

May 4, 1965

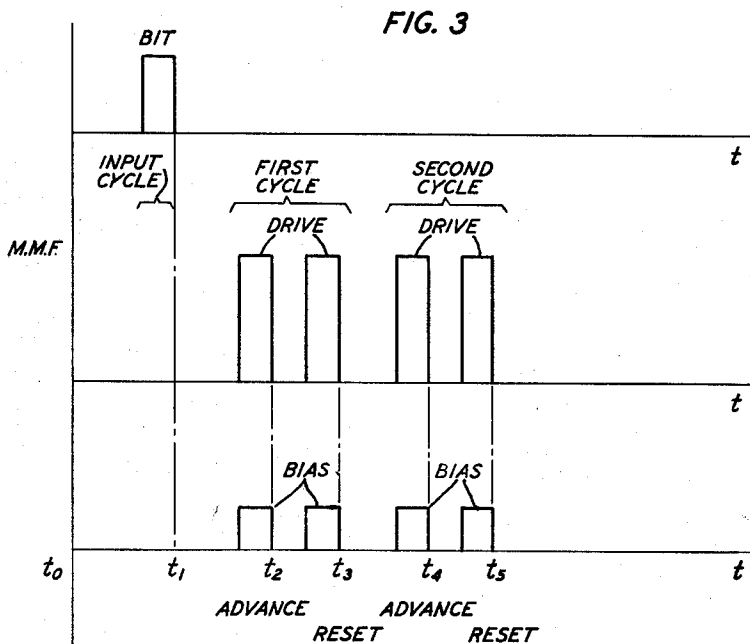
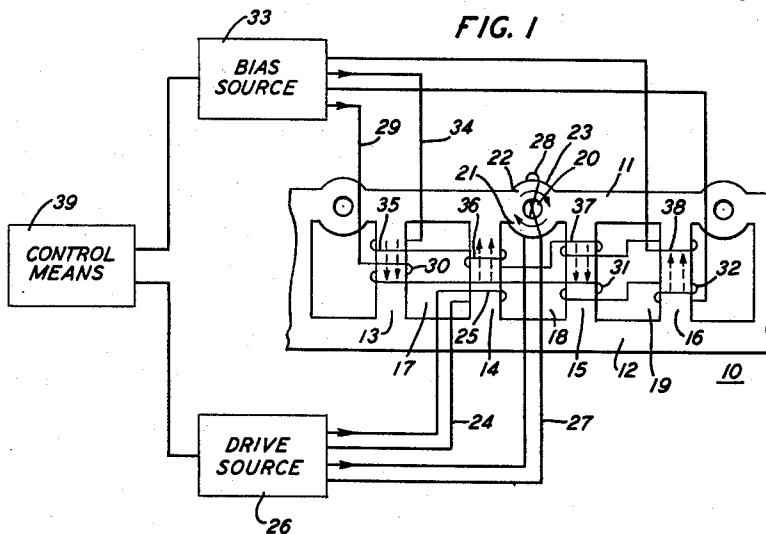
E. E. NEWHALL

3,182,297

MAGNETIC CONTROL CIRCUIT

Filed Dec. 31, 1962

3 Sheets-Sheet 1



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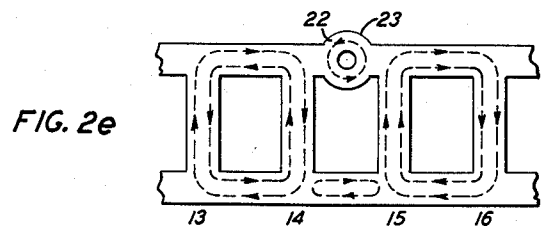
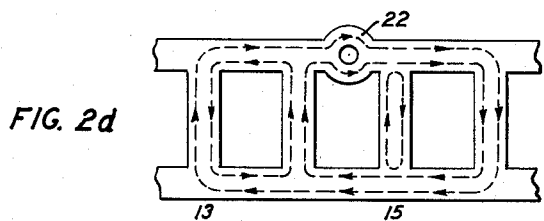
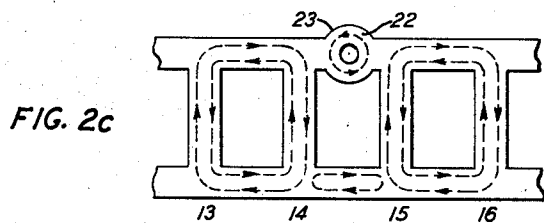
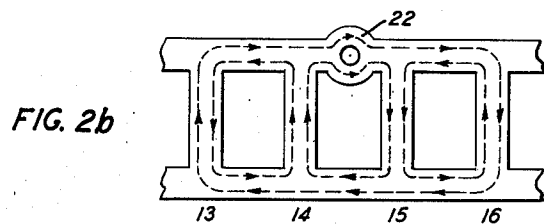
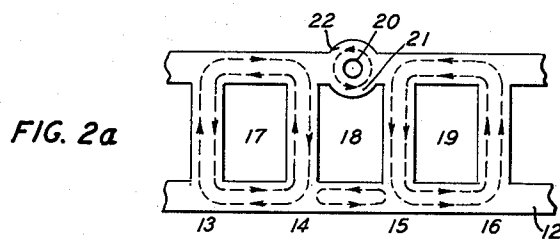
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E. E. NEWHALL
MAGNETIC CONTROL CIRCUIT

