

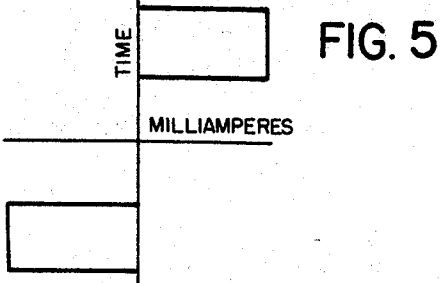
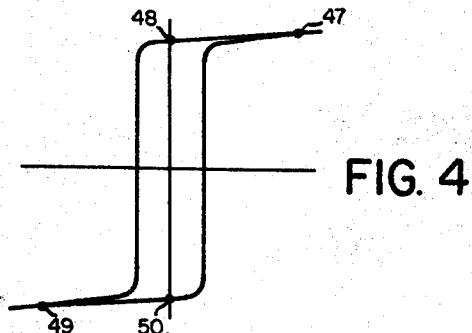
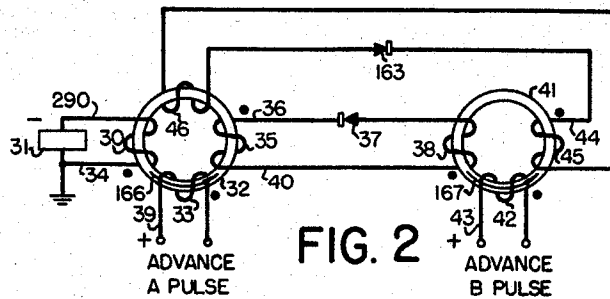
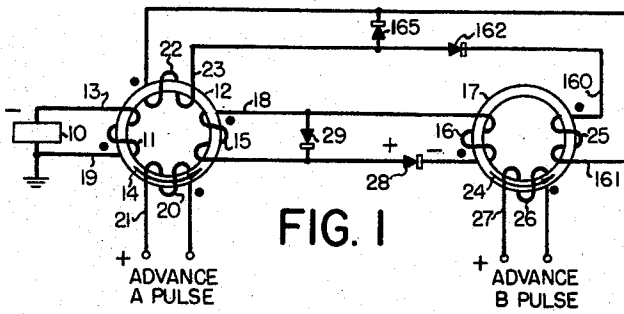
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I. L. AUERBACH
MAGNETIC COUNTER

