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3,211,962

CONTACT CONTROLLABLE SWITCHING ARRANGEMENT

Filed May 22, 1961

2 Sheets-Sheet 1

FIG. 1

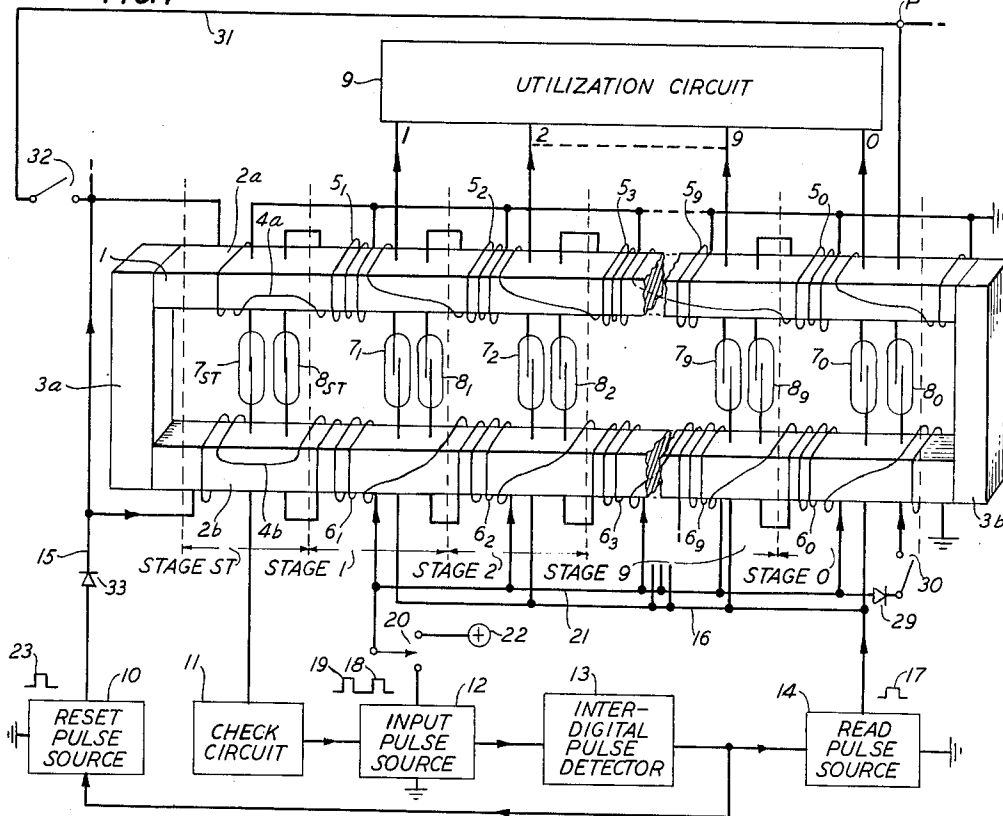


FIG. 2A

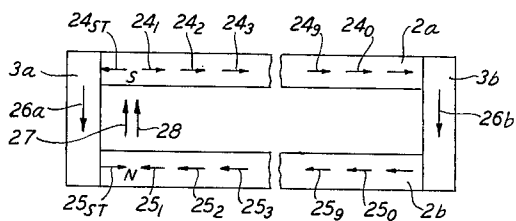


FIG. 2B

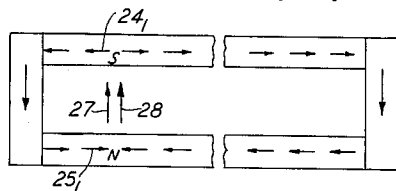
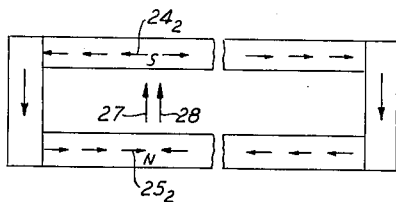


