Jan. 17, 1961 J. H. LANE ET AL 2,968,796

TRANSFER CIRCUIT

Filed Jan. 30, 1958

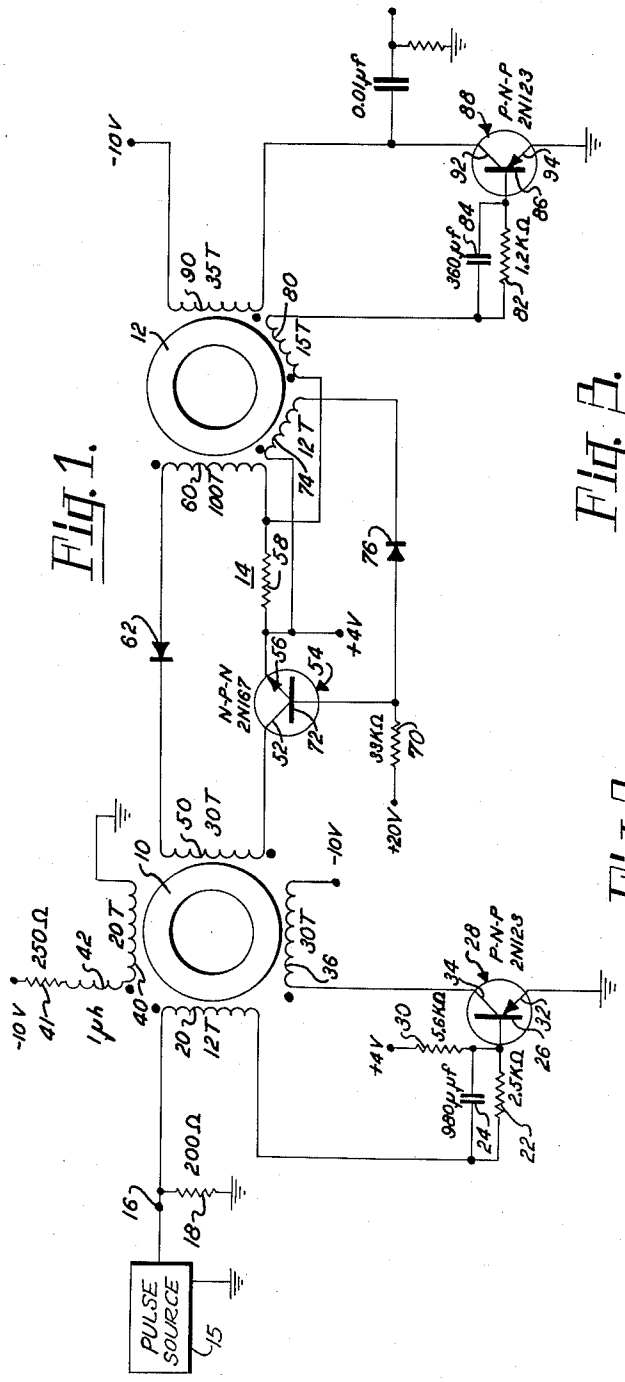


FIG. 1.

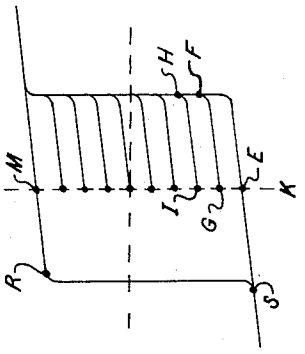


FIG. 3.

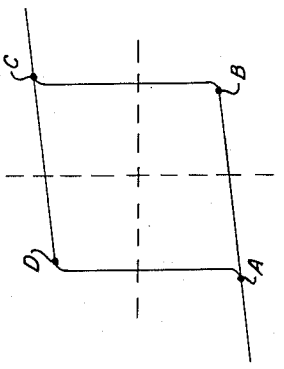


FIG. 4.

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TRANSFER CIRCUIT

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3 Claims. (Cl. 340—174)

This invention relates to magnetic storage devices and more particularly to a transfer circuit for conveying information from one magnetic element to another.

This invention is an improvement over the application of T. C. Chen and R. A. Tracy entitled "Magnetic Device" bearing Serial No. 498,257, filed on March 31, 1955, and assigned to the same assignee as this application.

When magnetic elements such as magnetic cores are employed for information storage purposes, it is often essential or desirable to transfer information from one magnetic core to another. To accomplish this, various sorts of transfer circuits have been employed and resort made to various techniques. Basically there is the problem of reliably transferring information in the least possible time with a minimum of driving power. Normally where more speed is desired, greater power is required and this results in overloading the driving equipment with a consequent impairment of reliability. With these considerations in mind and with due regard for economies in manufacture and repair, a transfer circuit is provided according to the present invention which is relatively simple in construction, reliable in operation and capable of performing at a much greater speed than such previously known devices.