2,960,684

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2 Sheets-Sheet 1



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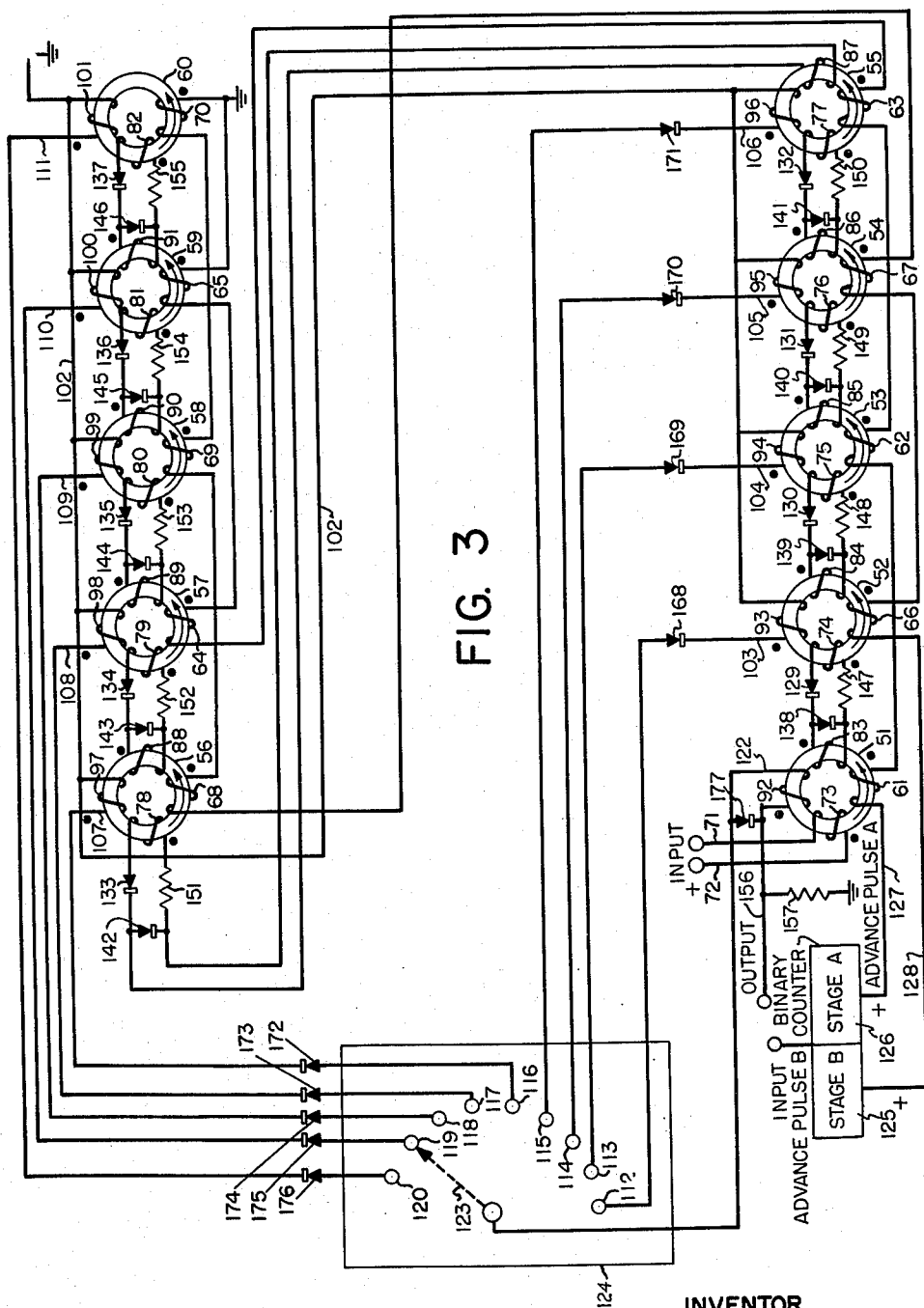
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MAGNETIC COUNTER

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This invention relates generally to counting devices and it relates more particularly to counting devices comprising magnetic cores to perform a counting operation.

Usually counting operations are performed by mechanical, electromechanical, or electronic means. Mechanical and electromechanical means present characteristics of wear and slowness of operation inherent in devices of that nature having moving mass. The electronic coding devices sometimes referred to as counting rings are often composed of gas tubes or vacuum tubes. Both gas tubes and vacuum tubes exhibit properties of changing characteristics with continued wear and age which involve problems of design and maintenance. It would be desirable to have a counting device which is rapid in operation and whose characteristics are substantially invariant with time and use. Magnetic materials have such characteristics and a counting circuit utilizing magnetic elements would mark a definite improvement in the art.

An object of this invention is to provide a counting device whereby information is indicated by the magnetic flux remanence condition of magnetic material.

Another object of the invention is a magnetic counting device having no moving parts.

A third object is a counting device whose characteristics will not change appreciably with wear and age.

A further object of the invention is a counting apparatus comprising magnetic cores and requiring a minimum of maintenance.

A fifth object of the invention is a counting device having a variable radix so that it can be made to count to a prescribed count merely by the appropriate setting of a switch. Such counter can also be used as a variable length delay line.

In accordance with one embodiment of the invention, the counting means comprises a first plurality of magnetic cores and a second plurality of magnetic cores. A first plurality of coupling means is adapted to couple the said first and second pluralities of magnetic cores together in a series relationship in such a manner that the individual ones of said first and second pluralities of magnetic cores are arranged in alternate fashion. A first plurality of winding means is adapted to individually energize each of said first plurality of magnetic cores in a predetermined magnetic polarity. A second plurality of winding means is adapted to energize said second plurality of magnetic cores in a predetermined magnetic polarity. A third winding is adapted to energize the first magnetic core in said series arrangement of cores. A fourth plurality of readout windings are each individually associated with each of said magnetic cores other than the first magnetic core. Selector means is adapted to connect the windings of said fourth plurality of readout windings to said third winding in such a manner that the said third winding is individually and exclusively connected to any one of said fourth plurality of readout windings. Said first magnetic core has associated there-

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with an input winding which, when excited, will cause said first magnetic core to assume a remanence of a first polarity. Current source means are provided to alternately excite said first plurality of winding means and said second plurality of winding means.