FIG. 2C



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FIG. 3

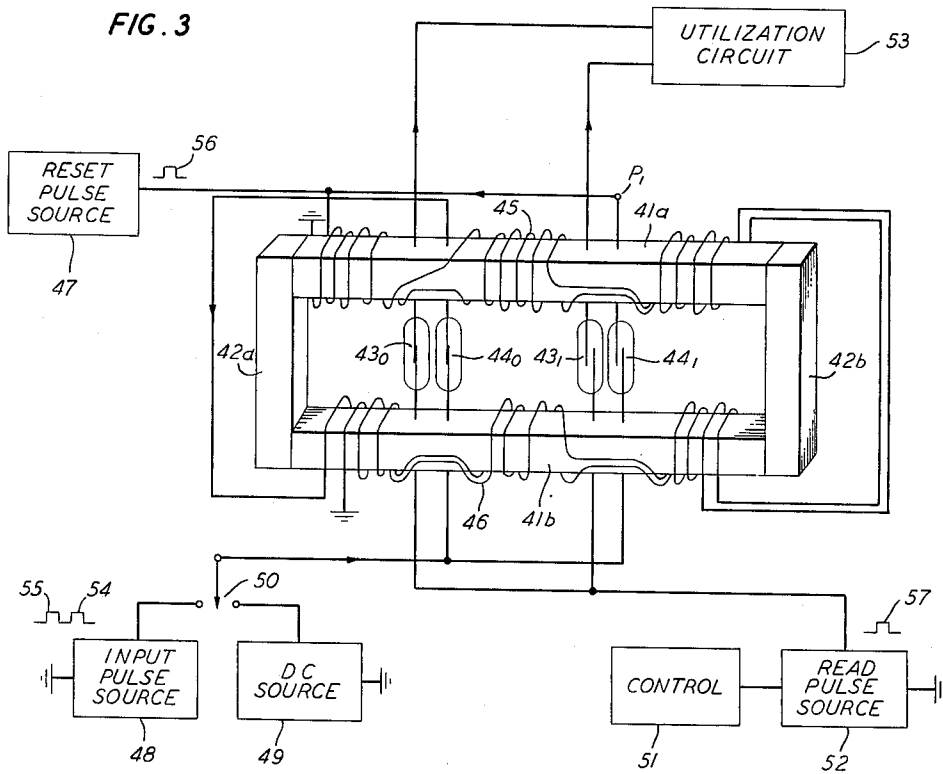


FIG. 4A

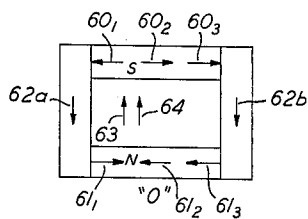
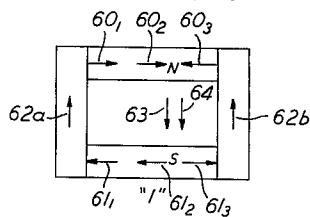


FIG. 4B



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3,211,962 CONTACT CONTROLLABLE SWITCHING ARRANGEMENT

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13 Claims. (Cl. 317-137)

This invention relates generally to contact controllable switching arrangements and more particularly to such arrangements utilizing remanently magnetic elements and metallic contacts and specifically to such arrangements wherein their subsequent operations are determined by the conditions of their previously operated contacts.

Contact controllable switching arrangements have general use in many areas; for example, in telephone switching systems they may take such forms as counters, registers, binary cells and interconnecting circuits. In these arrangements particularly sets of switches are successively operated by signals traveling through contacts of previously operated switches of preceding stages.

Ordinary electromechanical relays have been priorly combined to make such switching arrangements and have been extensively used in ordinary switching systems. However, with the advent of modern electronic switching systems the use of such ordinary relay switching arrangements has become limited or undesirable by the presence of such factors as slow contact response time requiring long duration actuation signals in the order of milliseconds, heavy power requirements, need for a means to hold the relays in operated states, requiring continuous holding power or complicated latching arrangements and structural and circuitual complexity. Modern electronic switching systems are characterized by such advantageous features as fast switching times of the order of microseconds, simplicity of circuitry, good transmission characteristics, and economical use of electrical power. Thus, if ordinary relay switching arrangements are utilized in modern electronic switching systems, these advantages will not be fully realized. Yet, it has been found that the direct metallic contact characteristics of ordinary relays advantageously permit undistorted transmission of signals with large volume ranges and with little noise interference. Thus, in spite of the presence of such disadvantageous factors as listed above, ordinary relays continue to be extensively used in modern electronic switching systems requiring high quality transmission of signals covering large volume ranges.

The problem then is to find a contact controllable switching arrangement which will enable full realization of the advantages and potential of modern electronic switching systems, yet retain the advantageous characteristics of metallic contact of ordinary relays.

As a solution to this problem, priorly, remanent magnetic cores have been combined to perform switching functions for use in both ordinary and modern electronic switching systems. Although the magnetic core arrangements are oftentimes complex in structure and operation, thereby hindering optimum realization of the advantages of modern electronic switching systems, they are in many respects compatible with such systems being responsive to microsecond actuation signals, being conservative in use of electrical power and requiring no holding power and therefore provide a partial solution to the problem. However, such magnetic core switching arrangements do not have the above-mentioned characteristics of direct operation of metallic contacts as in the ordinary relay. Thus, where high quality transmission of large volume range signals is a prominent requirement of a modern electronic switching system, remanent magnetic core

switching arrangements do not provide a satisfactory solution to the problem and therefore have not been priorly utilized to such a great extent as the ordinary relay switching arrangement.

If the above-mentioned advantageous characteristics of direct metallic contact operation, relatively short duration actuation and no holding power are integrated into a contact controllable switching arrangement of a simple design and operation, the problem will be solved and such an arrangement will be compatible with and will greatly enhance modern electronic switching systems.

Accordingly, it is a general object of this invention to improve the prior art by eliminating the aforementioned disadvantageous features and by combining the aforementioned advantageous features of high speed actuation and metallic contact operation into a contact controllable switching arrangement.

It is a more particular object of this invention to enable high speed actuation and high quality transmission of high volume range signals without requiring continuous holding power by a contact controllable switching arrangement.

It is a more specific object of this invention to utilize the difference in response times of magnetic cores and metallic contacts to enable sequential operation by a contact controllable switching arrangement.

