

June 8, 1965

H. N. WAGAR

3,188,612

SEQUENTIAL ARRANGEMENT

Filed May 17, 1962

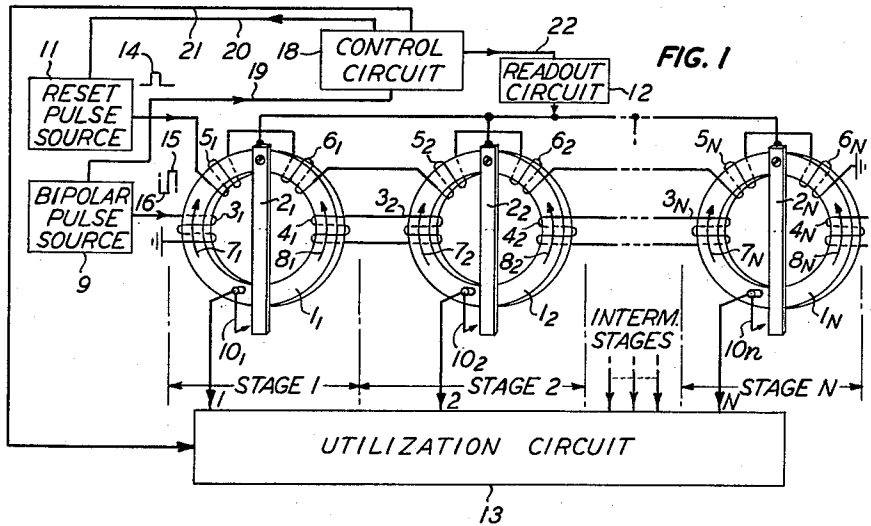
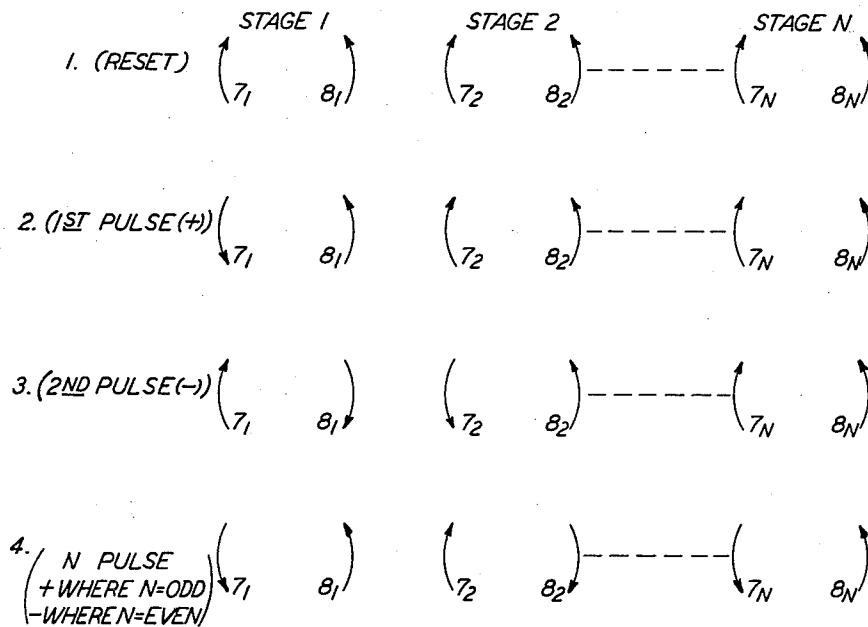


FIG. 2



INVENTOR
H. N. WAGAR
BY
Turner
ATTORNEY

3,188,612

SEQUENTIAL ARRANGEMENT

Harold N. Wagar, Madison, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed May 17, 1962, Ser. No. 195,640

14 Claims. (Cl. 340-174)

This invention relates to sequential arrangements, particularly to such arrangements having multiple stages and capable of counting successive pulses and more particularly to such arrangements which employ remanently magnetic elements for each stage thereof.

