PF2155, M-2155 or similar.
1 PC board, 114 x 130mm, coded 79CL7
1 Pack of 11 keyswitches (see text)
1 PC board, 89 x 91mm, coded 79KB7
1 Mains cord and plug
1 Length of 6-pair telephone cable
1 Length of 2-wire cable, light figure-8 type
Grommets, cable clamps, termination block, etc.

SEMICONDUCTORS
4 4011 CMOS integrated circuits
2 4017 CMOS integrated circuits
1 4068 CMOS integrated circuit
1 BD263 Darlington transistor
5 1N4001 power diodes or similar

CAPACITORS
1 47pF ceramic or polystyrene
2 .001uF polyester
1 .047uF polyester
1 0.47uF 25VW tantalum
1 2.2uF 25VW electrolytic PC-type
1 4.7uF 25VW electrolytic PC-type type
1 1000uF 16VW PC-type electrolytic

RESISTORS
All half-watt 5%: 2 x 1k, 1 x 4.7k, 3 x 10k, 1 x 100k, 2 x 1M

Note: Resistor wattage ratings and capacitor voltage ratings are those used in the prototype. Components with higher ratings may generally be used, providing they are physically compatible. Components with lower ratings may also be used in some cases, provided that the ratings are not exceeded.

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

$35.00

This includes sales tax, but does not include the cost of the electric latch release mechanism required.

sequence. Any incorrect digit or correct digit in the wrong position immediately causes the counter to be reset to zero again. Only if all seven digits have been keyed in correctly does the counter reach the count of 7, and cause the latch release to be activated.

In greater detail, note that each of the outputs 01-07 of the counter is taken to one input of a series of 2-input NAND gates, IC1a — IC2c. The other input of each gate is connected to one of the seven programming links, and thence to one of the 10 output lines from the keyboard scanning section. The outputs of the 2-input gates are taken in turn to seven of the inputs of IC3, an 8-input NAND gate. The output of IC3 is taken via IC2d, connected as a negative-input OR gate, to the reset input of the counter.

The second input of IC2d is connected to the output of IC5a via a 100k/2.2uF delay circuit, which performs two functions. One function is to hold the second input of IC2d low when power is first applied to the circuit, forcing the output of IC2d high and ensuring that IC7 powers up in the reset-to-zero state. The second function will be made evident shortly.

Of the two "key pressed" strobe signals generated by the keyboard scanning circuit, the undelayed signal from IC5d is taken to the eighth input of IC3. The delayed signal from IC5c is taken to the clock input of IC7, the verification counter.

Although IC7 is reset to zero when power is first applied to the circuit, this is not the verification circuit's normal "quiescent" condition — which is with IC7 set to the count of 1. It moves into this state as soon as any key is pressed (it doesn't matter which key).

This happens in the following manner. With IC7 reset to zero, none of the gates IC1a — IC2c are enabled because outputs 01-08 of the counter are all at logic low. Regardless of the key pressed, then, all of the outputs of these gates will remain at logic high. As a result the undelayed "key pressed" pulse from IC5d will be able to progress through IC3 and then IC2d, and force IC7 back to the reset-to-zero state (in case it was not already in that state). However shortly afterward the delayed pulse from IC5c will be fed to the clock input of IC7, incrementing it to the count-of-1 state.

It is in the latter state that IC7 becomes capable of responding to the correct sequence of input digits as programmed by the wire links.

When the circuit is awaiting the first digit in the sequence, IC7 has a high logic level at output 01 (pin 2). This enables gate IC1a. If the correct key is then pressed, corresponding to the keyboard line connected to IC1a's input via link 1, this gate will therefore produce a logic low at its output.

As a result of this, gate IC3 will be disabled and the "keypressed" signal from IC5d will not be able to pass through to reset IC7. When the delayed signal from IC5d arrives at the clock input of IC7 it will therefore be able to increment the counter to its next count, with output 02 high ready for the next digit.

The thing to note is that the undelayed "key pressed" pulse from IC5d is only prevented from resetting IC7 if the correct digit key has been pressed, to enable the currentlyactive two-input gate and disable IC3. Pressing any other key will not cause IC3 to be disabled, and the counter will be reset to zero and then incremented back to 1 again.