It is a further object of this invention to increase the utility, economy, simplicity, and reliability of such contact controllable switching arrangements.

These and other objects of this invention are attained in a specific illustrative embodiment thereof to be herewith briefly described in general terms. The features of this invention enabling the attainment of these objects will be enumerated following this brief description. The specific embodiment comprises a plurality of switching stages sharing a common magnetic structure having two side rails of a remanent magnetic material interconnected by two end members, preferably of nonremanent magnetic material providing a flux path between the respective ends of the side rails. Each, except the first, of the stages includes opposite parts and adjacent portions of the side rails, a reed switch of the type disclosed in W. B. Ellwood Patent 2,289,830, July 14, 1942, bridging and magnetically coupling the opposite parts, and a set and a reset winding inductively coupling these opposite portions. The first or reset stage is similar to the remaining stages but does not have any set windings. The opposite side rail portions of each stage are situated between the switches of that stage and the preceding stage. The set windings of each stage are wound about these portions and connected to the switch of the respective preceding stage. Thus, in accordance with the principles of this invention, when the reed switch of a particular stage is operated, an electrical path is provided for energization of the set windings of the next adjacent stage. The consequently energized set windings of the next adjacent stage determine the magnetization of the side rail portions thereof.

The material utilized in the side rails exhibits a plurality of stable remanent magnetization states and has the properties of high coercive force and low permeability. Thus, the remanent magnetization states of the side rail portions of various stages can be established and altered independently of each other. In accordance with the principles of this invention, the remanent magnetization states of particular side rail portions are independently changed to effect operation of the switches. When opposite remanent magnetization states are established at the adjacent side rail portions, separated by a side rail part, an independent magnetic pole is established therebetween at the part, thereby to induce a corresponding

magnetic pole on a reed of a switch magnetically coupled to the side rail part. If independent magnetic poles of opposite polarity are induced on both reeds of the switch, magnetic flux flows through the reeds and the reeds mutually attract to cause closure thereof. On the other hand, if the magnetic poles are of similar polarity, then no substantial amount of flux flows through the reeds and the switch opens due to the tension in the reeds tending to force them apart. When similar remanent magnetization states are established at the adjacent side rail portions, no independent magnetic pole is established therebetween at the side rail part. Thus, no magnetic poles are induced on the respective reeds and the switch remains open.

In a normal condition the reset stage is operated and the remaining stages are released. This normal condition is, in accordance with the principles of this invention, attained by a pulse applied to the reset windings establishing predetermined remanent magnetization states in all side rail portions such as to establish opposite independent magnetic poles at the side rail parts associated with the reset stage to thereby induce corresponding magnetic poles on the respective reeds of the reset stage switch. This causes magnetic flux to flow through the reeds and the reset switch to consequently operate. The switches of the remaining stages do not have any substantial magnetic poles on their respective reeds and the reeds remain open.

In this normal or reset condition, a series of input pulses is applied simultaneously to the set windings of all the stages. However, only that set winding having an electrical operating path to ground is energized. Thus, with only the reset stage operated in the reset condition, the first pulse is selectively steered through the reed switch of the reset stage to energize the set windings of the next adjacent second stage. The energized second stage set winding generates a magnetic field which reverses the remanent magnetization states of the side rail portions associated with the second stage. As a result, opposite magnetic poles are established at the side rail parts of the second stage and corresponding magnetic poles are induced on the respective reeds of the second stage switch and the magnetic poles formerly present at the side rail parts of the reset stage are destroyed. The flux loop formerly closed through the reset stage switch is opened and caused to close through the switch of the second stage, thereby closing the second stage switch and opening the reset stage switch through which the input pulse has just traveled. This action is possible because, advantageously, the input pulse switches the remanent magnetization of the side rail portions within the order of a few microseconds and the resultant remanent magnetization causes the release of the reset stage switch and the operation of the second stage switch in their normal response time of the order of one millisecond. Thus, the inherent time delay between the actuation or energization and the response of the reed switches enables the previously operated reset stage switch to steer the first pulse to the set winding of the second stage causing operation of the second stage switch before the concurrent release of the reset stage switch.

The second and successive input pulses, in accordance with the principles of this invention, are similarly selectively steered by the operated second and successive other previously operated switches of respective preceding stages to the set windings of the next adjacent third and successive other stages to cause reversal of the remanent magnetization states of the side rail portions thereof and thereby operate the successive stages and concurrently release the previously operated stages. Accordingly, a particular number of input pulses will stepwisely operate a number of switches and hold operated a particular switch corresponding thereto. For example, a series of three pulses will, by the step-by-step action hereinabove

disclosed, operate and hold operated the fourth stage switch.

In one aspect of this invention each stage has associated therewith a pair of reed switches, one utilized for control purposes, as hereinabove discussed, and the other utilized for sensing or interconnection purposes. In accordance with the principles of this invention, at the termination of a number of input pulses the corresponding operated stage is sensed by a read pulse applied simultaneously to all of the stages. Thus, in the example cited, the operated fourth stage enables the read pulse to be transmitted to a particular part of a utilization circuit. This read pulse is simultaneously applied to the reset windings and, because of the inherent time delay discussed above, the operated fourth stage switch is sensed concurrently with the operation of the reset stage switch and the release of the operated fourth stage switch.

