MAGNETIC CORE SELECTION SYSTEM HAVING PLURAL CODED INPUTS

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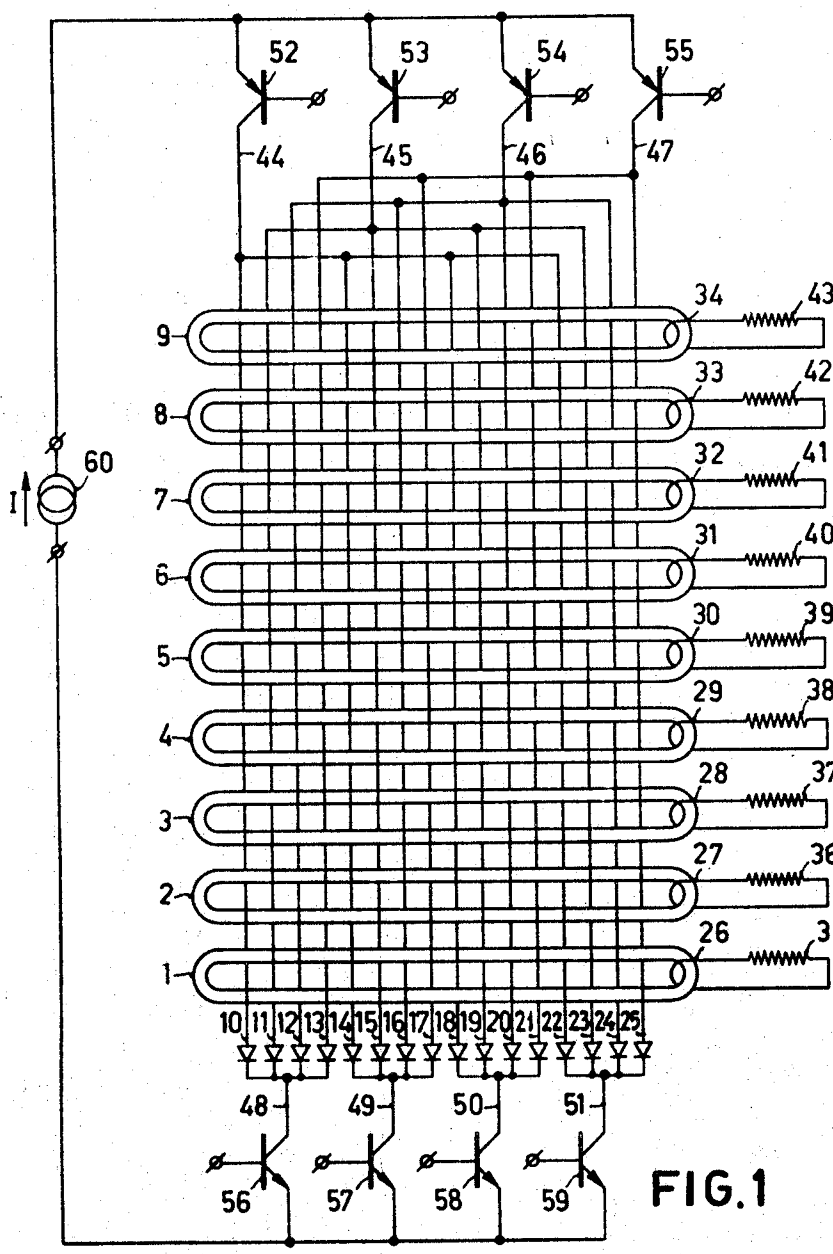

FIG.1

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FIG. 2a

	52	53	54	55
a_1	+	+	−	−
a_2	+	−	+	−
a_3	+	−	−	+

	56	57	58	59
b_1	+	+	−	−
b_2	+	−	+	−
b_3	+	−	−	+

FIG. 2b

FIG. 2c

$a_1 b_1$	9	34
$a_2 b_1$	8	33
$a_3 b_1$	7	32
$a_1 b_2$	6	31
$a_2 b_2$	5	30
$a_3 b_2$	4	29
$a_1 b_3$	3	28
$a_2 b_3$	2	27
$a_3 b_3$	1	26