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Exactly the same thing happens for each of the succeeding digits. Once the counter has reached the count of 2, for example, the only key that can make it progress to the count of 3 is the key which causes gate IC1b to produce a low output and disable IC3. Any other key allows IC3 to pass the reset pulse, so that IC7 is forced back to the count of 1 again. And so on.

So that only the correct sequence of digits keyed in without a false digit between them will cause IC7 to count up to the count of 8. Any false digit any where in the sequence will force IC7 right back to "first base".

Note that in the foregoing explanation, we have talked about the "key pressed" pulses from IC5d and IC5c as if they were narrow pulses. In fact they are quite long, lasting as long as a key is held depressed. However the essential thing is that the clock signal from IC5c triggers IC7 on its positive-going transitions, which occur about 5 microseconds after the reset signal from IC5d falls to the inactive level — just after the key is released.

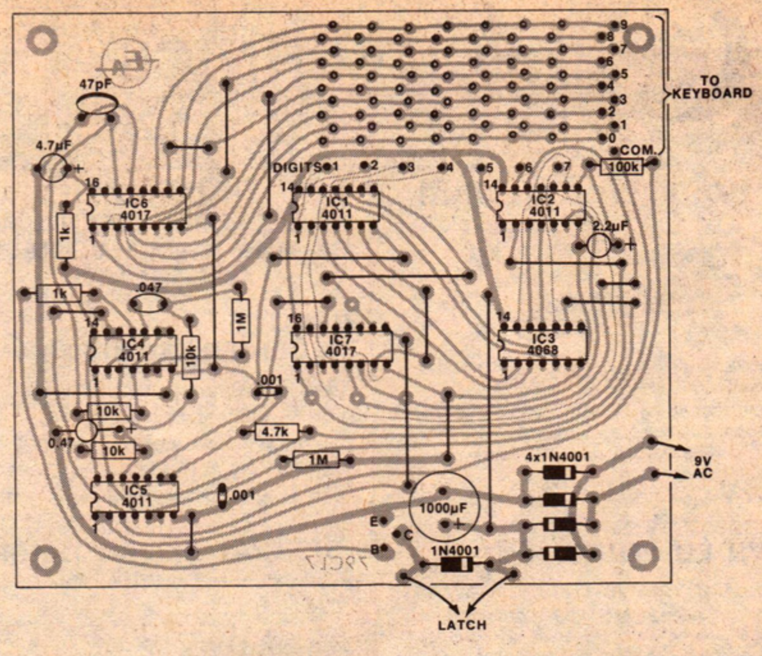
What this means is that when a key is pressed, IC7 will either be immediately reset to zero if the wrong key is pressed, or will remain at its current count if the correct key is pressed. Then when the key is released, the counter will increment — to either the count of 1 or the next apppropriate count,as the case may be.

Assuming the correct sequence of digits has been keyed in, counter IC7 finally reaches the count of 8 and its output 08 goes high. As gate IC5a is connected to this output as an inverter, its output accordingly goes low. This does two things, the first of which is to activate the latch release mechanism via gate IC4d (also wired as an inverter) and the BD263 Darlington transistor.

