United States Patent [15] 3,686,659
Bostrom [45] Aug. 22, 1972

[54] ELECTRONIC LOCKING DEVICE

[72] Inventor: Sten L. Bostrom, Hagersten, Sweden

[73] Assignee: Dasy Inter S.A., Geneva, Switzerland

[22] Filed: Jan. 5, 1970

[21] Appl. No.: 634

[52] U.S. Cl. ....340/274, 70/277, 317/134, 340/149 R

[51] Int. Cl. G08b 13/06

[58] Field of Search ......340/274, 276, 164 R, 149 R, 340/149 A; 317/134; 70/277

[56] References Cited

UNITED STATES PATENTS

3,093,994	6/1963	Richard	317/134 X
3,283,550	11/1966	Bradway	317/134 X
3,347,072	10/1967	Rose	317/134 X
3,508,031	4/1970	Cooper	317/134 X
3,411,046	11/1968	Swannick	317/134
3,024,452	3/1962	Leonard	340/274
2,882,455	4/1959	Ferguson	70/277 X
3,392,558	7/1968	Hedin et al.	70/277

Primary Examiner—David L. Trafton
Attorney—Hammond & Littell

[57] ABSTRACT

A locking device, comprising a mechanical locking means adapted to be electrically controlled, a source of electric energy, a receiver for receiving such energy, a key insertable into a mating keyhole means and arranged to thereby connect said source to said receiver for transmission of electric energy thereto, a number of target terminals distributed and spaced according to a first predetermined pattern within said keyhole means, an equal number of output terminals on said key distributed and spaced according to said first pattern, each output terminal being arranged, upon the correct insertion of said key into said keyhole means, to cooperate with a respective target terminal to supply electric energy thereto, a plurality of electric energy conducting paths within said key each leading from said source to at least one of said output terminals, a plurality of electric circuit components comprised within said paths and arranged to modify predetermined characteristic properties of electric energy propagated along said paths, to thereby generate output conditions on said output terminals according to a second predetermined pattern specific for the key, a plurality of circuit means each having an input connected to at least one of said target terminals and each being arranged to generate an output signal when receiving as an input signal a predetermined value of some characteristic property of the electric energy, a plurality of bistable devices each connected to a respective of said circuit means and arranged to be actuated when receiving an input signal therefrom, said bistable devices being arranged to be actuated according to a third predetermined pattern when said second predetermined pattern corresponds to the pattern of predetermined input signal values to said circuit means, said third output pattern from the bistable devices being effective to open said mechanical locking means and manual means for modifying the electric properties of at least one of said paths.