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
$a_1 b_1$	+	+	−	−	+	+	−	−	−	−	+	+	−	−	+	+	9
$a_2 b_1$	+	−	+	−	+	−	+	−	−	+	−	+	−	+	−	+	8
$a_3 b_1$	+	−	−	+	+	−	−	+	−	+	+	−	−	+	+	−	7
$a_1 b_2$	+	+	−	−	−	−	+	+	+	+	−	−	−	−	+	+	6
$a_2 b_2$	+	−	+	−	−	+	−	+	+	−	+	−	−	+	−	+	5
$a_3 b_2$	+	−	−	+	−	+	+	−	+	−	−	+	−	+	+	−	4
$a_1 b_3$	+	+	−	−	−	−	+	+	−	−	+	+	+	+	−	−	3
$a_2 b_3$	+	−	+	−	−	+	−	+	−	+	−	+	+	−	+	−	2
$a_3 b_3$	+	−	−	+	−	+	+	−	−	+	+	−	+	−	−	+	1

FIG. 2d

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MAGNETIC CORE SELECTION SYSTEM HAVING PLURAL CODED INPUTS

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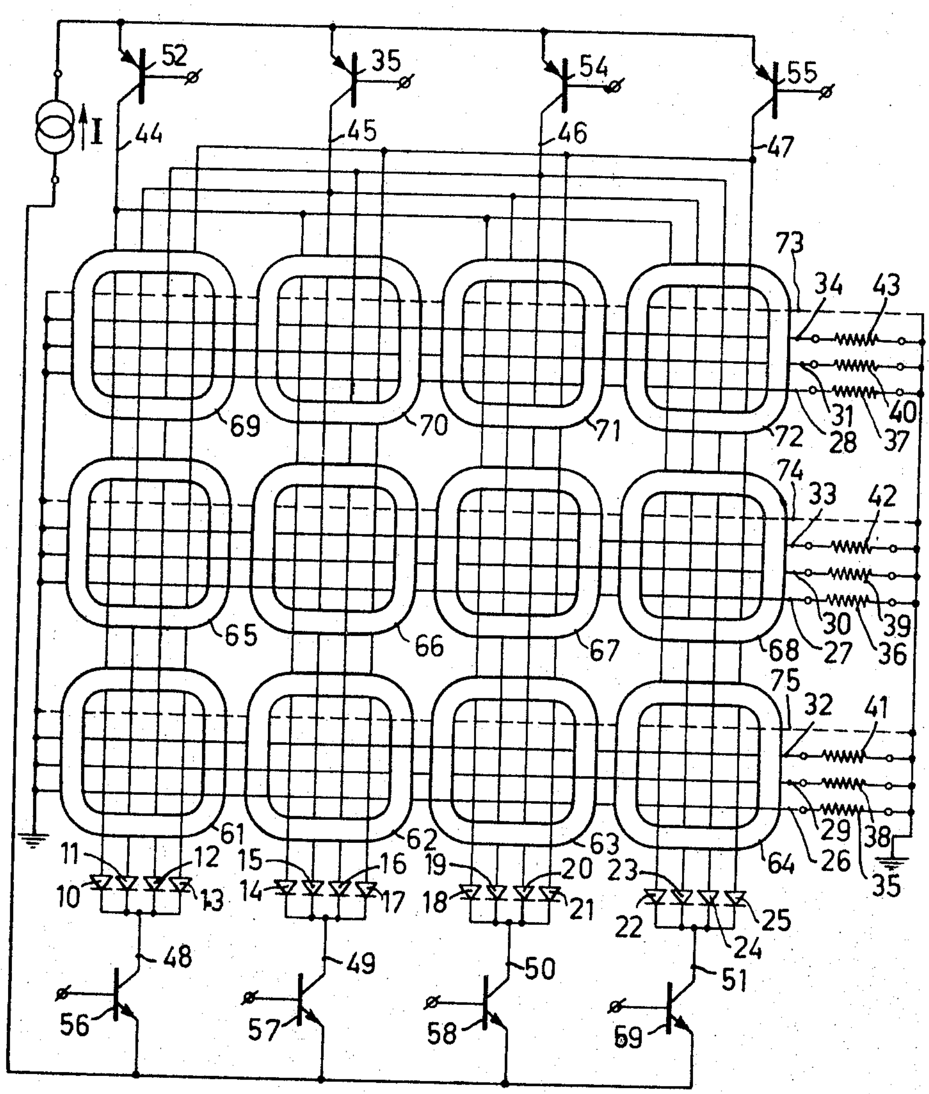