In another aspect of this invention, two stages of this switching arrangement are utilized as a binary cell, the stages representing the binary states. The first or the binary "1" stage switch is connected to the set windings of the second or binary "0" stage and the second stage switch is connected to the set windings of the first stage. Thus, depending upon which of the two switches is operated, an actuating pulse is steered through the set windings of the other stage to thereby operate the other switch.

A general feature of this invention is a contact controllable switching arrangement in which a plurality of magnetically responsive switches are magnetically coupled to a remanent magnetic member having set windings thereon connected to predetermined ones of the switches for operating the switches under the control of previously operated ones of the switches.

Another feature of this invention is such a contact controllable switching arrangement in which a reset winding is wound on the member and an energizing means is provided for energizing the reset winding to selectively establish a remanent magnetization state in the member to operate a first of the switches.

A further feature of this invention is such a contact controllable switching arrangement in which an input means is provided for energizing the set winding through operated ones of the switches for selectively altering the remanent magnetization state in the member to operate the others of the switches.

A further feature of this invention is such a contact controllable switching arrangement in which a means is provided interconnecting the switches such that a re-entrant type of counter is formed.

A feature of one aspect of this invention is the provision of a plurality of pairs of magnetically responsive switches in such contact controllable switching arrangements.

A feature of another aspect of this invention is a binary cell comprising two switches of such contact controllable switching arrangements interconnected by a means such that successive control pulses alternately operate the two switches.

A still further feature of this invention is a contact controllable switching arrangement in which a plurality of magnetically responsive switches are magnetically coupled to a pair of side rails of remanent magnetic material interconnected by end members with the switches providing paths for a plurality of magnetic flux loops and in which reset windings are inductively coupled to the side rails and in which energizing means is provided to energize the reset windings to determine the remanent magnetization states of side rail portions thereunder to close a first of the magnetic flux through a first of the switches thereby operating the first switch and in which set windings are inductively coupled to the side rails under the control of predetermined ones of the switches and in which input means are provided to energize the set windings to alter the remanent magnetization states of side rail portions thereunder to individually complete the plurality of

magnetic flux loops through individual ones of the switches thereby operating the switches.

A yet further feature of this invention is a contact controllable switching arrangement in which a plurality of magnetically responsive switches are magnetically coupled to different parts of a pair of side rails of remanent magnetic material interconnected by end members and in which the side rails have windings wound thereabout adjacent the different parts under the control of the switches and in which means is provided under the control of operated ones of the switches for energizing the windings to selectively establish appropriate remanent magnetic poles at the different side rail parts to cause closure of the plurality of switches in a predetermined order.

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

FIG. 1 is a schematic representation of one illustrative embodiment of this invention;

FIGS. 2A, 2B, and 2C are pictorial representations of the states of remanent magnetization of the various portions of the side rails and the flux flow through the operated switch during different steps of operation;

FIG. 3 is a schematic representation of one aspect of this invention showing a binary cell; and

FIGS. 4A and 4B are pictorial representations of the states of remanent magnetization of the various portions of the side rails and the flux flow through the switches in the binary states.

Referring now to the drawing, in FIG. 1 there is depicted in block diagram form a reset pulse source 10, a check circuit 11, an input pulse source 12, an interdigital pulse detector 13, a read pulse source 14, a utilization circuit 9, all of types well known in the art, and pictorially a magnetic structure 1. The magnetic structure 1 is shown having a pair of side rails 2a and 2b of remanent magnetic material interconnected by end members 3a and 3b of non-remanent magnetic material. Wound on the upper and lower side rails 2a and 2b are reset windings 4a and 4b and a plurality of set windings 5 and 6, respectively. The reset windings 4a and 4b are shown interconnected between ground and reset pulse source 10 by conductor 15 and diode 33; the reset pulse source 10 generates reset pulse 23. Magnetically coupling opposite parts of the upper and lower side rails 2a and 2b are a plurality of pairs of reed switches 7 and 8 each pair of which are operated together as a stage.

The reed switches 7₁-7₀ are shown interconnected between terminals 1-0 respectively of the utilization circuit 9 and common conductor 16, which common conductor is connected to read pulse source 14. Thus, when any of the reed switches 7₁-7₀ is closed, a signal, such as read pulse 17, can be transmitted therethrough from source 14 to the corresponding terminal of the utilization circuit 9. The reed switch 7_{st} is shown interconnected between ground and the check circuit 11, which check circuit is connected to input pulse source 12. Thus, when reed switch 7_{st} is closed, an operating path is completed to ground, enabling operation of the check circuit 11, which in turn controls operation of the input pulse source 12. The input pulse source 12, is shown connectable through switch 20 to common conductor 21 which is connected to the set windings 6₁-6₀. Each of the set windings 6₁-6₀ is connected to one reed of a respective one of switches 8_{st}-8₀. The other reeds of switches 8_{st}-8₀ are connected to set windings 5₁-5₀, respectively, and from there to ground, as shown. Thus, when any of the switches 8_{st}-8₀ is closed and switch 20 is closed to its lower position, the input pulse source 12 will, in a manner to be described hereinafter in greater detail, apply a signal, such as pulses 18 and 19, through the set winding 6, through the closed switch 8, through the set winding 5 to ground, thereby energizing the respective set windings. If the switch 20 is closed to the upper position, the con-

stant voltage source 22 will likewise energize the set windings.

