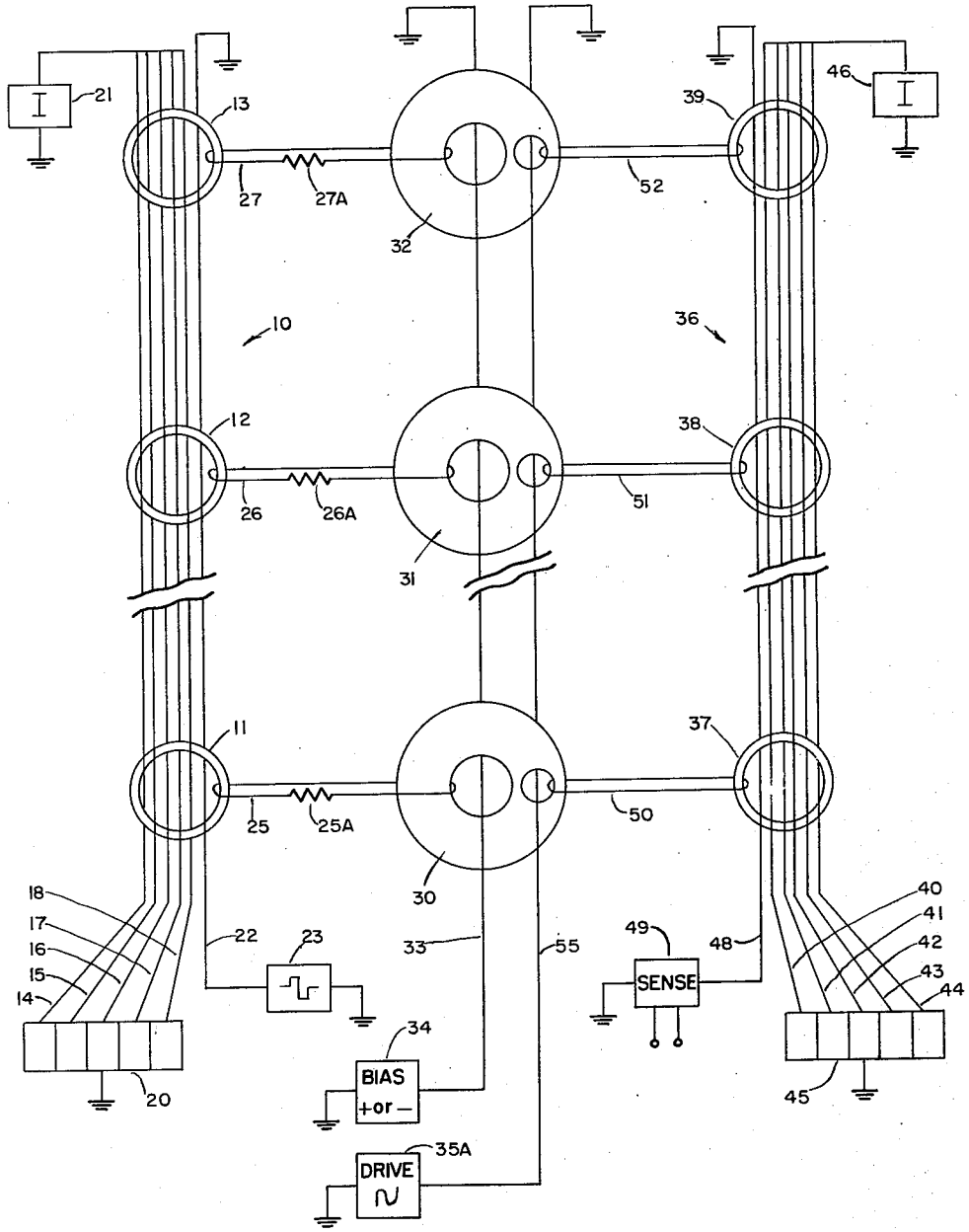
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ELECTRICAL APPARATUS FOR STORING AND MANIPULATING DIGITAL DATA

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INVENTOR.
SAMUEL D. HARPER

BY Henry L. Hanson

ATTORNEY

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ELECTRICAL APPARATUS FOR STORING AND MANIPULATING DIGITAL DATA

Samuel D. Harper, Newton Highlands, Mass., assignor to Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., a corporation of Delaware

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A general object of the present invention is to provide a new and improved apparatus for electrically storing digital data. More specifically, the present invention is concerned with a new and improved apparatus for utilizing saturable magnetic core devices having substantially rectangular hysteresis characteristics for controlling the switching and storing of digital information.