3,182,297

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3 Sheets-Sheet 2



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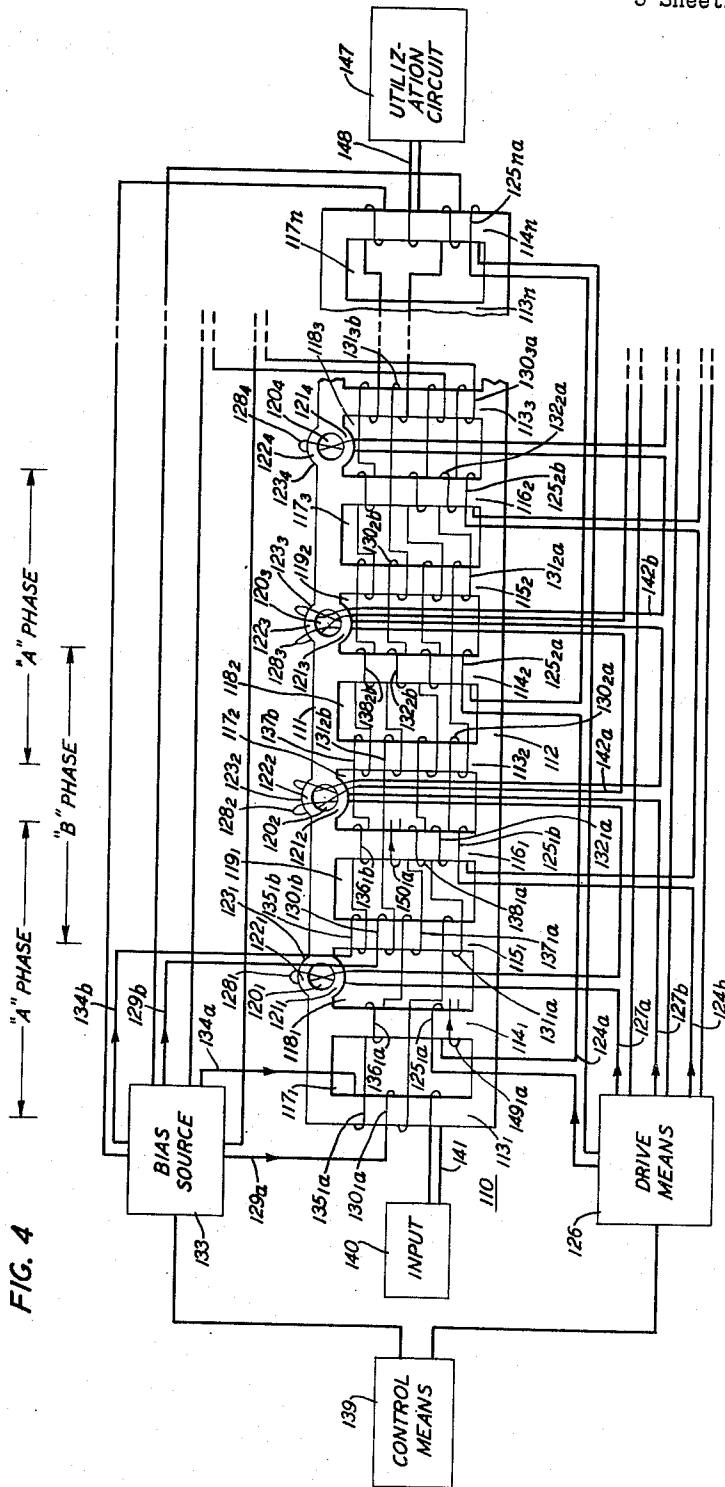
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MAGNETIC CONTROL CIRCUIT

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3,182,297

MAGNETIC CONTROL CIRCUIT

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Filed Dec. 31, 1962, Ser. No. 248,456

13 Claims. (Cl. 340-174)

This invention relates to magnetic information storage and transfer circuits. More particularly, this invention relates to the transfer of information from one location in a magnetic structure to another.

Various magnetic elements such as the toroidal core, the transfluxor and the ferrite sheet have been employed as the basic unit upon which magnetic circuits have been generated, typically for information handling. The general relating characteristic of these elements is that they are composed of materials having substantially rectangular hysteresis loops and thus exhibit two maximum remanent, stable magnetic states and associated switching thresholds.

The toroidal core offers one magnetic flux path acting as a simple electrical-magnetic transducer for electric pulses introduced thereto through inductively coupled electrical conductors. Typically, one core is coupled by an electrical conductor to a second core for the transfer of information therebetween. A certain degree of complication is necessary in the transfer circuit to avoid among other things the bidirectional propagation of the information between cores.

In the prior art, the transfluxor offers further versatility over the toroidal core in that it provides a plurality of magnetic flux paths therein. Transfluxors like the toroidal cores typically are connected by electrical conductors for the transfer of information therebetween. However, in the case of transfluxors the transfer circuit may be simpler because the internal flux path structure is capable of carrying some of the burden carried in toroidal core arrangements by the transfer circuit.

The transfer circuits for both toroidal cores and transfluxors typically are wired by hand and consequently there is considerable expense involved. The ferrite sheet offers the possibility that the transfer circuit can be avoided altogether. We are concerned here primarily with the transfer of information from one location to another in a ferrite sheet.