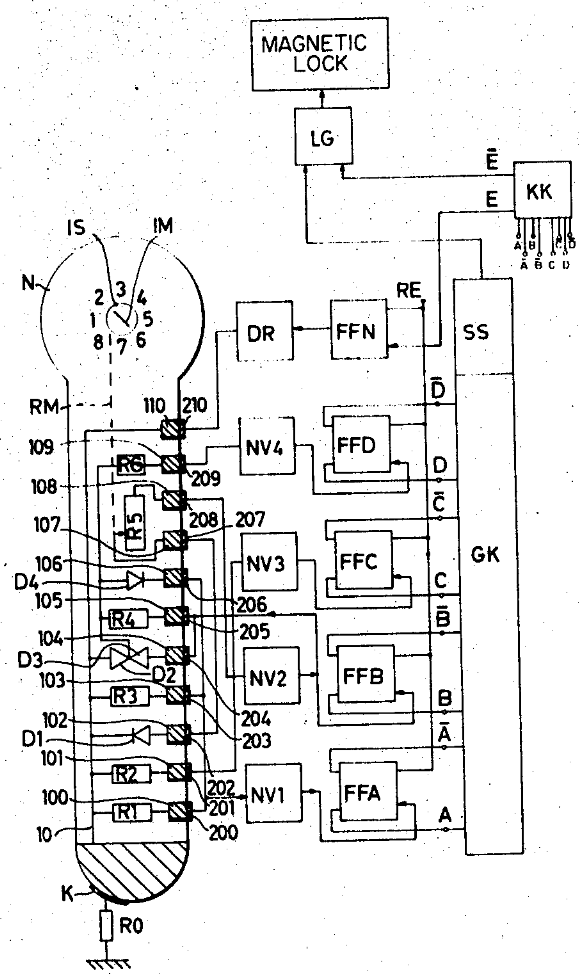
3 Claims, 4 Drawing Figures

United States Patent

Bostrom

[15] **3,686,659**

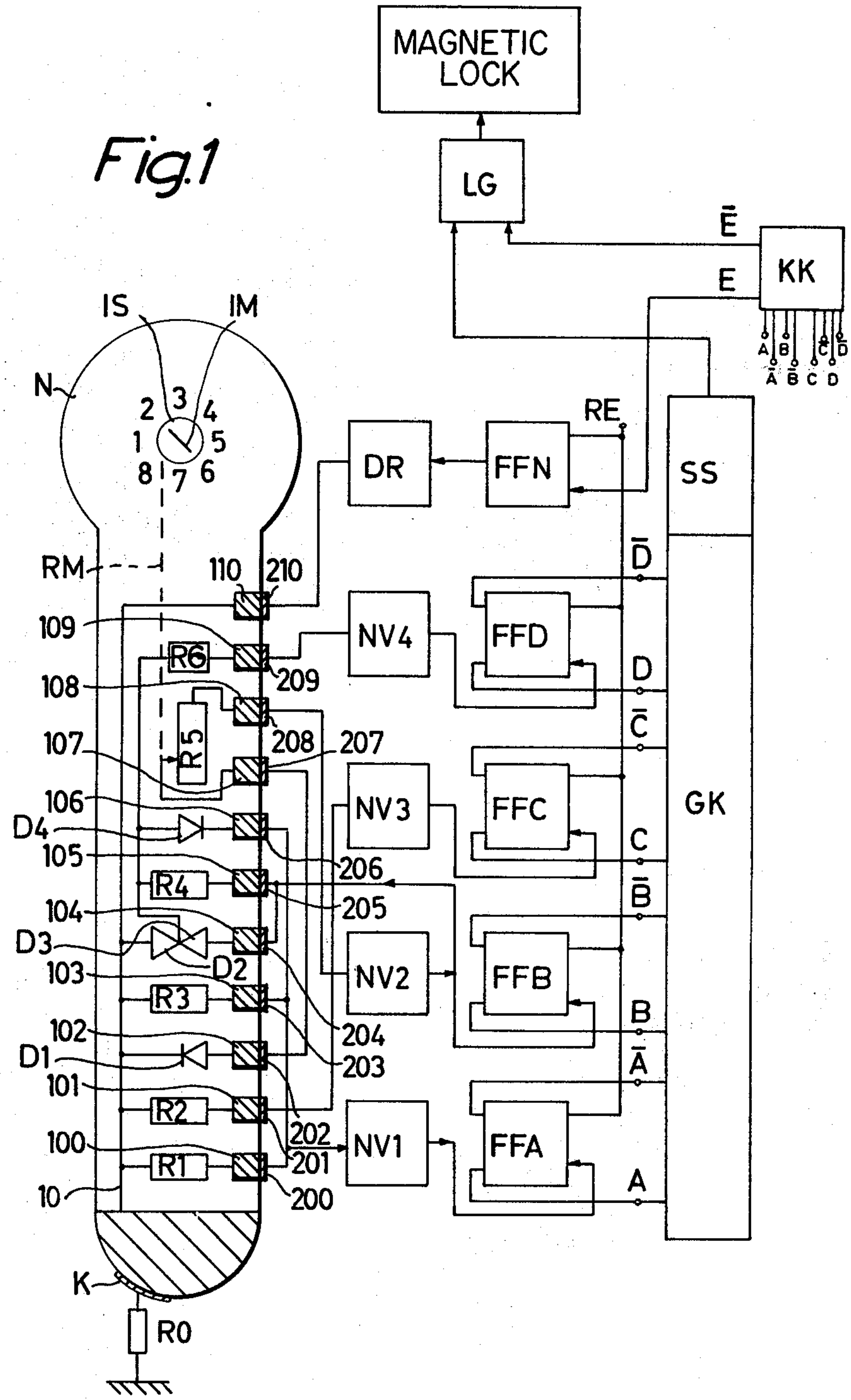
[45] **Aug. 22, 1972**



Patented Aug. 22, 1972 3,686,659

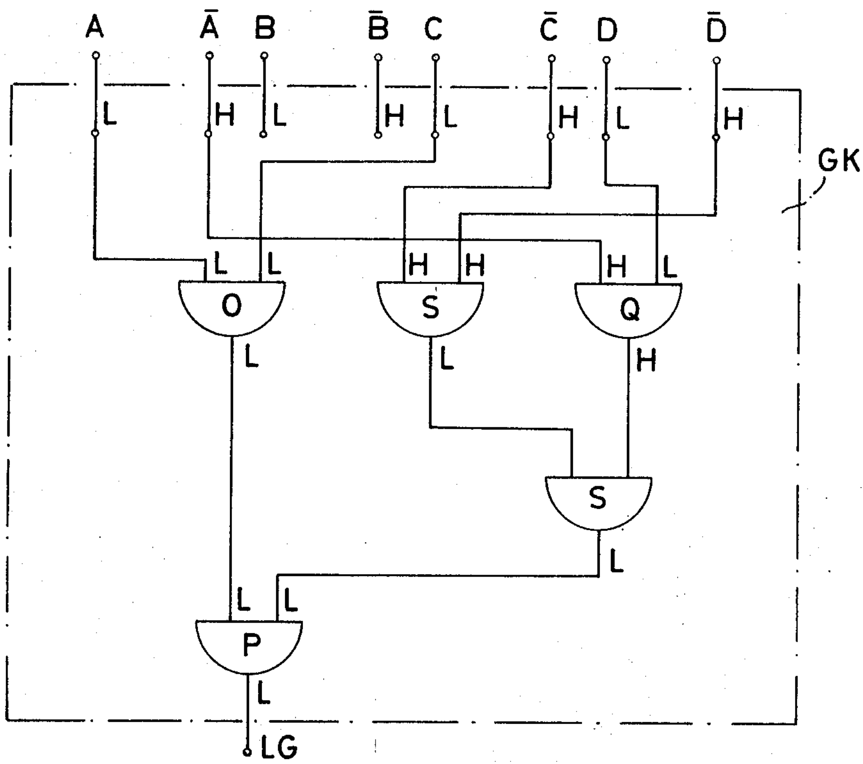
