United States Patent

Eisenreich

[15] **3,673,467**

[45] **June 27, 1972**

[54] **RESISTIVELY-CODED SECURITY SYSTEM**

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[52] **U.S. Cl.** **317/134,** 317/153, 338/260
[51] **Int. Cl.** **E05b 49/00,** H01c 1/02
[58] **Field of Search** 317/134; 70/277, 278

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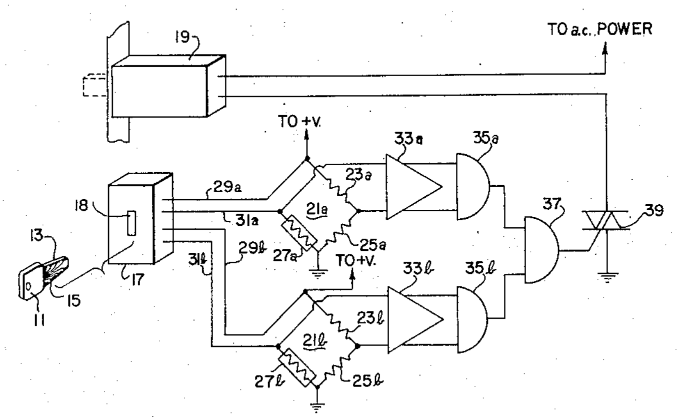
[57] **ABSTRACT**

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 actuatable 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