In a preferred embodiment of this invention, information transferred from a first core to a second core is conveyed by a transfer circuit including an output winding on the first core, an input winding on the second core, a diode connected between the two windings to prevent the flow of reverse currents and a switch device such as a transistor, vacuum tube or the like connected between the two windings. The switch device normally is biased into a current conductive state, closing the circuit between the two windings. A second winding is provided on the second core and connected to the switch device in a manner to overcome the effect of the bias and inhibit current conduction during a reset operation of the second core. As long as inforamtion signals are presented to the transfer circuit by the first core the switch device remains closed, and these signals are conveyed to the second core. When the second core is reset, the second winding thereon causes the switch device to be opened and current flow inhibited in the transfer circuit during the period the second score undergoes a change in magnetic state in a reset operation. In effect the transfer circuit decouples the first and second cores whenever the second core is reset. This reduces the power required to reset the second core which thereby relieves the power requirements of the driving equipment, resulting in increased reliability of operation. In addition the period of a reset operation is decreased thereby permitting the transfer of information from one magnetic core to another in a shorter period. Hence the speed of operation may be increased by approximately a factor of two over some previously known devices.

These and other features of this invention may be more

fully appreciated when considered in the light of the following specification and drawings in which:

Fig. 1 shows one illustrative circuit arrangement incorporating the principles of the present invention;

Fig. 2 illustrates the manner in which one of the cores in Fig. 1 is operated along its hysteresis characteristic curve;

Fig. 3 illustrates the manner in which the other core in Fig. 1 is operated along its hysteresis characteristic curve.

Referring first to Fig. 1, magnetic elements **10** and **12** are coupled by a transfer circuit designated generally at **14**. While the type of information transferred between the cores may be any one of several types employed for mathematical or other logical functions, a counting device is arbitrarily selected for illustrative purposes. In the usual sequence of operations for a device of this sort, pulses to be counted are applied to a terminal **16** from a pulse source **15** and are temporarily stored in the magnetic element **10**, preferably a magnetic quantizing core, and is subsequently conveyed through the transfer circuit **14** to the magnetic element **12** which may be a magnetic core also arranged as a counting core. The quantizing core **10** receives the pulses to be counted and provides a "quantizing" output pulse proportioned to step the count core **12** up its hysteresis characteristic a preselected amount. As pointed out subsequently, the magnetic counting core **12** requires nine pulses in order to change it from its initial magnetic state to the opposite magnetic state. Each pulse causes the core to step up its hysteresis curve substantially the same amount to assume a different condition of magnetization along its characteristic curve. The tenth pulse causes the magnetic core **12** to be reset to its initial magnetic state, in a manner explained subsequently. It is now apparent that functionally the magnetic core **10** acts as a quantizer core and the magnetic core **12** as a count core.

Pulses applied to an input terminal **16** develop a voltage drop across a resistor **18**. The pulses are applied through a winding **20** and an RC network, including a resistor **22** and a condenser **24**, to a base electrode **26** of a transistor **28**. Each pulse applied to the terminal **16** is sufficiently negative to overcome the effect of a positive cutoff bias applied through a resistor **30** to the base electrode **26** and cause current conduction from the emitter electrode **32** to the collector electrode **34**. The emitter electrode **32** is connected to ground while the collector electrode **34** is connected through a winding **36** to a negative source of voltage. Because of the cutoff bias applied to the base electrode **26**, no current normally flows through the transistor **28**. When a negative pulse is applied to the input terminal **16**, sufficient in magnitude to overcome the biasing effect of the positive 4 volts, current flows from the emitter **32** to the collector **34** through the winding **36** to the negative source of voltage. Because of the current flow through the winding **36**, the magnetic core **10** commences to change its magnetic state, and as a result of this change a signal is induced in the winding **20** which aids the input signal at the terminal **16** to overcome the cutoff bias applied to the base **26**. The input signal has a short duration but is sufficiently long to insure that the feedback action from the winding **36** to the winding **20** is initiated. After the input signal terminates the positive feedback action between the winding **36** and the winding **20** continues to maintain the transistor **28** in the conductive condition until the magnetic core **10** undergoes a complete change in magnetic state.

