RESISTIVELY-CODED SECURITY SYSTEM

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ABSTRACT

An electronic key-actuated security system including keys each constituted by a plurality of electrically resistive elements. Key-receiving means includes conductors which provide connections with resistive elements of a key received. The system includes a plurality of bridges each associated with one of the resistive elements of a key received. Each of said bridges has first, second and third impedance arms, a respective one of the key resistive elements being connected as a fourth impedance arm of each said bridge. The first and second arms define a first preset impedance ration, and the third and fourth arms define a second impedance ration, the bridge being electrically balanced when these ratios are equal. Logic gate means is interconnected with each of the bridges and supplies an output signal when all of the bridges are balanced. Electrically actuable means, e.g., a latch, is responsive to this output signal for indicating thereby the receiving of a key having resistive elements causing balancing of all the bridges. A key for use with the system includes a nonconductive portion adapted to be inserted in the key-receiving means. Pairs of contacts are bilaterally symmetrical with respect to an axis of symmetry extending in the direction of insertion of the key with the result that the key is adapted for bilateral insertion.

10 Claims, 8 Drawing Figures
FIG. 7

TO VOLTAGE

SYSTEM CIRCUITS

TO LATCH

FIG. 8

TO OTHER COMPARATORS

LATCH OPERATE SIGNAL

TO LATCH
RESISTIVELY-CODED SECURITY SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to electronic lock systems or electronic security systems, and more particularly to a key-actuated electronic security system employing keys each constituted by a plurality of electrically resistive elements, the system being responsive to the receiving of a key having elements of predetermined resistance.

Generally speaking, electronic lock circuits heretofore have been of either digital or analog types. The present invention concerns a lock system of the analog type. Lock systems of the digital variety typically use binary techniques which, while facilitating the manipulation of information derived from a key of the system, may suffer from complexity. Where the manipulation of information is not of paramount importance, the use of an analog electronic lock system offers the significant advantage of simplicity while making possible highly efficient key coding. In an analog system, a relatively large number of key combinations may be provided while using relatively few hitting positions for each key.

In electronic lock systems of the analog variety, it has been previously proposed to use keys having resistively coded elements. Disclosures of electronic lock systems employing this type of key may be found, for example, in U.S. Pat. Nos. 3,093,994, 3,134,254, 3,283,550 and 3,518,655. In one type of prior art lock system, a key is employed which may have either a resistance-resistive element or a capacitive element operative in response to a key. Thus the range and number of possible discrete levels of resistance (or capacitance) which can be used for the element of the key may be limited in number in order to assure discrimination between different levels of the keys or because sensitivity of the circuit is limited. Accordingly, the total number of possible key combinations is relatively small, restricting the utility of the system. Heretofore, there has been no provision in prior art systems for different "levels" of keys, such as master keys, et cetera. In addition, such systems have not facilitated the use of so-called multiple keying wherein different keys may each be received at different receptacles but will cause operation of the same circuitry at a single key-receiving point, or the use of duplex keying wherein different keys may be inserted in the same key receptacle but wherein each key is adapted to cause operation of different circuitry. Another difficulty which may be found in the use of such prior art circuitry is that the circuits may tend to be so sensitive to changes in temperature as to be unsatisfactory in use. For example, if an oscillator is employed, its frequency may undesirably shift sufficiently to cause improper operation with changes in temperature. Or it may be necessary to resort to complicated temperature-compensating circuitry in order to effect immunity to changes in temperature. An even more significant problem encountered in simple bridge-type circuits of the type described is that they may be easily "picked." For example, one attempting to defeat the system may utilize simple measuring techniques to ascertain the value of resistances in the bridge circuit and thereby determine the resistance needed to gain entry.

BRIEF SUMMARY OF THE INVENTION

Among the several objects of the invention may be noted the provision of an electronic key-actuated security system; the provision of an electronic key-actuated security system of the analog type employing keys each constituted by a plurality of electrically resistive elements; the provision of such a system wherein each resistive element of a key may have one of many possible discrete levels of resistance; the provision of such a key wherein the resistance of an electrically resistive element of the key may vary from a few ohms to many megohms in value; the provision of such a system wherein there is an extremely high number of total possible key codes, i.e., number of combinations of resistance levels of the resistive elements of keys; the provision of such a system wherein keys may be provided of several different levels such as master, grand master, great grand master, etc.; the provision of such a system wherein multiple keying may be used; the provision of such a system wherein duplex keying may be used; the provision of such a system providing great sensitivity to differences in values of resistance elements of keys of the system, assuring accurate discrimination between keys; the provision of such a system which is relatively immune to changes in temperature over a wide range; the provision of such a system which is exceedingly difficult to defeat or "pick;" the provision of such a system which is reliable, long-lasting and highly efficient in operation; the provision of such a system which is easily and economically manufactured; and the provision of a key for such a system which is adapted for bilateral insertion in key-receiving means of the invention. Other objects and features will be in part apparent and in part pointed out hereinafter.