Hereinafter, the term remanently magnetic will refer to that type of magnetic material which exhibits a plurality of stable remanent magnetization states and has the properties of high coercivity and low permeability.

Sequential arrangements are useful as counters, shift registers and the like, and are used extensively in many different situations. In the past, high speed sequential operation has been attained by use of a remanently magnetic core type of arrangement. This type of arrangement generally comprises two remanently magnetic cores per stage, one for permanent storage and the other for temporary storage. In some cases a capacitor is employed as the temporary storage instead of a remanently magnetic core. In any case, the counting or shifting operation consists of remanently magnetizing the entire permanent core in one step, then reverse remanently magnetizing the entire permanent core to cause appropriate remanent magnetization of the entire temporary core in the next step. The third step shifts the information to the permanent core of the next stage. Advantageously, the entire counting or shifting operation could be accomplished with substantially high speed. However, as disadvantages, this type of arrangement requires a temporary storage element in each stage and also separate input and shifting circuitry.

Another type of sequential arrangement which eliminates or substantially reduces these two disadvantages is disclosed in copending application Serial No. 111,506 filed May 22, 1961 by C. A. Lovell. This type of arrangement comprises a pair of remanently magnetic side rails and a plurality of magnetizable switches bridging the side rails. By selectively remanently magnetizing sections of the side rails particular switches are caused to operate sequentially. Advantageously, readout is attained through the switches, enabling thereby high quality signal transmission. As a disadvantage to this type of arrangement, however, the counting pulses are transmitted through a previously operated stage switch to cause operation of a next adjacent switch. Hence, even though the speed of actuation may be substantially high, the total counting time is dependent upon the response time of an individual switch multiplied by the number of stages actuated and the counting pulses must be spaced apart a sufficient interval to account for the switch response time. Although this counting speed may be adequate in some instances, in other instances still higher counting speeds and closer spacing of the counting pulses may be desirable.

Accordingly, it is an object of my invention to provide an improved sequential arrangement.

Another object of my invention is to increase the counting speed of such an arrangement.

A further object of my invention is to reduce the number of storage elements per stage in such an arrangement.

Yet further objects of my invention are to reduce the actuating and shifting circuitry of such an arrangement, to simplify the operating modes thereof, to reduce the power requirement thereof, to increase the reliability and

economy of such an arrangement, and to increase their utility.

These and other objects of my invention are attained in an illustrative embodiment thereof which briefly comprises a plurality of remanently magnetic cores of toroidal shape, each having a magnetizable armature of soft magnetic material disposed across its diameter to define thereby half sections of each core. There is a continuous magnetic circuit around the core. The armature is physically and magnetically connected at one end thereof to the core and is movable at the other end thereof between the core and a contact provided on a post anchored to the core. However, the armature is insulated from the core to provide an airgap between the armature and core. Thus, the reluctance between the armature and core is higher than the reluctance between the half sections of the cores. Each of the half sections of each core has wound thereabout a reset winding and an actuation winding. The reset windings are interconnected in a series or parallel manner to a source of reset pulses. In accordance with the principles of my invention, one of the actuation windings of each core is connected to an actuation winding of the preceding core while the other actuation winding is connected similarly to a succeeding core winding. One actuation winding of the first core is connected to a pulse source which generates odd numbered pulses of positive polarity and even numbered pulses of negative polarity.

According to my invention, each of the cores forms one stage of a sequential arrangement. In a reset condition, all of the stages have their armatures attracted to their associated cores, apart from the contacts. The reset condition is effected by applying a positive reset pulse from the reset pulse source to the reset windings to establish opposing remanent magnetization states (from a series standpoint) in the two half sections of each core. This causes opposite remanent magnetic poles at core portions adjacent the armature. Consequently, magnetic flux is caused to flow through the armature and the airgap between the armature and the core to effect attraction of the armature to the core, disengaged from its associated contact.