Magnetic core devices of the bistable type have been used in various circuits for purposes of storing digital data and also for purposes of manipulating digital data in logical circuits. One such magnetic core device useful in digital storage and manipulation is the transfluxor. The transfluxor is characterized by its ability to be switched to a completely saturated or partially saturated state depending upon the input signals applied thereto. When the core is completely saturated, the core is considered to be in a blocked state as it will then be in such a condition that it will be impossible to electromagnetically couple any signals through the core. When the core of the transfluxor is partially saturated, the core is capable of being switched in a limited region thereof so that an alternating current signal may be coupled out of the core by the flux changes which do take place in the limited region. An article discussing the transfluxor will be found in the March 1956 issue of the Proceedings of the I.R.E., starting at page 321. Reference should be made to this article for a more detailed discussion of the physical characteristics of the transfluxor and the manner in which it functions.

In accordance with the teachings of the present invention, the transfluxor has been arranged in a unique combination in a random access type of memory circuit with a high degree of selectivity and providing a random access memory wherein the read-out is non-destructive.

It is accordingly a more specific object of the present invention to provide a new and improved random access memory circuit using a transfluxor as the principal storage element in the circuit.

Working in combination with the transfluxor memory elements in the present circuitry are a pair of saturable core switching chains. These switching chains are so arranged that selective combinations of cores in the chain circuit will be saturated while one core in the chain will remain unsaturated. This core may then be referred to as the selection core and serve as a means for selecting a particular transfluxor arranged in a similar chain for purposes of reading or writing. The reading into the transfluxor is such that once the selection core has been selected, a signal may be coupled from that core to the main control aperture of the transfluxor. Whether or not the signal from the selection core will be effective on the transfluxor will be dependent in part upon a bias signal which is applied to the transfluxors of the circuit. To determine whether a one or a zero should be written into any particular core, the polarity of the bias signal applied to the main control aperture of the transfluxor will be controlling.

In order to determine the state of any one transfluxor in the circuit, an alternating current signal may be applied to the output apertures of the transfluxors. Thus, upon selecting a particular transfluxor by a switching chain of magnetic cores, a signal will or will not be coupled out of the transfluxor depending upon whether or not the particular transfluxor is in the blocked or partially blocked state. When a signal is coupled out, it may then be picked up by way of a sense winding which is positioned in the output selection chain circuit.

It is accordingly a still more specific object of the present invention to provide a transfluxor circuit having a saturable magnetic core coupled to an input control aperture of the transfluxor and a further output saturable core coupled to the output aperture of the transfluxor.

A still further more specific object of the present invention is to provide a new and improved transfluxor setting circuit comprising a saturable element adapted to be used for coupling an alternating signal to a transfluxor control aperture and wherein said control aperture has a further direct current bias signal applied thereto which is of a polarity to determine whether or not the transfluxor is switched to a saturated or partially saturated state.

Another feature of the present invention lies in its ability to be readily manufactured and assembled. In accordance with the teachings of the invention, the windings associated with the selection core chains on the input and the output of the transfluxor are in effect single passes made through the cores of the chain. In a similar manner, the bias windings for the transfluxor make a single pass throught the transfluxor as does the drive signal for the output aperture of the transfluxors. Thus, if each transfluxor of the memory circuit is prewired with its associated input and output selection cores, the control windings and output windings may then be threaded through the circuits with a single pass and formed in a long line or memory chain. Once formed, these lines may then be folded or coiled into a small enclosure for packaging purposes. Further, the number of units incorporated in any one memory circuit will be limited only by the physical limitation of the number of windings or leads that can be passed through the core elements.