Briefly, the present invention involves the provision of apparatus for use in an electronic key-actuated security system including keys each constituted by a plurality of electrically resistive elements. Key-receiving means is provided including conductors for providing connections with resistive elements of a key received. The apparatus further comprises a plurality of bridge circuits each associated with one of the resistive elements of a key received, each of the bridge circuits having first, second and third impedance arms. The key-receiving means is adapted to connect a respective one of said resistive elements as a fourth impedance arm of each bridge circuit. The first and second impedance arms define a first preset impedance ratio and the third and fourth impedance arms define a second impedance ratio. Each bridge circuit is adapted to be electrically balanced when these ratios are equal. A differential-input voltage comparator associated with each of said bridge circuits has an output which is a function of said ratios. Logic gate means is responsive to the output of each of the voltage comparators for supplying an output signal when said ratios are equal for each of the bridge circuits. Electrically actuable means such as a latch is responsive to this output signal for indicating thereby the receiving of a key having resistive elements of respective resistance values causing balancing of all of the bridge circuits. A key for the system comprises an electrically nonconductive member having a portion adapted for insertion in the key-receiving means, this portion having an axis of symmetry extending in the direction of insertion thereof in the key-receiving means. There are pairs of electrically conductive contacts on the nonconductive member, and individual electrically resistive elements connected respectively across the pairs of contacts. The two contacts of each pair are bilaterally symmetrical with respect to said axis of symmetry whereby the key is adapted for bilateral insertion in the key-receiving means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic diagram of an electronic lock system of the present invention, illustrated as controlling an electric latch;

FIG. 2 is a detailed schematic circuit diagram of the system of FIG. 1;

FIGS. 3 and 4 are perspective views of two respective key embodiments of the present invention, each having a plurality of resistive elements;

FIG. 5 is a schematic circuit diagram of portions of a system of the type shown in FIG. 1 and adapted to provide so-called multiple keying;

FIG. 6 is a schematic circuit diagram of portions of the circuitry of the type shown in FIG. 1. Adapted to provide so-called duplex keying;
FIG. 7 is a schematic circuit diagram, partly in block-diagrammatic form, showing circuitry for providing alarm signalling in response to use of an improper key; and FIG. 8 is a circuit somewhat similar to FIG. 7 showing a different type of alarm circuit for providing alarm signalling in response to insertion of an improper key.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, an electronic key-actuated security system of the present invention includes a key 11 having a plurality of electrically resistive elements, such as resistors incorporated therein, with which electrical connection is adapted to be made by contacts along opposite edges 13 and 15 thereof. A key receptacle 17 includes an aperture 18 adapted to receive the key and which has suitable contacts serving as conductors which provide electrical connections with the resistive elements of key 11 when the key is inserted and thereby received by receptacle 17. If key 11 is a correct key, an electric strike or latch 19 is adapted to be energized to permit opening of a door or the like.

Interconnected with receptacle 17 are a pair of bridge circuits 21a and 21b, each of which is associated with one of the resistive elements of key 11. Each of bridges 21a and 21b includes a first impedance arm provided by a first resistor 23a, 23b, a second impedance arm provided by a second resistor 25a, 25b, and a third impedance arm provided by a third resistor 27a, 27b, the latter constituting code-change resistors. A respective resistive element of key 11 is connected by receptacle 17 when key 11 is received therein as a fourth impedance arm of each bridge. For this purpose, a pair of leads 29a, 31a connects bridge 21a with receptacle 17 and a pair of leads 29b, 31b connects bridge 21b with receptacle 17.

The junctions of the respective leads 29a, 29b and respective resistors 23a, 23b are each connected to a suitable source of power, designated +V, as shown. The opposite junctions of each bridge, i.e., between respective resistors 27a, 27b and respective resistors 25a, 25b, are each grounded. Accordingly, the pairs of resistors 23a, 25a and 23b, 25b each define a first preset impedance ratio for each bridge and the pairs constituted by the resistive elements of key 11 and associated code-change resistors 27a and 27b define a second impedance ratio. Each of bridges 21a and 21b is adapted to be electrically balanced when these respective first and second impedance ratios are equal, as is known.