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SHEET 1 OF 3

FIG.1

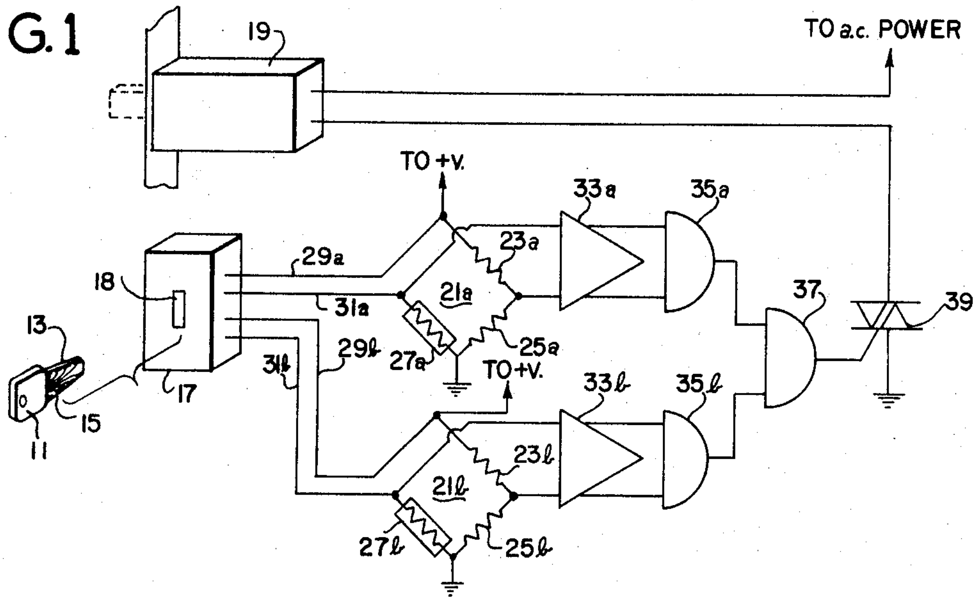

FIG.2

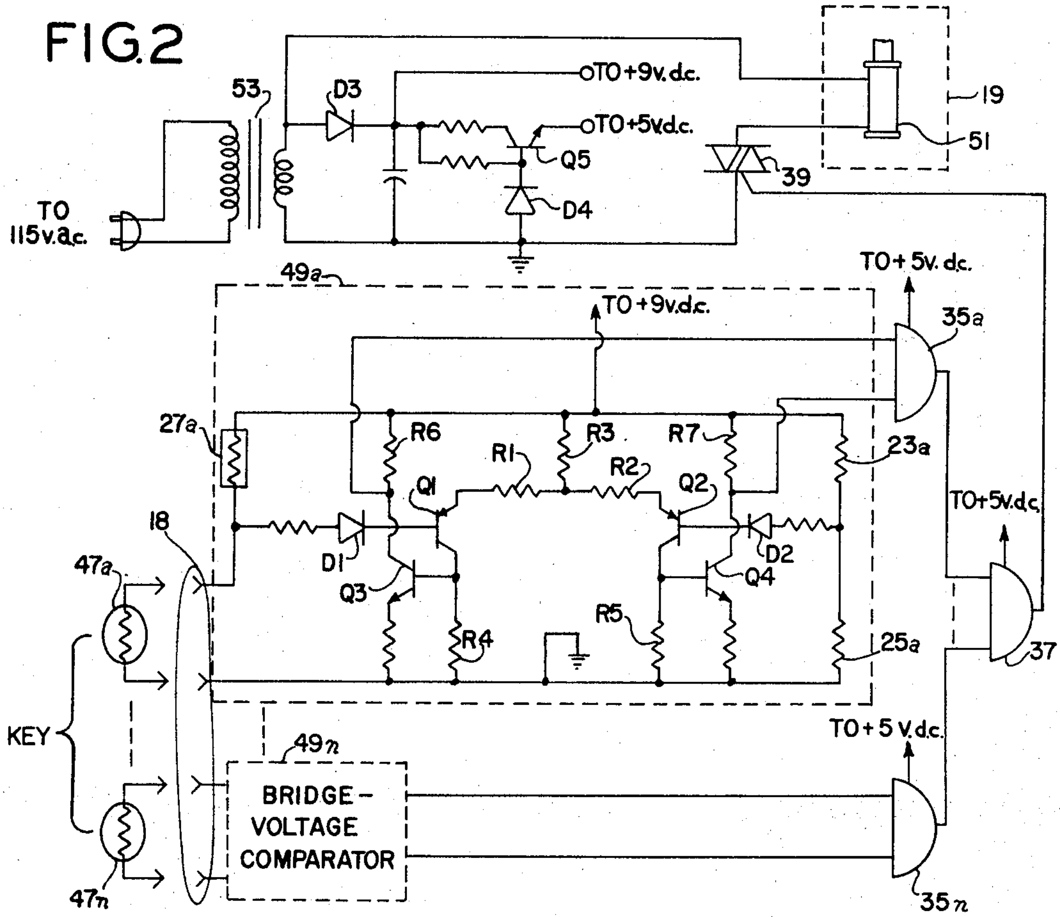

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FIG.3

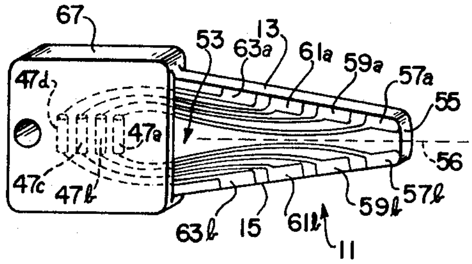

FIG.4