One of the major continuing problems in the information handling art is the expeditious transfer of information from one location to another as, for example, in a ferrite sheet. More specifically, information, for example, in the ladder-shaped ferrite sheet or "laddic" disclosed in Patent No. 2,963,591 of T. H. Crowley and U. F. Gianola, issued December 6, 1960, is transferred from location to location through flux carrying legs. However, under certain circumstances this transfer may be attended by flux leakage which may result in the attenuation of flux induced therein and propagated therealong. More particularly, a binary input signal inducing a prescribed flux condition to the first rung of such a ladder-shaped structure may be transferred in the form of flux to a preselected remote rung by switching the flux in the first rung by a suitable drive pulse and holding fixed the flux in all the intermediate rungs. The lowest reluctance path available to the flux switched in the first rung is through the preselected rung. However, this preselected rung is in parallel with rungs which may permit some flux leakage. In such cases, only a portion of the flux switched in the first leg is transferred to the preselected remote rung. Accordingly, in structures such as ferrite sheet shift register circuits which may require a large number of such rungs, the flux switched in successive preselected rungs during successive phases of operation of the shift register

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may be characterized by an accumulating flux loss which eventually results in the loss of the binary signal identity therein. The loss of the binary signal identity can, of course, be prevented by providing flux amplification means at suitable points along the flux path. Typically, such amplification means includes transistors or other similar components and accompanying circuitry and, accordingly, is expensive relative to all-magnetic amplification, that is, amplification of the binary signal within the ferrite sheet.

An object of this invention is the all-magnetic amplification of binary signals.

A more specific object of this invention is the transfer of information in the form of an internally regenerated remanent flux condition from one address to another in a ferrite sheet.

Another object of this invention is a new and improved ferrite sheet shift register.

The foregoing and other objects of this invention are realized in one specific embodiment wherein a ferrite sheet is apertured to form a pair of side rails and four transverse interconnecting legs therebetween, thus defining an ordered sequence of three apertures. A winding means is energy coupled to the second interconnecting leg for causing repeated flux switching therein when activated by first and second pulses. Further windings are provided to each of the four interconnecting legs for preferring, when properly activated, the fourth leg for the flux closure path when the second leg is switched to one maximum remanent state, and for preferring the third leg when the second leg is switched partially toward the other maximum remanent state, thus accumulating in the fourth leg flux in increments for the ultimate switching of flux there.

Thus, in accordance with this invention, it is a feature thereof that flux is transferred in increments from a transferor to a transferee location in a ferrite sheet.

In accordance with the principles of this invention, it is a feature thereof that the transferor portion of a ferrite sheet be switched from one magnetic state to another repeatedly while the transferee portion is biased to undergo, synchronously with the switching, a prescribed change in flux closure path provided for the flux switched in the transferor portion.

In accordance with an embodiment, it is another feature of this invention that the transferor and transferee locations be controllably, magnetically separable from remaining portions of the ferrite sheet.

The invention and the further objects and features thereof will be understood more fully with reference to the following description rendered in conjunction with the accompanying drawing, wherein:

FIG. 1 depicts an arrangement of a ferrite sheet including transferor and transferee locations within an information address and the accompanying circuitry by which information is transferred therebetween in accordance with this invention;

FIGS. 2a, 2b, 2c, 2d, and 2e illustrate the changes in flux distribution in the various legs of the ferrite sheet during the operation of the arrangement of FIG. 1 in accordance with this invention;

FIG. 3 depicts the time sequence of the applied pulses for the arrangement of FIG. 1 in accordance with this invention; and

FIG. 4 depicts a shift register based on the modular arrangement of FIG. 1.

It is to be understood that the figures are not necessarily to scale, certain dimensions being exaggerated for purposes of illustration only.

The invention, its structural requirements and operation can best be described in terms of a basic module from which practical embodiments are produced by repetition and interconnection. Accordingly, FIG. 1 depicts a portion 10 of a ferrite sheet apertured to form

a pair of side rails 11 and 12 and four interconnecting legs 13, 14, 15 and 16, thus forming an ordered sequence of three apertures 17, 18 and 9. Each of the side rails and legs is taken as having the same minimum cross-sectional area and thus the same flux carrying capacity. Although the ferrite sheet is shown partially extended in each direction along the line of the apertures, the above referenced elements comprise the basic magnetic module in accordance with this invention, the extensions serving only to illustrate the interconnection of the module with additional modules as will become apparent hereinafter. In this module, side rail 11 is divided by an additional aperture 20 adjacent aperture 18. The aperture 20 provides in side rail 11 thereabout a circular flux path including legs 21 and 22, each having a minimum cross-sectional area of half that of the other legs of the structure and thus half the flux carrying capacity thereof. Accordingly, there is formed a gate 23 similar to that described in the copending application of D. B. Armstrong and U. F. Gianola, Serial No. 818,146, filed June 4, 1959.

A conductor 24 is inductively coupled to leg 14 by winding 25 and is connected to a variable amplitude drive pulse source 26. A conductor 27 is inductively coupled to both legs 21 and 22 by a figure 8 winding 28 and connected to the variable amplitude drive pulse source 26. A conductor 29 is coupled serially in a like sense to legs 13 and 15 and in an opposite sense to leg 16 by windings 30, 31 and 32, respectively, and is connected to variable amplitude bias pulse source 33. A conductor 34 is coupled serially and in an alternating sense to legs 13, 14, 15 and 16 by windings 35, 36, 37 and 38, respectively, and is connected to the variable amplitude bias pulse source 33. The pulse sources 26 and 33 are controlled by a synchronizing and control means 39. The pulse sources 26 and 33 may comprise any pulse source well known in the art suitable for providing the necessary pulses as described herein. Accordingly, the pulse sources will not be described in detail, the description of their function being sufficient for a complete understanding of this invention. Similarly, control means 39 may comprise any known means for effecting coincident bias and drive pulses and providing the proper timing for applied pulses as described herein. The sense of the coupling windings, the direction of flux, the drive pulses and resulting changes of flux will be understood more fully from the following description of the operation of the arrangement of FIG. 1 rendered in conjunction with FIGS. 2a through 2e and 3.