In accordance with one feature of the invention the counting device comprises a plurality of magnetic cores utilized in stages by means of having a remanence condition of a first polarity represent a first condition of a given stage and having a remanence condition of a second polarity represent a second condition of said given stage.

In accordance with another feature of the invention each magnetic core has a readout winding thereon which acts in cooperation with said selector switching means to enable the counting device to be preset to count to any total not greater than the maximum capacity of the counting device.

These and other objects and features of the invention will be more fully understood from the following detailed description when read in conjunction with the drawings in which:

Fig. 1 is a schematic circuit diagram of a two stage counter utilizing one type of coupling between the two stages;

Fig. 2 is a schematic circuit diagram of a two stage counter utilizing a different type coupling between the two stages;

Fig. 3 is a schematic circuit diagram of a ten stage counter utilizing a third type coupling means between the said stages;

Fig. 4 is a drawing of a typical hysteresis loop of the magnetic cores used in Figs. 1, 2, and 3; and

Fig. 5 is a chart showing typical input pulses applied to the input windings of the first magnetic cores in Figs. 1, 2, and 3.

Referring now to Fig. 1, input signal source 10 is connected to input winding 11 of magnetic core 12. Winding 11 is wound around the magnetic core 12 in such a manner that negative input pulses impressed upon input lead 13 will cause magnetic core 12 to become positively saturated in a direction arbitrarily indicated by arrow 14. The output terminals of winding 15 of core 12 are connected to the terminals of winding 16 of magnetic core 17. The output winding 15 is wound around core 12 in such a manner that positive voltage will be induced on terminal 18 of said winding 15 when the magnetic flux in core 12 is switched from a negative polarity to a state of positive polarity. This is indicated by the dot notation utilized throughout Figs. 1, 2, and 3. More specifically, for example, the dot appearing adjacent terminal 19 of winding 11 indicates that a positive current flowing into terminal 19, will, if producing a change in flux from negative polarity to positive polarity in core 12, cause a positive current to flow out of the winding 15 at terminal 18. Thus, in the Figs. 1, 2, and 3 a dot appearing at one terminal of a winding indicates that a current of a given polarity flowing into that terminal will tend to produce an induced current of said given polarity flowing from the terminal of another winding on the same core having a dot adjacent thereto. Advance A pulse winding 20 is wound around magnetic core 12 in such a manner that when a positive pulse is applied upon terminal 21 the magnetic core will become negatively saturated regardless of its prior magnetic flux condition. Winding 22 is wound around magnetic core 12 in such a manner that when a positive input pulse is applied upon the dotted terminal thereof, the magnetic core 12 is caused to become positively saturated regardless of its prior magnetic flux condition. The positive magnetic flux flow in magnetic core 17 is indicated by the direction of the arrow 24. Winding 16 and output winding

25 are wound in a manner indicated by the dot notation. Advance B pulse winding 26 is wound around core 17 in such a manner that a positive pulse applied upon terminal 27 will cause magnetic core 17 to become negatively saturated irrespective of its prior magnetic flux condition. Asymmetrical device 28 performs the function of permitting current to flow in a circuit comprising winding 15 of magnetic core 12, asymmetrical device 28, and winding 16 of magnetic core 17 in one direction only. The polarities of asymmetrical device 28 and all other asymmetrical devices in Figs. 1, 2, and 3 are as indicated with respect to asymmetrical device 28. Asymmetrical device 29 performs the function of short circuiting output winding 15 of magnetic core 12 when the magnetic flux condition of magnetic core 17 is caused to change from a positive polarity to a negative polarity by application of a positive pulse upon terminal 27 of winding 26, which pulse constitutes the advance B pulse. The output winding 25 of core 17 is connected to winding 22 of core 12 in such a manner that a positive advance B pulse, applied upon terminal 27 of winding 26 and causing the flux in core 17 to change from a positive remanence to negative saturation, will produce a current in winding 25 of core 17 which will flow through winding 22 of core 12 in such a direction as to cause core 12 to become positively saturated and subsequently, to assume a positive remanence. This, of course, is under the assumption that core 17 was in a condition of positive remanence at the time an advance B pulse was applied to terminal 27 of winding 26. Asymmetrical device 165 performs the function of short circuiting the current flow induced in winding 22 when advance A pulse is applied to winding 20 and thus preventing it from flowing through winding 25. Asymmetrical device 162 performs the function of permitting a current flow of one polarity only through the coupling circuit comprising winding 25 and winding 22. The application of an advance A pulse upon conductor 21 followed by an advance B pulse applied upon conductor 27 will cause the aforementioned cycle of operation to reoccur.