3 Sheets-Sheet 1

Fig.1



INVENTOR.
STEN-LENNART BOSTRÖM
BY
Hammond and Littell
ATTORNEYS

Fig. 2



INVENTOR.
STEN-LENNART BOSTRÖM

BY

ATTORNEYS

Fig. 3

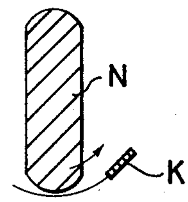
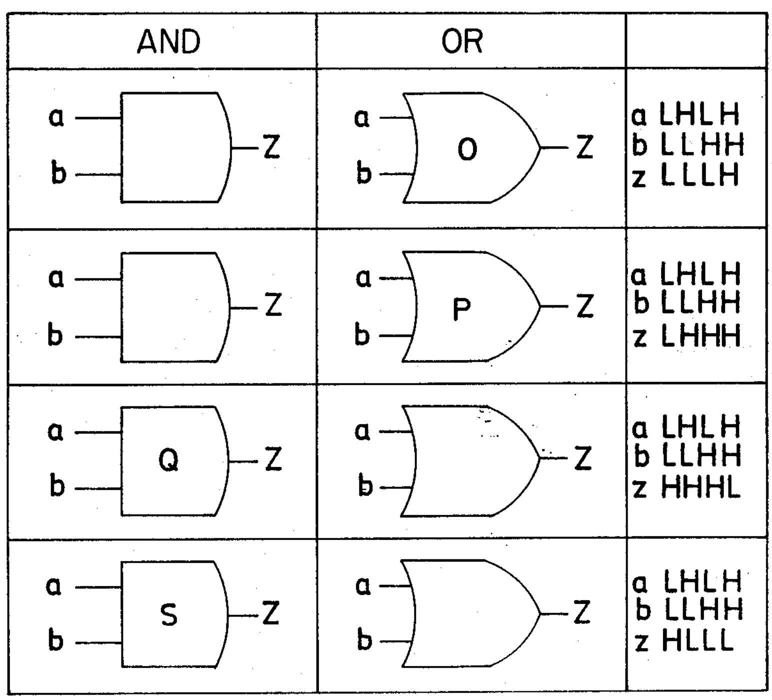