Connected across each bridge by a pair of leads is a respective voltage comparator 33a, 33b. These comparators are each differential amplifiers of the differential output type and which have a pair of differential input terminals and a pair of differential output terminals. The comparators 33a, 33b may advantageously be monolithic linear integrated-circuit differential amplifiers which are commercially available. The potentials at the output terminals of each comparator 33a, 33b are of predetermined equal level when the levels of potentials applied to the input terminals thereof have a predetermined relationship. In accordance with this invention, this predetermined relationship, which may be constituted by equal potentials of a fixed or predetermined value, is selected as indicative of the balancing of the respective bridge. If the resistive elements of key 11 are of the respective resistance levels causing balancing of both of the bridges 21a, 21b, key 11 may be said to be a proper key for the system.

Preferably, resistors 27a, 27b are each readily changeable. By changing resistors 27a, 27b, a different key, i.e., one having different resistor elements, must then be used to cause balancing of bridges 21a, 21b. Thus resistors 27a, 27b constitute key code changing impedances. For example, these resistors 27a, 27b may each be constituted by a potentiometer or may instead be incorporated in a plug which may be readily removed, thereby to permit replacement with a resistor of different value. The changeable nature of resistors 27a, 27b is shown by the rectangular symbols employed for these resistors throughout the drawings.

Balancing of each bridge 21a, 21b is detected by respective two-input AND gates 35a, 35b. Each AND gate has its two inputs connected across the differential output terminals of the respective voltage comparator 33a, 33b. These AND gates 35a, 35b, which are preferably of the integrated circuit variety widely available, are each adapted to supply, in effect, an output signal or intermediate signal when potentials of predetermined equal magnitude are applied concurrently to the two input terminals thereof. Such an output signal may be said to be supplied when, in reality, the output of the AND gate switches from a "low" to a "high" state, as is known in the electronics arts.

Voltage comparators 33a, 33b are chosen to have sufficient gain such that, when the respective bridge 21a, 21b is balanced, the potentials at the output terminals of the comparator are each of a level which is sufficient to cause the respective AND gate 35a, 35b to deliver an output signal, thereby indicating balancing of the respective bridge.

A further two-input AND gate 37 has each of its input terminals connected with the respective output terminal of AND gates 35a, 35b. Thus, when each of the latter gates delivers an output signal (i.e., goes "high"), AND gate 37 delivers an output signal which is indicative that both of bridges 21a, 21b are balanced.

It should be understood that additional bridges may be employed, each having a voltage comparator connected thereto and an AND gate connected across the differential output of the comparator, all as described above. In such case, key 11 may have additional resistive elements each of which is connected as an arm of an additional bridge by receptacle 17. If such additional bridge circuits are employed, AND gate 37 would have additional inputs as necessary corresponding to each such additional circuit so that this AND gate will provide an output signal when all of the bridges are balanced.

The output terminal of AND gate 37 is interconnected with the gate or triggering electrode of a triggerable semiconductor switching device constituted by triac 39 whose main terminals are connected in a circuit with latch 19 between a suitable source of power, such as 112 V A.C., and ground. When AND gate 37 delivers an output signal, triac 39 is triggered to cause energization of latch 19 thereby to permit opening of the door or the like secured by the latch.

Without the use of amplifying devices, such as a voltage comparator, for the purpose of providing gain, relatively few discrete levels of resistance can be measured using a bridge circuit. For that reason, amplification is desirable. Although amplification has been previously employed in connection with lock systems utilizing a bridge which measures the resistance of a key element, conventional single-ended amplifiers are not readily temperature-compensated. Or at best, limited compensation is possible, e.g., 4,000 parts per million per degree centigrade.

On the other hand, differential amplifier voltage comparators of the type described herein, providing temperature compensation of high order over a great range of temperatures, may be readily obtained. Further, the incorporation of such devices provides sufficient amplification or gain to permit the resistance of key resistive elements to range from a few ohms to several megohms in value. Accordingly, ordinaries commercially-available resistors may be employed. Each resistive element of a key of the present system may, therefore, be selected from over 100 discrete resistance levels, allowing wide margin for error. Further, commercially available resistors for use as key elements may be obtained which provide temperature coefficients as low as ±0.1%, or even better, providing relatively great degree of accuracy.
four resistive elements are used, providing four so-called bitting positions, the lock or security system provides (100)', i.e., 10', resistance combination.

A further advantage in using integrated circuit voltage comparators of the type described is that the system is thereby relatively immune to changes in supply voltage. Also, the system is not appreciably affected by aging of components.

A practical embodiment showing specific circuitry is shown in FIG. 2 wherein a key is illustrated as having two resistive elements 41a, 41n which may be two of several such elements 41a, 41b, . . . , 41n et cetera. Elements 41a, 41n are adapted to be interconnected by receptacle 18 with respective bridge-voltage comparator circuits 49a, . . . , 49n, et cetera.