FIG. 3

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MAGNETIC CORE SELECTION SYSTEM HAVING PLURAL CODED INPUTS

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ABSTRACT OF THE DISCLOSURE

The application discloses a magnetic core switching assembly for selectively actuating a plurality of loads such as the row or column conductors of a magnetic storage. The assembly shown comprises a plurality of magnetic cores each of which is threaded by a plurality of energizing windings. The windings are interconnected at one end in a first group pattern each group consisting of multiple windings and being connected through a switch to one pole of the energizing source. The other end of the windings are interconnected in a second group pattern each group consisting of multiple windings and being connected through a switch to the other pole of the energizing source. The switches of the first and second groups are actuated in multiple in a desired pattern to energize the core of a desired output winding and produce cancelling effects in the other cores.

The invention relates to a magnetic core switch comprising a number of magnetic cores and energizing windings and output windings arranged on the magnetic cores, each energizing winding of a magnetic core being connected in series with an energizing winding of a number of further magnetic cores, while for energizing a given output winding energizing currents are fed to a number of selected series combinations of energizing windings, the effects of said currents supporting each other in the selected output winding and compensating each other in all other output windings.

In such a magnetic core switch a selected output winding is energized via one or more magnetic cores by a number of energizing currents for supplying a load current to a load connected to the selected output winding, said magnetic core switches being advantageously employed for driving the row- and column-conductors of magnetic memories with reading and writing pulses of high power by the co-operation of low-power energizing pulses produced in a number of selected energizing circuits via the series combinations of energizing windings.

The invention has for its object to provide a new construction for a magnetic core switch of the kind set forth, in which the number of switches required for the selection of the energizing circuits, for example the number of transistors, is considerably reduced.

The magnetic core switch according to the invention is characterized in that each conductor of a group of auxiliary conductors is connected through the series combination of energizing windings and a unilaterally conduct ing element, connected in series with the former to each conductor of a second group of auxiliary conductors, and in that each auxiliary conductor has added to it a switch in series combination. The switches added to one group of auxiliary conductors and the switches added to the other group of auxiliary conductors connect a common current supply source between the auxiliary conductors of the one group and the auxiliary conductors of the other group for the supply of current to a number of selected series combinations of energizing windings

a number of selected switches of those added to one group of auxiliary conductors and a number of selected switches of those added to the other group of auxiliary conductors are put into circuit.

The invention will be described more fully with reference to the drawing, in which:

FIG. 1 shows an embodiment of a magnetic core switch according to the invention.

FIGS. *2a*, *2b*, *2c* and *2d* show a few diagrams for explanation of the magnetic core switch shown in FIG. 1.

FIG. 3 shows a second embodiment of a magnetic core switch according to the invention.

The magnetic core switch shown in FIG. 1 comprises a number of magnetic cores **1** to **9**, a number of energizing windings **10** to **25**, arranged on the magnetic cores and a number of output windings **26** to **34**, also arranged on the magnetic cores. The output windings **26** to **34** have connected to them the row- or column-conductors of a magnetic storage, which conductors constitute loads for the output windings, and represented in FIG. 1 by the impedances **35** to **43**. The number of energizing windings, which amounts to 16 in the embodiment shown, is much greater in practical embodiments of magnetic core switches; it may be for example 256 or more.