The input pulse source 12 is also connected to the interdigital pulse detector 13, which detector is connected to both the read pulse source 14 and the reset pulse source 10. At the termination of each series of input pulses, the interdigital pulse detector 13 concurrently enables read pulse source 14 and reset pulse source 10. Accordingly, in a manner to be hereinafter described in greater detail, the stored information is sensed and concurrently the arrangement is returned to its reset condition in preparation for the next series of pulses.

The specific embodiment of FIG. 1 depicts a plurality of stages Stage ST . . . Stage 0 sharing the common magnetic structure 1 with each stage having a pair of reed switches 7 and 8, and set windings 5 and 6 wound on opposite portions of the side rails 2a and 2b. Hereinafter, this arrangement will be discussed with reference to its stages. The particular condition of the arrangement shown in FIG. 1 (switches 7_{st} and 8_{st} closed and the other switches open) is the normal or reset condition before any input pulses have been applied to operate the other stages.

Referring now to FIGS. 2A, 2B and 2C there are depicted on outlines of the magnetic structure 1 of FIG. 1 a plurality of arrows. The plurality of arrows 24 and 25 represents the states of remanent magnetization of portions of the upper and lower side rails 2a and 2b respectively of each of the stages Stage ST . . . Stage 0. Arrows 26a and 26b represent the direction of magnetic flux flow through the end members 3a and 3b which end members are of nonremanent magnetic material. If the end members are, as discussed below, of remanent magnetic material, the arrows 26a and 26b would represent the states of remanent magnetization. Arrows 27 and 28 represent the direction of magnetic flux flow closed through the reed switches 7 and 8, respectively. Where the arrows 24 and 25 represent opposite states of remanent magnetization between adjacent portions of the side rails, an independent magnetic pole is induced at a side rail part therebetween. For example, in FIG. 2A at the side rail part between arrows 24_{st} and 24₁ a south magnetic pole is induced and at side rail part between arrows 25_{st} and 25₁ a north magnetic pole is induced. FIG. 2A represents the magnetic flux states of the various portions of the magnetic structure in the normal or reset condition wherein stage ST is operated. FIG. 2B shows the magnetic flux conditions after the operation of stage 1 and, similarly, FIG. 2C shows the magnetic flux conditions after the operation of stage 2.

Before any of the stages can be operated by the input pulses, at least one of the stages must be operated. In the embodiment of FIG. 1, prior to the application of any input pulses stage ST is operated by the reset pulse source 10 initially applying a signal, such as reset pulse 23, through conductor 15 and diode 33 simultaneously through the reset windings 4a and 4b to ground. This pulse energizes the reset windings to thereby set the remanent magnetization states of the side rail portions of all the stages Stage ST . . . Stage 0 to that as shown by arrows 24 and 25 in FIG. 2A. Thus, opposite magnetic poles are established at the side rail parts magnetically coupled by the reset stage switches. Corresponding magnetic poles are induced on the respective reeds of switches 7_{st} and 8_{st}, as shown, which magnetic poles cause magnetic flux to flow therethrough in a direction as shown by arrows 27 and 28, thereby causing closure of two flux loops. One of the closed flux loops extends in a counterclockwise direction and is represented, inter alia, by arrows 27 and 26a and the other extends in a clockwise direction and is represented, inter alia, by arrows 28 and 26b. As a result, the respective reeds attract and thereby close. Thus, in response to the reset pulse 23 this arrangement is set to its normal or reset condition with the switches 7_{st} and 8_{st} operated as shown in FIG. 1.

The instant reset switch 7_{st} closes an operating path which is, as discussed, completed to ground and the check circuit 11 is operated to inform the input pulse source 12 to start transmission of the input pulses. Assume, in the following example, that the input signal comprises two pulses 18 and 19 of appropriate value and duration. With switch 20 closed to its lower position, the input pulse source 12 applies the pulses 18 and 19 to the common conductor 21. The first pulse 18, due to the closed switch 8_{st} , is steered through only set winding 6_1 , thence through closed switch 8_{sb} and through set winding 5_1 to ground, thereby energizing the respective set windings associated with stage 1. The energization of the set windings reverses the remanent magnetization states of the side rail portions directly thereunder to that as shown by arrows 24_1 and 25_1 in FIG. 2B. As a result, independent magnetic poles are transferred from the side rail parts magnetically coupled by switches of stage ST to the side rail parts magnetically coupled by respective reeds of the switches of stage 1 as shown. Thus, the magnetic flux loops formerly closed through the switches of stage ST are opened and caused to close instead through the switches of stage 1, thereby concurrently releasing the reed switches 7_{st} and 8_{st} of stage ST and operating switches 7_1 and 8_1 of stage 1.