Sequential operation is effected by applying the pulses to the actuation winding of the first stage core. Responsive to the first pulse, of positive polarity, the remanent magnetization of a half section of the first core is reversed. Thus, both half sections are similarly remanently magnetized (from a series standpoint) thereby causing magnetic flux to by-pass the armature. Consequently, the armature, under force of its natural stiffness, is released from the core and caused to engage with its associated contact after termination of the first pulse.

The second pulse, being of opposite (negative) polarity, completely reverses the remanent magnetizations of both half sections of the first core. This is made possible because both remanent states are opposite to the magnetizing force and because the reluctance between the half sections is lower than the reluctance between the core and the armature. The changes of remanent states of both half sections induce a signal in the other actuation winding of the first core. This signal is transmitted to the second core to cause change of the remanent magnetization of a half section thereof. Consequently, the remanent magnetizations of both half sections of the second core are in similar states, and magnetic flux is caused to by-pass the armature. Accordingly, the armature, under force of its natural stiffness, is caused to engage with its associated contact after termination of the second pulse.

After the armature is engaged, succeeding pulses do not affect its engaged condition because each successive pulse either does not affect the remanent states of the

core sections (same polarity pulse) or completely reverses the entire core (opposite polarity pulse) so fast that the armature is retained in its engaged condition. Since the flux path around the two half sections of a core is of lower reluctance than that between the core and armature the remanent magnetization of both half sections can be reversed without substantial flux diversion through the armature. Similarly, the third and succeeding alternately bipolar pulses effect operation of the third and corresponding stages, and the associated engaged armatures remain in the engaged condition, unaffected by subsequent pulses.

The counting operation does not depend upon the state of any of the switches of the preceding stages. Accordingly, in this manner, the entire train of actuation pulses can be terminated before response of the preceding and the corresponding stage switches.

A feature of my invention is a sequential arrangement wherein I provide at least a pair of remanently magnetic cores, each definable in at least two sections, first means for oppositely remanently magnetizing the sections of each core, second means for reversing the remanent state of only one section of the first core, and third means for changing that reversed remanent state and the remanent state of the other section of the first core to cause reversal of the remanent magnetization of only one section of the second core.

A further feature of my invention is such an arrangement wherein the third means comprises a first winding on one section of each core and circuit means interconnecting these windings, and wherein the second means comprises a second winding about the other section of the first core.

A still further feature of my invention is such an arrangement wherein I further provide read out means for determining the remanent states of the two cores, which means comprises a soft magnetic armature connected to, but insulated from, each core and magnetically coupled to the two sections thereof. When opposite remanent states are present on the two sections of a core, its associated armature will be attracted thereto. When the remanent state of only one section of a core is changed from the opposite remanent states, the armature is released from the core.

A complete understanding of these and other objects, advantages, and features of my invention may be gained from a consideration of the following detailed description and drawing, in which:

FIG. 1 depicts an illustrative embodiment of my invention; and

FIG. 2 depicts with representative arrows the remanent magnetization states of the cores of the embodiment of FIG. 1 during various states of operation.

Turning now to the drawing, in FIG. 1 I show a plurality of stages 1 . . . N, each having associated therewith a toroidal shaped remanently magnetic core 1. Diametrically disposed across each core 1 is a magnetizable soft magnetic armature 2. The armature 2 is insulated from the core 1 (e.g., by a thin plastic film between the armature and the core) and attached thereto at the top end and free therefrom at the bottom end in the manner shown. In this manner a high reluctance path is provided between the core and the armature. The armature is closely magnetically coupled at both ends to the core. The free end of the armature 2 is similarly insulated from the core 1 (e.g., by a plastic film) and is movable between contact 10 and core 1. Contact 10 is positioned on a post which is anchored in core 1. The top end of the armature 2 is connected to a read out circuit 12, and the contact 10 is connected to a utilization circuit 13. Accordingly, when armature 2 is engaged with contact 10 an electrical connection is made between the read out circuit 12 and the utilization circuit 13. Both the read out and utilization circuits can be of any type known in the art. For example, the read out circuit can comprise a source of current and the utilization circuit

can comprise a temporary register and connecting network.