Fig. 4



INVENTOR.
STEN-LENNART BOSTRÖM
BY
ATTORNEYS

ELECTRONIC LOCKING DEVICE

The present invention relates to a tamperproof locking device, which permits a practically unlimited number of combination and which is practically impossible to use are unauthorized manner and practically impossible to imitate.

For this purpose a locking device according to the invention comprises a locking device, comprising a mechanical locking means adapted to be electrically controlled, a source of electric energy, a receiver for receiving such energy, a key insertable into a mating keyhole means and arranged to thereby connect said source to said receiver for transmission of electric energy thereto, a number of target terminals distributed and spaced according to a first predetermined pattern within said keyhole means, an equal number of output terminals on said key distributed and spaced according to said first pattern, each output terminal being arranged, upon the correct insertion of said key into said keyhole means, to cooperate with a respective target terminal to supply electric energy thereto, a plurality of electric energy conducting paths within said key each leading from said source to at least one of said output terminals, a plurality of electric circuit components comprised within said paths and arranged to modify predetermined characteristic properties of electric energy propagated along said paths, to thereby generate output conditions on said output terminals according to a second predetermined pattern specific for the key, a plurality of circuit means each having an input connected to at least one of said target terminals and each being arranged to generate an output signal when receiving as an input signal a predetermined value of some characteristic property of the electric energy, a plurality of bistable devices each connected to a respective of said circuit means and arranged to be actuated when receiving an input signal therefrom, said bistable devices being arranged to be actuated according to a third predetermined pattern when said second predetermined pattern corresponds to the pattern of predetermined input signal values to said circuit means, said third output pattern from the bistable devices being effective to open said mechanical locking means and manual means for modifying the electric properties of at least one of said paths.

The energy receiver can electromagnetically operate one or several mechanical locking means. The key is arranged in such a way that when it is inserted into a keyhole, it will actuate a starting means which causes the source to deliver electric energy to the key, so that said energy is transmitted to the receiver. The key is provided with means which can be manually actuated to control or actuate one or several paths of electric energy or intensities of electric energy through the key to the receiver. In an embodiment of the invention some of the targets of receiver comprise amplifiers connected thereto, which, when receiving a predetermined input energy from their target, suitably actuate an associated flip-flop or change-over switch. The flip-flops or the change-over switches each control a logical gate unit, which is provided with a series of inputs and, when a predetermined input condition pattern is present on the series of inputs, controls a means for actuating the lock, but for all other input condition patterns than the pre-determined correct pattern makes actuation of the lock impossible. The key is arranged to direct electric current along different paths in the key to different output terminals of the key located adjacent corresponding targets terminals of the receiver. Thereby the key can damp or reduce, amplify or increase different parameters of electricity respectively in different ways. In a key operated by alternating current energy said key can be arranged to modulate the phases of different components of the alternating current in different ways. The key can also be arranged to direct or diverge different parameters of electricity to different output terminals of the key located right in front of and communicating with different desired target terminals of the receiver. The logical gate unit is suitably assembled of a number of serial stages of parallel simple AND-gates or OR-gates or both. The key intended to operate with direct current potentials comprises resistance components that apply different potentials on different output terminals of the key for delivery to respective target terminals of the receiver. The starting or initiating means, therefore, is suitably a ground connection contact and a contact, which are inter-connected by the key. In the receiver there are suitable means to feed blocking potential to the means operating the lock or other coupling means. The source of electric energy can also be arranged to selectively excite oscillators in the key, which provide different target terminals with different frequencies via filters associated therewith.

The invention will now be described more in detail in connection with an example of an embodiment illustrated in the accompanying drawings in which:

FIG. 1 shows a key inserted in a keyhole,

FIG. 2 shows an example of a gate unit of the locking device,

FIG. 3 schematically illustrates a cross section through the key and

FIG. 4 shows a table of examples of different types of gates which can be used.