The remanent magnetization states of the side rails, such as represented by arrows 24_1 and 25_1 , are switched in the order of a few microseconds and the independent magnetic poles are transferred in the same length of time. The normal response time of the reed switches, on the other hand, is in the order of one millisecond. In accordance with the principles of this invention, this inherent time delay between the switching of the remanent magnetization state and the response of the reed switches is advantageously utilized in the manner described to permit transmission of input pulse 18 through closed reed switch 8_{st} to cause actuation of the reed switches 7_1 and 8_1 of the next adjacent stage 1 before the concurrent release of the previously operated switches 7_{st} and 8_{st} of the preceding stage.

The second pulse 19 is applied in a similar manner by the input pulse source 12 through closed switch 20 and common conductor 21, through only set winding 6_2 , thence through closed switch 8_1 , and set winding 5_2 to ground, thereby energizing the set windings of stage 2. This reverses the remanent magnetization states of the side rail portions directly under the set windings 5_2 and 6_2 as shown by arrows 24_2 and 25_2 in FIG. 2C. In a manner similar to that described with respect to pulse 18, the independent magnetic poles are transferred from the side rail parts magnetically coupled by the switches 7_1 and 8_1 of stage 1 to the side rail parts magnetically coupled by respective reeds of switches 7_2 and 8_2 of stage 2 to thereby concurrently release stage 1 and operate stage 2.

After the termination of the series of input pulses 18 and 19 and before the beginning of the next series of input pulses, there is a substantial time lag. In response to this time lag, interdigital pulse detector 13 enables the operation of read pulse source 14 and reset pulse source 10. The consequently enabled read pulse source 14 thereupon applies read pulse 17 through conductor 16, through only closed switch 7_2 of stage 2, to terminal 2 of the utilization circuit 9. The consequently enabled reset pulse source 10 at the same time applies reset pulse 23 through conductor 15, diode 33, reset windings $4a$ and $4b$ to ground, thereby causing the remanent magnetization states of the various portions of the side rails to be set in the manner as shown by arrows 24 and 25 in FIG. 2A, causing the release of the previously operated switches 7_2 and 8_2 of stage 2 and the concurrent operation of switches 7_{st} and 8_{st} of stage ST. Because of the above-mentioned inherent time delay, the read pulse 17 is transmitted through the closed switch 7_2 before the release of

switch 7_2 and the operation of the stage ST by the reset pulse 23.

In the illustrative example described, it was assumed that the normal condition involved an initially operated first stage, and that the operate condition involved successive operation of the succeeding stages by a series of successive input pulses. By appropriate connections the normal condition may involve an initially operated one of any of the stages and the successive input pulses may, with the set windings connected to appropriate ones of the control switches 8, operate any others of the stages in a predetermined order. For example, with the fifth stage initially operated as the normal or reset condition, the successive input pulses may in accordance with the principles of the invention, operate stages one, eight, three or any other stages in a predetermined order. The input pulses, as in the example described, travel through an operated switch to cause actuation of another switch though not necessarily of the next adjacent stage.

Referring again to FIG. 1, common conductor 21 is shown connected by diode 29 and switch 30 to one reed of switch 8_0 of stage 0. The other reed of switch 8_0 is connected to terminal P and from there via conductor 31 and switch 32 to conductor 15. Thus, when switches 30 and 32 are closed, a re-entrant type of counter is formed. Assuming for illustrative purposes that in the above-cited example there are instead, 11 input pulses, the tenth input pulse operates, in the manner described, stage 0 and closes switches 7_0 and 8_0 . The eleventh pulse travels through common conductor 21, diode 29, closed switch 30, closed switch 8_0 through conductor 31 and closed switch 32 to the reset windings $4a$ and $4b$, thereby operating, as in the manner discussed, stage ST. Similarly, following the termination of the 11 input pulses, the interdigital pulse detector 13 enables operation of the read pulse source 14 and reset pulse source 10, thereby concurrently sensing and resetting the arrangement. If the re-entrant type of counter discussed is used as one unit of a decimal counter, it is apparent that only ten stages including stage ST will be included in one unit. When so employed, terminal P is connected to common conductor 21 of the next unit and conductor 15 is also connected to the reset windings of the next unit. Thus, when so employed, the particular units will register the number of pulses counted. For example, if 25 input pulses are applied, the first unit will have stage 5 operated and the second unit will have stage 2 operated. The sensing and resetting of the entire decimal counter is accomplished in the same manner as above described.

Referring now to FIG. 3, there is depicted two stages of an arrangement similar to that depicted in FIG. 1 utilizable as a binary cell or as often termed a flip-flop. There is shown a pair of side rails $41a$ and $41b$ of a remanent magnetic material connected by two end members $42a$ and $42b$ of a nonremanent magnetic material. Bridging and magnetically coupling opposite parts of the side rails are two pairs of reed switches. The first pair, 43_0 and 44_0 , represents the binary 0 state and the other pair 43_1 and 44_1 , represents the binary 1 state. Reeds 43_0 and 43_1 are utilized for sensing purposes and are interconnected between the utilization circuit 53 and the read pulse source 52, which read pulse source is connected to a control circuit 51. The reed switches 44_0 and 44_1 are utilized for control purposes and are connectable at one reed through the switch 50 to either the input pulse source 48 or to the D.-C. source 49. The other reed of switch 44_0 is connected to set "1" winding 46 to ground. The set "1" winding 46 is shown wound around the lower and upper side rail $41b$ and $41a$, respectively, to ground. The other reed of switch 44_1 is connected to terminal P, and to the set "0" winding 45, which winding 45 is wound on both the upper and lower side rails $41a$ and $41b$, respectively, to ground. Also connected to the set "0" winding 45 is reset pulse source 47.