The foregoing objects and features of novelty which characterize the invention as well as other objects of the invention are pointed out with particularity in the claims annexed to and forming a part of the present specification. For a better understanding of the invention, its advantages and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

Referring to the single figure, there is here illustrated a transfluxor memory circuit wherein random access to the memory circuit is achieved by an input magnetic core selection chain and an output magnetic core selection chain. By this circuitry, it is possible to write a one or a zero into any one of the transfluxor units of the memory and it is also possible to interrogate any one of the transfluxor units without disturbing the magnetized state of the transfluxor unit. In other words, the read-out may be considered as a non-destructive read-out.

Considering the circuit more specifically, the numeral **10** designates an input core selection chain. This selection chain, in the present circuit, is illustrated as a three core chain although it will be readily apparent that a much larger number of cores may be incorporated in the selection chain as well as in the other core and digit locations of the circuit. The chain **10** comprises, as illustrated, three magnetic core devices **11**, **12**, and **13**. These core devices are preferably of the bistable type which may be operated as saturable type signal switches. The numerals **14**, **15**, **16**, **17**, and **18** are the selection wires for the cores **11**, **12**, and **13**. These selection wires are connected to appropriate switching means **20** which are adapted to control the current flow in the selection wires from a suitable current generator **21** connected to the other end of the selection wires. Wires passing thorugh the cores **11**, **12**, and **13** are so arranged that

all of the cores, except one, will be saturated when any one particular selection is being made in the memory circuit. A further winding 22 passes through each of the cores 11, 12, and 13. This winding is coupled to an alternating current source 23 which may well be producing square waves.

Each of the cores 11, 12, and 13 have output windings 25, 26, and 27, respectively. In series with these windings are resistors 25A, 26A, and 27A. These latter resistors may be used to prevent the associated windings from acting as shorting turns on the selection cores. When a particular selection has been made by the switching circuit 20, the core which was selected and is not saturated will be capable of being switched by the alternating current signal from the square wave generator 23. Since the core will be switched, there will be a signal induced in the associated output winding which may be coupled to the associated transfluxor.

In the present circuit, three transfluxors are illustrated and these carry the reference numerals 30, 31, and 32. The coupling winding 25 from the core 11 is coupled to the control aperture of the transfluxor 30. The coupling winding 26 of the core 12 is coupled to the control aperture of the core 31 and the coupling winding 27 of the core 13 is coupled to the transfluxor control aperture 32.

Also passing through the control aperture of each of the transfluxors 30, 31 and 32 is a bias winding 33, the latter of which is connected to a suitable current bias source 34 which may be switched in a suitable manner to produce either a positive or negative bias signal on the winding 33. The amplitudes of these bias signals from the source 34 are such that the presence of an alternating signal from one of the selection cores when added to the one bias signal will be sufficient to switch the transfluxor into a blocked state. If the other bias signal is applied, the transfluxor will be switched from the blocked estate to the partially blocked state. The latter bias is referred to as negative and that which enables the transfluxor to be blocked is positive.

In order to determine the state of the transfluxors 30, 31 and 32 there is provided an output aperture in each of the cores of the tarnsfluxors through which a drive winding is passed. The drive winding in the present drawing is identified by the numeral 35 and is connected to a suitable alternating current drive generator source 35A.

The output selection for the transfluxors will be determined in accordance with a second magnetic core type switching chain 36. This chain embodies the same general constructional features of the chain 10 and will be seen to comprise three saturable core elements 37, 38 and 39. A plurality of selection windings are passed through the cores in a predetermined manner and the selection windings are identified by the numerals 40, 41, 42, 43, and 44. Controlling the selection is a suitable switching means 45 which may be selectively operated in any desired manner by a suitable addressing means, not shown, to control the current flow through the selection wires from a suitable current source 46.

Also coupled to the output selection cores 37, 38 and 39 is a sense winding 48 which is in turn coupled to a suitable sense amplifier circuit 49. In the case of the output selection chain, all of the cores except one will be saturated in any particular selection. The core which is selected will be capable of receiving an alternating current signal from the associated transfluxor if such a signal is present and coupled thereto. The coupling between the transfluxor 30 and the core 37 is by way of a coupling winding 50. The coupling between the transfluxor 31 and the core 38 is by way of the coupling winding 51. The coupling between the transfluxor 32 and the core 39 is by way of the coupling winding 52. In a chain of a number of cores, an improvement in signal to noise ratio is obtained if half of the couplings thread the output selection cores in one direction and half in the other direction.