As is evident from FIG. 1 the key N on its handle is provided with a dial IS having an indication mark IM and a scale cooperating therewith on the side of the key handle. The exemplary figure graduation on the scale shown is divided in eight positions **1–8**. Another dial can be arranged on the opposite side of the handle. In addition to, or instead of dials, one or several rings having or cooperating with figure markings for setting a code number of several digits may be provided in a manner well known in the combination locks art. In order to simplify the description, it is here assumed that only the dial IS shown is present and that said dial, via a belt RM, actuates a setting means in the form of for example a resistor R5 located in the interior of the key, which will be described in detail below. The position of the dial shown with the digit **2** opposite the indication mark IM is assumed to be the correct code position for the key in question.

When the key N is inserted into a mating keyhole, the physical shape of which may be "female" if the key is "male," the end of the key, for example when being turned in the direction of the arrow appearing in FIG. **3** actuates a contact K (FIGS. **1** and **3**) in the bottom of the hole, which contact via a resistance RO connects the key to ground. During this turning operating of the key a row of contact elements **100–110** in the key will also come in contact with a corresponding row of contact elements **200–210** in the keyhole (FIG. **1**).

The left hand terminals of a series of resistors R1, R2, R3 and the left hand terminals of the two diodes D1 and D2 are connected to a ground return line 10 in the key, which at one side is connected with the contact K and at the other side with the contact or input terminal 110 of the key. The other terminals of the resistors R1, R2, R3 and of the diodes D1 and D2 are connected to the respective contact elements or output terminals 100, 101, 103 and 102. The diode D2 is connected via a second counterdirected diode D3 to the contact element or output terminal 104. From the connection point between the diodes D2 and D3 a circuit containing a resistor R6 leads to the contact element or output terminal 109. A resistor R4 and a diode D4 are at one of their terminals connected to said connection point and at their other terminals are connected to the contact elements or output terminals 105 and 106, respectively. A variable resistor R5 has its sliding contact driven by the belt RM connected to the contact element or output terminal 107 and its other terminal connected to the contact element or output terminal 108.

The contact elements or target terminals 200, 203 and 206 of the keyhole are interconnected. They have a common connection with a threshold amplifier NV1. The contact elements or target terminals 202 and 207 are interconnected as are the contact elements or target terminals 204 and 205. The contact element or target terminal 201 is connected to a threshold amplifier NV3. The contact element or target terminal 208 is connected contact element a threshold amplifier NV2, and the contact element or target terminal 209 is connected to an amplifier NV4. The contact or output terminal 210 is connected to a driving circuit or source of electric energy DR, which supplies, for example, −12 volts to the return line 10 via the contact elements 110, 210 when a correctly set mating key is inserted in the keyhole, but +12 volts when an incorrect or incorrectly set key is inserted. The output from the amplifier NV2 is connected with the interconnected contact elements 204 and 205. Each amplifier NV1–NV4 is connected with an associated bi-stable flip-flop FFA, FFB, FFC and FFD, respectively. The driving circuit DR is biased by a flip-flop FFN. Each flip-flop FFA, FFB, FFC, FFD has two outputs indicated respectively by reference letters A and $\bar{A}$, B and $\bar{B}$, C and $\bar{C}$, D and $\bar{D}$. These outputs are each individually connected to an associated input in a gate circuit GK, which has an end portion SS, which in turn is connected to a locking gate LG operating a magnetic lock, for example. A combination circuit KK has inputs connected to the respective outputs from the flip-flops FFA–FFD, as is evident from the corresponding letter indications at said inputs. The circuit KK has two outputs E and $\bar{E}$ connected to the flip-flop FFN and the gate LG. All the flip-flops are connected to a reset terminal RE.

The gate unit GK can be designed in a great number of different ways. By way of example, a number of elementary types of gates of the AND- and OR-type of which said gate unit can be composed are shown in FIG. 4.

In the table of FIG. 4, four types of AND-gates are shown in the left column, four types of OR-gates in the middle column, and in the right column the input and output conditions for said gates are shown. In the table, a and b indicate inputs and z outputs. Only gates having two inputs a,b and one output z are shown, but it is obvious that a great number of other types of more complicated gates known per se can be used for designing the unit GK.