Referring to FIGS. 4A and 4B, arrows 60 and 61 represent states of remanent magnetization of portions of the side rails; arrows 62a and 62b represent the directions of magnetic flux flow through the end members; and arrows 63 and 64 represent flux flow closed through the switches. FIG. 4A represents the binary "0" state and FIG. 4B represents the binary "1" state. Initially, in a manner similar to the explanation of the embodiment of FIG. 1, the binary cell is set to an initial "0" condition by the reset pulse source 47 applying a pulse, such as reset pulse 56, to the set "0" winding 45 to ground. This establishes the remanent magnetization states of the various portions to that shown by arrows 60 and 61 in FIG. 4A causing opposite independent magnetic poles to be established at the side rail parts magnetically coupled by switches 43₀ and 44₀. Corresponding magnetic poles are induced on the respective reeds of switches 43₀ and 44₀ causing their closure.

With the switch 50 closed to the left position, and the binary cell in the binary "0" state, the input pulses, such as 54 and 55, are applied to the reed switches 44. The first pulse 54 is steered through closed switch 44₀, through set "1" winding 46 to ground. This changes the remanent magnetization of all the side rail portions to that as shown by arrows 60 and 61 in FIG. 4B, thereby causing closure of the switches 43₁ and 44₁ and the concurrent release of switches 43₀ and 44₀ to set the binary cell to a binary "1" condition. In a similar manner, the next pulse 55 is applied by input pulse source 48 through closed switch 50, through closed switch 44₁, and through set "0" winding 45 to ground. This changes the remanent magnetization states again to that shown by arrows 60 and 61 in FIG. 4A causing closure of switches 43₀ and 44₀ and the concurrent release of switches 43₁ and 44₁ thereby setting the binary cell to a binary "0" condition.

After a predetermined number of input pulses, for example two pulses such as pulses 54 and 55, the control circuit 51 enables the operation of the read pulse source 52. The read pulse source 52 applies a pulse, such as pulse 57, simultaneously to reed switches 43₁ and 43₀. As a result of the pulses 54 and 55 the binary cell is in the "0" condition, i.e., with switches 43₀ and 44₀ operated. Thus, pulse 57 travels through operated switch 43₀ to the utilization circuit 53.

With a few minor alterations, this binary cell may, as would be apparent, be used for many purposes. For example, if the switch 50 is in the right position, the D.-C. source 49 causes, in a similar manner, alternate continuous operation of the two pairs of switches, thereby making a free running multivibrator out of this binary cell. The resulting output signal is taken from any appropriate part of the circuit, such as terminal P₁. If the terminal P₁ is connected to the control switches 44 of another similar binary cell (not shown), this arrangement can be used as one stage of a binary counter. Accordingly, when a particular stage is in the binary "1" condition, the input pulse will switch that particular stage to a binary "0" condition and will also be transmitted to the next stage. If the read pulse source 52 were a constant current source (not shown), a monostable oscillator circuit would be formed.

In the arrangements depicted in FIGS. 1 and 3, the side rails are of a remanent magnetic material and the end members are of a nonremanent magnetic material; i.e., of a highly permeable material. Although such a material is preferable for use in the end members, remanent magnetic material can also be used. In this case, the state of remanent magnetization thereof must be preset so as to cause a proper flow of magnetic flux or a winding must be inductively coupled thereto to control the remanent magnetization states. In either situation the dimensions of the end members are not critical. In the depicted embodiment the side rails have their dimensions of length substantial in comparison with the diam-

eter, thereby enabling the remanent magnetization of particular portions thereof to be, as described, established independent of each other. These dimensions along with the dimensions of the end members can, as is known in the art, be adjusted such that advantageously only one set winding per stage and only one reset winding per arrangement need be positioned on either of the side rails. In such a case the input and reset pulses must be of an appropriate magnitude to cause the switching of the states of remanent magnetization of portions of both side rails.

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

What is claimed is:

1. A contact controllable switching arrangement comprising a magnetic structure of a material exhibiting a plurality of stable remanent magnetization states and defining a plurality of magnetic circuits, a plurality of magnetically responsive switches magnetically coupled to said structure, each switch associated with a respective one of said magnetic circuits and providing a magnetic flux path for the said respective magnetic circuit, first means for selectively establishing a particular flux path in said structure to complete a first of said magnetic circuits through a first of said switches to operate said first switch and second means including an electrical circuit through a respective operated one of said switches for selectively reversing said particular flux path in at least one particular portion of said structure to operate another of said switches by completing an associated one of said magnetic circuits through said other switch.