Referring now to Fig. 2 a negative signal input means is applied to winding 30 through conductor 290 from signal input pulse source 31. Such an input pulse will cause the magnetic flux in core 32 to assume positive remanence which is arbitrarily defined as being in the direction of the arrow 166. In accordance with the same dot notation used with respect to Fig. 1 a positive current flow into winding 30 from conductor 34 will tend to produce a positive current flow out of winding 35 along terminal or conductor 36. This positive current flow is blocked by asymmetrical device 37. A positive advance A pulse signal applied upon conductor 39 of winding 33 will cause magnetic flux in magnetic core 32 to become negatively saturated in the direction opposite the arrow 166 and produce a positive current flow out of winding 35 on terminal 40 which will flow through winding 38, asymmetrical device 37, and back to winding 35 to cause the magnetic core 41 to become positively saturated in a direction arbitrarily defined as being in the direction of arrow 167. This advance A pulse also produces a positive current flow out of the undotted terminal of winding 46 which passes through asymmetrical device 163 and winding 45 in a direction to assist in the switching of core 41 to positive saturation. Positive advance B input pulse applied upon terminal 43 of winding 42 will cause the magnetic core 41 to become negatively saturated opposite the direction of the arrow 167 from the positive remanence state and will produce a positive current at the undotted terminal of winding 45. This current may be traced through winding 46 of magnetic core 32 and back through asymmetrical device 163 to winding 45 to cause magnetic core 32 to become positively saturated. This advance B pulse also produces a positive current flow out of the undotted terminal of winding 38 which

passes through asymmetrical device 37 to winding 35 in a direction to assist in the switching of core 32 to positive saturation.

In Fig. 4 there is shown a typical saturation curve of the magnetic material used in the magnetic cores of Figs. 1, 2, and 3. In the curve, point 47 represents positive saturation; point 48 represents positive remanence; point 49 represents negative saturation, and point 50 represents negative remanence.

Referring now to Fig. 3, there is shown a schematic circuit diagram of the invention. Each of magnetic cores 51 to 60 inclusive preferably has a hysteresis loop similar to the one shown in Fig. 4. A suitable material which may be used is deltamax. It is to be noted that other materials having suitable hysteresis loop characteristics can also be used. A cross sectional area of each core is approximately .00025 square inches and the mean length is approximately 1.16 inches.

Windings 61 to 65, inclusive associated respectively with odd numbered magnetic cores 51, 53, 55, 57, and 59 comprise the advance A windings. Windings 66 to 70, inclusive, associated respectively with even numbered magnetic cores 52, 54, 56, 58, and 60 comprise the advance B windings. Each of the advance A windings and the advance B windings in the preferred embodiment herein described are comprised of approximately 150 turns. Input leads 71 and 72 are connected to a first input winding 73 on core 51, which is comprised of approximately 100 turns. Input windings 74 to 82 are comprised of approximately 40 turns and are associated respectively with magnetic cores 52 to 60. Output windings 83 to 91 are comprised of approximately 80 turns and are associated respectively with magnetic cores 51 to 59. Detecting windings 93 to 101 are comprised of about 200 turns and are associated respectively with magnetic cores 52 to 60. Winding 92 serves as a second input winding to core 51. Corresponding terminals of detecting windings 93 through 101 are connected to common conductor 102. Conductors 103 to 111 connect detecting windings 93 through 101 to respective contacts 112 to 120 of selector means 124, shown schematically in Fig. 3, for purposes of illustration, as a mechanical switch. Terminal 122 associated with winding 92 of core 51 is connected to arm 123 which is adapted to selectively make contact with individual ones of contacts 112 through 120. Asymmetrical devices 168 to 176 are each individually associated with the outputs of windings 93 to 101 respectively in such a manner that current induced in said windings by a magnetic flux change from negative to positive polarity in the associated magnetic core will be impeded by the high back impedance thereof. Asymmetrical device 177 performs the function of short circuiting current induced in winding 92 when the magnetic flux of core 51 is switched from positive to negative polarity, thus preventing said induced current from flowing through switch 165 and through one of the windings 93 through 101.

