June 3, 1969 R. A. BILLHARDT 3,448,435

MAGNETIC REED SWITCHING MATRIX

Filed June 17, 1966

FIG. 1

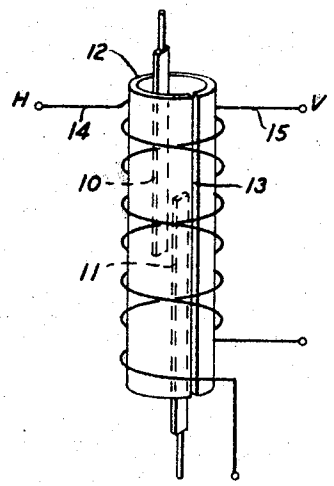



FIG. 3

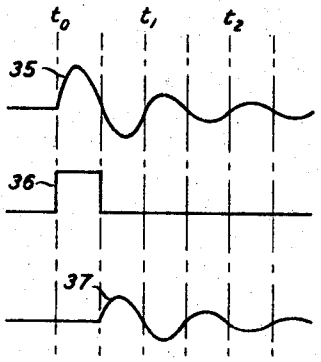
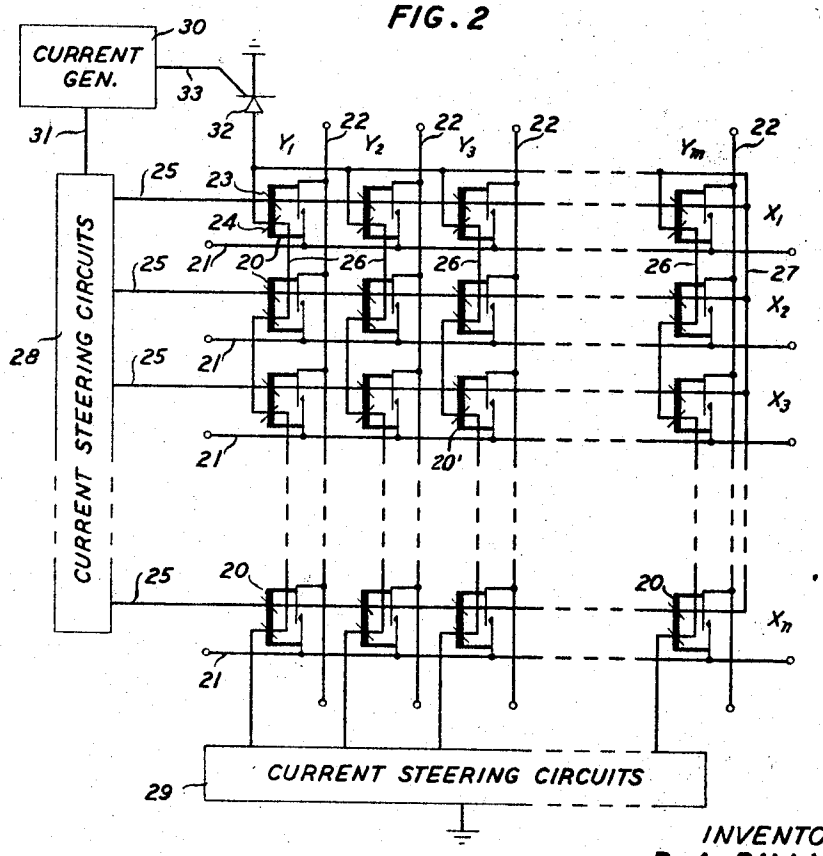



FIG. 2




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# MAGNETIC REED SWITCHING MATRIX

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U.S. Cl. 340—166 19 Claims

This invention relates to electrical switching devices and, particularly, to such devices having a plurality of contacts arranged in a coordinate array.