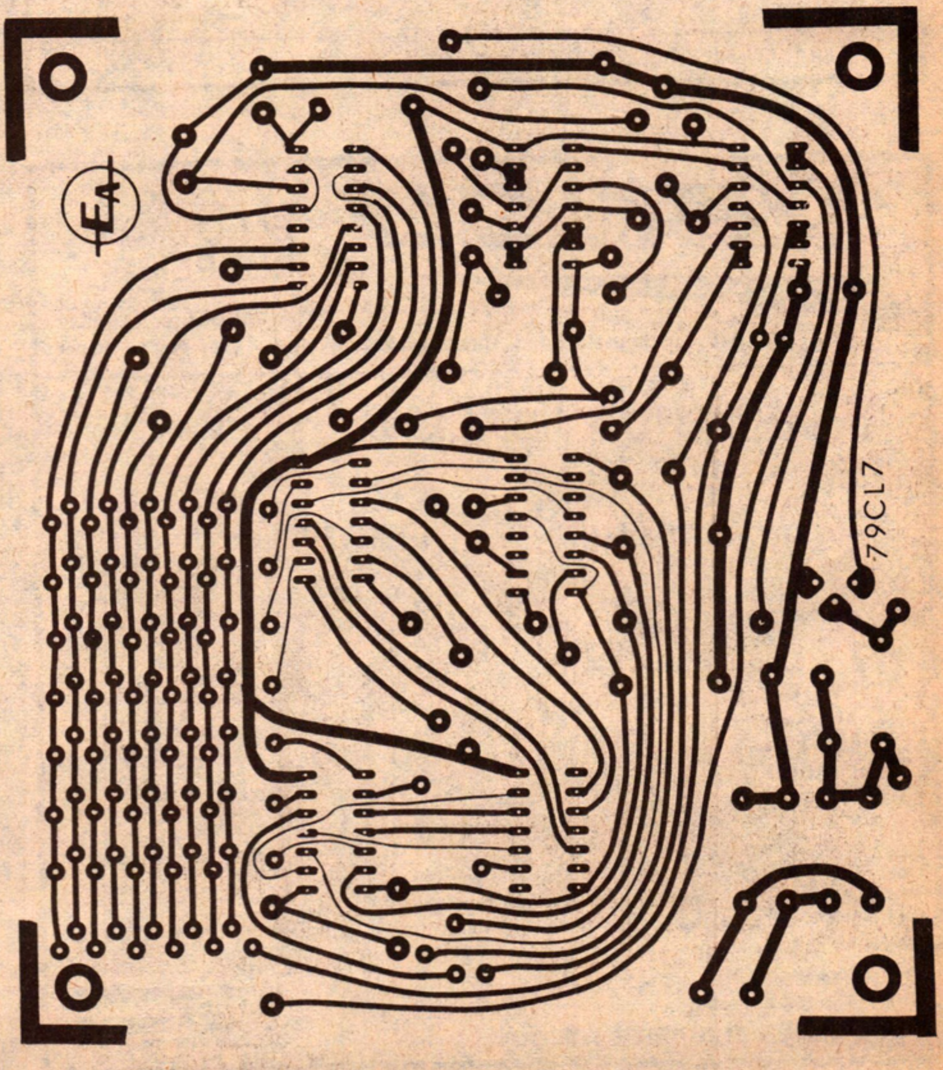
The second thing that happens is that the low at the output of IC5a is fed to the second input of IC2d, via the 100k/2.2uF delay circuit. As a result the second input of IC2d goes low after approximately 150 milliseconds, resetting IC7 to its zero state once again and deactivating the latch release mechanism.

Note that since IC7 is again reset to the zero state, it must be forced into its count-of-one state before it can accept the correct code sequence again. As when power is first applied, then, you have to key in a "dummy" digit before you key in the correct code. This is really no trouble, and if anything will make it harder for an intruder to find the correct combination.

The latch release or "electric strike" mechanism we have used with the lock is designed for pulsed operation, and thus operated quite happily from the



Use this overlay diagram in conjunction with the circuit to assemble your unit. Don't forget to add programming links to make up the 7-digit code you require.



Here is an actual size reproduction of the main PC pattern.

150ms pulse delivered by the circuit. The pulse of current triggers an internal release mechanism, which allows the door to be opened at any time afterwards — there's no need to hurry. The release resets as soon as it springs back into place when the door is opened.

Made in Spain by Golmar S.A., the mechanism is designated type CV-24 and is rated to draw about 1A from a nominal 12V DC supply. It is imported by Habitech Pty Ltd, of 14 Northcote Street, St. Leonards, NSW 2065, who sell directly to the public, but you can also buy it from their interstate distributors or from sepecialist locksmiths. The recommended retail price is $37.00.

