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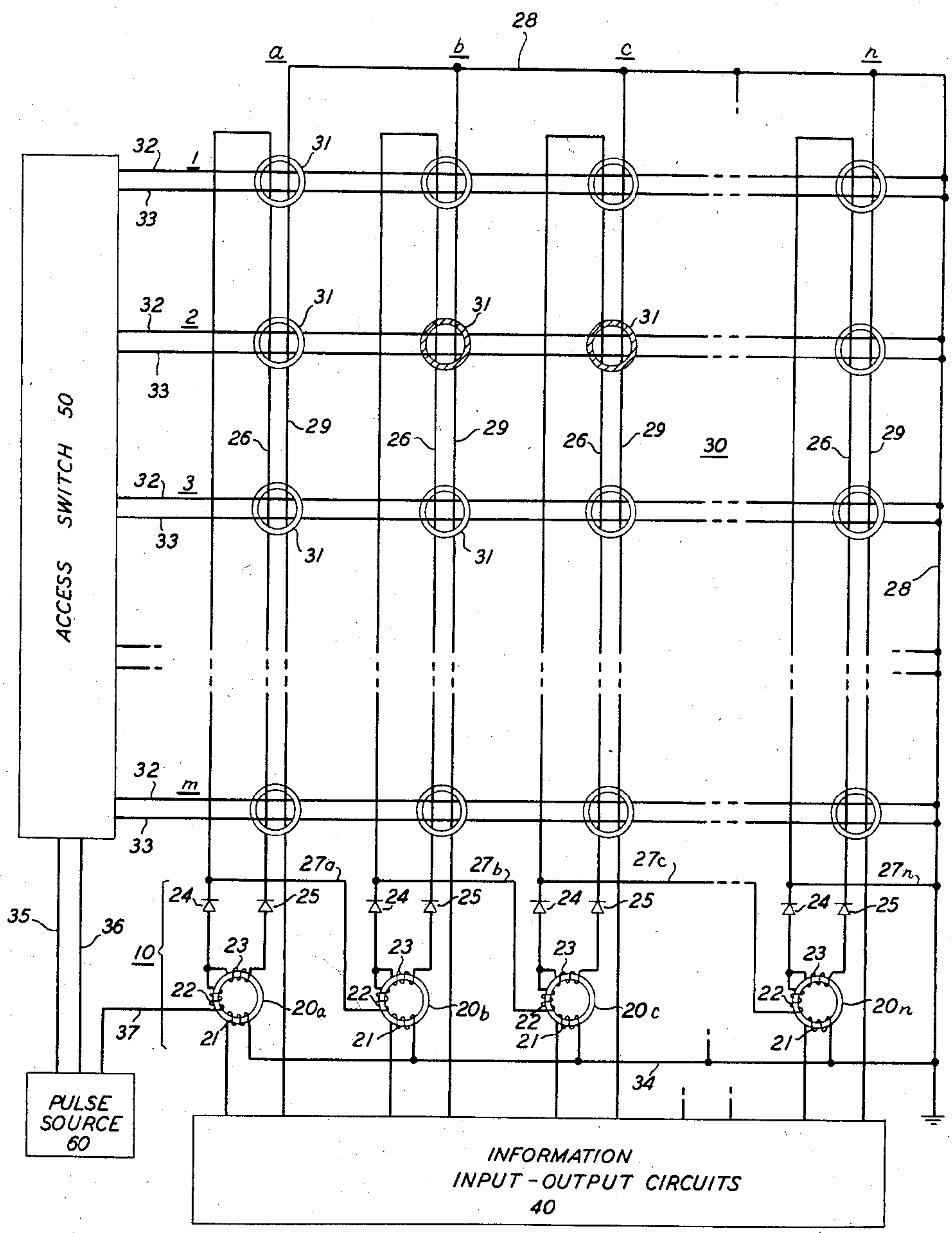

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MAGNETIC CORE SWITCHING CIRCUIT

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This invention relates to magnetic core circuits and particularly to such circuits comprising switches presettable in accordance with a predetermined code.

The property of certain ferrites of remaining in a particular condition of magnetic saturation to which driven by an applied magnetomotive force is well known. This property, manifested in the core by a substantially rectangular hysteresis characteristic, presents in such cores a convenient means for accomplishing essential switching functions in gating and logic operations of data processing systems. When a core is "set," that is, is in one particular condition of remanent saturation, a current pulse, producing a magnetomotive force in a direction opposite to the "set" condition, applied to an activating winding inductively coupled to the core, will cause the core to switch to the opposite, or "reset," condition of remanent saturation. This switching or change of direction of flux in the core, will induce a voltage in an output winding also inductively coupled to the core. If, however, the core under discussion is already in the "reset" magnetic condition, virtually no flux change will result as the current pulse is applied to the activating winding and no effective voltage will be induced in the output winding of the core. Under these circumstances it is obvious that the presence of a signal on output terminals connected to the output winding of the core at the application of an advance pulse will be determined by the particular condition of magnetic saturation to which the core has previously been driven.