In the right column, where the input conditions and output conditions for the gates shown are exhibited in table form, the two possible conditions are indicated by letters L and H, respectively, which for example can signify low voltage and high voltage, respectively. It is evident from the top of said column that an input condition L on both inputs a and b gives an output condition L on output 2, that input conditions H and L on a and b, respectively, and the reverse combination of L and H on inputs a and b gives output condition L on output z, but that input condition H on both inputs a and b gives condition H on output z.

In FIG. 2 an example of possible design of the circuit GK is shown, using only the types of OR-gates O and P and AND-gates Q and S shown in FIG. 4. In FIG. 2 it is assumed that the correct key has been inserted in the lock and the flip-flops FFA, FFB, FFC, FFD are then all in the setting conditions with the condition L on the left hand terminals and the condition H on the right hand terminals. Thus on the input terminal series in FIG. 2 the conditions L and H, counted from left to right, are present. Said conditions are fed to the gate circuit GK and to the combination circuit KK. The gate circuit GK is assumed according to FIG. 2 to comprise three gates O,S,Q connected to said input terminals, but the terminals B and $\bar{B}$ are shown without connection. The first gate O receives L on both inputs and then delivers L. The second gate S receives H on both its inputs and then delivers L. The third gate Q receives H on one input and L on the other, and then delivers H, which all is in accordance with the table of input- and output conditions for the respective type of gate according to FIG. 4. The three output conditions L, L, H, respectively, are delivered to other gates, and more particularly the conditions L and H from the gates S and Q, respectively, are delivered to a second gate S, which for said input conditions gives the output condition L. This condition and the condition L from gate O is delivered to a further gate P, which then gives the output condition L which is transmitted to the locking gate LG, so that this gate can operate, i.e., unlocking the magnetic lock.

As mentioned, the indicated series of output conditions from the terminals A,$\bar{A}$, B,$\bar{B}$, C,$\bar{C}$, D,$\bar{D}$, were transmitted also to the combination circuit KK, which is also composed of gates, i.e., of the kind shown in FIG. 4. Said circuit is arranged in such a way that on its output E, when the input combination of condition L and H is the one shown in FIG. 2, i.e., the one which corresponds to insertion of the correct key, it gives such information to the flip-flop FFN that said flip-flop does not bias DR, which then gives out −12 volts to the contact element 210 and thence to the key. Any other incorrect input combination of L and H to the circuit KK results in change-over of the flip-flop FFN, which then changes over the driving circuit DR, so that instead said circuit DR, for example, gives a +12 volts to the key, as will be described below in greater detail. The other output $\bar{E}$ from the circuit KK is connected to the locking gate LG, which, when the correct key is used, receives for example the condition L on its right hand input, but when the wrong key is used receives the condition H. The left hand input of LG is fed, as is evident from FIG. 2, with the condition L, when the key is the correct one, but otherwise with the condition H. The conditions L on both inputs of the gate LG, which for example can be of the type shown in the second row in FIG. 4, gives an operating current to the magnetic lock on the output from LG. The magnetic locking means is shown in FIG. 1.

The mode of operation of the locking device will be described in connection with the embodiment shown in the drawing. Certain values of the voltages used will be assumed, and consequently certain special values of the components will also be assumed.

Thus the amplifiers NV1–NV4 are assumed to be set for the lower threshold voltages –3 volts, –7.5 volts, –5 volts, –2 volts, respectively, and the resistance values used are assumed to be selected in such a way that said values of the voltages are obtained when the source of the driving voltage DR gives –12 volts to the contact **110** of the key. The upper threshold voltages of the amplifiers, i.e., the voltages above which they do not function, are assumed to be somewhat above said lower threshold voltages.

The operation of the system will be described, assuming that the correct key has been inserted in the lock.

The driving circuit then, as mentioned, gives –12 volts to the contact **110** and the circuit **10**. The resistances R1 and R3 are then assumed together to give –3 volts to the amplifier NV1 via the contacts **200** and **203**. Said potential is also present on the diode D4 via contact **106**. This voltage, –3 volts, is the correct voltage for the amplifier NV1, and therefore the changeover of the flip-flop FFA takes place, so that said flip-flop gives the condition L on the terminal A and the condition H on the terminal $\bar{A}$.