Coordinate array switches having electrical contacts at their crosspoints and operated electromagnetically have long been known in the art. Such switches have found extensive application wherever it is advantageous to select among $mn$ crosspoints by $m+n$ terminals. Electromagnetic switching devices adapted to act as the crosspoint elements are also known in the art and may take various and numerous forms. When such switching devices are organized in a coordinate matrix it is necessary that each is able to operate as a threshold element. That is, its selection within a plurality of like devices arranged in a coordinate array typically depends upon its ability to respond to coincident currents applied to the two coordinate circuits defining it within the array. However, it must also, when not selected, reject either of the two coincident currents applied alone when it lies in either of the coordinates defining a selected switching element.

Both of these conditions are met in one prior art electromagnetic switching device termed a "ferreed," one embodiment of which is described, for example, in the patent of T. N. Lowry, No. 3,037,085, issued May 29, 1962. The device there described adds one highly advantageous feature which not only permits the switching element to respond to two coincident currents and reject either one applied alone, but makes provision for a specific operative response to the latter singly applied currents. As the coincident currents are applied to the two coordinate energizing circuits defining a selected ferreed within the array, each of the nonselected ferreeds lying along the two coordinates of the selected ferreeds is released. This advantageous operation termed "differential excitation," is accomplished by means of a novel energizing arrangement in which two pairs of windings are "differentially" associated. The winding pairs are coupled to discrete portions of a magnetic structure associated with the reed spring contacting means. Energizing both winding pairs simultaneously induces a flux in the structure which closes through the reed spring means to cause their operation. The winding pairs each include coils each of which has sufficient turns to cause a flux switching in its coupled structure portion but one has twice as many turns as the other. The unequally wound coils of each pair are also cross connected to the differently wound coils of the other pair. The energization of the two cross connected coils alone during a selection operation is effective to divert the flux in the magnetic structure to an alternate path or paths from the reed spring means to permit their restoration.

Where switches of the character briefly described in the foregoing are used in quantity, the cost of their fabrication becomes an important consideration. In this connection, one aspect of the fabrication which measures large is the winding operation. Any reduction in the number and complexity of the windings without disturbing the function of a switching device will produce substantial savings in the cost of manufacture of large arrays.

It is one object of this invention to reduce the number of windings in a differentially excited relay arrangement without changing its basic function.



Another object of this invention is to provide a new and novel relay device adapted for use in coordinate array switches.

The foregoing and other objects of this invention are realized in one specific embodiment thereof which comprises a coordinate array of magnetically responsive relay devices. The relay devices are arranged in rows and columns along which the energizing circuits are aligned in a wellknown manner. Each of the relay devices may comprise a magnetic switch of the general character described in Patent No. 3,075,059 of A. L. Blaha et al., issued Jan. 22, 1963. Such a switch comprises, in its simplest form, a pair of reed springs enclosed in a magnetic sleeve of a magnetic material having a high residual flux density compared to its saturation flux density.

The magnetic sleeve of each switch in the array has coupled thereto a pair of interwound coils, one of which is connected in its row energizing circuit and the other of which is connected in its column energizing circuit. The selection of a relay or switch within the array is accomplished in the generally known manner of coincidently energizing the two coils of the selected switch. This, in turn, is achieved by energizing the particular row and column energizing circuits of the switch array serving the selected switch. Although such a coincident selection operation is well known, it should be borne in mind that the energizing currents on the defining row and column circuits must also release any and all of the nonselected operated switches appearing in this row and column.

According to one feature of this invention, the operation of a selected switch and the release of any operated switch in the row and column of the selected switch are accomplished by applying decaying alternating currents to the selected row and column energizing circuits. It is well known that a decaying alternating current applied to a winding coupled to a magnetic member will effectively demagnetize the member. In the case of any operated switch appearing on a row or column energizing circuit the magnetic sleeve will be demagnetized sufficiently to permit the bias of the reed spring contact means to restore the contacts to their unoperated state. In accordance with the principles of this invention, the row and column decaying alternating currents are applied so that one of the currents is effectively initiated one-half cycle after the other. The windings are coupled to the switch in opposite senses so that the two currents will effectively cancel at the selected switch with the exception of the current applied to one of the coils during the half cycle delay of the other current.