The cores 1 are definable in two half sections, each half of which is independently remanently magnetizable. The reluctance between the two half sections is relatively lower than the reluctance between the core and the armature. The significance of these comparative reluctances will be made known in the below discussion of the operation of this embodiment. The remanent magnetizations of the sections are represented by arrows 7 and 8. Two windings having appropriate numbers of turns, are inductively coupled to each half section of each core: actuation or control windings 3 and 4 and reset windings 5 and 6. The reset windings 5 and 6 are interconnected between reset pulse source 11 and ground. Winding 4 of each core is connected to winding 3 of the next succeeding core. For example, winding 4_1 of core 1 is connected to winding 3_2 of core 2. Winding 3_1 of core 1, which may be called an input winding, however, is grounded at one terminal thereof and is connected at the other terminal thereof to a source 9 of alternately bipolar pulses. Although winding 4_N for core N is not shown connected, within the broad aspects of my invention such a winding can be employed to perform various functions such as to enable the control circuit 18 to actuate reset pulse source 11 and cause thereby re-entrant operation of the counter arrangement. The bipolar pulse source 9 can be of any type which generates odd numbered pulses of positive polarity and even numbered pulses of negative polarity. For example, source 9 can comprise positive and negative polarity batteries connectable through a manually operable switch to winding 3_1 . It would also be apparent that source 11 can be a positive battery connectable through a manually operable switch to winding 5_1 .

In one particular embodiment of my invention, I employ four stages each having a circular core. Each of the cores and associated armatures has the following dimensions: outer diameter, 0.25 inch; inner diameter, 0.15 inch; thickness of core, 0.009 inch; width of armature, 0.050 inch; thickness of armature, 0.016 inch. The armature is made of an iron-nickel alloy having a hysteresis loop with maximum permeability occurring at a magnetizing force of about 0.3 oersted and at a magnetic induction of about 20,000 gauss. The material employed in the cores comprises an iron-manganese-cobalt-vanadium alloy having a substantially rectangular hysteresis loop with a coercive force of about 35 oersteds and a residual induction of about 18,000 gauss. The number of turns is governed by the constant N^2/R set at 1000. This constant is a well known concept employed in winding calculations of magnetic structures and is the ratio of the $(NI)^2$ or ampere turns squared to I^2R or power. (N =number of turns, R =resistance of the winding, and I =value of current applied to the winding.) In this particular embodiment, I find that the switching (i.e., changing the magnetic remanence) of one half section can be done by a magnetizing force or, as commonly known, NI or 42 ampere turns, and that switching of both half sections can be done by a magnetizing force or NI of 89 ampere turns.

Returning to FIG. 1, I also depict a control circuit 18 connected to reset pulse source 11, utilization circuit 13, and read out circuit 12 by means of conductors 20, 21, and 22, respectively. The bipolar pulse source 9 is connected to the control circuit 18 by conductor 19. The control circuit can be of any known type and functions in a known manner to control the reset and read out operation of my invention. Its operation will be explained in greater detail below.

Operation of my illustrative embodiment depicted in FIG. 1 can best be understood by also referring to FIG. 2 which illustrates with representative arrows 7 and 8 the remanent magnetization states of the half sections of each core during various steps of operation. When the remanent magnetizations of both half sections of a

core are opposite to each other as viewed from a series standpoint, such as shown for all the stages in line 1 of FIG. 2, opposite magnetic poles will be induced at the top and bottom parts of the cores to which is coupled the armature 2. Thus, magnetic flux is caused to flow through the armature and its air gap and the armature is attracted thereby to the core. On the other hand, when the remanent magnetization of one half section is similar in direction to that of the other half section of a core, such as shown for core 1₁ of stage 1 in line 2 of FIG. 2, magnetic flux is caused to by-pass the armature 2. The armature 2 thereupon releases from the core 1 by its own natural spring action and makes contact with its associated contact 10. Each of the armatures can be mechanically biased to aid this releasing action.