The selection and the individual energization of the energizing windings, whilst using a switch added in series combination to each energizing winding involves, in practice, very great numbers of switches, for example transistors, and a transistor selection arrangement having a very great number of outputs. In order to economize the number of transistors the energizing windings are arranged in k groups of m energizing windings, on the one hand, and in m groups of k energizing windings on the other hand, wherein $m.k=n$, n designating the total number of energizing windings. This grouping is obtained by connecting each conductor of a group of k auxiliary conductors via an energizing winding and a decoupling diode connected in series with the former to each conductor of a group of m auxiliary conductors. The energizing windings are then located so to say at the crossings of two crossing groups of auxiliary conductors one group of k auxiliary conductors and the other group of m auxiliary conductors. The decoupling diodes bring about that between a conductor of one group and a conductor of the other group only one path of connection is possible via an energizing winding and a diode connected in series therewith. The 16 enerigizing windings **10** to **25** of the magnetic core switch shown in FIG. 1 are arranged on both sides in four groups of 4 energizing windings by connecting each conductor of the group of 4 auxiliary conductors **44** to **47** via an energizing winding and a diode connected in series therewith to each conductor of the group of 4 auxiliary conductors **48** to **51**.

Each conductor of the group of k auxiliary conductors and each conductor of the group of m auxiliary conductors has added to it, in series combination, one switch so that the total number of switches is $k+m$. The switches added to the group of k auxiliary conductors and the switches added to the group of m auxiliary conductors are termed for evident reasons the upper switches and the lower switches. Thus the emitter-collector paths of the transistors **52** to **55** are added, in series combination, to the auxiliary conductors **44** to **47** and the emitter-collector paths of the transisors **56** to **59** are added, in series combination, to the auxiliary conductors **48** to **51**. The economy in transistors thus achieved is very considerable, since for a magnetic core switch comprising for example 256 energizing windings the factors k and m being chosen to be 16 and 16 the number of transistors is equal to 32.

The upper switches and the lower switches connect a common current supply device between the conductors of the group of k auxiliary conductors on the one hand

and the conductors of the group of m auxiliary conductors on the other hand for the supply of current to a number of selected energizing windings a number of selected upper switches and a number of selected lower switches are put into circuit. Thus the emitter-collector path of the transistors **52** to **55** are connected to an output terminal of the current source **60**, and the emitter-collector paths of the transistors **56** to **59** are connected to a second output terminal of the current source **60**. For the supply of current to a number of selected energizing windings a number of transistors of the group of transistors **52** to **55** and a number of transistors selected from the group of transistors **56** to **59** are driven at their base electrodes.

It is advantageous to choose for the transistors used as upper switches a conductivity type differing from that of the transistors used as lower switches and to connect the emitter-collector paths of the transistors on the emitter side to the current supply device. It is thus achieved that the transistors not participating in the current supply of a number of selected energizing windings can be blocked by means of comparatively low blocking voltages operative between the emitter and the base electrodes, irrespective of the comparatively high switching voltage operative during the current supply in the collector circuits of said transistors. For this reason transistors **52** to **55** are of the pnp-type conductivity and the transistors **56** to **59** are of the npn-conductivity type as shown, the emitter-collector path of the transistors are connected on the emitter sides to the current source **60**.

For energizing a magnetic core $k/2$ upper switches and $m/2$ lower switches are selected and then switched on, so that the $k/2$ connected upper switches and the $m/2$ connected lower switches convey currents, which flow from the current supply device through the $k/2$ switched-on upper switches and the $k/2 \cdot m/2$ energizing windings and the $m/2 \cdot$ switches-on lower switches back to the current supply device. The energizing currents flowing through the selected $k/2 \cdot m/2$ energizing windings energize one magnetic core, whereas all other magnetic cores remain unenergized during the supply of current. The selected energizing windings surround in the same direction a given, selected magnetic core, so that the magnetic effects of the energizing currents on this magnetic core support each other, whereas any other magnet core is surrounded by the selected energizing windings as many times in one direction as in the other direction, so that the magnetic effects of the energizing currents on these magnetic cores compensate each other. This effect of the magnetic core switch shown in FIG. 1 will be explained more fully with reference to the energization of one of the magnetic cores **1** to **9**, for example the magnetic core indicated at **6**.