The initial half cycle current applied to one of the windings of the selected switch is determined to be of sufficient magnitude to induce a flux in the magnetic structure for operating the reed spring means. The remainder of this initially applied current is cancelled, at the selected switch, by the other current to leave the operated state of the selected switch undisturbed. After the termination of the concurrent energizing currents, the residual flux of the magnetic sleeve of the selected switch leaves the switch operated until the application to one of its windings alone of a decaying alternating current. At that time the presently selected switch will release in a manner outlined in the foregoing. A novel relay arrangement is thus presented in this invention which is fully operative in a differential excitation mode. At the same time, the number of coils required is reduced by half and the winding complexity is substantially minimized.

The foregoing and other objects and features of this invention will be better understood from a consideration of the detailed description of one specific embodiment

thereof which follows when taken in conjunction with the accompanying drawing in which:

FIG. 1 shows one illustrative switch element advantageously adapted for the practice of this invention;

FIG. 2 is a schematic diagram of an illustrative coordinate switch array operating according to the principles of this invention; and

FIG. 3 shows in idealized waveform the currents employed in the operation of the switch array of FIG. 2.

One specific switching device advantageously adapted for the practice of this invention is shown in FIG. 1, which device in a number of aspects is similar to the switch described in the aforecited patent of A. L. Blaha et al. The switch of FIG. 1 comprises a pair of reed springs **10** and **11** which are arranged in overlapping fashion to provide a pair of electrical contacts at the overlapping portions in a well-known fashion. The reed springs are of a magnetically permeable material which is also electrically conductive and in practice will be connected in the electrical circuit controlled by the switch. The reed springs **10** and **11** are normally mounted in a glass envelope which for the sake of simplicity has been omitted from the drawing. The reed springs **10** and **11** are normally spring biased apart at the overlapping contact areas. Enclosing the reed springs **10** and **11** and running longitudinally coaxially therewith is a cylindrical magnetic sleeve **12** of a magnetic material having substantially rectangular hysteresis characteristics. The sleeve **12** has a slot **13** therein lying longitudinally parallel with its axis to reduce eddy currents during the operation of the switch.

A pair of equal turn windings **14** and **15** are coupled in opposite senses around the sleeve **12**, being labelled H and V, respectively, in accordance with their function in a coordinate switch array which will be described hereinafter. The number of turns of the windings **14** and **15** is determined with respect to the particular current to be employed in the operation of this invention so that the energization of either winding will induce a remanent flux in the sleeve **12**. This flux, generated longitudinally in the sleeve **12**, finds a closure path through the reed springs **10** and **11** thereby creating opposite poles at the overlapping contact areas sufficient to overcome the spring bias of the reed springs. The circuit through the reed springs is thus closed and will remain closed as a result of the remanent flux induced in the sleeve **12**. The reed springs **10** and **11** are permitted to open, in accordance with this invention, by restoring the magnetic sleeve **12** to a substantially demagnetized state. The normal spring bias of the reed springs **10** and **11** is then sufficient to overcome whatever negligible residual flux remains after the demagnetization step. This demagnetization step will be better understood when described in connection with a coordinate switch array according to this invention depicted in FIG. 2.

The switch array comprises a plurality of switching devices **20** of the character shown in FIG. 1, arranged in rows $x_1$, $x_2$, $x_3$ . . . $x_n$ and columns $y_1$, $y_2$, $y_3$ . . . $y_m$. The switches **20** are depicted in schematic form, employing the well-known mirror symbols to represent the windings and their polarity. Each of the switches **20** is shown as provided with a single pair of reed springs for establishing a connection between any one of a plurality of row conductors **21** and any one of a plurality of column conductors **22**. The conductors **21** and **22** are provided with terminals for connection in any system in which a crosspoint switch may be adapted for use. Although only a single pair of reed springs is shown for describing the principles of this invention, it will be appreciated that double spring pairs may be employed to accomplish particular system operations. Each of the switches **20** has coupled thereto a pair of equal turn windings **23** and **24** represented in FIG. 2 by short diagonal lines intersecting the core structures in directions corresponding to the winding polarity. The magnetic sleeves of the switches **20** are represented by double vertical lines.