Advance A windings 61 through 65 are connected in series to the output of advance A pulse source 126 through conductor 127. Advance B windings 66 to 70 are connected in series to the advance B pulse source 125 through conductor 128. Asymmetrical devices 129 to 137 are connected in series with each of the coupling networks between adjacent magnetic cores to perform the function of permitting current to flow in one direction in the coupling circuit, but not in the other direction. Asymmetrical devices 138 to 146 individually shunt each of the coupling circuits coupling together adjacent magnetic cores. Each of the asymmetrical devices 129 through 137 and 138 through 146 are of the selenium type although other types of asymmetrical devices such as germanium diodes having suitable characteristics may also be used. Current limiting resistors 147 to 155 are each connected in series with individual coupling circuits

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coupling together adjacent magnetic cores. It is to be noted that a coupling circuit consists of, for example, the output winding 83 of core 51, the input winding 74, of core 52, asymmetrical devices 129 and 138, and resistance 147. Output signals from the device will appear on output terminal 156 which is connected to ground through resistance 157.

Referring now to Fig. 1, the operation of the circuit shown therein will be described in detail. A negative pulse such as shown in the lower half of Fig. 5 applied upon input conductor 13 from source 10 will cause magnetic core 12 to become saturated in a positive polarity which is indicated by a direction of the arrow 14. This causes a voltage of positive polarity to be generated on terminal 18 of coil 15. The current flow may then be traced through winding 15, terminal or conductor 18, asymmetrical device 29, back to the winding 15. No appreciable current will flow through winding 16 because of the high back impedance of asymmetrical device 28 as compared with the low forward impedance of asymmetrical device 29. If now a positive advance A pulse such as shown in the upper half of Fig. 5 is applied upon conductor 21 connected to winding 20, the magnetic core 12 will be caused to assume a condition of negative magnetic flux saturation such as indicated by point 49 of Fig. 4 and at the expiration of the advance pulse the core will assume a condition of negative remanence as indicated by point 50 of Fig. 4. During the transition of magnetic flux from positive remanence to negative saturation in magnetic core 12 a voltage is induced in winding 15 having its negative polarity on conductor 18. A circuit may then be traced from the negative potential on conductor 18 through winding 16, asymmetrical device 28, to the positive terminal of winding 15. This current flow will cause magnetic core 17 to assume a condition of positive saturation in the direction of arrow 24 and at the expiration of this current flow core 17 will assume a condition of positive remanence as indicated by point 48 of Fig. 4. This condition of positive saturation is indicated by point 47 of the curve of Fig. 4. If, subsequently, a positive advance B pulse is impressed on conductor 27, the magnetic flux condition of magnetic core 17 will be caused to change from a positive remanence indicated by point 48 of Fig. 4 to a negative saturation indicated by point 49 of Fig. 4, and thus causing a voltage to be induced in winding 25 having its positive polarity impressed upon terminal 161 and its negative polarity upon terminal 160. A path may then be traced from the conductor 160 through asymmetrical device 162, conductor 23, winding 22, and to conductor 161 to winding 25. This current flow through winding 22 will cause magnetic core 12 to assume a condition of positive saturation as indicated by point 47 of Fig. 4. At the cessation of said current flow through winding 22 the magnetic core 12 will assume a condition of positive remanence as indicated by point 48 of Fig. 4. The cycle is thus completed and subsequent application of advance A pulses and advance B pulses through windings 20 and 26 respectively will cause the cycle to be repeated.