Circuits 49a, 49n are essentially identical and each is, in effect, a combined bridge and voltage comparator. Circuit 49a includes first and second impedance arms provided by resistors 23a and 25a, respectively, connected in a series circuit between a positive d.c. supply potential and ground. A key code changing impedance is constituted by a resistor 27a which is either a potentiometer or is readily removable to permit its replacement by a resistor of another value, as described hereinabove. Key resistive element 47a provides a fourth impedance arm of the bridge. Resistors 27a and element 47a similarly are series-connected between the positive supply and ground. Resistive element 47n provides a fourth arm of a bridge of circuitry 49n, et cetera.

Resistive element 47a and code changing resistor 27a together provide a voltage divider, the potential at their junction being a function of their respective impedance or resistance values. The same is true of interconnected resistors 23a and 25a, whose junction provides a potential which is fixed and thus serves as a reference potential. These two junctions serve as opposite nodes of the bridge, and across which is connected a differential-input voltage comparator.

The latter voltage comparator includes a pair of PNP transistors Q1 and Q2 whose emitters are connected via respective resistors R1 and R2 to a common emitter resistor R3, thence to the positive supply potential. Respective load resistors R4 and R5 connect the emitters of Q1 and Q2 to ground. The bases of transistors Q1 and Q2 are each connected through a respective diode D1 and D2 to one node of the bridge and thus will be more or less conductive according to the difference between the node potentials, one transistor becoming more conductive as the other becomes less conductive, and vice versa.

Connected to the top of each of resistors R4 and R5 is the respective base electrode of one of two further transistors Q3 and Q4, each of which has its collector and emitter terminals connected in a series circuit, including a respective collector load resistor R6, R7 between the positive supply potential and ground.

The two input terminals of AND gate 35a are each connected to the junction of one of these resistors R6, R7 and the respective collector of transistors Q3, Q4. These latter junctions constitute balanced differential output terminals of the voltage comparator whose potentials are of predetermined equal level when the levels applied to the input terminals of the comparator (i.e., the aforesaid opposite nodes of the bridge) have a predetermined relationship defined by balancing of the bridge (the potentials at these nodes then being equal). The output of AND gate 35a goes "high" thereby delivering, in effect, an output signal when the predetermined equal output potentials of the voltage comparator (which are present when the bridge is balanced) are delivered to the input terminals of this AND gate. The same operation occurs as to the circuitry 49n as well as any other bridge-voltage comparator circuits of the system.

The several AND gates 35a, . . . , 35n, etc., have their output terminal connected to the input terminals of AND gate 37 whose output terminal, as explained, delivers an output signal when all of the several bridges are balanced.

From the foregoing, it may be seen that AND gates 35a, . . . , 35n, etc., as well as AND gate 37, together constitute logic gate means connected to the output terminals of the voltage comparators and which provide an output signal when the potentials at each pair of comparator output terminals are each of predetermined equal level indicative of bridge balancing.

The output terminal of AND gate 37 is interconnected with the gate electrode of triac 39, whose main electrodes are connected in series with a solenoid 51 of latch 19 across the secondary winding of a step-down transformer 53. This secondary winding also supplies a suitably low voltage which is rectified by a diode D3 to provide +9 . . . v.d.c. for each of the bridge-voltage comparator circuits 49a, . . . , 49n, etc., and, by means of a zener diode D4 and transistor Q5 conventionally controlled thereby, well-regulated +5 v.d.c. for operation of the several AND gates.

An output signal from AND gate 37 therefore causes triggering of triac 39 to effect operation of solenoid 51 of latch 19, thereby permitting the door, etc., otherwise locked by latch 19 to be opened. Alternatively, latch 19 may be substituted for by signal means having a light or buzzer, etc., in place of solenoid 51, or by interface with desired electrical apparatus. In any case, latch 19 constitutes one type of suitable electrically actuable means responsive to the output signal from AND gate 37 for indicating, by its operation, the receiving of a key having resistive elements of resistance values causing balancing of all the bridges.

Naturally, the system may be designed to operate a door latch that will respond to relatively low voltage, and operation of the system then may be obtained through use of batteries where that is desired, such as in the case of an emergency or power failure.

In order to provide additional assurance against "picking" or illicit decoding, a security system of the present invention may have bridges each of which has impedance arms which define different impedance ratios as between the several bridges. Thus the reference potential defined by the pair of series-connected fixed resistors described above may vary from bridge to bridge or from system to system thereby greatly increasing the difficulty in attempting to illicitly measure by electronic techniques the fixed and code-setting resistances of each bridge. One who somehow ascertains such values at one key-receiving station would, accordingly, not be able to utilize such information to gain access at other key-receiving stations.