The windings **23** of each of the rows are serially connected in row energizing conductors **25** and the winding **24** of each of the columns are serially connected in column energizing conductors **26**. Each of the conductors **25** and **26** is connected at one end to a common bus **27**. The row energizing conductors **25** are each connected at the other end to row current steering circuits **28** and the column energizing conductors **26** are each connected at the other end to column current steering circuits **29**. The current steering circuits **28** and **29** may comprise any means well known in the art capable of selectively switching a current from a current generator **30** via an input lead **31** to any one of the row energizing conductors **25** and closing a circuit to ground from any one of the column energizing conductors **26**. Since such circuits are readily evisioned by one skilled in the art, they are shown in the drawing only in block symbol form. A plurality of energizing circuits may now be traced from the current generator **30**, input lead **31**, current steering circuits **28**, the row energizing conductors **25**, common bus **27**, column energizing conductors **26** and current steering circuits **29** to ground. Each of the parallel circuits so traced will include both of the windings **23** and **24** of a switch **20**.

In addition to the circuit paths thus traceable, each of the row energizing conductors **25** may be connected directly to ground by an alternate path bypassing the column conductors **26**. The common bus **27** is also connected to ground through a diode **32** having a control lead **33** connected to an output of the current generator **30**. The diode **32** may conveniently comprise a silicon controlled diode of a character well known in the art. The current generator **30** makes available two outputs: A gating pulse to control the diode **32** and a decaying alternating current. Circuits for generating such an alternating current from which current a single pulse may be extracted are readily devised by one skilled in the art. Accordingly, the details of such a circuit need not be described for an understanding of the organization and practice of this invention.

An illustrative operation of the switch array of FIG. 2 is conveniently described with reference to the current chart of FIG. 3. For purposes of illustration it will be assumed that the switch is to complete a connection between the row conductor **21** and the column conductor **22** lying in the row $x_3$ and column $y_3$, respectively, which define the switch **20'**. An operation of the switch **20'** is initiated at the time $t_0$ by the generation of a decaying alternating current depicted in several cycles in FIG. 3 by the idealized waveform **35**. The first half-cycle of the current **35** is positive and is applied to the selected energizing conductor **25** via the lead **31** and the current steering circuit **28**. The latter circuits are controlled to accomplish the selection in accordance with the particular operation of the system with which the switch array of FIG. 2 may be adapted for use. The first half-cycle of the current **35** is transmitted along the selected energizing conductor **25** and thereby via each of the windings **23** of the switches **20** lying in the row $x_3$ and thence to the common bus **27**. At this point, a path to ground has been prepared along the selected column energizing conductor **26** lying in the selected column $y_3$ by the current steering circuits **29** also in accordance with the operation of external circuitry not shown. However, also at the time $t_0$, the current generator **30** generates at its output lead **33** a positive pulse **36**. The positive pulse **36** is applied to the control input of the diode **32** to enable the latter element for the period of the initial half-cycle of the current **35**. As a result, a direct short to ground is provided for the initial positive half-cycle of the latter current thereby by passing the selected column energizing conductor **26**. It will thus be seen that only the winding **23**, including the winding **23** of the selected switch **20'**, of the row $x_3$, are energized during the initial half-cycle of the cur-

rent 35. As a result of the first positive half-cycle of the current 35 thus applied, remanent fluxes will be induced in each of the magnetic sleeves of the switches 20.