Considering the operation of the present circuit, it is first assumed that any transfluxor which has been switched into the blocked state has a zero written therein. If the transfluxor is switched to the partially saturated or unblocked state, it is assumed to have a one written therein. It is further assumed that it is desired to write a zero into the transfluxor core 30. To do this, it is necessary to activate the switching circuit 20 so that cores 13 and 12 will be saturated and the core 11 will not be saturated. Thus, if the selection switches associated with the windings 14, 16, 17 and 18 are all closed so that current will be flowing through each of the associated wires, the core 11 will not be saturated while the cores 12 and 13 will be saturated. It is further assumed that the bias signal on the transfluxor 30 from the source 34 will be a positive bias signal. With the drive source 23 supplying an alternating signal to the winding 22 on the core 11, this core will be producing an output in the coupling winding 25 which will be applied to the main control aperture of the transfluxor 30. The presence of the alternating current in this coupling winding 25 when added to the bias signal from the bias source 34 on the bias winding 33 will be effective to switch core 30 into a blocked state so that the entire core will be saturated. Thus, a zero will have been written into the transfluxor 30.

When the transfluxor core 30 has been switched into the blocked state, due to a zero having been written therein, the application of a drive signal from the source 35A to the winding 35 through the output aperture of the transfluxor will not be effective to produce any alternating signal in the coupling winding 50. Thus, if the output selection chain 36 should be activated so that the core 37 was not saturated, no signals would be applied to this core and no signal will be picked up in the sense winding 48 which passes through the core 37.

In the event that it is desired to write a one into the transfluxor 30, the core 11 will again be selected in the above described manner. Since it is desired to write a one, the negative signal from the bias source 34 will be applied to the winding 33 passing through the control aperture of the transfluxor 30. The alternating signal coupled from the core 11 into the coupling winding 25 will be combined with the negative bias signal from the source 34 and will be effective to unblock the transfluxor. The magnitude of the unblocking signal which includes the bias signal and the alternating signal is selected so that it will not completely saturate the core in the opposite direction but merely change the saturated state of the core only on its inner dimension so that in effect the saturated state of the core is reversed only from the control aperture up to the edge of the output aperture of the transfluxor. When the transfluxor 30 has thus been unblocked, the presence of a drive signal from the source 36 acting on the winding 35 will be coupled out into the output coupling winding 50. If the core 37 is selected in the course of the read operation, the alternating signal coupled into the winding 50 will be coupled into the core 37 and thence to the sense winding 48. This will then be reproduced by the sense amplifier 49 and used in any desired manner to indicate that a one has been written into the transfluxor.

It will be apparent that if any one of the other cores in the input selection chain 10 are activated, data may be written into the associated transfluxors. Then, by way of the output selection chain, these transfluxors may be interrogated to determine the data stored in the respective transfluxors.

It will be readily apparent that since only a single pass of the wire through the selection cores and the transfluxor cores is required, these cores may be readily assembled in the course of manufacturing merely by threading the wires through the core units. Once the

entire unit has been assembled, it may then be coiled or formed in any desired manner within an enclosure with the only contacts in the circuit being made by way of the input and output connecting means.

While, in accordance with the provisions of the statutes, there has been illustrated and described the best forms of the invention known, it will be apparent to those skilled in the art that changes may be made in the apparatus described without departing from the spirit of the invention as set forth in the appended claims and that in some cases, certain features of the invention may be used to advantage without a corresponding use of other features.

Having now described the invention, what is claimed as new and novel and for which it is desired to secure by Letters Patent is:

1. A digital storage circuit comprising a plurality of transfluxor cores each having a control aperture and an output aperture, a control winding wound through said control aperture, an output winding wound through said output aperture, a first saturable switching chain comprising a plurality of saturable cores, all but one of which may be selectively saturated at any one time, electrical circuit means coupling the cores to each of the control windings of said transfluxors, a second saturable switching chain comprising a plurality of saturable cores, all but one of which may be saturated at any one time, electrical circuit means coupling the cores of said second chain to each of the output windings of said transfluxors, an alternating signal source coupled by electrical means to each of the cores of said first chain, a direct current bias signal source coupled by electrical means to the control aperture of each of said transfluxors, an alternating current drive signal source coupled by electrical means to said output aperture, and a sense winding electrically coupled to each of the cores of said second chain.