For the energization of the magnetic core **6** the transistors **52** and **53** on the upper side of the magnetic core switch are selected and the transistors **56** and **58** are selected on the lower side of the magnetic core switch and the selected transistors are then driven on their bases. The non-selected transistors on the upper side of the magnetic core switch are blocked by a blocking voltage operative between the base and the emitter, which voltage is positive on the base side and the non-selected transistors on the lower side of the magnetic core switch are blocked by a blocking voltage operative between the base and the emitter, which voltage is negative on the base side.

By the selection of the transistors on the upper side and on the lower side of the magnetic core switch a number of energizing windings are selected, i.e. the energizing windings **10**, **11**, **18** and **19**, which are connected on either side to a selected transistor. During the control the selected transistors convey currents which flow from the current supply source **60** in the direction of the arrow I through the transistors **52** and **53** on the upper side of the magnetic core switch and then through the energizing windings **10**, **11**, **18** and **19** and which flow back via the transistors **56** and **58** on the lower side of the magnetic core switch to the current supply source **60**.

The energizing windings surround a magnetic core in the direction which is assumed as positive, if the energizing winding lies above the lower limb and beneath the upper limb of the magnetic core. The windings surround a magnetic core in the negative direction, if the energizing winding is located beneath the lower limb and above the upper limb of the magnetic core. The selected energizing windings **10**, **11**, **18** and **19** surround the magnetic core **6** in the positive direction and surround any other magnetic core as many times in the positive direction as in the negative direction. The magnetic effects of the energizing currents on the magnetic core **6** support each other and the magnetic effects of the energizing currents on any further magnet core neutralize each other, so that solely the magnetic core **6** is energized and a positive voltage is induced only into the output winding **31** arranged on the magnetic core **6**.

During the energization of the magnetic core **6** voltages are induced into all further energizing windings not conveying current, the polarity of said voltages depending upon the direction in which the energizing windings surround the magnetic core **6**. In some energizing windings not conveying current the induced voltages are operative in the reverse direction of the diodes connected in series herewith, so that these energizing windings cannot be traversed by currents, whereas in the other windings not conveying currents the induced voltages are operative in the pass direction of the diodes connected in series herewith. The non-selected transistors, however, are blocked for voltages in the pass direction of the diodes, so that the non-selected transistors cannot become conductive and in neither of the two cases currents can flow through the non-selected energizing windings.

In order to energize the other magnetic cores two transistors on the upper side and on the lower side of the magnetic core switch are each time selected and then driven. The effect of the magnetic core switch is quite identical to that described above for the magnetic core **6**. The various ways in which two of the transistors **52** to **55** and two of the transistors **56** to **59** can be selected are illustrated in the rectangular diagrams of FIGS. 2*a* and 2*b* respectively, in which the columns correspond to the transistors and a + sign represents a selected transistor and — sign represents a non-selected transistor and in which each row represents a possibility of selection. In total there are three ways of selecting two transistors on the upper side of the magnetic core switch and there are three ways of selecting two transistors on the lower side of the magnetic core switch, so that there are nine different combinations of two transistors on the upper side and on the lower side of the magnetic core switch, which correspond to the nine magnetic cores **1** to **9**. The combination of the row *a***1** of the selection diagram of FIG. 2*a* with the row *b***2** of the selection diagram of FIG. 2*b* corresponds to the magnetic core **6**, since for the energization of the magnetic core the transistors **52** and **53** on the upper side and the transistors **56** and **58** on the lower side of the magnetic core switch are selected. All possible combinations of a row of the selection diagram shown in FIG. 2*a* with a row of the selection diagram of FIG. 2*b* are plotted in FIG. 2*c* at the side of the indication of the magnetic core corresponding each time to the combination of two rows.