Basically, this invention is concerned with the transfer of information in terms of a particular flux pattern from one location in a ferrite sheet to another. Consequently, one test in determining the efficacy of a particular arrangement is to examine during operation thereof the initial, intermediate and final flux patterns, tracing the changes therein in response to the applied pulses and comparing the final pattern with the desired results.

FIGS. 2a through 2e are a sequence of apertured ferrite sheet portions corresponding to portion 10 of FIG. 1 and depicting therein the initial, intermediate and final flux patterns for legs 13, 14, 15 and 16 of FIG. 1 assuming the presence of a degenerate, stored binary "one" in a location defined by legs 13 and 14 and a binary "zero" in a location defined by legs 15 and 16. In this connection the term "degenerate" characterizes a partially switched flux condition in a leg or pair of legs as is described more fully hereinafter. Input means for providing this stored "one" in the case illustrated by FIG. 1 would be a terminal leg of a preceding module as shown in FIG. 1.

For the purposes of the description of the operation of the arrangement of FIG. 1, it will be assumed that an initial normal flux distribution is present in structure 10 of FIG. 1 when the leg pairs 13-14 and 15-16 include flux in the counterclockwise direction as shown by the dotted lines and arrows in FIG. 1. Thereafter, the flux

distribution is as represented by the broken lines in the various legs of the structure as shown in FIG. 2a, for example. Each of the lines is taken to represent one-half of the total flux value which can be induced in a particular leg and the arrows indicate the polarity of the flux present. Since each of the legs and side rails is flux-limited to the same degree in view of the equal minimum cross-sectional areas, the flux magnitude represented by the broken flux lines is thus consistent in each case. The "clear" flux distribution assumed then is one in which a maximum remanent flux is present in the structure 10 of FIG. 1 in closed loops through the adjacent legs as shown. In accordance with the flux behavior convention to be assumed in describing the operation of this invention, oppositely directed lines within a single leg, where they occur hereinafter, may be regarded as oppositely poled fluxes which find closure by linking with other such fluxes in the same or other legs. Accordingly, a degenerate, stored binary "one" is assumed to be present when legs 13 and 14 include some flux in a clockwise direction shown initially as oppositely directed lines in FIG. 2a for legs 13 and 14. In addition, it is assumed for convenience that each leg and side rail carries one unit of flux in order to provide a magnetic structure wherein each of the possible flux closure paths is flux limited to the same flux magnitude. The efficacy of the arrangement of FIG. 1 is illustrated then if the degenerate, stored binary "one" can be transferred to legs 15 and 16 in a regenerated condition, that is, if all flux in legs 15 and 16 can be switched from a counterclockwise direction to a clockwise direction.

The desired switch in the direction of flux in legs 15 and 16 is accomplished by the sequence of electrical pulses which induce the magnetomotive forces shown in FIG. 3 which is a plot of magnetomotive force (or M.M.F.) versus time t . Initially, a bit pulse terminating at time designated t_1 may be provided by, for example, a preceding magnetic leg switched in accordance with prior operation by electrical pulses inductively coupled thereto to introduce a degenerate "one" into legs 13 and 14. Subsequently, a bias pulse and a larger amplitude drive pulse are applied coincidently to conductor 29 by bias source 33 and to conductor 24 by drive source 26, respectively. Both the drive and bias pulses terminate at time t_2 . Then, coincident bias and drive pulses are applied to conductors 34 and 27 by way of bias and drive sources 33 and 26, respectively. Both these drive and bias pulses terminate at time t_3 . The first coincident bias and drive pulses constitute an advance phase of operation; the second coincident bias and drive pulses constitute a reset phase, both phases in a single cycle of operation to be described more fully hereinafter. The direction of current from sources 26 and 33 is chosen during the first bias and drive pulses to bias legs 13 and 15 upward, leg 16 downward, to bias legs 21 and 22 to the right, and to drive leg 14 upward, each of the directions as viewed in the drawing. In this connection, the term "bias" refers to a pulse of an amplitude sufficient only to drive a leg of magnetic material just short of its switching threshold. Thus the bias pulse produces in the magnetic structure a magnetic condition which adds to or subtracts from that produced by a coincident drive pulse, depending on the relative polarity and/or sense of magnetic coupling of the corresponding windings (as shown), to prefer or deter respectively the passage of flux along prescribed paths. Similarly, during the second coincident bias and drive pulses the flux in gate 23 is driven to complete a flux closure path about the circular flux path there, legs 13 and 15 are biased upward and legs 14 and 16 are biased downward, the directions again being as viewed in the drawing. In other words, during the first or advance phase corresponding to the coincident bias and drive pulses terminating at time t_2 , the preferred flux closure path comprises leg 14, gate 23 and leg 16. During the second or reset phase corresponding to the coincident bias and drive pulses terminating at

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time t_3 , the preferred flux closure path comprises leg 14, gate 23 and leg 15. Thus in the first cycle of operation comprising one advance and one reset phase, the flux in leg is switched once to the maximum positive remanent condition as shown because of the drive pulse applied to leg 14 and an additional time partially in the opposite direction of flux as shown because the drive pulse applied to conductor 28 forces gate 23 to go to neutral providing energy to leg 14 sufficient, when added to the energy provided by the coincident bias pulse, to enable leg 14 to switch.