In addition to the aforementioned principles of core switching another expedient of considerable importance in realizing the most advantageous use of magnetic cores is described by M. Karnaugh in his Patent No. 2,719,961 of October 4, 1955. In the circuits there described the output winding of a magnetic core is connected at its input to the output side of an activating winding. When an advance current pulse is applied to the activating winding and the core is caused to switch thereby, an electromotive force is induced across the output winding in the direction such as to cause the advance current to flow through that output winding. As applied in the arrangement of Karnaugh cited, the principle makes possible a selection switch comprising magnetic cores serially connected by activating windings. The advance current will then cause any set cores to be reset; the resetting causing the advance current to flow to desired loads through the output windings of the cores so reset. This principle of steering the advance current as determined by particular cores set is also applied generally in my copending application Serial No. 616,308, filed October 16, 1956. In that application coupling loops connecting pairs of cores of a shift register are connected so that the output winding of a core is similarly connected to the activating winding of that core. The advance current is then caused to pass either through the loop and operate to switch the succeeding core or it is caused to by-pass the output winding and switching winding of the succeeding core, depending upon whether or not the activated core is in a set condition.

The principles described above have been utilized according to this invention to provide a magnetic selection switch capable of selecting particular cores of a magnetic core memory matrix and supplying switching current to the cores selected. In connection with providing switching currents for word-organized coincident current matrices generally, simultaneous currents must be applied to the cores of the columns of the matrix in which the information bits of a word appear at the same time that a switching current is applied to cores of the row containing the word. Heretofore it has been found necessary to provide a driving current source for each of the columns of the matrix. According to the principles of this invention a considerable saving in the number of such driving current sources is realized. In theory, only one current source would be necessary to drive the cores of any number of columns reasonably contemplated in a magnetic core matrix by employing the switch of this invention.

Accordingly, it is an object of this invention to provide an improved means for supplying driving currents to a large number of magnetic core loads.

It is another object of this invention to provide an improved magnetic core means for selectively applying activating currents to predetermined ones of a plurality of loads and by-passing the remainder of the loads.

Another object of this invention is to selectively apply switching currents to groups of magnetic cores of a magnetic core matrix from a minimal number of current sources.

The foregoing and other objects of this invention are realized in one illustrative embodiment thereof comprising a series of magnetic cores capable of being switched from one condition of magnetic saturation to another by an applied magnetomotive force of suitable polarity. According to one feature of this invention each of the cores has an activating and an output winding thereon, the windings being serially connected. Load means, such as, for example, the switching leads of a magnetic core storage matrix, are connected between the terminals of the output windings of each core and each activating winding is also connected to the junction of the activating and output windings of a preceding core. Particular cores of the series are set in accordance with the particular loads to which current is to be applied. When an activating current is applied to the serially connected activating windings the particular cores set will be reset and, in accordance with the principle described hereinbefore, the activating current will flow in the output windings of the particular cores and to the loads connected thereto in series. Suitable unidirectional current elements are utilized in connection with each output winding to isolate the unwanted current path during the load selecting operation.

Thus, according to one aspect of this invention, each of the preset cores presents a closed current path to the selected load and each core not so preset presents an open current path to its associated load, a closed circuit path shunting the load being presented in the latter case.

A complete understanding of the objects and features of this invention together with its organization and structure can be gained from a consideration of the detailed description thereof which follows when taken in conjunction with the accompanying drawing, the single figure of which is a schematic representation of a magnetic core selecting switch according to this invention, depicted as applied to a well-known magnetic core information storage matrix and associated circuits.