It should be noted that the transistors selected in the manner described above result in the positive energization of a magnetic core and that for the negative energization of a magnetic core of one of the two rows a complement is used by replacing all + signs by — signs and all — signs by + signs. For the negative energization of the magnetic core **5**, which corresponds to the combination of the row *a***1** with the row *b***2**, the transistors **54** and **55** on the upper side and the transistors **56** and **58** on the lower side of the magnetic core switch are selected in accordance with the complement of the row *a***1** and the initial row *b***2**. During the control of the selected transistors energizing currents flow through the energizing windings **12**, **13**, **20** and **21**, which surround the magnetic core **6** in the negative direction and which surround any other magnetic core as many times in the positive as in the negative direction, so that a negative voltage is induced solely into the output winding **31** arranged on the magnetic core **6**.

The selection diagrams of FIGS. 2*a* and 2*b* represent orthogonal matrices, if +1 and −1 are considered to be + and − signs respectively. They have the property that the internal product of every two rows is zero, which means that the sum of the products of the corresponding elements of every two rows is equal to zero. The number of rows of these matrices is smaller than the number of columns by one. These matrices may be considered to be derived from orthogonal matrices which are constructed by the addition of a row having solely +1 elements. In general a magnetic core switch comprises k upper switches and m lower switches so that the diagrams in which it is indicated how $k/2$ upper switches and $m/2$ lower switches can be selected, represent orthogonal matrices having k and m columns respectively. From the literature orthogonal matrices are known which comprise as many rows and columns, the elements of which have the value +1 or the value −1, the number of columns being a power of 2 or the number of columns being a multiple of 4. Thus, in practice, the factors k and m are restricted in a sense such that orthogonal matrices having k and m columns respectively must be known. In any of these known orthogonal matrices there is a row, all elements of which are equal and have the value +1 or the value −1. By omitting this row, an orthogonal matrix can be derived from such a known orthogonal matrix for use as a selection diagram for the upper switches and the lower switches of the magnetic core switch.

The energizing windings surround the magnetic cores in accordance with a winding system which is found by multiplying the orthogonal matrices corresponding to the selection diagrams row by row in the manner known in matrix calculations as the formation of the direct or Kronecker product. The result of all possible multiplications of a row of the selection diagram shown in FIG. 2*a* with a row of the selection diagram shown in FIG. 2*b* is indicated in FIG. 2*d*. In the winding system shown in FIG. 2*d* of the magnetic core switch of FIG. 1 the columns correspond to the energizing windings **10** to **25** and the rows correspond to the magnetic cores **1** to **9**. With each row there is indicated the combination of rows corresponding to said row for the selection diagrams of FIGS. 2*a* and 2*b*.

FIG. 3 shows a second embodiment of a magnetic core switch according to the invention, in which the similarity to the magnetic core switch of FIG. 1 is illustrated by using the same reference numerals for the corresponding elements of FIG. 1.