The effect of the applied pulses of FIG. 3 on the flux distribution in the magnetic structure 10 can be understood most clearly in terms of FIG. 2 where complete flux closures are diagrammed to facilitate one manner of understanding the flux behavior during the present operation. Specifically, at time t_1 shown in FIG. 3, the flux in legs 13 and 14 of FIG. 2a is partially in a clockwise direction depicted in FIG. 2a as oppositely directed lines and corresponding to a stored degenerate, binary "one." Flux closures and linkages in the flux-limited path may be understood as being completed as depicted by the connection of the oppositely directed lines of legs 13 and 14 as shown in the figures. All the flux in legs 15 and 16 is in the counterclockwise direction corresponding to a stored "zero." Flux closures about legs 15 and 16 are shown again by the connection of oppositely directed lines. The flux in legs 21 and 22 at time t_1 is in a circular flux path closing about aperture 20 as shown, while the flux in the remaining portion of the side rail 12 beneath aperture 18, as viewed in the figure, closes upon itself as shown.

FIG. 2b illustrates the flux distribution at time t_2 as shown in FIG. 3. It will be remembered that the coincident advance bias and drive pulses terminating at time t_2 bias legs 13 and 15 upward, leg 22 to the right and drive leg 14 upward. Consequently, leg 14 is switched upward or to the maximum positive remanent condition as shown in the figure. Legs 22 and 16 provide the flux closure path accommodating the flux changes occasioned by the switching of leg 14. Thus, during the advance phase of the first cycle of operation, a relatively long flux closure path through leg 16 is preferred for the flux switched in leg 14.

FIG. 2c illustrates the flux distribution at time t_3 as shown in FIG. 3. It will be remembered that the coincident reset bias and drive pulses terminating at time t_3 bias legs 13 and 15 upward, legs 14 and 16 downward, and drive the flux in gate 23 into the circular flux path there, that is, switch the flux in leg 22. Consequently, leg 22 is switched to the left, leg 15 is switched upward and leg 14 is switched downward as viewed in the figure.

At this juncture in the operation, the first cycle of operation in accordance with this invention is completed. It should be noticed that each of legs 13, 14, 15 and 16 now includes oppositely directed lines. Thus, during the first cycle of operation a degenerate "one" has been transferred to legs 15 and 16. Moreover, during the advance portion of the first cycle of operation a relatively long flux path through leg 16 was preferred by the bias pulse as applied while leg 15 was excluded thereby from the flux path. During this same period the flux in leg 14 was switched to the maximum positive remanent condition. On the other hand, during the reset portion of the first cycle of operation, the bias pulse as applied prefers a relatively short flux closure path through leg 15 while excluding leg 16 from the path. During this same period, the flux in leg 14 is switched to the partially downward condition as viewed in the figure.

FIG. 2d illustrates the flux distribution at time t_4 as shown in FIG. 3. The second coincident advance bias pulse and drive pulse, respectively, terminating at time t_4 , as was the case with the first advance pulses, biases legs 13 and 15 upward, biases leg 22 to the right and drives leg 14 upward, all the directions being as viewed in the figure. Consequently, leg 14 is switched upward into

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the maximum positive remanent condition as shown in the figure. Legs 22 and 16 again provide the flux closure path accommodating the flux changes occasioned by the switching of leg 14.

FIG. 2e illustrates the flux distribution at time t_5 as shown in FIG. 3. The second coincident reset bias pulse and drive pulse, respectively, terminating at time t_5 , as was the case with the first reset pulses, biases legs 13 and 15 upward, biases legs 14 and 16 downward, and drives the flux in gate 23 into the circular flux path there, that is, switch the flux in leg 22. Thus, leg 22 is switched to the left, leg 15 is switched upward and leg 14 is switched downward as viewed in the figure.

The second cycle of operation is now complete. Again, during the advance phase, a relatively long flux path through leg 16 was preferred by the bias pulse as applied. Also, during the reset phase, a relatively short flux closure path through leg 15 was preferred by the bias pulse as applied. As a result of the second cycle of operation, an additional increment of flux, shown conveniently as one-half unit of flux, is transferred to legs 15 and 16. Thus the final distribution as shown in the figure comprises a flux pattern in legs 13 and 14 corresponding to a degenerate, stored "one" as shown initially in FIG. 2a. However, legs 15 and 16 now include flux lines indicating maximum positive and negative remanent conditions, respectively, corresponding to a regenerated, stored, binary "one." Thus, in accordance with this invention, amplification of information in terms of flux patterns is provided within a ferrite sheet without the necessity of providing costly and power consuming external amplifying circuits.

In the foregoing description, it was assumed that the input degenerate, binary "one," was characterized by one-half the flux capacity of each leg in the structure. However, conditions could exist where the input signal has degenerated to less than the one-half value in which case the two cycles of operation described will insure continual build-up of the signal for eventual regeneration thereof. Further, a particular bias and drive circuit configuration was assumed in the foregoing description for illustrative purposes only. It is contemplated herein to include other circuit configurations which permit operation in accordance with this invention. Moreover, the bias and drive pulses have been described as provided coincidentally, that is initiated and terminated simultaneously. However, it should be evident to one skilled in the art that the bias pulse may be initiated prior to the corresponding drive pulse. It is only necessary that the various legs of the structure 10 be in the bias conditions described when the corresponding drive pulse is applied.

The operation of the arrangement of FIG. 1 in accordance with this invention has been described only for the condition where a single degenerate "one" has been introduced because this invention is directed at regenerating such an input. In practice it is customary to introduce a sequence of binary bits. Moreover, the sequence of bits includes both binary "ones" and binary "zeros." Accordingly, for practical use of the arrangement of FIG. 1, additional circuitry of a conventional type is required for accommodating a "zero" as well as a "one" in sequence. Additional bits are introduced by additional input cycles after two first cycles and two second cycles of operation in the sequence shown in FIG. 3. These four cycles are required to transfer binary information or bits from one information address to another as, for example, in a shift register, as will become apparent hereinafter.