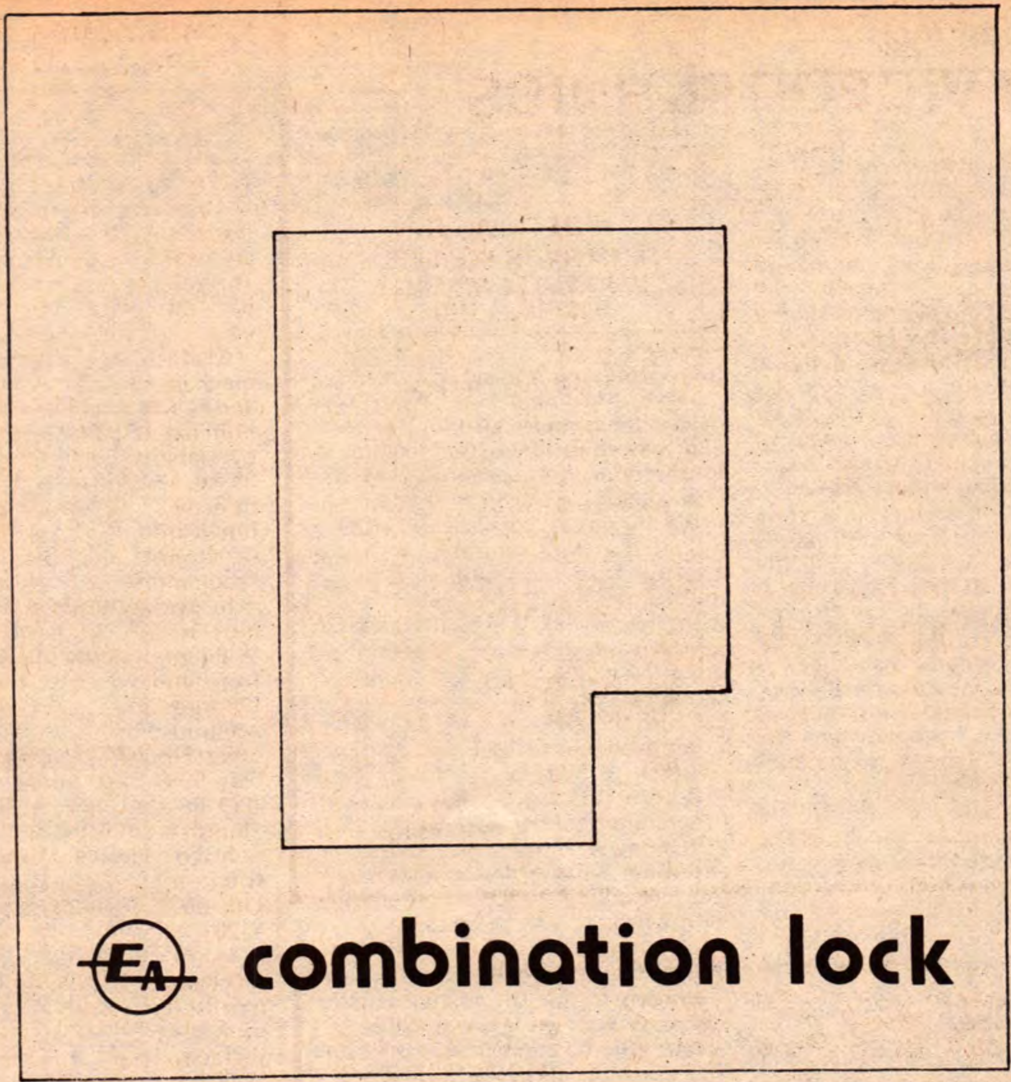
In Sydney you can buy them from North Shore Locksmiths of 75 Willoughby Road, Crows Nest 2065, or from Independent Locksmiths of 92 George Street, Parramatta 2150. In Melbourne they are available from Style Finnish (Security) Pty Ltd, Factory 5, 42 New Street, Ringwood 3134 (PO Box 80), and in Perth from Style Finnish (WA) Pty Ltd, 398 Rokeby Road, Subiaco 6008. In Brisbane the distributors are Vacumatic Distributors Pty Ltd, 36 Gladys Street, Stones Corner 4120.

As normally supplied the CV-24 mechanism is intended to replace a mortise-type strike plate, mating with a mortise-type spring return latch. A surface-mounting adapter plate is available if required, for an additional $3.00. Habitech also have available a version of th CV-24 which will operate with combination bevel-bolt latches and double-throw deadlocks, such as the Cisa type 52111 unit which they are also able to supply.

One thing you should bear in mind is that latch release mechanisms like the CV-24 will not work with some types of deadlock and deadlatch and may need modification to work properly with other types. We suggest that you seek advice from the suppliers listed or from your local locksmith, before committing yourself.

A somewhat more rugged, heavy-duty electric strike mechanism is also made locally by DK Security. Known as the DKS unit, it is available from North Shore locksmiths in Sydney. However this unit is designed for "continuous" rather than pulsed operation — that is, it will only release the latch while power is applied. It is also rather more expensive than the price of the Golmar unit.