Referring to FIG. 3, a key like that shown in FIG. 1 is similarly designated generally 11. The key includes a relatively flat, thin electrically nonconductive member 53 of tapered form having side edges 13 and 15 converging toward one another toward a narrow, rounded nose portion 55 adapted for insertion in aperture 18 of receivable 17. Member 53 may be of a suitable resilient synthetic resin material such as employed in printed circuit board construction. As is apparent, nose portion 55 has an axis of symmetry shown as a dotted line 56 extending in the direction of insertion in receptacle 17. There are pairs of electrically conductive contacts on the surface of member 53 and which are designated 57a, 57b, 59a, 59b, 61a, 61b, and 63a, 63b. Each of the a contacts is located on the face of member 53 adjacent edge 13 and the b contacts are similarly located adjacent edge 15. The two contacts of each pair are bilaterally symmetrical with respect to the axis of symmetry 56 of portion 55, i.e., the two contacts are each the same distance along a line perpendicular to the axis of symmetry.

Individual electrically resistive elements 47a, 47b, 47c and 47d are connected respectively across the pairs of contacts 57-63. Elements 47a-47d are concealed, molded or otherwise positioned in a somewhat thicker, generally rectangular handle portion 67 of the key. These elements 47a-47d are each connected by pairs of thin, flat strips extending back from the pairs of contacts 57-63 on the surface of member 53 and which are integral with the respective contacts. These strips may, for example, be provided by utilizing printed circuit techniques involving etching of metallic cladding on member
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7

53 according to a suitable pattern. Elements 47a–47d may be individual miniature resistors or may be provided through use of suitable thick film techniques or the like. Of course, while four resistive elements are shown, the key may have a greater or lesser number of elements, as appropriate. Also, some of the elements, e.g., two of them, may be adapted to be interconnected with circuitry at a particular receptive for unlocking a door, etc., at that location while another set of elements of the key may be adapted to unlock yet another door at some other location or locations.

The symmetry of contacts 57–63 provides an important advantage in that the key is not "handed," i.e., it is adapted for bilateral insertion in receptacle 17. Not only is this a great convenience, but if the system includes an alarm which operates in response to insertion of an improper key, such a symmetric key avoids alarm signalling which might occur if an asymmetrical key were inserted with improper orientation.

In order to assure that each of resistive elements 47a–47d will be positively interconnected when the key is inserted in receptacle 17, there may be pairs of contacts on the opposite side of the key which are identical with those on the front as shown in associated contact. Each of strips 77a–77e is connected, as illustrated, to one side of one of four resistive elements 47a–47d which are molded or otherwise positioned in a somewhat thicker, generally rectangular handle portion 79 of the key, as in the key of FIG. 3.

Strip 77e constitutes a common or "return" lead which is connected to one side of each of resistive elements 47a–47d and thus contact 75e associated with strip 77e together with each of contacts 75a–75d provides pairs of contacts which are adapted to provide connection of the resistive elements 47a–47d with individual bridge circuits of a system of this invention when the key is inserted in a receptacle.

By varying the position of the "return" contact as between different receptacles and keys, the use of keys having a particular "return" contact location can be excluded and thus recording can be effected without changing the values of key resistive elements to which the individual circuits of the system will respond. For example, the "return" contact may instead be the middle contact 75c, so that only keys having this configuration will cause operation of circuitry of the system.

FIG. 5 shows circuitry providing so-called multiple keying in which a single voltage comparator and logic AND gate combination is responsive to either one of two different key resistive elements connected by means at respective different sets of receptive contacts or received at receptacles which are at different locations.

A first pair of receptive contacts is designated 79a and a second pair of receptive contacts is designated 79b. Pairs of contacts 79a and 79b may be located in the same receptacle, such as receptacle 17 of FIG. 1, or may instead be at different receptive locations. The pair of contacts 79a is adapted to provide interconnection with a resistive element 47a of a key and the pair of contacts 79b provides interconnection with a resistive element 47b.

Voltage comparator 33 has its differential output terminals connected to the input terminals of AND gate 35, as in FIGS. 1 and 2, and the output terminal of the latter is connected to one input of a further AND gate as previously described. It should be understood that the system includes at least one other comparator-AND gate combination associated with a bridge circuit, etc., with which is connected some other resistive element (not shown) of the key when the key is inserted.

The circuitry shown includes a first voltage divider constituted by code-change resistor 27a and resistive element 47a, which is connected with resistor 27a and with the voltage source, designated +V, when the key is inserted so as to provide, at the junction of resistor 27a and element 47a, a first potential whose value is a function of these two impedances or resistance values. This potential is applied to one input of comparator 33 through an isolation diode D5a.