Referring now to Fig. 2, the operation of the circuit shown therein is very similar to the operation of the circuit shown in Fig. 1. The only difference in circuitry is that in Fig. 2 there are no asymmetrical devices corresponding to the asymmetrical devices 29 and 165 of Fig. 1. When a negative input pulse is applied upon input terminal 290 of winding 30 to cause core 32 to assume a condition of positive remanence from, for example, a condition of negative remanence, the voltage induced in winding 35 will produce a current flow through the high back impedance of asymmetrical device 37 which will be insufficient to cause any substantial change in the magnetic flux condition of magnetic core 41. However, as in the circuit of Fig. 1, advance A pulse occurring

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thereafter will switch core 32 back to positive saturation and thus produce a current flow through winding 38 in the proper direction and of sufficient amount to switch core 41 to positive saturation. Likewise, as in the circuit of Fig. 1, advance B pulse will thereafter advance this positive saturation condition, via windings 45 and 46, back to core 32.

Referring now to Fig. 3, the operation of the counter shown therein will be described in detail. In general, an input pulse representing one bit of information is applied upon input terminals 71 and 72. This information is then stepped along from core to core by alternately transmitting pulses from advance pulse B source and advance pulse A source which may be in the form of a binary counter device or a flip flop circuit or other equivalent circuitry. Assume that prior to the application of an input pulse, the magnetic core 51 contains a "0" binary bit, herein arbitrarily defined as corresponding to a magnetic flux condition of negative remanence. Then an input pulse applied upon terminals 71 and 72 of winding 73 associated with core 51 will cause said magnetic core 51 to become positively saturated as indicated by point 47 of Fig. 4. Upon cessation of said input pulse the magnetic core will assume a state of positive remanence as indicated at point 48 of Fig. 4. When an advance A pulse signal is caused to be transmitted to winding 61 through conductor 127 the magnetic core 51 is caused to change from a condition of positive remanence to negative remanence inducing a voltage in winding 83 of such a polarity as to cause a positive current flow in turn through resistance 147, winding 74 of core 52 and the low impedance of asymmetrical device 129 back to winding 83. This current flow through winding 74 is of sufficient magnitude to cause the associated magnetic core 52 to change its magnetic flux condition from a state of negative remanence as indicated by point 50 of Fig. 4 to a condition of positive saturation as indicated by point 47 of Fig. 4. Upon cessation of the pulse magnetic core 52 will return to a state of positive remanence as indicated by point 48 of Fig. 4. The voltage induced in winding 93 will produce no current since contact 112 of switching unit 124 is open and since asymmetrical device 168 is in a direction to block such current flow. The voltage induced in winding 84 will produce a current which will flow into the high back impedance of asymmetrical device 130 thus producing no substantial effect on the magnetization of magnetic core 53.

Assume now that an advance B pulse is applied to winding 66 of magnetic core 52 through conductor 128. Current flow is in such a direction as to cause the magnetic core 52 to switch from a condition of positive remanence indicated by point 48 of Fig. 4 to a condition of negative saturation as indicated by point 49 of Fig. 4. Upon cessation of the pulse the magnetic flux condition of core 52 will return to negative remanence as indicated by point 50 of Fig. 4. During the switch of magnetic flux condition in magnetic core 52 from positive remanence to negative saturation voltages are induced in windings 74, 93, and 84. The voltage induced in winding 84 will produce a current flow to winding 75 of core 53 in such a direction as to pass through the low impedance of asymmetrical device 130, thus causing magnetic core 53 to switch from a condition of negative remanence to a condition of positive saturation and subsequently return to a condition of positive remanence. The voltage induced in winding 74 will produce a current flow through the low impedance of asymmetrical devices 129 and 138 and through resistance 147. No appreciable effect occurs upon the magnetic flux condition of magnetic core 51. The voltage induced in winding 93 produces no current flow since the associated contact 112 is open and further because of the blocking effect of asymmetrical device 168. Subsequent alternate advance A pulses and advance B pulses will cause the positive remanence

flux condition to pass successively along magnetic cores 53 through 60 until it reaches the magnetic core whose winding (of windings 93 through 101) is connected to armature 123 of the switching unit 124. In Fig. 3 this would occur when the positive flux condition of magnetic core 59 was transferred to magnetic core 60, since winding 100 of core 59 is connected to button contact 119 which is in contact with switch armature 123.