Referring now specifically to the drawing, the selecting switch **10** embodying the principles of this invention is seen to comprise a plurality of magnetic cores **20** having a substantially rectangular hysteresis characteristic each of which is associated here with a column of similar cores of a coordinate array magnetic core storage matrix **30**. Designating each of the columns of cores of the matrix as *a*, *b*, *c*, . . . *n*, the cores of the switch **10** associated therewith are the cores 20_a, 20_b, 20_c, and 20_n, respectively. Each of the cores **20** has inductively coupled thereto an input winding **21**, an activating winding **22**, and an output winding **23**. The output windings **23** of each of the cores **20** are connected through diodes **24** and **25** to opposite ends of a write conductor **26** threading the cores **31** of each of the columns of the matrix **30**. One side of each of the output windings **23** is also connected to one side of an activating winding **22**. Connecting the one side of each of the activating windings **22** also to the other side of the activating winding **22** of a succeeding core through the diode **24** is an advance conductor **27**. In accordance with the manner in which the activating windings **22** and the output windings **23** are connected, two possible circuit paths are available at each section of the switch **10** represented by a core **20**. One circuit includes the activating winding **22**, the output winding **23**, the diode **25**, write conductor **26**, and advance conductor **27**. The other possible circuit by-passes the output winding **23** and write conductor **26**, and passes directly from the activating winding **22** through the diode **24** to the advance conductor **27**.

The magnetic core storage matrix may be comprised of the cores **31** arranged in rows and columns such as the columns *a*, *b*, *c*, . . . *n*, and the rows **1**, **2**, **3**, . . . *m*. In addition to the switching conductors **26** threading the cores **31** of the columns *a* through *n*, each of the columns of cores has threaded therethrough a detecting conductor **29** connected from information input-output circuits **40** to a ground conductor **28**. Each of the rows of cores **1** through *m* has threaded therethrough a pair of conductors: a read conductor **32** and a write conductor **33**, both of which conductors are connected between an access switch **50** and the ground conductor **28**. The input windings **21** of each of the cores **20** are connected on one side to the input-output circuits **40** and on the other side to a ground conductor **34**.

The information input-output circuits **40** and the access switch **50** may advantageously comprise the corresponding circuits used in connection with the magnetic core memory circuit which I have described in detail with J. H. Felker in our copending application Serial No. 555,889, filed December 28, 1955. Thus the access switch **50** of the type described by M. Karnaugh in the aforementioned patent and comprises a plurality of magnetic cores, alternate ones of which are driven by alternate phase switching pulses supplied by a pulse source **60** via the φ_1 and φ_2 conductors **35** and **36**. Each pulse operates in its phase in a manner such as to switch one core, thereby selecting a current path to a selected load and setting the next succeeding core of the next phase of operation. The switching pulses are in this manner alternately and sequentially applied to the conductors **32** and **33** of the rows of the matrix. Coincidentally with the φ_2 phase of operation of the switch **50** under the control of a pulse supplied by the source **60**, a current pulse is supplied via the φ_2 conductor **37** to the activating windings **22** of the selecting switch **10**. The pulse source **60** is advantageously of the magnetic core flip-flop type described in the above-mentioned application Serial No. 555,889 and in my application Serial No. 555,976, filed December 28, 1955.

In the first phase of operation of the access switch **50** a full-amplitude current pulse is applied to a read conductor **32** threading the cores of a row of the matrix. Assume, for purposes of description, this row to be the row **2** having contained therein the binary information word "011 . . . 0." The storage in the cores of that row of a binary "1" is, for convenience, indicated in the drawing by shading the cores. Upon the application of the φ_1 phase full-amplitude current pulse to the cores **31** of row **2**, the cores **31** of columns *b* and *c* of row **2** will be switched to their reset magnetic condition. The other cores of that row will not be switched and a voltage signal will be induced in the detecting conductors **29** of columns *b* and *c* only. The word thus read out of the matrix during the φ_1 or read phase is temporarily stored in the information input-output circuits **40**. In connection with the latter circuits, means may be provided to make this information available to external utilization devices, not shown, if and when desired. If the immediate restoration to the matrix of the information read out is desired, the circuits **40** are operative to apply switching current pulses to the input windings **21** of the cores 20_b and 20_c of the switch **10** to set the last-mentioned cores. If a new information word is to be written in the matrix to replace the word read out immediately preceding, appropriate cores **20** of the switch **10** may be set by the circuits **40** under the control of external switching means also not shown. Assuming the former case, that the word read out is to be restored to the same row of the matrix, a φ_2 or write phase half-amplitude current pulse is applied by the access switch **50** to the write conductor **33**. At the same time a half-amplitude current pulse is applied via the φ_2 conductor **37** from the pulse source **60** to the activating windings **21** of the cores **20**. This current pulse, termed "half-amplitude" in view of the fact that it is of substantially half the magnitude necessary to switch the magnetic condition of a core **31** of the matrix **30**, is nevertheless effectively "full-amplitude" with respect to the cores **20** of the switch **10**. The comparative magnetomotive forces developed by the φ_2 current pulses supplied by the source **60** are readily adjusted by a suitable selection of turns ratios of the conductors **26** and the windings **22**. Since the cores 20_b and 20_c were the only cores selectively set by the circuits **40** only these cores will be reset and, in accordance with the principles hereinbefore described, the φ_2 half-amplitude current pulse will be caused to flow in the output windings **23** of only those cores.