The magnet core switch of FIG. 3 comprises a number of magnetic cores **61** to **72** in four (m) vertical groups of three (k-l) magnetic cores and three (k-l) horizontal groups of 4 (m) magnetic cores. The energizing windings **10** to **25** are arranged in the manner shown in FIG. 1 on the upper side in four (k) groups of 4 (m) energizing windings and on the lower side in four (m) of 4 (k) energizing windings. The energizing windings of the same group on the lower side of a magnetic core switch are arranged on the magnetic cores of the same vertical group in accordance with a winding system which is the same for all vertical groups. The output windings are arranged in three (k-l) groups of three (m-l) output windings, and the output windings of one group are arranged on the magnetic cores of the same horizontal group in accordance with a winding system which is the same for all horizontal groups. It is indicated between brackets which values apply, in general, to magnetic core switches of this kind, having $k.m.$ energizing windings. For energizing an output winding the process is exactly the same as that of the magnetic core switch shown in FIG. 1, i.e. two ($k/2$) transistors on the upper side and two ($m/2$) transistors on the lower side of the magnetic core switch are selected in accordance with a row of the selection diagram shown in FIGS. 2*a* and 2*b*, after which the selected transistors are driven. The energizing currents then flowing through the selected $k/2.m/2$ energizing windings energize half of the number of magnetic cores of the same horizontal group, whereas all further horizontal groups are not energized. The magnetic cores energized in a horizontal group energize one output winding, whereas all other output windings of the same group remain non-energized. The selected energizing windings of those arranged on the same vertical group of magnetic cores surround one magnet core in the same direction and any further magnetic core as many times in the positive direction as in the negative direction whilst the magnetic cores energized in a horizontal group are surrounded by one output winding in the same direction, so that the voltages induced into these output windings support each other, whereas any further output winding of the same group surrounds as many energized magnetic cores in the positive direction as in the negative direction, so that the voltages induced into these output windings neutralize each other.

For explaining the operation of the magnetic core switch described above the energization of one of the output windings **26** to **34** is taken by way of example. For energizing the output winding **31** the transistors **52** and **53** on the upper side and the transistors **56** and **58** on the lower side of the magnetic core switch are selected and then driven in accordance with the rows *a***1** and *b***2** of the selection diagrams shown in FIGS. 2*a* and 2*b*, so that energizing currents will flow through the energizing windings **10**, **11**, **18** and **19**.

The positive direction of winding of the energizing windings is the same as that of FIG. 1 and an output winding surrounds the magnetic core in a positive direction, if the winding is located above the right-hand limb and beneath the left-hand limb of the magnetic core. The energizing windings **10** and **11** surround the magnetic core **69** in the positive direction and surround any other magnetic core of the same vertical group as many times in the positive direction as in the negative direction and the energizing windings **18** and **19** surround the magnetic core **71** in the positive direction and surround any other magnetic core of the same vertical group as many times in the positive direction as in the negative direction. The magnetic effects of the energizing currents on the magnetic core **69** and **71** respectively support each other, whereas the magnetic effects on the other magnetic cores of the same vertical groups as the magnetic cores **69** and **71** neutralize each other, so that only the magnetic cores **69** and **71** are energized in the same horizontal group. The output winding **31** surrounds the positively energized magnetic cores **69** and **71** in the positive direction and any of the output windings **34** and **28** associated with the same group surrounds the energized magnetic cores **69** and **71** in the opposite sense. Thus voltages are induced into the output winding **31**, which voltages support each other, whereas into each further output winding of the same group voltages are induced, which neutralize each other, so that an output voltage is produced solely through the load **40**, connected to the output winding **31**. In order to energize a further output winding the transistors are selected in accordance with the same rows of the selection diagrams of FIG. 2*a* and 2*b* as those indicated in FIG. 1, which is indicated in FIG. 2*c*.

The directions of winding of the energizing windings on the magnetic cores of a vertical group may be represented by a rectangular diagram of + and − signs having 4 (k) columns and 3 (k–l) rows, wherein the columns correspond to the energizing windings and the rows to the magnetic cores of a vertical group. Likewise the directions of winding of the output windings on the magnetic cores of a horizontal group may be represented by a rectangular diagram of + and − signs, having 4 (m) columns and 3 (m–l) rows, in which the columns correspond to the magnetic cores of a horizontal group and the rows to the output windings. These rectangular diagrams are identical to those shown in FIGS. 2a and 2b respectively, having 4 (k) columns and 3 (k–l) rows and 4 (m) columns and 3 (m–l) rows respectively. Between brackets it is indicated which values in general apply to magnetic core switches of this kind, having $k.m.$– energizing windings. The winding diagrams of the energizing windings and the output windings represent, if +1 and −1 are considered to be a + sign and a − sign respectively, orthogonal matrices, which can be derived from the known orthogonal matrices by omitting the row, all elements of which have the same value.