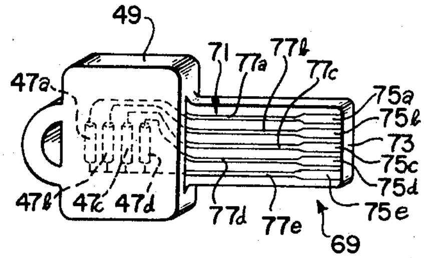

FIG.5

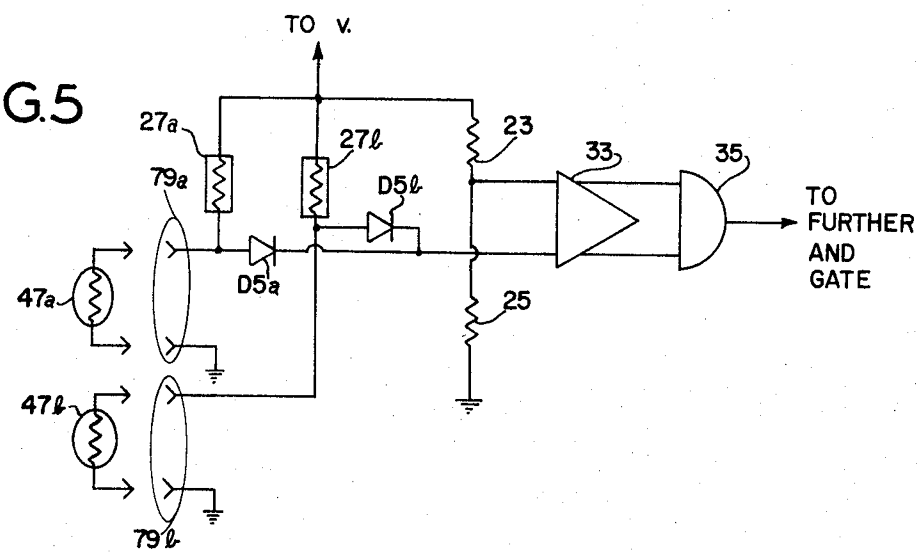

FIG.6

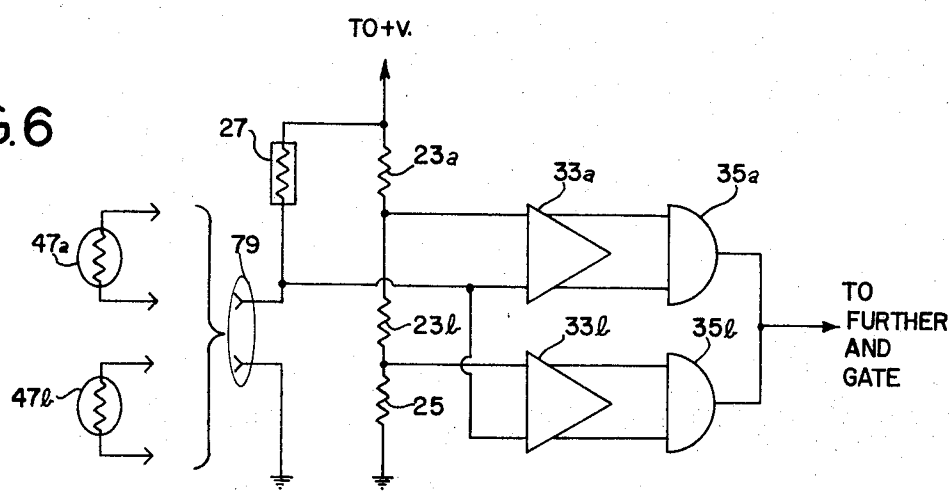

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FIG.7

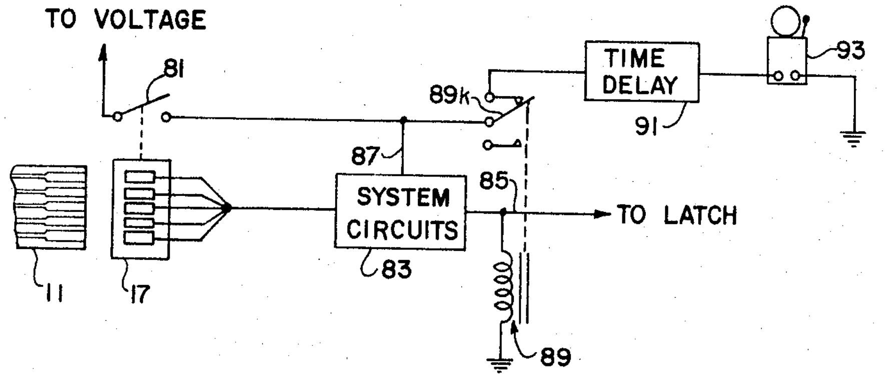
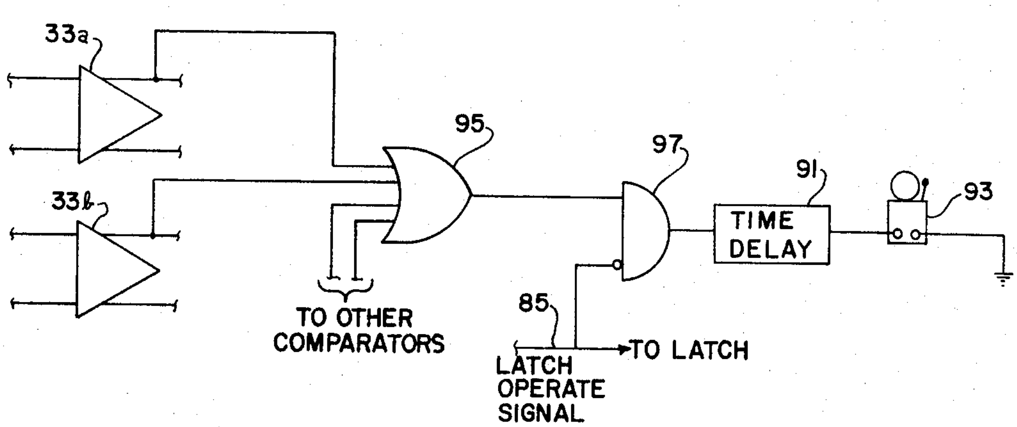