To use the DKS unit with our lock design, you will need to modify the circuit so that it energises the release for considerably longer than the 150ms provided for a pulsed release. You can do this by increasing the values of the



Actual size reproduction of the keyboard artwork.

RC delay components between IC5a and IC2d. If you increae the resistor from 100k to 1M and replace the capacitor with a 22uF/25VW solid tantalum, the release will be energised for about 12 seconds — which should be adequate.

This modification should also allow the lock circuit to be used with other ''continuous'' type release mechanisms. For example there is a Golmar release of this type, the CV-14, which is otherwise similar to the CV-24 unit. You could use the CV-14 unit with our lock, if you wish, by making the same modification.

As mentioned before, the code combination to which the lock responds can be programmed as you wish, to any combination of seven digits. Each digit is set simply by connecting the appropriate 2-input gate to the corresponding output line from the keyboard scanning circuit.

Don't make the code too simple — like 1234567 — or it is likely to be guessed too easily. Similarly it might not be a good idea to make it too complex, or it might be too hard to remember! A familar telephone number might be worth using, although it might not be wise to use your own — a burglar might well have the foresight to look up your name and number! Another idea might be to use your birthdate, or some other significant figure.

If you don't really want the full protection of a seven-digit code, you can shorten the required code sequence simply by connecting the input of IC5a to one of the earlier outputs of IC7, rather than to 08. Hence by connecting it to 06 you will need only a 5-digit code, and so on.

We have designed a PC board to accommodate virtually all of the combination lock circuitry, and make construction easy. The only components which don't fit on the PCB are the power transformer, which is too bulky, and the keyboard and latch release mechanism which are in any case best separated from the main unit.

The PCB measures 114 x 130mm, and is coded 79CL7. The pattern is reproduced actual size in this article, for those who may wish to trace it or copy it photographically. Alternatively, transparencies will be available from the Information Service, and you should also be able to buy finished boards shortly from the usual suppliers.

A close-up view of the keyboard. The "CLR" key is a dummy.

Wiring up the unit should be fairly straightforward using the PCB overlay diagram and the photographs as a guide. We suggest that you leave the ICs until last when wiring up the unit, however, as they are CMOS devices

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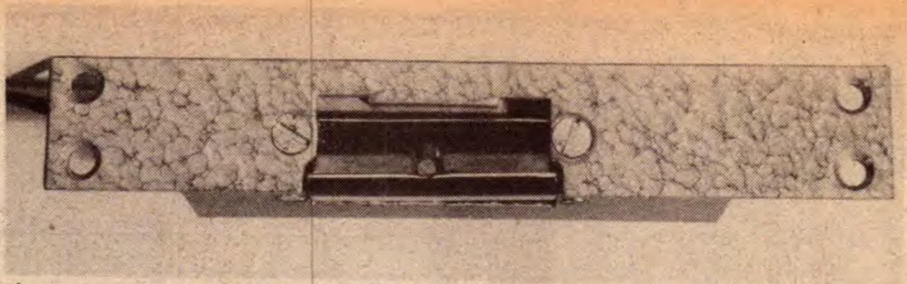


Close-up view of the Golmar CV-24 door-latch mechanism.

and can be damaged by excess static charge.

As you can see the PCB provides a matrix of holes near one corner for convenient setting of the combination code. The seven gate inputs for the verification circuit are along the side of the matrix, and all you have to do is fit a wire link from each one to any of the 10 digit lines available in a staggered row along from it. The entry keyboard or keyboards also connect to a row of holes at the end of the matrix area.

We suggest you connect the entry keyboard to the main lock unit via a length of 12-conductor ("6-pair") telephone cable, which is available from many parts stockists. This cable is round, and can be easily run through holes in walls, skirting boards and architraves. An alternative would be flat "rainbow" cable. The circuit will work reliably with up to about 5 metres of cable between the keyboard and the main lock unit, which should be adequate for most applications.

The entry keyboard should be mounted conveniently adjacent to the outside of the door to which the release mechanism is fitted. If the door is on an external entrance, the keyboard should be suitably protected from the weather as most switches are not fully waterproof.

For the keyboard itself we used a set of keyswitches which were kindly supplied by Pre-Pak Electronics, of 718 Parramatta Road, Croydon, NSW. There are eleven switches in the set, and they come with integral numbered keytops. The eleventh key is labelled "CLR". The set is available from Pre-Pak for $5.50, plus postage if applicable.