The potential –12 volts applied to the resistor R2 is assumed to give –5 volts to the amplifier NV3, which is the correct voltage to said amplifier, and therefore the flip-flop FFC is charged over to the conditions L and H on the outputs C and $\bar{C}$, respectively.

The driving circuit DR further gives –12 volts to the top terminal of the diode D1 and of the diode D2. From diode D1 said potential is received at the sliding contact of the resistor R5, which is set in the way described above by means of the dial IS. The resistance value of resistor R5 is assumed to be set so that –7.5 volts from R5 is delivered to the amplifier NV2 via the contacts **108, 208**, which is the correct voltage for said amplifier, so that the corresponding flip-flop is changed over to the conditions L and H on the outputs B and $\bar{B}$, respectively.

From resistors R1 and R3 the potential –3 volts is present on the lower terminal of the diode D4. With –12 volts on the top terminal and, for example, –7.5 volts from the output of NV2 the diode D2 is blocked. On the top terminal of the diode D4 the potential –7.5 volts is thus present from the connection point between D2 and D3. The diode D4 thereby will be blocked. From said connection point also the potential –7.5 volts is delivered to the top terminal of the resistor R6. The last mentioned resistor then is assumed to give –2 volts via the contacts **109, 209** to the amplifier NV4, which is the correct voltage for said amplifier, so that the flip-flop FFD is changed over and gives the conditions L and H on the outputs D and $\bar{D}$, respectively.

All the outputs $\bar{A}$, $\bar{B}$, $\bar{C}$, $\bar{D}$ then have the condition L according to FIG. **2** and all the outputs A, B, C, D then have the condition H, also according to FIG. **2**.

According to FIG. **2** it is then understood that the condition L is obtained to the gate LG. Then likewise the condition L is obtained on output $\bar{E}$ to the aforementioned gate LG. Thereby the lock is automatically opened.

If, on the contrary, an incorrect key is inserted in the lock at least one of the amplifiers NV1–NV4 from the beginning receives the wrong voltage.

If it is assumed that, for example, the incorrect key has only a single discrepancy from the correct key, e.g., the resistor R1 having an incorrect value, then the amplifier NV1 receives the wrong input voltage. Thus its output voltage will be 0 volt, and the flip-flop FFA will not change over, because its output A receives the condition H and its output $\bar{A}$ receives the condition L (which according to FIG. **2** is the opposite condition compared to the correct one, namely L,H). The combination circuit KK further receives the wrong input condition and gives out the condition H on the output $\bar{E}$ to the gate LG, which then cannot operate. Further, it is evident from FIG. **2** and **4** that the condition H on A and L on $\bar{A}$ gives the output condition H on gate 0 instead of L, and L instead of H on gate Q. The other gate S thereby receives the wrong output condition H and both the inputs of the gate receive the condition H instead of L. Thereby the wrong input condition H at the locking gate is obtained, because of which said gate remains blocked.

If alternatively, for example, the gate NV2 receives –3 volts instead of the correct voltage of –7.5 volts, the output voltage from NV2 will be incorrect and the flip-flop FFB will not change over, its output condition being reversed compared to what is shown in FIG. 2. However, the terminals B and $\bar{B}$ are not connected to the gate unit GK. Said gate is thereby unaffected and, assuming that all other input conditions in the beginning are the correct ones, as in FIG. 2, said unit gives out the correct condition L to locking gate LG. But the combination circuit KK receives the wrong input voltage series and thereby gives the condition H to the gate LG, which thereby would be blocked and remain inactive. Thus even if one has not connected the terminals B,B to the unit GK, the gate LG thereby not function, and this non-functioning condition is further reinforced by the other conditions, which simultaneously would take place in the key N. Because NV2 receives only –3 volts and thereby gives out the potential –3 volts, the diode D3 will be conducting with 0 volt from NV2 and short circuit the resistor R4. The diode D4 also receives 0 volt and thus blocks the amplifier NV1 from the contact **206**. The resistor R6 receives the wrong voltage, whereby the amplifier NV4 cannot function. Because the input conditions to the gate unit GK thereby will differ from the correct conditions, the wrong condition is now received at locking gate LG. The combination circuit KK also gives a changeover signal to the flip-flop FFN, which changes over the driving circuit to give out +12 volts to the circuit **10** via the contacts **210, 110**.