Another voltage divider connected between the voltage source +V and ground is constituted by resistors 25 and 25A whose junction provides a predetermined reference potential to the other input terminal of comparator 33.

If, when the key is inserted, resistive element 47a has a "correct" value, the potentials applied to the input terminals of comparator 33 will have a predetermined relationship, e.g., they are of a predetermined equal level, and consequently the output terminal of comparator 33 will be connected to the output terminal of the latter is connected to the input terminal of the former as previously described. This potential is applied to the first said input terminal of comparator 33 through an isolation diode D5b.

Accordingly, regardless of which of elements 47a or 47b is connected, operation is the same and it will be apparent that the same circuitry responds to different key-resistive elements. This makes possible not only the use of master keys but also facilitates the separate location of a plurality of receptacles, each of which may be connected to a single circuit.

Those skilled in the art will recognize that the various resistors 23, 25, 25A, and appropriate key element 47 will comprise a bridge circuit as previously described, the arms on one side of the bridge depending upon which of elements 47a or 47b is connected. It will be apparent that key elements additional to those shown can also be connected using the principles of FIG. 5.

In FIG. 6, circuitry is illustrated which provides so-called duplex keying in which a single pair of key receptive contacts 79 is adapted to provide connection of one of a plurality of key-resistive elements 47a and 47b for the purpose of causing ic operation of different comparator-AND gate circuit combinations.

A first combination of voltage comparator 33a and AND gate 35a is adapted to supply an output signal in response to a predetermined resistance value of key element 47a and a second combination including a comparator 33b and AND gate 35b is adapted to supply an output signal in response to a predetermined resistance value of key element 47b. The junction of code-change resistor 27 and whichever of key elements 47a or 47b is connected provides a first potential to one input terminal of each of comparators 33a and 33b. The other input terminal of each of these two comparators is provided with a different preselected reference potential by a voltage divider including resistors 23a, 23b and 25 series-connected between the voltage source +V and ground. Accordingly, if either of comparators 33a or 33b is provided with input potentials of proper predetermined relationship, the associated AND gate 35a or 35b will provide an output potential or signal. It will be understood that a system of the invention may include several circuits like that shown in FIG. 6 with each connected to supply an input signal to a multi-input AND gate such as AND gate 37 of FIG. 1.

This circuitry is highly advantageous in permitting the use, in a lock system of this invention, of various levels of keys including so-called change keys, master keys, grand master
keys, and so forth. To this end, a single pair of contacts 79 may be connected to several comparator-AND gate circuit combinations, each such combination being operative in response to a different level of keying.

A security system of the present invention may be provided with an alarm signal or the like operative in response to the insertion of an incorrect key. Accordingly, a guard may be called for a photograph may be taken of the individual attempting to use an incorrect key. Reference to key receptacle 17 may be provided with a microswitch or the like having a set of normally open contacts 81 adapted to close when the key 11 is inserted in receptacle 17. Contacts 81 may be connected in a circuit with a voltage source, as indicated, so as to provide, when closed, voltage to the various system circuits 83 (such as shown in Fig. 2) via a lead 87. The circuitry 83 is shown to have a lead 85 providing an output signal for opera-
tion of a latch in response to insertion of a "proper" key. The winding of a relay 89 is shown connected between lead 85 and ground, and this is adapted for energization by the output signal causing latch operation. Relay 89 is shown to include a set of normally closed contacts 89K connected in circuit between lead 85 and ground for one side of a time delay cir-
cuit 91. The latter may comprise a conventional time delay relay or the like adapted to close a circuit after a predetermined time delay interval following energization thereof. For this purpose, the other side of time delay circuit 91 is connected to an alarm bell 93 or other suitable alarm signalling means, operation of which is used for identifying purpose. If a proper key is inserted, the resultant output signal on lead 85 will energize relay 89 to prevent opera-
tion of the alarm 93.

In operation, insertion of key 11 closes contacts 81 to ener-
gize the system circuits 83 for normal operation and to ener-
gize time delay circuit 91. If time delay circuit 91 is not deenergized by operation of relay 89 in response to an output signal on lead 85, delay circuit 91 will complete a connection between contacts 89K and alarm bell 93 to give an aural alarm. The alarm signal thus provided may be used for identification purpose. If a proper key is inserted, the resultant output signal on lead 85 will energize relay 89 to prevent operation of the alarm 93.