Before the counter arrangement can count pulses, it must be in a reset condition; i.e., with all of the armatures attracted to the cores. Line 1 of FIG. 2 shows the remanent magnetization states of the half core sections of the depicted stages 1-N during the reset condition. These remanent states are established by reset pulse source 11 applying a pulse of appropriate magnitude and polarity, e.g., positive pulse 14, to the interconnected reset windings 5 and 6. Magnetic fluxes are caused to flow through the respective armatures 2, in the manner described, thereby to cause attraction of the armatures 2 to their associated cores 1. Initially, the control circuit 18, by means of a signal applied via conductor 20 can enable actuation of reset pulse source 11, thereby to cause application of a reset pulse to the reset windings. The counter arrangement is now prepared to receive and count pulses.

Assume that two pulses, e.g., pulses 15 and 16, are to be counted. The bipolar pulse source 9 applies the first pulse 15, which is of positive polarity and appropriate magnitude, to winding 3₁. This causes the remanent magnetization of the left half section to be altered to that as shown in line 2 of FIG. 2 by arrow 7₁. Consequently, magnetic flux is caused to by-pass the armature 2₁ of stage 1, in the manner described, and armature 2₁ is caused to release and engage with contact 10₁. The remaining cores of the remaining stages are unaffected by the first pulse 15.

The second pulse 16 is of negative polarity and also of appropriate magnitude. Thus, when applied by bipolar pulse source 9 to winding 3₁, it causes change of the remanent magnetizations of both half sections of core 1₁ as shown in line 3 of FIG. 2, by arrows 7₁ and 8₁. This particular changing of remanent states is made possible because the remanent magnetization in both cores is opposite the magnetizing force and because the reluctance between the continuous two half sections of the cores is lower than the reluctance between the cores and armatures. It is comparatively easier to drive flux from the left half section through the right half section than to drive flux from the left half section through the armature. A signal is induced in winding 4₁ of core 1₁ and is transmitted to winding 3₂ of core 1₂. This signal in turn alters the remanent magnetization of the left half section of core 1₂ of stage 2 to that as shown by arrow 7₂ in line 3 of FIG. 2. Thus, in the manner described, magnetic flux is caused to by-pass the armature 2₂, effecting its release and engagement with contact 10₂. Armature 2₁, which is engaged with contact 10₁, is not affected by the second pulse 16. In a similar manner, pulse N of appropriate polarity will cause alteration of the remanent magnetizations of whole cores of preceding stages and of the left half core section of the stage corresponding to the number of pulses in the series. Any number of stages can be employed and actuated by even pulses of negative polarity and odd pulses of positive polarity. Advantageously, in my arrangement the counting cycle or operation is independent of the position of the armatures; to put it another way, an entire train of pulses can

be terminated before response of any or all of the armatures.

The magnitudes of the input pulses, e.g., 15 and 16, must be sufficient to cause switching of a corresponding half section as well as the two half sections of all preceding cores. For example, in the above discussion of FIG. 1, the second pulse 16 must be of sufficient magnitude or energy to switch both half sections of core 1₁ and one half section of core 1₂. Furthermore, the magnitudes of the pulses must be sufficient to overcome resistive losses in the windings. In most cases, these losses are not substantial.