FIG.8



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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 bitting 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 resistive or capacitive element (or both) which, if correct in value, is adapted to cause oscillation of an oscillator at a frequency causing operation of a reed relay. In another type of lock system, keys having resistive elements are adapted to be connected with a single bridge circuit for effecting balancing of the bridge if the key is correct. Typically, in prior art analog lock systems, there is employed only a single frequency-responsive or resistance-responsive circuit 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 actuatable 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 circuit 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 **21*a*** and **21*b***, each of which is associated with one of the resistive elements of key **11**. Each of bridges **21*a*** and **21*b*** includes a first impedance arm provided by a first resistor **23*a***, **23*b***, a second impedance arm provided by a second resistor **25*a***, **25*b***, and a third impedance arm provided by a third resistor **27*a***, **27*b***, the latter constituting code-change resistors.

A respective resistance 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 **29*a***, **31*a*** connects bridge **21*a*** with receptacle **17** and a pair of leads **29*b***, **31*b*** connects bridge **21*b*** with receptacle **17**.

The junctions of the respective leads **29*a***, **29*b*** and respective resistors **23*a***, **23*b*** are each connected to a suitable source of power, designated +V, as shown. The opposite junctions of each bridge, i.e., between respective resistors **27*a***, **27*b*** and respective resistors **25*a***, **25*b***, are each grounded. Accordingly, the pairs of resistors **23*a***, **25*a*** and **23*b***, **25*b*** 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 **27*a*** and **27*b*** define a second impedance ratio. Each of bridges **21*a*** and **21*b*** 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 **33*a***, **33*b***. These comparators are each differential amplifiers of the differential-input, balanced differential output type and which have a pair of differential input terminals and a pair of differential output terminals. The comparators **33*a***, **33*b*** may advantageously be monolithic linear integrated-circuit differential amplifiers which are commercially available. The potentials at the output terminals of each comparator **33*a***, **33*b*** 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 **21*a***, **21*b***, key **11** may be said to be a proper key for the system.

Preferably, resistors **27*a***, **27*b*** are each readily changeable. By changing resistors **27*a***, **27*b***, a different key, i.e., one having different resistor elements, must then be used to cause balancing of both bridges **21*a***, **21*b***. Thus resistors **27*a***, **27*b*** constitute key code changing impedances. For example, these resistors **27*a***, **27*b*** 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 **27*a***, **27*b*** is shown by the rectangular symbols employed for these resistors throughout the drawings.

Balancing of each bridge **21*a***, **21*b*** is detected by respective two-input AND gates **35*a***, **35*b***. Each AND gate has its two inputs connected across the differential output terminals of the respective voltage comparator **33*a***, **33*b***. These AND gates **35*a***, **35*b***, 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 **33*a***, **33*b*** are chosen to have sufficient gain such that, when the respective bridge **21*a***, **21*b*** 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 **35*a***, **35*b*** 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 **35*a***, **35*b***. 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 **21*a***, **21*b*** are balanced.

It should be understood that additional bridges may be employed, each having a voltage comparator connected thereacross 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 **19** 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, ordinary 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 compensation as great a degree as desired.

Since each key resistive element may have resistance of at least approximately 100 levels, the total number of possible key codes or combinations is given approximately by 100^n, where n is the number of individual resistive elements which are each connected to a bridge of the system. For example, if four resistive elements are used, providing four so-called bitting positions, the lock or security system provides $(100)^4$, i.e., 10^8, resistance combinations.