A stored "zero" characterized as a "clear" flux condition is introduced in sequence by the absence of a pulse during the corresponding input cycle. As a consequence, the flux condition shown in legs 13 and 14 of FIG. 1 is not altered thereby. During the following advance phase the drive pulse applied to leg 14 attempts to drive

the flux in leg 14 in a direction in which the leg is already saturated. Again the clear pattern remains undisturbed. During the following reset cycle as shown in FIG. 3 the flux in gate 23 already is closed about the circular path and no flux change is produced by the drive pulse applied to gate 23 during this cycle. Thus at the end of two cycles of operation after the introduction of a "zero" into the module of FIG. 1 the counterclockwise or "clear" flux pattern still remains in legs 15 and 16.

The advantages of the circuit arrangement of FIG. 1 and its operation will be understood more clearly from a description of the shift register 110 of FIG. 4. Shift register 110 is fabricated in a single ferrite sheet by what may be thought of as repetition and interconnection of a plurality of the basic module described in FIG. 1. The ferrite sheet is apertured to form a pair of side rails 111 and 112 and interconnecting legs therebetween which can be thought of in sets of four to correspond to the legs of the module of FIG. 1 and which are designated 113₁, 114₁, 115₁, 116₁, et cetera, with the subscript denoting the set. The legs form an ordered sequence of the apertures which are designated 117, 118 and 119 to correspond to apertures 17, 18 and 19 of FIG. 1 and repeating n times. The side rail 111 includes additional apertures 120₁ through 120 _{n} adjacent every other aperture of the ordered sequence of apertures. Each aperture 120 provides in side rail 111 thereabout a circular flux path including legs 121 and 122 which have subscripts denoting its ordered sequence, thus forming gates 123₁, 123₂, . . . 123 _{n} . A conductor 124 _{a} is inductively coupled to each leg 114₁ . . . n by a corresponding winding 125₁ . . . n (a) in series and to a variable amplitude drive pulse source 126.

A conductor 127 _{a} is coupled serially to all the legs 121 and 122 which have odd numbered subscripts by a corresponding figure 8 winding 128 and is connected to variable amplitude drive pulse source 126. Similarly, a conductor 127 _{b} is coupled serially to all the legs 121 and 122 which have even numbered subscripts by a corresponding figure 8 winding 128 and is connected to variable amplitude drive pulse source 126. A conductor 129 _{a} is coupled serially in a like sense to legs 113 and 115 and in an opposite sense to leg 116 of each set of legs by windings 130 _{a} , 131 _{a} and 132 _{a} , respectively, bearing additional subscripts to correspond to the various sets of legs, and is connected to a variable amplitude bias pulse source 133. A conductor 134 _{a} is coupled serially and in an alternating sense to each of legs 113, 114, 115 and 116 by windings 135 _{a} , 136 _{a} , 137 _{a} and 138 _{a} , respectively, bearing corresponding additional subscripts, and is connected to variable amplitude bias pulse source 133. A conductor 124 _{b} is coupled to each leg 116₁ . . . n by a corresponding winding 125₁ . . . n (b) in series and is connected to variable amplitude drive pulse source 126. A conductor 129 _{b} is coupled serially in a like sense to legs 115 and 113 and in an opposite sense to leg 114 of each set of legs by windings 130 _{b} , 131 _{b} and 132 _{b} , respectively, and is connected to variable amplitude bias pulse source 133. Thus, illustratively, the windings of conductor 129 _{b} are merely shifted two legs from those of conductor 129 _{a} . Similarly, a conductor 134 _{b} is coupled serially and in an alternating sense to each of legs 115, 116, 113 and 114 in that order by way of windings 135 _{b} , 136 _{b} , 137 _{b} and 138 _{b} , respectively, and is connected to variable amplitude bias pulse source 133. Control means 139 activates the pulse sources 126 and 133 to move through the register information supplied by a conventional pulse generating input 140 to leg 113₁ by way of conductor 141. Magnetic isolation between sets of legs is provided during operation by way of conductors 142 _{a} and 142 _{b} including related sets of figure 8 windings through the even and odd apertures 120, respectively, (shown for convenience only through apertures 120₂ and 120₃). Conductors 142 are connected to drive source 126 by way of conductor 127 _{a} and 127 _{b} to be activated alternately

for driving the flux about the odd or even sets of apertures into the circular flux path during the corresponding "A" and "B" phases of operation as will become clearer hereinafter.

During the first and second cycles of operation, two advance and two reset pulses as shown in FIG. 3 are applied by sources 126 and 133 through the conductors having the subscript "a." Thus, operation during these cycles designated the "A" phase of operation, is initiated in the sets of four legs starting with legs 113 as indicated by the vertical lines limiting the "A" phase designation in FIG. 4. Normally, input source 140 saturates legs 113₁ and 114₁. In such a case, the first module of the shift register need not undergo first and second cycles of operation as described because legs 115 and 116 will become saturated during the first cycle of operation. However, input source 140 could be the output of some complicated circuit which provides a degenerate flux condition in legs 113₁ and 114₁, as described, in which case two cycles of operation per module would be necessary. Accordingly, a versatile shift register in accordance with this invention includes circuitry which provides in the first module for the described two cycles of operation. Consequently, whether or not regeneration of the input signal is required, the operation is essentially as described in connection with FIGS. 2 and 3, resulting in a (regenerated) "one" in leg 116₁. Magnetic isolation between the first and second sets of legs in the "A" phase of operation is achieved by way of gate 123₂ activated by the pulses applied to conductor 127 _{a} . During the third and fourth cycles or the "B" phase of operation as shown in FIG. 4, a second set of two advance and two reset pulses as shown in FIG. 3 are applied by sources 126 and 133 through the conductors having the subscript "b." Thus operation during these cycles is limited to the sets of four legs starting with legs 115 similarly indicated, the transfer of information from one information address to another requiring one "A" phase and one "B" phase of operation. Magnetic isolation between the sets of legs 115, 116, 113 and 114, the operational sets of legs during the third and fourth cycles, or the "B" phase of operation is achieved by way of gates 123₁ and 123₃, et cetera, activated by the pulses applied to conductor 127 _{b} . It is helpful to note that the basic modules of FIG. 1 overlap each other by two legs when operated in the two phase per bit mode of operation described in connection with the shift register of FIG. 4. Accordingly, leg 113₁ is the initial leg of the register and leg 114 _{n} is the terminal leg, the regenerated "one" being transferred initially to legs 114₂ by the "B" phase of operation. The process repeats until the regenerated "one" is stored in leg 114 _{n} and activates utilization circuit 147 by way of conductor 148.