2. The invention defined in claim 1 wherein said magnetic structure comprises a pair of side rails and at least one end member interconnecting said side rails, and wherein said plurality of magnetically responsive switches bridge the said side rails and are magnetically coupled thereto, said side rails and said plurality of switches defining a plurality of magnetic circuits through said end member.

3. The invention defined in claim 2 wherein said plurality of magnetically responsive switches are grouped and operated in pairs, each of said pairs providing a closed flux path for a different one of said magnetic circuits.

4. The invention defined in claim 2 wherein said first means comprises a reset winding inductively coupled to at least one of said side rails and comprises means for energizing said reset winding to establish a particular flux path in predetermined portions of said side rails to complete said first magnetic circuit through said first switch to operate said first switch after said energizing of said reset winding has ceased.

5. The invention defined in claim 4 wherein said second means comprises a plurality of set windings inductively coupled to at least one of said side rails, each winding connected respectively to a different one of said magnetically responsive switches, and comprises means for energizing said set windings to reverse a flux path of particular portions of said side rails to complete another of said magnetic circuits through another of said switches thereby to operate said other switch.

6. The invention defined in claim 1 comprising two switches, and further comprising a signal source and means for connecting said first means and said second means whereby an operating signal from said source travels through an operated one of said switches to operate the other of said switches and to release the said operated one switch.

7. A contact controllable switching arrangement having a plurality of stages responsive to successive pulses of a train of pulses comprising a magnetic structure including a pair of side rails of a magnetic material exhibiting a plurality of stable remanent magnetization states and at least one end member providing a magnetic flux

path between said side rails, each of said stages having a pair of electrical contacting members bridging said side rails and magnetically coupled thereto, means for selectively establishing predetermined ones of said magnetization states in predetermined portions of said side rails to close the pair of electrical contacting members of the first of said stages, and means including an electrical path through the operated pair of electrical contacting members of the preceding ones of said stages and responsive to the said successive pulses of said train of pulses for selectively changing particular ones of said states in particular portions of said side rails to successively operate the pairs of electrical contacting members associated with the next succeeding stages of said switching arrangement and to concurrently release the said operated pairs of electrical contacting members of the said preceding stages.

8. The invention defined in claim 7 wherein said last-mentioned means comprises a winding in each of said stages inductively coupled to one of said side rails and connected to the pair of electrical contacting members associated with the preceding respective one of said stages.

9. The invention defined in claim 8, further comprising means responsive to a predetermined number of pulses of said train of pulses for causing said first-mentioned means to again selectively establish said predetermined ones of said magnetization states in predetermined portions of said side rails.

10. A contact controllable switching arrangement having a plurality of stages comprising a pair of side rails of a material exhibiting a plurality of stable remanent magnetization states, an end member connecting said pair of side rails, each of said stages including a control winding on a portion of at least one of said side rails and a pair of magnetically responsive contact elements connected to said side rails and magnetically coupled thereto, first means for selectively altering the said remanent magnetization states of said side rail portions to induce opposite magnetic polarities on a first pair of said contact elements to close said first pair of contact elements, and second means for successively inducing opposite magnetic polarities on the pair of contact elements in each succeeding stage of said switching arrangement to successively close said pairs of contact elements, said second means comprising a source of control signals and means interconnecting said control windings with an operated pair of contact elements of the stage immediately preceding the particular stage to be operated and means for energizing said control windings whereby a control signal from said source for operating the said particular stage travels through said operated pair of contact elements of said preceding stage and through the control winding associated with said par-

ticular stage to selectively change the said remanent magnetization states of particular portions of both of said side rails to induce opposite magnetic polarities on the pair of contact elements in said particular stage.

11. The invention defined in claim 10 and wherein said plurality of stages comprises a two-stage binary cell, and wherein said second means further includes means for operating the first pair of contact elements of a first stage of said binary cell when the pair of contact elements of the second stage of said binary cell is operated whereby a control signal from said source travels through said operated second pair of contact elements and through said first means to induce opposite magnetic polarities on said first pair of contact elements.

12. The invention defined in claim 10, further comprising means responsive to a predetermined number of pulses for repeating operation of said first means.

13. A contact controlling switching arrangement comprising a magnetic frame having perimeter portions capable of exhibiting discrete remanent magnetization states, a plurality of magnetically operable switches disposed in said frame, said switches having magnetically permeable reeds, said reeds being capable of coupling flux between said perimeter portions of said frame, means for establishing a first remanent magnetization state in said perimeter portions of said frame to substantially exclude the magnetic field corresponding to said remanent magnetization state from said reeds, means for reversing the remanent magnetization state in two of said perimeter portions of said frame to direct a composite magnetic field including a portion of the field corresponding to said established first remanent magnetization state and the field corresponding to said reversed remanent magnetization state through a first one of said reeds, and means responsive to the operation of said first one of said reeds upon the directing therethrough of said composite magnetic field for reversing the remanent magnetization state of two further ones of said perimeter portions to direct a composite magnetic field through another one of said reeds and substantially exclude said field corresponding to said first-mentioned reversed magnetization state and the field corresponding to said second-mentioned reversed magnetization state from said first one of said reeds.

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