The gating pulse 36 is terminated at the end of the initial half-cycle of the current 35 whereupon the diode 32 is restored to its nonconducting state. The path to ground at the diode 32 being thus opened, the second half-cycle and subsequent cycles of the current 35 are conductor to ground via the selected column energizing conductor 26 of the column $y_3$ and the current steering circuits 29. The polarity of the windings 23 and 24 of the switches 20 being opposed, the current seen at the winding 24 of the selected switch 20', being at the second half-cycle, is of opposite polarity to that appearing on the winding 23 of the same switch. This current is depicted as the idealized waveform 37 in FIG. 3. It is apparent that the magnetomotive drives generated by the currents 35 and 37 will effectively cancel at the selected switch 20', permitting the remanent flux established during the first half-cycle of the current 35 to operate its reed springs.

At each of the other nonselected switches 20, lying in the row $x_3$ and column $y_3$, on the other hand, the currents 35 and 37 are applied to either of the windings 23 and 24 alone. As a result, these decaying currents demagnetize whatever residual flux existed in the magnetic sleeves of the nonselected switches 20, thereby permitting the restoration of whatever reed springs had been closed during a previous operation. As mentioned previously, during the initial half-cycle of the current 35, not only the selected switch 20', but each of the other switches 20 lying in the row $x_3$ will have an operative flux induced in its magnetic sleeve sufficient to cause the operation of the reed springs. However, the response time of the springs will be sufficiently slow relative to the duration of the half-cycle that they will not close before the start of demagnetization at the second half-cycle of the current 35.

It will be appreciated that, although a specific arrangement has been described for applying concurrent decaying alternating currents to two selected coordinate conductors, alternating current sources individual to the two sets of coordinate conductors could equally well be employed. Similarly, any other switch element than the one depicted in FIG. 1 suitable for performing the functions described in the foregoing may be employed in the practice of this invention.

What is claimed is:

1. An electrical switch circuit comprising a plurality of magnetically responsive switch devices arranged in rows and columns, each of said switch devices having a first winding and an oppositely poled, second winding thereon, a plurality of row conductors, each including the first windings of the switch devices of a row, a plurality of column conductors each including the second windings of the switch devices of a column, and means for selectively aplying first and second decaying alternating currents of substantially equal frequency and amplitude to said row and column conductors, respectively, one of said first and second currents being applied one-half cycle before the other.

2. An electrical switch circuit as claimed in claim 1 in which each of said switch devices comprises a magnetic core means and a pair of reed spring contacting means, said core means and said contacting means defining a magnetic flux circuit.

3. An electrical switch circuit as claimed in claim 2 in which said magnetic core means is of a magnetic material having substantially rectangular hysteresis characteristics.

4. An electrical switch circuit as claimed in claim 3 in which said magnetic core means comprises a sleeve enclosing said reed spring contacting means.

5. An electrical switch circuit comprising a plurality of magnetically responsive switch devices arranged in rows and columns, each of said switch devices having a first winding and an oppositely poled, second winding thereon, a plurality of row and column conductors each serially including the first and second windings, respectively, of the switch devices of said rows and columns, means for selectively applying first and second decaying alternating currents of substantially equal frequency and amplitude to said row and column conductors, respectively, and means for suppressing the first half cycle of one of said first and second currents.

6. An electrical switch device as claimed in claim 5, in which each of said switch devices includes a magnetic core means of a magnetic material having a high residual flux density relative to its saturation flux density.

7. A coordinate switch array comprising a plurality of magnetically responsive switch devices at the crosspoints of said array, a first and an oppositely poled, second winding for each of said switch devices, and means for operating a selected one of said switch devices defined in said array by a first and second coordinate and for releasing the remaining switch devices defined by said first and second coordinates comprising means for applying a first decaying alternating current to the first windings of the switch devices defined by said first coordinate and means for applying a second decaying alternating current to the second windings of the switch devices defined by said second coordinate a half-cycle removed from said first curent.