After termination of the series of pulses 15 and 16, the control circuit 18 detects, through conductor 19, a pause between that series of pulses and the next series of pulses to follow. In response to the pause between the two series of pulses, the control circuit 18 applies a signal through conductor 22 to enable actuation of read out circuit 12. Accordingly, a read out signal will pass from the read out circuit 12 through armatures 2₁ and 2₂, contacts 10₁ and 10₂, of stages 1 and 2, respectively, and to the utilization circuit 13, thereby indicating to the utilization circuit that two pulses were contained in the counted series of pulses. Concurrently with this read out of information, control circuit 18 applies a signal through conductor 20 to reset pulse source 11 to cause reset of the counter in the manner described in preparation for the next following series of pulses. By means of a signal from the control circuit 18 via conductor 21, the utilization circuit 13 is also informed of the termination of the counted series of pulses in order that the sensed information can be shifted.

Although I have shown the use of an armature on each core for the purposes of read out, within the broad aspects of my invention, other methods can be employed to read out the counted or shifted information. For example, another winding might be provided on each core and pulsed to determine the remanent magnetization states of the entire core of each stage. As further examples, a contact engageable when the armature is attracted to the core can be used separately or in addition to the contact 10 depicted in the illustrative embodiment; to put it another way, the armature-contacts can be arranged to perform "make" or "break" or "transfer" functions. In such cases, the utilization circuit 13 would recognize, if connected to such a contact, absence of a signal through the armatures of the actuated stages. Moreover, a winding could be used to recognize existence or absence of magnetic flux through armature 10 and thereby effect read out of the counted or shifted information.

It is to be understood that the above-described arrangement is illustrative of the principles of my invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of my invention.

What is claimed is:

1. A sequential arrangement for shifting stored information exclusive of shift pulse circuitry comprising at least a first and a second remanently magnetic core, magnetic means dividing said core into two separately magnetizable sections, reset means coupled to each of said sections for oppositely remanently magnetizing said two sections of each core through said magnetic means, a pulse source, input winding means coupled to one section of said first core and effective upon the receipt of a first pulse from said source for altering in a first step the remanent magnetization of only said one section of said first core and effective upon the receipt of a subsequent pulse from said source for altering in a second step the remanent magnetizations of both sections of said first core exclusive of said magnetic means, and coupling means exclusively responsive to alterations in the remanent magnetizations of said first core in response to said pulses on said input winding for altering the remanent magnetization of only one section of said second core.

2. The invention defined in claim 1 wherein said pulse source comprises a source of alternate polarity pulses and means connecting said input winding means to said source, wherein said reset means comprises means for magnetizing said one section in a first direction, wherein said input winding means is effective upon receipt of a first pulse of a first polarity for magnetizing only said one section of said first core in a second direction, and effective upon the receipt of a subsequent pulse for changing the direction of magnetization of both of said first core sections, wherein said arrangement further comprises read out means associated with each said core for ascertaining the magnetic state of the sections thereof, and wherein said coupling means comprises a second winding on the other section of said first core, a third winding on said one section of said second core, and means interconnecting said second and third windings.

3. A sequential arrangement comprising at least a first and a second toroidal-shaped and closed magnetic core structure, each definable in half sections thereof, means for oppositely remanently magnetizing said half sections of each core, a source of alternate polarity pulses, a first winding being on one half section of said first core and effective for altering in a first step the remanent magnetization of only said one half section of said first core and for altering in a second step the remanent magnetizations of both first core half sections, second means under the control of alterations in the remanent magnetizations of both first core half sections for altering the remanent magnetization of only one half section of said second core, said second means including a second winding on the other half section of said first core interconnected with a third winding on one half section of said second core, and read out means including a plurality of magnetizable armatures, each operatively associated with a respective core and magnetically coupled to both half sections thereof whereby responsive to said opposite remanent magnetizations of both half sections of a core its associated armature will be attracted thereto and whereby responsive to said altered remanent magnetization of only one half section of a core its associated armature will be released therefrom.