We have designed a small PCB to mount these switches. It measures 89 x 91mm, and is coded 79KB7. As you can see from the photographs it provides for the CLR switch as well as the ten numbered switches, even though the CLR switch is not connected into circuit. The idea behind this is that the CLR key becomes a dummy, to provide further potential confusion to an unauthorised person trying to gain entry.

As an alternative to the keyswitches we have used, you could use ten standard miniature pushbuttons and perhaps mount them in a small diecast metal box. The choice of keyboard and how you mount it near the door is up to you.

Don't forget that as well as the cable between the lock unit and the keyboard you also need to run a 2-wire cable to the latch release mechanism. However this can be light-duty figure-8 cable of the type used for hifi speaker connections, so it should pose few problems.

The lock circuit PCB and power transformer are housed in a small inexpensive instrument case. The case we used came from Dick Smith Electronics, and measures 184 x 70 x 160mm. It is listed under the number H-2744 in the DSE catalog.

We mounted the PCB on "Richco" moulded nylon supports, which are available from most parts stockists. The transformer was at the rear of the PCB, with the power, keyboard and latch release cables entering via grommeted holes. Needless to say the mains cable should be properly clamped after entry, with the active and neutral taken to a connector strip and the earth lead soldered to a lug bolted to the case.

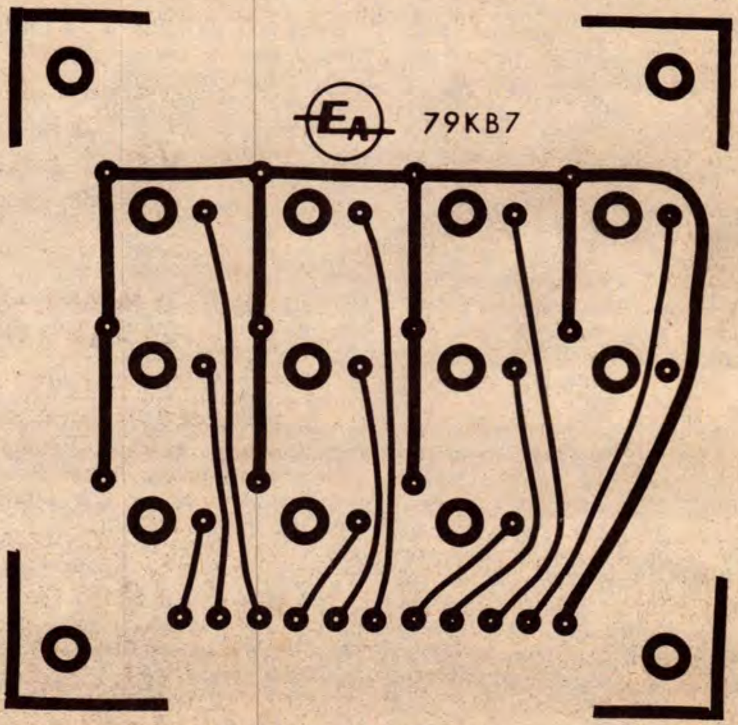
When the keyboard cable and programming links are wired to the PCB along with the power supply parts and other passive components, the ICs can be added to complete the job. Remember to take the usual precautions when dealing with CMOS devices: use a small soldering iron, preferably of the low voltage separate-element type, and use a cliplead to connect the tip and barrel of the iron to the "earthy" copper track on the PCB.

When soldering in each IC it is a good idea to solder the two supply pins first, so that the internal protection diodes can function as soon as possible. With the 16-pin devices these are pins 8 and 16; for the 14-pin devices they are pins 7 and 14.

When you have finished wiring up the electronic lock we suggest that you check over all PCB connections, etc before turning on the power for the first time. Similarly it is a good idea to make sure all of the polarity or orientation-conscious components are mounted the correct way around on the PCB.

If all is well, it should be possible to turn on, key in a dummy digit and then the code combination you have programmed into the links, and hear the release mechanism operate.

A final point. Although we have described the electronic combination lock with a simple mains-type power supply, it would obviously be possible to power it from a 12V battery supply if required. This means that you could use it for a car, boat or other application away from the mains. It also means that you could use a battery back-up system, to allow the lock to operate in case of power failure. We leave these optional eleborations up to you.



Actual size reproduction of the keyboard PC pattern.