Accordingly, the φ_2 high-amplitude current pulse will follow the circuit which may be traced from the source **60** as follows: conductor **37**, activating winding **22** of the core 20_a, diode **24**, advance 27_a, activating and output windings **22** and **23** of the core 20_b, diode **25**, write conductor **26** of column *b*, advance conductor 27_b, activating and output windings **22** and **23** of the core 20_c, diode **25**, write conductor **26** of column *c*, advance conductor 27_c, et cetera, and finally the activating winding **22**, diode **24**, and advance conductor 27_n to ground. Thus for particular columns of the matrix, the activating current pulse will by-pass the output winding **23** and the write conductor **26** of the cores **20** not set by the circuits **40**.

Upon the application of the φ_2 half-amplitude current pulse to the write conductors **26** of the columns *b* and *c* by the operation of the switch **10** coincidentally with the application of a φ_2 half-amplitude current pulse to the write conductor **33** of the row **2** by the operation of the access switch **50**, the cores **31** intersected by the conductors **26** of columns *b* and *c* and conductor **33** of row **2** will be set in accordance with the principles of coincident current core switching generally. In this manner the originally read out binary information word "011 . . . 0" is restored to the row **2** of the matrix. It should be noted that, according to a feature of this invention, the output from the switch **10** to the loads, herein the columns of cores of the matrix **30**, can be controlled with precision since this current is equal to the activating current applied by the source **60**.

When the half-amplitude current pulse is applied to the activating windings **22** of the cores **20**, all of the cores **20** set by the operation of the circuits **40** will be reset. All of the cores **20** of the switch **10** will now be in a condition to be again set in accordance with an information word read from another row or with a new information word to be stored in that row.

It is to be understood that although a magnetic core storage matrix is shown in connection with the present invention, other loads requiring well regulated current inputs selectively applied may be driven by the present switch **10**. In addition, switching circuits other than those advantageously employed herein may be used to perform the switching and logic functions of a magnetic memory arrangement in which the switch of the present invention is also employed. It is further to be understood that what has been described is only one illustrative embodiment of the principles of the present invention and modification and changes may be made therein by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. An electrical circuit comprising a plurality of magnetic cores each having a substantially rectangular hysteresis characteristic, output and activating windings for each of said cores, a first circuit means for connecting the activating winding of each of said cores to the activating winding of a succeeding core, load means associated with each of said cores, a second circuit means for serially connecting the activating winding of each of said cores respectively through the output winding of the same core and one of said load means to the activating winding of a succeeding core, means for selectively setting particular ones of said cores, and means including a current source for applying a switching current pulse to said activating windings.

2. An electrical circuit as claimed in claim 1, in which each of said output windings and said activating windings has a unilateral conducting element connected to the output side thereof.

3. An electrical circuit comprising a series of magnetic cores each having a substantially rectangular hysteresis characteristic, input, output, and activating windings for each of said cores, the output side of each of said activating windings being connected respectively to the input side of each of said output windings, a first plurality of circuit means for connecting respectively said output side of each of said activating windings to the input side of a succeeding activating winding, a plurality of load means, a second plurality of circuit means including respectively said plurality of load means for connecting respectively said output side of each of said activating windings through the output winding of the same core to the input side of a succeeding activating winding, a third plurality of circuit means individually connected to said input windings and including a first current source, means for controlling said third plurality of circuit means to selectively set particular cores of said plurality of cores, and means including a second current source for applying a switching current pulse to the activating winding of the first core of said series, said first and second plurality of circuit means each being isolated in a manner such as to comprise only two alternate paths for said switching current pulse at said output side of each of said activating windings.

4. An electrical circuit as claimed in claim 3 in which each circuit means of said first and said second plurality of circuit means has included therein a unilateral conducting element.

5. An electrical circuit comprising a plurality of magnetic cores each having a substantially rectangular hysteresis characteristic, means for setting predetermined cores of said plurality of cores, output and activating windings for each of said cores, a source of activating current, a first current path for said activating current including said activating windings in series, load means for each of said cores, and a second current path for said activating current including each of said activating windings and the output windings and load means of said predetermined cores in series.