4. A sequential arrangement for shifting stored information exclusive of shift pulse circuitry comprising a pair of remanently magnetic switching devices, each including at least two independently remanently magnetizable elements and magnetic means coupling said elements, means coupled to each said element for initially oppositely remanently magnetizing through said magnetic means said two elements of each device to cause operation thereof, a pulse source, input winding means on only one element of one of said devices effective upon receipt of a first pulse from said source for reverse remanently magnetizing only one element of said one device thereby to cause release thereof and effective upon the receipt of a subsequent pulse for changing the remanent magnetization of the two elements of said one device while maintaining said one device released, second means including magnetic intercoupling means between said devices and exclusively responsive to said change of remanent magnetization of said two elements of said one device in response to said pulses for reverse remanently magnetizing only one element of the other device, and third means governed by said magnetic means for ascertaining the operated and released condition of said devices.

5. The invention defined in claim 4 wherein said second means comprises a transfer winding on at least one element of each device and circuit means interconnecting said transfer windings and wherein said third means comprises read out means coupled to each said device and operated when the two elements thereof are oppositely magnetized and released upon the initial change of magnetic state of one of said elements as indicated by said magnetic means.

6. The invention defined in claim 5 wherein said two

elements of each device are magnetically intercoupled to form a continuous magnetic circuit and said magnetic means comprises means for shunting said magnetic circuit and wherein said pulse source comprises a source of alternate polarity pulses and means connecting said source to said input winding.

7. A sequential arrangement for shifting stored information exclusive of shift pulse circuitry comprising an array of remanently magnetic to cores, magnetic means dividing said cores into at least a first and a second section, reset means for oppositely remanently magnetizing said first and second sections of each core through said magnetic means, a signal source, input winding means coupled to the first section of a first one of said cores effective upon the receipt of a first signal from said source for changing the remanent magnetization of only said first core first section and effective upon the receipt of a subsequent signal from said source for altering the remanent magnetization of both sections of said first core independently of said magnetic means, means for inductively coupling the first and second sections of adjacent pairs of said cores and exclusively responsive to changes of the remanent magnetizations of both sections of said first core in response to said signals for sequentially altering the remanent magnetization of only one section in each different successive core, and means controlled by said magnetic means for ascertaining the state of magnetization of each said core.

8. The invention defined in claim 7 wherein said sequentially altering means comprises means inductively coupling said sections of one core to particular sections of adjacent cores whereby through said coupling one section of each successive core is altered in remanent magnetization in response to altering of the remanent magnetizations of two sections of a next preceding core.

9. The invention defined in claim 8 wherein said inductive coupling means includes a winding on each section of each core and means interconnecting the winding on the second section of one core to the winding on the first section of the next adjacent succeeding core.

10. A sequential arrangement comprising an array of remanently magnetic cores, each definable in at least two sections, means for oppositely remanently magnetizing said two sections of each core, inductive coupling means including a winding on each section of each core and means interconnecting the winding of one section of one core to the winding of one section of the next adjacent succeeding core, said inductive coupling means effective to alter the remanent magnetizations of one section of each successive core in response to the altering of the remanent magnetization of two sections of the next preceding core, a plurality of magnetizable armatures, each magnetically coupled to said two sections of each core, and contact means, said armatures being movable between said cores and said contact means whereby responsive to said opposite remanent magnetizations of said two sections of said cores their associated armatures will be attracted thereto and disengaged from said contact means and whereby responsive to said successive alteration of the remanent magnetization of only one section of each different successive core their associated armatures will be successively released therefrom and engaged with said contact means.

11. A sequential arrangement for shifting stored information independently of shift pulse circuitry comprising a first and a second closed ring shaped core of remanently magnetic material, magnetic means dividing each said core into two separately magnetizable sections; reset means for initially establishing in opposite states the remanent magnetizations of said two sections of each core, through said magnetic means said reset means comprising a reset winding on each section of each core, a reset pulse source, and means for interconnecting said reset windings to said reset pulse source; a control winding inductively coupled to each section of each core; a

source of alternate polarity input pulses; circuit means for connecting said input pulse source to a control winding on one section of said first core whereby responsive to a first input pulse from said source the remanent magnetization state of said one section of said first core is altered and whereby responsive to a second input pulse from said source the remanent magnetization states of both sections of said first core are altered independently of said magnetic means; and circuit means for interconnecting the control winding on the other section of said first core to a control winding on one section of said second core whereby altering of the remanent magnetization states of both sections of said first core under exclusive control of said control winding connected to said input pulses causes altering of the remanent magnetization state of only one section of said second core.