In the situation where the input source 140 introduces a stored "zero" following a previously introduced stored "one," the flux distribution already present in the recipient module for example including legs 113, 114, 115 and 116 is as shown in FIG. 2e. Since a partially switched flux condition already obtains there, a "one" condition would be regenerated during the following two cycles of operation unless the module is reset prior to the introduction of the stored "zero." Accordingly, after the "A" phase of operation terminates or, in other words, after the second cycle of operation as shown in FIG. 3, the first two legs of each module in the "A" phase are driven to the "clear" state. Similarly, after the "B" phase or after four cycles of operation, the first two legs of each module in the "B" phase are driven to the "clear" state. Means for driving the various legs of a shift register in this manner are well known in the art. One means shown in FIG. 4 comprises a conductor (not shown) inductively coupled to all legs 114 except the terminal leg of the register. For clarity the inductive coupling is shown illustratively by winding 149_{1a} about leg 114₁ only. The conductor is connected to any con-

ventional pulse source (not shown) suitable for inducing through winding 149_{1a} a magnetomotive force in a sense to drive the flux in legs 114 to saturation in the counterclockwise direction or to the "clear" state as shown in FIG. 1. Similarly, a second conductor (not shown) is inductively coupled to legs 116 shown illustratively by winding 150_{1a} about leg 116₁ also connected to the same or other conventional pulse source (not shown) suitable for driving leg 116₁ to the "clear" state.

No effort has been made to exhaust the possible embodiments of this invention. It will be understood that the embodiments described are merely illustrative of the preferred form of the invention and various modifications may be made therein without departing from the scope and spirit of this invention.

What is claimed is:

1. An information transfer circuit comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to include first, second, third and fourth legs therein, means for applying to said ferrite sheet alternating first and second pulses for repeatedly switching between said first magnetic state and said second magnetic state the flux in said second leg, and means for alternately selecting simultaneously with said first and second pulses respectively a flux closure path through said fourth and third legs for the flux switched in said second leg.

2. An information transfer circuit comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to include first, second, third and fourth legs therein, first winding means coupled to said second leg, second winding means coupled to each of the four legs, means for applying alternating first and second pulses to said first winding means repeatedly to switch the flux in said second leg between said first and said second stable magnetic state and means connected to said second winding means for magnetically biasing preselected ones of said legs for selecting a flux closure path through said second and fourth legs during said first pulses and a flux closure path through said second and third legs during said second pulses.

3. An information transfer circuit comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to include first, second, third and fourth legs therein, first winding means coupled to said second leg, second winding means coupled to the first, third and fourth legs, third winding means coupled to each of the four legs, means for applying alternating first and second pulses to said first winding means repeatedly to switch the flux in said second leg between said first and said second stable magnetic state, means connected to said second winding means for magnetically biasing said first, third and fourth legs for selecting a flux closure path through said fourth leg for the flux switched in said second leg during said first pulses, and means connected to said third winding means for magnetically biasing preselected ones of said legs for selecting a flux closure path through said third leg for the flux switched in said second leg during said second pulses.

4. An information transfer circuit comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said ferrite sheet being apertured to form first and second spaced apart side rails interconnected by first, second, third and fourth transverse spaced apart legs thus defining a sequence of three apertures, said first side rail including a fourth aperture adjacent the second aperture of said sequence of three apertures defining a circular flux path thereabout, means for applying to said ferrite sheet first and second pulses for repeatedly switching between said first and said second stable magnetic state the flux in said second leg, means for alternately selecting simultaneously with said first and second pulses respectively a flux closure path through said fourth leg and through said third leg for the flux switched

in said second leg, and means for alternately switching simultaneously with said first and second pulses respectively the flux in said circular flux path between the circular path and a path in the direction of said fourth leg.

5. An information transfer circuit comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to form first and second spaced apart side rails interconnected by first, second, third and fourth transverse spaced apart legs thus defining a sequence of three apertures, said first rail including therein a fourth aperture adjacent the second of said sequence of three apertures defining a circular flux path thereabout, first winding means coupled to said second leg, second winding means coupled to each of the four legs, third winding means coupled to said first side rail at said fourth aperture, means for applying alternating first and second pulses to said first winding means repeatedly to switch the flux in said second leg between said first and said second stable magnetic state, means connected to said second winding means for magnetically biasing preselected ones of said legs for selecting a flux closure path through said second and fourth legs during said first pulses and a flux closure path through said second and third legs during said second pulses, and means connected to said third winding means for alternately switching simultaneously with said first and second pulses respectively the flux in said circular path between said circular flux path and a path in the direction of said fourth leg.