6. In an information storage system, first groups of magnetic cores, a second group of magnetic cores individually associated with each of said first groups of cores, each of said cores having a substantially rectangular hysteresis characteristic, a plurality of switching leads, each of said switching leads being inductively coupled to the cores of each of said first groups of cores respectively and each of said switching leads being associated respectively with each of the cores of said second group, means for setting particular cores in said second group in accordance with a predetermined code, an activating and an output winding for each core of said second group of cores, circuit means including a current source for applying an activating current to said activating windings, said circuit means including a first current path for said activating current including said activating windings in series and a second current path for said activating current including each of said activating windings and the output windings and switching leads of said particular cores in said second group in series.

7. A selecting switch comprising a plurality of magnetic cores each being capable of assuming two conditions of magnetic remanence, input, output, and activating windings for each of said cores, means including a first current source for selectively applying setting currents to said input windings to set particular cores of said plurality of cores in accordance with a predetermined code, load means for each of said cores, first circuit means for connecting said activating windings, said output windings, and said load means of each of said cores in series, and a plurality of second circuit means for shunting respectively the output windings and load means of each of said cores.

8. A selecting switch as claimed in claim 7, in which each of said second circuit means includes a unidirectional current element and also comprises means including a current source for applying an activating current to said activating windings to switch said particular cores, the output windings of said particular cores being in a sense such that the voltage induced thereacross by said core switching causes said activating current to pass through the first circuit means of said particular cores.

9. A selecting switch as claimed in claim 8, each of said load means comprising a switching conductor inductively coupled to a plurality of information storage elements each capable of assuming two stable states responsive to applied activating currents.

10. A selecting switch comprising a plurality of magnetic cores each having a substantially rectangular hysteresis characteristic, an output and an activating winding for each of said cores, load means individually associated with each of said cores, a plurality of circuit means for connecting respectively the output side of the activating winding of each of said cores to the input side of the activating winding of another of said cores, each of said circuit means comprising a pair of parallel paths, one of said paths including the output winding of the core having the activating winding from which said circuit means is connected, a unilateral conducting element, and a load means, the other of said paths including a unilateral conducting element, means for selectively setting particular ones of said cores in accordance with a predetermined code, and means including a current source for applying activating current to said activating windings to switch said particular ones of said cores, said output windings on said particular ones of said cores being in a sense such that the switching of said cores induces a voltage thereacross in a direction to control the conduction of said activating current through a selected one of said paths of said circuit means connected to the activating windings of said particular ones of said cores.

11. An electrical circuit comprising a plurality of magnetic cores each having a substantially rectangular hysteresis characteristic, an input, an output, and an activating winding for each of said cores, a load means associ-

ated with each of said cores, a plurality of circuit means for connecting the output side of the activating winding of each core of said plurality of cores to the input side of the activating winding of a respective succeeding core of said plurality of cores, each of said plurality of circuit means comprising a first and a second conducting path, said first path including a first unilateral conducting means connected to the activating winding of a core and said second path including the output winding of said last-mentioned core, a second unilateral conducting element, and one of said load means connected to said last-mentioned output winding; means for selectively applying setting currents to said input windings to set particular ones of said cores in one condition of remanent magnetization, and means for applying an activating current to said activating windings to switch said particular ones of said cores to the other condition of remanent magnetization, said output windings of said particular cores being in a sense such that the voltage induced thereacross by said core switching causes said activating current to pass through the portions of said second path of said circuit means connected to the activating windings of said particular cores.

12. In an information memory matrix, a first and a second plurality of magnetic cores each being capable of assuming two conditions of magnetic remanence, said first plurality of cores being arranged in rows and columns, the cores of each of said columns having a switching lead threaded therethrough, an activating, an input, and an output winding for each core of said second plurality of cores, means for selectively applying current

pulses to said input windings to set particular ones of said second plurality of cores to one of said conditions of magnetic remanence, a plurality of circuit means for connecting respectively the output side of the activating winding of first cores of said second plurality of cores to the input side of the activating winding of a succeeding second core of said second plurality of cores, each of said plurality of circuit means including two paths, one of said paths including the output winding of a said first core of said second plurality of cores and a switching lead, means for applying an activating current pulse to said activating windings to switch said particular ones of said second plurality of cores to the other condition of magnetic remanence, said output windings of said particular cores being in a sense such that the voltage induced thereacross by said core switching causes said activating current to pass through the said ones of said paths of said circuit means connected to the activating windings of said particular cores, which said ones of said paths include switching leads.

13. In an information storage system according to claim 12, each of said activating windings and said output windings having a unidirectional current element connected in the output side thereof.

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