12. A sequential arrangement comprising a first and a second closed ring shaped core of remanently magnetic material, each of said cores being definable in two sections; reset means for initially establishing in opposite states the remanent magnetizations of said two sections of each core, said reset means comprising a reset winding on each section of each core, a reset pulse source, and means for interconnecting said reset windings to said reset pulse source; a control winding inductively coupled to each section of each core; a source of alternate polarity input pulses; circuit means for connecting said input pulse source to a control winding on one section of said first core whereby responsive to a first input pulse from said source the remanent magnetization state of said one section of said first core is altered and whereby responsive to a second input pulse from said source the remanent magnetization states of both sections of said first core are altered; circuit means for interconnecting the control winding on the other section of said first core to a control winding on one section of said second core whereby altering of the remanent magnetization states of both sections of said first core causes altering of the remanent magnetization state of only one section of said second core a magnetizable and electrically conductive armature disposed diametrically across each core and magnetically coupled to the two sections thereof and a contact associated with each core, said armatures being movable between their associated cores and their associated contacts whereby responsive to said opposite remanent magnetization states of said two sections of each core their associated armatures will be attracted thereto thereby to break contact from their associated contacts and whereby responsive to said altering of the remanent magnetization state of only one section of each core their associated armatures will be released therefrom thereby to make contact with their associated contacts.

13. In a sequential arrangement having the characteristics of metallic contact read out and operable by a series of short duration electronic pulses, the combination comprising a series of remanently magnetic devices,

each of said devices including a pair of magnetically interconnected remanently magnetic elements and a movable soft magnetic armature magnetically coupled commonly to said elements, means for oppositely remanently magnetizing both elements of each device to cause operation of said armatures thereof, and means for causing sequential releases of the armatures of said devices in response to corresponding successive pulses after termination of the corresponding pulses, said last-mentioned means comprising inductive coupling means between the elements of adjacent pairs of devices whereby the series of pulses will cause changes of the remanent magnetizations of only one element of corresponding devices by changes of the remanent magnetizations of both elements of all preceding devices causing energy to be transferred from said preceding devices through said intercoupling means to said corresponding devices.

14. In a sequential arrangement having a plurality of stages each operable by a corresponding one of a series of pulses, the combination comprising a pair of magnetically intercoupled remanently magnetic elements in each stage; means for oppositely remanently magnetizing both elements of each stage to cause operation thereof; a source of said pulses; a first winding on one element of a first one of said stages; means connecting said first winding to said source, said first winding responsive to a first pulse for reversing the remanent magnetization of only said one element of said first stage and responsive to subsequent pulses for changing the remanent magnetization of both first stage elements; means for magnetically intercoupling the elements of adjacent stages, said intercoupling means comprising a second winding on the other element of said first stage, a winding on each of the elements of each remaining stage, means interconnecting said second winding on the second stage, and means interconnecting the remaining windings of next adjacent stages whereby the remanent magnetization of only one element of a particular stage corresponding to a particular pulse is reversed by changes of the remanent magnetizations of both elements of the first and other preceding stages; and read out means including a magnetizable member in each stage, said member being movably associated with and magnetically coupled to said pair of elements of a corresponding stage whereby responsive to said opposite remanent magnetizations of both elements of said stages said members will be moved to a first position and responsive to reversal of the remanent magnetization of only one element of a stage its associate member will be moved to a second position.

References Cited by the Examiner

UNITED STATES PATENTS

2,963,687 12/60 Briggs.
2,995,637 8/61 Feiner et al.

IRVING L. SRAGOW, *Primary Examiner*.