8. A coordinate switch array comprising a plurality of magnetically responsive switch devices at the crosspoints of said array, means for selectively applying cancelling magnetomotive drives to said switch devices comprising a first winding for each of said switches, a first source of decaying alternating current, means for selectively connecting said first source to the first windings of the switches defined by one coordinate of said array, a second winding for each of said switches, a second source of decaying alternating current, and means for selectively connecting said second source to the second windings of the switches defined by another coordinate of said array; and means for applying a resultant magnetomotive drive to the switch of said array defined by said one and said other coordinate comprising means for suppressing the first half-cycle of the current generated by one of said first and second sources of alternating current.

9. A coordinate switch array as claimed in claim 8, in which each of said first windings is oppositely poled from each of said second windings.

10. A coordinate switch array as claimed in claim 8 in which said first and said second sources of alternating current produce decaying alternating currents of substantial equal frequency and absolute amplitudes and opposite polarity.

11. A coordinate switch array as claimed in claim 8 in which said means for suppressing the first half-cycle of current generated by one of said first and second sources comprises gating means for grounding said current generated by one of said first and second sources and means for enabling said gating means only during said first half-cycle.

12. A coordinate switch array as claimed in claim 11 in which said gating means comprises a controlled diode means.

13. A coordinate switch array comprising a plurality of magnetically responsive switch devices at the crosspoints of said array, a first and an oppositely poled, second winding for each of said switch devices, a first plurality of coordinate circuits including the first windings of the switch devices of one of the coordinates of said array, a second plurality of coordinate circuits including the second windings of the switch devices of another of the coordinates of said array, common connecting means for one end of each of said first and second plurality of coordinate circuits, an energizing circuit comprising a source of decaying alternating current and means for se-

lectively connecting said first and second plurality of coordinate circuits in said energizing circuit; a bypass circuit connected to said common connecting means including a normally nonconducting gating means, and means for enabling said gating means only during a first half-cycle of said decaying alternating current.

**14.** A switch array comprising a plurality of magnetically responsive switch devices, a first and an oppositely poled second winding for each of said switch devices, a first plurality of selecting circuits, a second plurality of selecting circuits, each of the selecting circuits of said first plurality and each of the selecting circuits of said second plurality including, respectively, the first and second windings of a unique one of said switch devices, common connecting means for one end of each of said first and second plurality of selecting circuits, an energizing circuit comprising a source of decaying alternating current, first means for connecting one of said first selecting conductors in said energizing circuit, second means for connecting one of said second selecting conductors in said energizing circuit; and a bypass circuit connected to said common connecting means including a normally nonconducting gating means and means for eablig said gatig meas oly durig then means and means for enabling said gating means only during the first half-cycle of said decaying alternating current.

**15.** An electrical switch device comprising a magnetic core means having a pair of windings, electrical contact means operated responsive to flux in said core means, means for inducing a flux in said core means comprising means for applying a first decaying alternating current to one of said windings and means for applying a second decaying alternating current to the other of said windings one-half cycle after said first current, the polarity of said windings and said first and second currents being such as effectively to cancel the fields generated by said first and second currents except during said half-cycle, and means for restoring said contact means comprising means for applying one of said first and second decaying alternating currents to one of said pair of windings alone to demagnetize said core means.

**16.** An electrical switch device as claimed in claim **15** in which said core means has a high residual flux density relative to its saturation flux density.

**17.** An electrical switch device as claimed in claim **16** in which said electrical contact means comprises magnetically permeable reed springs and said core means and said reed springs comprise a magnetic flux circuit.

**18.** An electrical switch device as claimed in claim **17** in which said core means comprises a sleeve enclosing said reed springs.

**19.** An electrical switch device comprising a magnetic core means, electrical contact means operated responsive to flux in said core means, means for applying a first and an oppositely poled, second decreasing alternating magnetic field to said core means, said second field being initiated in a half-cycle after said first field, for inducing a flux in said core means to operate said contact means, and means for applying one of said first and second fields alone to said core means substantially to remove said flux from said core means to permit restoration of said contact means.

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U.S. Cl. X.R.

307—88; 340—174