The pulse appearing on armature 123 from winding 100 of magnetic core 59 will flow through winding 92 of magnetic core 51 and to the output conductor 156. Asymmetrical device 175 is oriented, like its companion asymmetrical devices 168 to 174 and 176, to allow current flow through winding 92 in such a direction as to cause magnetic core 51 to become positively saturated and, upon the termination of the said current pulse, to assume a condition of positive remanence. Then, upon the alternate application of advance A pulses and advance B pulses the cycle of operation reoccurs in that the condition of positive remanence is caused to pass from core 51 consecutively along the row of magnetic cores 51 through 60 until it reaches magnetic core 59 when the voltage induced in winding 100 of magnetic core 59 by an advance pulse impressed upon winding 65 will cause a current to flow through button contact 119, armature 123, through winding 92 of magnetic core 51, and to output terminal 156.

In the schematic diagram shown in Fig. 3 the selector 124 is arranged to count to nine. However, by moving switch armature 123 to button contacts 112, 113, 114, 115, 116, 117, 118, or 120 the circuit will count to two, three, four, five, six, seven, eight, or ten, respectively. This can readily be seen from an examination of Fig. 3 by noting which button contact is associated with which magnetic core. During the operation of the device, a pulse successively appears on each of the contacts of the selector but only that pulse on the contact to which the armature is connected is re-entered and circulated through the core loop. The successive appearance of a pulse on each of the button contacts 112 through 120 as a pulse is passed through the core loop enables the device to be operated as a cyclical distributor, if desired.

It is possible, if desired, to have more than one pulse circulating in the counting ring at a given time. For example, if the counting ring is set to count to eight and two pulses are circulated at a distance of four cores apart there will be an output pulse for every four advance pulses. Similarly, if the input pulses are a distance of three or five cores apart and the counting ring is set to count to eight there will be an output pulse at alternate intervals of three and five advance pulses.

It is to be understood that the invention described herein is a preferred embodiment of the same and that various changes in circuit constants, number of elements or circuit arrangement may be made without departing from the spirit or scope of the invention.

What is claimed is:

1. An electrical circuit comprising a plurality of three or more magnetic cores arranged in succession in a magnetic core register, each of such cores being characterized by having a substantially rectangular hysteresis loop, a plurality of windings on each of said cores, said windings including a set winding, an activating winding, and an output winding, electrical circuitry interconnecting successive ones of said cores, such electrical circuitry including a separate transfer circuit between each core and the succeeding core, an input source connected to the set winding of the first core and forming a series input to said magnetic core register for passing current through said set winding to thereby establish the said first core in a first magnetic remanent state in response

to pulses from said input source, means connecting the activating windings in series, energizing means connected to said activating windings for resetting said cores into a second magnetic remanent state to establish an output voltage signal in the transfer circuit of any such core in said first remanent state to thereby advance the core settings along said register, each of said output windings being connected to a separate output terminal point for producing a parallel output from said register and means connecting one end of each of said output windings to the last of said series activating windings.

2. An electrical circuit comprising a plurality of magnetic cores each of which is characterized by having a substantially rectangular hysteresis loop and each having a number of windings thereon, said windings including a set winding, an activating winding, and an output winding, said activating windings being connected in series and one end of each of said output windings being connected to the last of said series activating windings, means including said set windings for determining the magnetization of certain of said cores in one direction, and means for applying an activating pulse to said activating windings in series to determine the magnetization of said cores in the other direction.

3. A variable-length recirculating magnetic core register comprising a succession of three or more magnetic cores each capable of assuming first and second stable states of magnetic remanence, an input winding and an output winding on each such core, an input voltage source connected to at least the input winding of the first core for establishing such first core in said first magnetic remanent state to represent a binary bit therein in response to pulses from said input source, asymmetrical conductive electrical circuit means interconnecting the input winding on each of said cores other than said first core with the output winding on the preceding core, voltage means for resetting said cores into said second magnetic remanent state to establish an output voltage signal in the output winding of any such core in said first remanent state and thereby to advance said binary bit along said cores, a separate output electrical circuit electromagnetically coupled to each said core other than said first core, input electrical circuit means electromagnetically coupled to said first core, selector switch means separately connected electrically to said separate output circuits and to said input electrical circuit means to the first core, and means for activating said selector switch means to selectively connect the output circuit of one of said cores to said input circuit means of said first core whereby an output signal from a selected core is recirculated into said first core.

4. A magnetic core register according to claim 3 further including output load means electrically connected to said input electrical circuit means for delivering output signals from said register.

5. A magnetic core register according to claim 3 in which each said separate output electrical circuit includes a separate winding.

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