The magnetic core switch shown in FIG. 3 may be further improved by adding to each horizontal group of magnetic cores a short-circuited output conductor, which surrounds all magnetic cores of the horizontal group in the same direction. This additional short-circuited conductor surrounds for example all magnetic cores in the positive direction. This additional short-circuited conductor is indicated in FIG. 3 in broken lines at **73**, **74** and **75**.

The improvement acquired by using these short-circuited conductors will be explained by considering the energization of the output winding **31**. During the energization of the output winding **31** the energizing currents then flowing energize the magnetic cores **69** and **71**, which thus induce voltages which support each other in the output winding **31** and neutralise each other in any further output winding of the same group. Without the use of the short-circuited conductor **73**, the non-energized magnetic cores **70** and **72** constitute inductive loads, which are operative in series with the load **40**, connected to the output winding **31**. This undesirable inductive load does not occur with the use of the short-circuited conductor **73**. The short-circuited conductor **73** surrounds the magnetic cores **69** and **71** also in the positive direction, so that the voltage induced in the short-circuited conductor **73** has the same value across the magnetic cores **69** and **71** as the voltage of the output winding **31** across the magnetic cores **61** and **71**. The voltage induced in the short-circuited conductor **73** via the magnetic cores **60** and **71** is suppressed owing to the short-circuiting of the conductor across the magnetic cores **70** and **72**, which are surrounded by the output winding **31** and the short-circuited conductor **73** in opposite senses, so that the voltage in the output winding **31** across the magnetic cores **70** and **72** is equal to and has the same sign as the voltage across the magnetic cores **69** and **71**. The overall voltage in the output winding **31** is therefore twice as high as the voltage across the magnetic cores **69** and **71**. The winding ratio between the output winding **31** and the energizing windings has thus apparently become twice as high. The energizing windings are transformation-like coupled with the output windings by the use of the short-circuited winding **73** via all magnetic cores **69** to **72** of the same horizontal group, so that one

half of the number of magnetic cores does not always constitute an inductive load for the other half. It should be noted that any further output winding in the same group as the output winding **31** surrounds the magnetic cores **70** and **72** in the opposite direction, so that the voltages induced by the magnetic cores **70** and **72** in said output windings neutralise each other.

What is claimed is:

1. A magnetic core switch assembly comprising a plurality of magnetic cores, input means for energizing said cores, a plurality of energizing windings threading said cores, said energizing windings being interconnected at one end thereof in a first given pattern to form a plurality of first groups of conductors and being interconnected at the other end thereof in a second given pattern to form a plurality of second groups of conductors, the product number of said first and second groups being equal to the number of said energizing windings, unidirectional conducting elements connected in series with each of said windings, a plurality of switch means connected in series with said windings and interconnecting each of said groups of conductors and said input means, output windings coupled to said cores, and means for selectively energizing one of said cores and an associated output winding comprising means for selectively actuating a plurality of said switches in a given pattern to produce additive current excitation of said one core and neutralizing excitation of others of said cores.

2. A magnetic core switch assembly as claimed in claim **1** wherein the number of said energizing windings is equal to $m.k$, wherein m groups of k conductors and k groups of m conductors constitute said first and second groups of conductors, and wherein said core energizing means comprises means for selectively actuating $m/2$ switch means connected to said first group of conductors and $k/2$ switch means connected to said second group of conductors.

3. A magnetic core switch assembly as claimed in claim **1** wherein the switch means interconnecting said first group of conductors and said input means comprises a transistor of one conductivity type, and the switch means interconnecting said second group of conductors and said input means comprises a transistor of the opposite conductivity type.

4. A magnetic core switch assembly as claimed in claim **1** further comprising a short-circuit winding threading a plurality of said cores.

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