The final result will be that, in addition to the amplifiers NV1, NV2, NV4 dealt with above, the amplifier NV3, which from the beginning has had the correct voltage, also receives the wrong voltage thereby giving out an output voltage of 0 volt to its flip-flop FFC, which returns to rest position. The zero position of all the threshold amplifiers means that one cannot obtain any knowledge of the correct key setting from electrical measurements made at the lock.

The electric circuit components within the key are advantageously not made as distinct components, but are for example integrated circuits. Circuits of thin film, mini- or microcircuits can also be used, which are cast in the very key itself in order to make it impossible to arrive at any conclusions as to its design by dismantling the key. Then it will be impossible to dismantle the key without destroying its circuit components beyond recognition. One can suitably use such integrated components, in which certain connections have been cut or broken. It is evident that a very great number of different couplings of the components in the key can be made. Further, the key can comprise elementary components other than resistors and diodes, as for example condensers, inductors, filters, etc., and be fed with one or more alternating currents of the same or different frequencies instead of with direct current. Different magnetic components can also enter in the design. The same possibilities of variation are also present in the case of the stationary part of the locking device, and its components are of course adapted to the components in the key design. The energy transmission to the receiver can also be made inductively.

In FIG. **1** only terminals **100–110** from the key and corresponding terminals **200–210** in the keyhole have been shown. However, it is obvious that a very great number of such series of terminals or contacts can be arranged on the periphery of the key, with the remainder being dummies, of which a certain small number will be used in reality, i.e., be connected to the actual current circuit components of the key. The keyhole then of course shall have the corresponding number of input contacts. The key can also be provided with only a small number of output contacts, while the keyhole itself can have a great number of input contacts. It is obvious that innumerable different combinations of keys and the locks belonging thereto can be obtained by means of the invention.

Further, a great number of combination possibilities are created by the gate device GK permitting selection between a very great number of different gate types, it being possible, by taking into account the present state of the electrical circuit design art, to obtain a practically innumerable number of different locking devices.

The invention has been described above in connection with a very simple embodiment, and a number of modifications have been dealt with in summary, but it is understood that the invention is not limited thereto but that its scope is limited only by the accompanying claims.

What I claim is:

1. A locking device, comprising

a. mechanical locking means adapted to be electrically controlled,

b. a source of electric energy,

c. a receiver for receiving such energy,

d. a key insertable into a mating keyhole means and arranged to thereby connect said source to said receiver for transmission of electric energy thereto,

e. a number of target terminals distributed and spaced according to a first predetermined pattern within said keyhole means,

f. an equal number of output terminals on said key distributed and spaced according to said first pattern, each output terminal being arranged, upon the correct insertion of said key into said keyhole means, to cooperate with a respective target terminal to supply electric energy thereto,

g. a plurality of electric energy conducting paths within said key each leading from said source to at least one of said output terminals,

h. a plurality of electric circuit components comprised within said paths and arranged to modify predetermined characteristic properties of electric energy propagated along said paths, to thereby generate output conditions on said output terminals according to a second predetermined pattern specific for the key,

i. a plurality of circuit means each having an input connected to at least one of said target terminals and each being arranged to generate an output signal when receiving as an input signal a predetermined value of some characteristic property of the electric energy,

j. a plurality of bistable devices each connected to a respective of said circuit means and arranged to be actuated when receiving an input signal therefrom, said bistable devices being arranged to be actuated according to a third predetermined pattern when said second predetermined pattern corresponds to the pattern of predetermined input signal values to said circuit means, said third output pattern from the bistable devices being effective to open said mechanical locking means, and

k. manual means for modifying the electric properties of at least one of said electric energy conducting paths.

2. A locking device according to claim **1**, further comprising starting means arranged to actuate said source of electric energy to produce such energy upon correct insertion of said key into said keyhole means.

3. A locking device according to claim **1**, further comprising means for blocking said mechanical locking means and for modifying the output from said source upon sensing an input condition pattern to said gate unit different from said third pattern.

* * * * *