2. A digital storage circuit comprising a plurality of transfluxor cores each having a control aperture and an output aperture, a control winding wound through said control aperture, an output winding wound through said output aperture, a first saturable switching chain comprising a plurality of saturable cores, all but one of which may be selectively saturated at any one time, electrical circuit means coupling the cores to each of the control windings of said transfluxors, a second saturable switching chain comprising a plurality of saturable cores, all but one of which may be saturated at any one time, electrical circuit means coupling the cores of said second chain to each of the output windings of said transfluxors, an alternating signal source coupled by electrical means to each of the cores of said first chain, a direct current bias signal source coupled by electrical means to the control aperture of each of said transfluxors, said bias signal source having an amplitude which is a fraction of the amplitude of signal necessary to saturate the transfluxor cores, an alternating current drive signal source coupled by electrical means to said output aperture, and a sense winding electrically coupled to each of the cores of said second chain.

3. A digital storage circuit comprising a plurality of transfluxor cores each having a control aperture and an output aperture, a control winding wound through said control aperture, an output winding wound through said output aperture, a saturable switching chain comprising a plurality of saturable cores, all but one of which may be selectively saturated at any one time, circuit means coupling the saturable cores to each of the control windings of said transfluxors, an alternating signal source coupled by electrical circuit means to each of the cores of said chain, a direct current bias signal source coupled by electrical circuit means to the control aperture of each of said transfluxors, and an alternating current drive signal source coupled by electrical circuit means to said output aperture.

4. A digital memory circuit comprising a transfluxor core having a control aperture and an output aperture, a saturable core, winding means coupling said saturable core to said control aperture, output winding means coupled to said output aperture, winding means connected to said core to selectively saturate said saturable core, a first alternating current source coupled by electrical circuit means to said saturable core, a direct current bias source coupled by electrical circuit means to said control aperture, and a second alternating current source coupled by electrical circuit means to said output aperture.

5. A digital memory circuit comprising a transfluxor core having a control aperture and an output aperture, a first saturable core, a second saturable core, winding means coupling said first core to said control aperture, winding means coupling said second core to said output aperture, winding means connected to said first and second cores to selectively saturate said cores, a first alternating signal source coupled by electrical circuit means to said first saturable core, a second alternating signal source coupled by electrical circuit means to said output aperture, and a direct current bias winding coupled by electrical circuit means to said control aperture.

6. A digital memory circuit comprising a transfluxor core having a control aperture and an output aperture, a saturable core, winding means coupling said saturable core to said control aperture, a resistor connected in series with said winding means, output winding means coupled to said output aperture, winding means connected to said saturable core to selectively saturate said core, a first alternating current source coupled by electrical circuit means to said saturable core, a direct current bias source coupled by electrical circuit means to said control aperture, and a second alternating current source coupled by electrical circuit means to said output aperture.

7. A digital storage circuit comprising a plurality of transfluxor cores each having a control aperture and an output aperture, a control winding wound through said control aperture, an output winding wound through said output aperture, a first saturable switching chain comprising a plurality of saturable cores, all but one of which may be selectively saturated at any one time, electrical circuit means coupling the cores to each of the control windings of said transfluxors, a second saturable switching chain comprising a plurality of saturable cores, all but one of which may be saturated at any one time, said second switching chain further comprising a plurality of selection windings positioned in said cores for the selective saturation thereof and wound so that the direction of the winding passes through the cores may be alternated to minimize the noise in said chain, electrical circuit means coupling the cores of said second chain to each of the output windings of said transfluxors, an alternating signal source coupled by electrical circuit means to each of the cores of said first chain, a direct current bias signal source coupled by electrical circuit means to the control aperture of each of said transfluxors, an alternating current drive signal source coupled by electrical circuit means to said output aperture, and a sense winding electrically coupled to each of the cores of said second chain.

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