In Fig. 8, alarm circuitry of another embodiment is illus-
trated. This embodiment includes a logic OR gate 95 having a plurality of input terminals each interconnected with a respective one of the output terminals of the voltage comparators 33a, 33b, etc., of the system. The output terminal of OR gate 95 is connected to one input of an AND gate 97 having another input terminal (shown as an inverted-input terminal) which is connected to output signal lead 85 of the system cir-
cuitry (by means of which lead an output signal causing latch operation is provided). The output of AND gate 97 is connected to time delay circuit 91 of the type described above, which is in turn connected to alarm bell 93 or other suitable alarm signalling means.

If any of comparators 33a, 33b, etc., provides an output signal in response to connection of a key-secure element, even if of an improper value, the resultant input signal to OR gate 95 will cause the latter to provide an output signal to AND gate 97. If no output signal is provided on lead 85, AND gate 97 will supply an output signal energizing time delay circuit 91. After a predetermined time delay, alarm bell 93 will be energized. However, insertion of a proper key will provide a signal on lead 85 which will cause there to be no output poten-
tial from AND gate 97, and thus operation of alarm 95 will be prevented.

It may be noted that a system of this invention facilitates the making of a permanent record of the use of keys. Because the system may be designed to respond to keys whose resistive ele-
ments are differently coded, the keys may be used for identification purposes and a conventional print-out ohmmeter may simply be connected with a key receptacle to make a printed record of the resistance values of keyresistive elements from which it may later readily be determined which individuals have used their keys.

In general, a high level of security is provided by a system of the invention and this is enhanced by the fact that duplication of keys is relatively difficult.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above construc-
tions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illu-
strative and not in a limiting sense.

What is claimed is:

1. Apparatus for use in an electronic key-actuated security system including keys each constituted by a plurality of elec-
trically resistive elements, said apparatus comprising:

key-receiving means including conductors for providing connections with resistive elements of a key received;

a plurality of bridges, each associated with a resistive ele-
ment of a key received, each of said bridges including first, second and third impedance arms, said key-receiving means being adapted to connect a respective one of said resistive elements as a fourth impedance arm of each of said bridges, said first and second impedance arms defining a first preset impedance ratio, said third and fourth impedance arms defining a second impedance ratio, each of said bridges having first and second output terminals having a potential thereon with the potential developed at said first terminal being indicative of the first preset impedance ratio and the potential developed at said second terminal being indicative of said second impedance ratio, each of said output terminals being electrically balanced to apply equal potentials to said first and second output terminals when said impedance ratios are equal; a plurality of differential amplifiers, each asso-
ciated with one of said bridge circuits, and each having an output which is a function of said impedance ratios;

logic gate means interconnected with said differential amplifiers and responsive to an output signal of said dif-
ferential amplifier which is indicative of predetermined ratios being developed between the potentials on said first and second output terminals of each of said bridges for supplying an output signal only when said potentials developed on said first and second output terminals of each of said bridges form said predetermined ratios; and

electrically actuable means responsive to said output signal for indicating thereby the receiving of a key having resistive elements of respective resistance values causing said predetermined ratios to be developed on all of said bridges.

2. Apparatus as set forth in claim 1 wherein said logic gate means comprises a plurality of AND gates each associated with one of said bridges and each connected for providing an intermediate signal in response to balancing of the associated bridge, and a further AND gate interconnected with each of the first-said AND gates and adapted to supply the first-said output signal in response to intermediate signals from each of the first-said AND gates.

3. Apparatus for use in an electronic key-actuated security system including keys each constituted by a plurality of elec-
trically resistive elements, said apparatus comprising:

key-receiving means including conductors for providing connections with resistive elements of a key received;

a plurality of bridge circuits, each associated with a resistive element of a key received, each of said bridge circuits in-
cluding first, second and third impedance arms, said key-
receiving means being adapted to connect a respective one of said resistive elements as a fourth impedance arm of each of said bridge circuits, said first and second im-
pedance arms defining a first preset impedance ratio, said third and fourth impedance arms defining a second im-
pedance ratio, each of said bridge circuits being adapted to be electrically balanced when said ratios are equal;

a plurality of differential amplifiers, each associated with one of said bridge circuits, and each having an output which is a function of said ratios;

logic gate means responsive to the outputs of said dif-
ferential amplifiers for supplying an output signal when said ratios are equal for each of said bridge circuits;
each of said differential amplifiers including a pair of inputs connected across a respective one of said bridge circuits and a pair of differential outputs connected to a respective pair of inputs of said logic gate means; and
electrically actuable means responsive to said output signal for indicating thereby the receiving of a key having resistive elements of respective resistance values causing balancing of all of said bridge circuits.