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 **41***a*, **41***n* which may be two of several such elements **41***a*, **41***b*, . . . , **41***n*, et cetera. Elements **41***a*, **41***n* are adapted to be interconnected by receptacle **18** with respective bridge-voltage comparator circuits **49***a*, . . . , **49***n*, et cetera.

Circuits **49***a*, **49***n* are essentially identical and each is, in effect, a combined bridge and voltage comparator. Circuit **49***a* includes first and second impedance arms provided by resistors **23***a* and **25***a*, 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 **27***a* 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 **47***a* provides a fourth impedance arm of the bridge. Resistor **27***a* and element **47***a* similarly are series-connected between the positive supply and ground. Resistive element **47***n* provides a fourth arm of a bridge of circuitry **49***n*, et cetera.

Resistive element **47***a* and code changing resistor **27***a* 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 **23***a* and **25***a*, 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 **35***a* 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 **35***a* 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 **49***n* as well as any other bridge-voltage comparator circuits of the system.

The several AND gates **35***a*, . . . , **35***n*, 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 **35***a*, . . . , **35***n*, 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 **49***a*, . . . , **49***n*, 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 actuatable 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 receptable **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 **57***a*, **57***b*; **59***a*, **59***b*; **61***a*, **61***b*; and **63***a*, **63***b*. 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 **47***a*, **47***b*, **47***c* and **47***d* are connected respectively across the pairs of contacts **57–63**. Elements **47***a*–**47***d* are concealed, molded or otherwise positioned in a somewhat thicker, generally rectangular handle portion **67** of the key. These elements **47***a*–**47***d* 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

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 receptacle 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. There is then a redundant set of contacts and electrical connection is thus maintained even if one contact should fail to make a good connection.

In FIG. 4, another embodiment of a key of the system is designated generally 69 and includes a nonconductive member 71 of generally rectangular shape having a straight edge or nose portion 73 adapted for insertion in a suitable receptacle. Five electrically conductive contacts 75a–75e are located on the flat surface of member 71 adjacent the edge or nose portion 73. Contacts are thin and flat, and may be of metallic cladding such as used in printed circuit board construction. Extending back from contacts 75a–75e, away from edge 73, are thin, flat strips 77a–77e, each of which is integral with its associated contact. Each of strips 77a–77d 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–47 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 recoding 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 receptacle contacts or received at receptacles which are at different locations.

A first pair of receptacle contacts is designated 79a and a second pair of receptacle 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 receptacle 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 level 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 23 and 25 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 terminals of the comparator will provide output potentials of predetermined equal level causing AND gate 35 to deliver an output potential thereby indicating that key element 47a is correct.

If key element 47b is connected, then a voltage divider is similarly constituted by a code-change resistor 27b and element 47b so as to provide at their junction a potential whose level is a function of these two resistances. 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 and 27, and appropriate key element 47 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 receptacle contacts 79 is adapted to provide connection of one of a plurality of key-resistive elements 47a and 47b for the purpose of causing 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 or a photograph may be taken of the individual attempting to use an incorrect key. Referring to FIG. **7**, the 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 operation 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 switch contacts **81** and one side of a time delay circuit **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, one terminal of which is grounded.

In operation, insertion of key **11** closes contacts **81** to energize the system circuits **83** for normal operation and to energize 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 any suitable 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 illustrated. 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 **33*a***, **33*b***, 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 circuitry (by means of which lead an output signal causing latch operation is provided). The output terminal 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 **33*a***, **33*b***, etc., provides an output signal in response to connection of a key-resistive element, even if of an improper value, the resultant input signal to OR gate **95** will cause the latter to provide an input 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 potential 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 elements 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 constructions 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 illustrative 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 electrically 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 element 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 bridges being adapted to be 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 associated 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 differential 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 the potentials developed on said first and second output terminals of each of said bridges form said predetermined ratios; and

electrically actuatable 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 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 preset impedance ratio, said third and fourth impedance arms defining a second impedance 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 differential 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 actuatable 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 preset impedance ratio, said third and fourth impedance arms defining a second impedance 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 actuatable 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 actuatable 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 respective 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 actuatable 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 actuatable 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.

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