6. An information transfer circuit comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to form first and second spaced apart side rails interconnected by first, second, third and fourth transverse spaced apart legs thus defining a sequence of three apertures, said first side rail including therein a fourth aperture adjacent the second of said sequence of three apertures, first winding means coupled to said second legs, second winding means coupled to said first, third and fourth legs, third winding means coupled to each of the four legs, fourth winding means coupled to said first side rail at said fourth aperture, means for applying alternating first and second pulses to said first winding means repeatedly to switch the flux in said second leg between said first and said second stable magnetic state, means connected to said second winding means for magnetically biasing said first, third and fourth legs for selecting a flux closure path through said fourth leg for the flux switched in said second leg during said first pulse, means connected to said third winding means for magnetically biasing said four legs for selecting a flux closure path through said third leg for the flux switched in said second leg during said second pulse, and means connected to said fourth winding means for alternately switching simultaneously with said first and second pulses respectively the flux in said circular flux path between the circular path and a path in the direction of said fourth leg.

7. An information transfer circuit in accordance with claim 6 wherein said second winding means comprises an electrical conductor inductively coupled to said first and third legs in the same sense and to said fourth leg in the opposite sense, and said third winding means comprises an electrical conductor inductively coupled to said first, second, third and fourth legs serially in an alternating sense.

8. A shift register comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to form a plurality of sets of first, second, third and fourth legs, and means for incrementally driving the fourth leg of each of said plurality of sets of legs to a stable magnetic state, said means comprising first winding means coupled to the second of each of said sets of legs, second winding means coupled to each leg of each of said sets of legs, means for applying to said first winding means first and second pulses for repeatedly switching the flux in each second leg, and means for applying to said second winding means

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third and fourth pulses synchronous with said first and second pulses for magnetically biasing preselected ones of said legs for selecting alternately a flux closure path first through the fourth leg and second through the third leg of each of said sets of legs for the flux switched in the corresponding second leg during said first and second pulses respectively.

9. A shift register comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said ferrite sheet being apertured to form first and second side rails and a transverse sequence of interconnecting legs defining therebetween a first sequence of apertures, said first side rail including a second sequence of apertures one adjacent every second aperture of said first sequence of apertures and each defining thereabout a circular flux carrying path, each of said second apertures being defined by a first and second leg of said first sequence of legs, each successive four legs starting with each of said first legs constituting a set of legs, means for incrementally driving the flux in the fourth legs of each of said sets of four legs to a stable magnetic state, said means comprising means for applying first and second pulses to said ferrite sheet for repeatedly switching between said first stable magnetic state and said second the flux in each of said second legs, and means for alternately selecting simultaneously with said first and second pulses respectively a flux closure path through the fourth and third legs of said set of four legs for the flux switched in said second leg, input means for introducing information to the first leg of the first set of four legs, and utilization means for accepting information from said fourth leg of the terminal set of four legs.

10. A shift register comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to form a plurality of sets of first, second, third and fourth legs, and means for incrementally driving the fourth leg of each of said plurality of sets of legs to a stable magnetic state, said means comprising first winding means coupled to the second leg of each of said sets of legs, second winding means coupled to each first, third and fourth leg of each of said sets of legs, third winding means coupled to each leg of each of said plurality of sets of legs, means for applying to said first winding means first and second pulses for repeatedly switching the flux in each second leg, means for applying to said second winding means third pulses synchronously with said first pulse for magnetically biasing each first, third and fourth legs to preselect each fourth leg as the flux closure path for the flux switched in each second leg during said first pulses, and means for applying to said third winding means fourth pulses synchronously with said second pulses for magnetically biasing each first, second, third and fourth legs to preselect each third leg as the flux closure path for the flux switched in each second leg during said second pulses.

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11. A shift register comprising a ferrite sheet of a material capable of assuming a first and second stable magnetic state, said sheet being apertured to include first and second side rails interconnected by a plurality of operational sets of first, second, third and fourth legs forming therebetween a sequence of apertures divisible into sets of three apertures, said first side rail including an additional aperture adjacent every other aperture of said sequence of apertures, said shift register being operated in first and second phases, means for selecting alternately said first leg and said third leg as the initial legs of said operational sets of legs during said first and second phases respectively, first winding means coupled to each second leg of each set of legs in each phase, second winding means coupled to each first, third and fourth legs of each set of legs in each phase, third winding means coupled to each first, second, third and fourth legs of each set of legs in each phase, means for applying to said first winding means first and second pulses repeatedly to switch said second leg, means for applying third pulses to said second winding to magnetically bias said first, third and fourth legs for selecting said fourth legs as the flux closure path for the flux switched in said second legs during said first pulses, means for applying fourth pulses to said third winding to magnetically bias said first, second, third and fourth legs for selecting said third legs as the flux closure path for the flux switched in said second legs during said second pulses, means for applying fifth and sixth pulses to said first side rail at said additional aperture synchronously with said first and second pulse respectively for switching the flux in the circular flux path thereabout toward said fourth leg and back again, and means for alternating between said first and second phases.

12. A shift register in accordance with claim 11 including an input means connected to the first leg of the first operational set of legs in said first stage, and including a utilization circuit connected to the fourth leg of the last operational set of legs in said second phase.

13. A shift register in accordance with claim 12 including a fifth winding means coupled to said first side rail at said additional apertures, and means connected to said first fifth winding means for holding fixed in said circular path the flux at the additional apertures adjacent the fourth leg of each set of legs during said first phase and holding fixed in said circular path the flux at the additional apertures adjacent the fourth leg of each set of legs during said second phase to isolate magnetically the operational sets of legs of the current phase from the corresponding next preceding and next succeeding legs.

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