4. Apparatus for use in an electronic key-actuated security system including keys each constituted by a plurality of electrically resistive elements, said apparatus comprising:

key-receiving means including conductors for providing connections with resistive elements of a key received;
a plurality of bridge circuits, each associated with a resistive element of a key received, each of said bridge circuits including first, second and third impedance arms, said key-receiving means being adapted to connect a respective one of said resistive elements as a fourth impedance arm of each of said bridge circuits, said first and second impedance arms defining a first predetermined impedance ratio, said third and fourth impedance arms defining a second predetermined ratio, each of said bridge circuits being adapted to be electrically balanced when said ratios are equal;
a plurality of differential input voltage comparators, each associated with one of said bridge circuits, and each having an output which is a function of said ratios; logic gate means responsive to the outputs of said voltage comparators for supplying an output signal when said ratios are equal for each of said bridge circuits; electrically actuable means responsive to said output signal for indicating thereby the receiving of a key having resistive elements of respective resistance values causing balancing of all of said bridge circuits; and
said logic gate means comprising a plurality of AND gates each associated with one of said bridge circuits and each having a pair of inputs connected for being supplied with input potentials of preselected equal level in response to balancing of the associated bridge circuit to cause the AND gate to provide a potential at the output thereof, and a further AND gate having input terminals interconnected with the outputs of each of the first-said AND gates, the output of said further AND gates supplying said output signal when each of the first-said AND gates provides a respective output potential.

5. Apparatus as set forth in claim 4 further comprising a plurality of voltage comparators each having a pair of differential inputs connected across a respective one of said bridge circuits and a pair of differential outputs connected to a respective pair of inputs of one of the first-said AND gates.

6. Apparatus as set forth in claim 5 wherein said electrically actuable means comprises an electric latch and a triggerable semiconductor switching device interconnected for energizing said latch when triggered, said output signal causing triggering of said switching device.

7. Apparatus as set forth in claim 6 including an alarm signalling device, time delay means operative in response to receiving of a key for energizing said signalling device after a predetermined time delay period following the receiving of the key, and means operative in response to said output signal for preventing energization of said signalling device.

8. Apparatus as set forth in claim 7 including a logic OR gate having a plurality of inputs each interconnected with one of said voltage comparators, and wherein said means for preventing energization comprises a still further AND gate having one input terminal interconnected with the output terminal of said OR gate, another input terminal adapted to be supplied with a potential in the absence of said output signal, and an output terminal connected for causing energization of said time delay means, said output signal thereby preventing energization of said time delay means so as to prevent energization of said signalling means.

9. Apparatus for use in a key-actuated security system including keys each constituted by a plurality of electrically resistive elements, said apparatus comprising:

key-receiving means including conductors for providing connections with resistive elements of a key received; a plurality of voltage dividers, each including a preset impedance and each adapted to have a resistive element of a received key interconnected with said preset impedance by said key-receiving means and with a voltage source to provide a first potential whose level is a function of said impedance and the resistance value of the interconnected resistive element;
means for supplying a reference potential; a plurality of voltage comparators, each associated with one of said voltage dividers and each having a pair of differential input terminals and a pair of differential output terminals, the potentials at the output terminals of each comparator being of predetermined equal levels when the levels of potentials applied to the input terminals thereof have a predetermined relationship; circuit means for applying said first potential provided by each voltage divider to one of said input terminals of the respective comparator and applying said reference potential to the other of said comparator input terminals; logic gate means, including an AND gate, connected to each of said output terminals and providing an output signal when the potentials at each pair of said comparator output terminals are each of said predetermined equal levels; and electrically actuable means responsive to the output signal from said logic gate means for indicating thereby the receiving of a key having resistive elements of resistance values producing said predetermined relationship.

10. A key-actuated security system comprising:
a key including a plurality of electrically resistive elements, each of a preselected resistance value; means for receiving said key including conductors for providing connections with resistive elements of said key; a plurality of circuit means each associated with a resistive element of said key, each of the circuit means including a preset impedance and each adapted to have the associated resistive element of said key interconnected with said preset impedance by the key-receiving means, each of the circuit means providing a first potential whose level is a function of said preset impedance and the resistance value of the interconnected resistive element; means for supplying a reference potential; a plurality of voltage comparators each associated with one of said circuit means and each responsive to said first and reference potentials, each of said comparators including output terminals providing potentials which are of predetermined equal level when said first and reference potentials have a predetermined relationship; logic gate means interconnected with the output terminals of each of said comparing means and providing an output signal when the output potentials at each pair of output terminals are each of said predetermined equal level; and electrically actuable means responsive to said output signal for indicating thereby that said key when received has resistive elements of preselected resistance values producing said predetermined relationship.