Referring now to Fig. 2, the changes which take place in the magnetic core **10** are illustrated. Prior to receipt of an input pulse to be counted on the terminal **16** in Fig. 1, the magnetic core **10** is biased at or to the left of the

point A in Fig. 2 by a direct current flowing through a winding 40 in Fig. 1. This current is supplied from a negative source of voltage through a resistor 41, a choke 42 and the coil 40 to ground. As soon as an input pulse to the terminal 16 causes current conduction in the emitter-collector circuit of the transistor 28, the magnetization of the core 10 changes toward the point B in Fig. 2. Once the change in flux of the core 10 is initiated the feedback action between the windings 36 and 20 maintains the transistor 28 in the conductive state, and the magnetization of the core 10 passes through the point B in Fig. 2 and continues toward the point C. As the magnetization of the core 10 approaches the point C, the feedback between the winding 36 and the winding 20 commences to decrease. This causes the effective bias at the base electrode 26 to become slightly more positive. The effect is to reduce current conduction in the transistor 28 which in turn decreases current flow in the winding 36. The feedback to the winding 20 is thus reduced. The decrease in the feedback signal continues in a cumulative manner until the cutoff bias coupled to the base electrode 26 assumes control and cuts off current conduction in the transistor 28. As a result of the D.C. bias in the winding 40, the magnetization of the core 10 moves from the point C in Fig. 2 toward the left to the point D, then down at or to the left of the point A. A signal is induced in the winding 50 as the core 10 changes its magnetization from the point A to the point C in Fig. 2. As a result of this signal current flows from the winding 50 to the collector electrode 52 of a transistor 54, then to the emitter electrode 56, through a resistor 58, a winding 60, a diode 62 and back to the winding 50. When the core 10 undergoes a change in its magnetic state from the point C to the point A in Fig. 2, a signal is induced in the winding 50, but this signal is of a reverse polarity which is ineffective to cause current conduction in the transfer circuit 14 because the diode 62 is back-biased and does not conduct.

The quantized signal delivered to the winding 60 in response to a pulse to be counted causes only an incremental change in the magnetization of the core 12. Assuming that the core 12 in Fig. 1 is in the state of magnetization indicated by the point E in Fig. 3 when a signal is applied to the winding 60, the magnetization of the core 12 changes from that indicated at point E in Fig. 3 to that indicated at point F. When the signal to the winding 60 terminates the magnetization of the core 12 changes from point F back to the point G. If another pulse is applied to the input terminal 16 in Fig. 1, the preceding sequence of events described with respect to the core 10 and the transfer circuit 14 are repeated; the winding 60 on the core 12 is pulsed; and the magnetization of the core 12 moves from point G, out to point F and up to point H. When the pulse signal in the winding 60 terminates, the magnetization of the core 12 moves from the point H back along the left to the point I. In a similar manner subsequent pulses to the input terminal 16 causes the magnetization of the core 12 to move upwardly along the line KL in increments as illustrated. At the end of nine pulses the magnetization of the core 12 is that indicated by the point M in Fig. 3.

The transistor 54 in Fig. 1 is normally biased in the conductive state by means of a positive bias source coupled through a resistor 70 to the base electrode 72. A positive bias source is connected directly to the emitter electrode 56. A winding 74 and a diode 76 are connected between the emitter 56 and the base 72. When the transistor 54 is conducting, the voltage drop between the emitter 56 and the base 72 is made less than the breakdown voltage of the diode 76. Consequently no current flows through the winding 74 and the diode 76, and no magnetomotive force is applied to the core 12 by the winding 74. The plus 4 volts bias source coupled to the emitter 56 is also supplied through the resistor 58, a winding 80, an RC network comprising a resistor 82 and a condenser 84 to a base electrode 86 of a transistor 88. The transistor 88 is normally biased off by means of the positive 4-volt bias connected to the resistor 58. Accordingly, the winding 80 supplies no magnetomotive force to the magnetic core 12.

The quantized voltage developed across the winding 50 in Fig. 1 from any one of the first nine pulses to be counted delivered to the terminal 16 is distributed to the various elements serially connected in the transfer circuit 14. However, the major portion of the signal from the winding 50 is developed as a drop across the winding 60 on the magnetic core 12 because the impedance of this winding is very high for each of the first nine pulses. The portion of the signal across the winding 50 developed as a voltage drop across the resistor 58 is nominal in value, while the voltage drop through the collector-emitter circuit of the transistor 54 and the voltage drop across the diode 62 are negligibly small. When the tenth pulse is applied to the input terminal 16, the resulting pulse across the winding 50 finds a low impedance in the winding 60; as a consequence a larger current flows in the transfer circuit 14; and most of the voltage induced in the winding 50 is developed as a voltage drop across the resistor 58. It is readily seen from Fig. 3 that the tenth pulse finds the magnetic core 12 saturated and in the magnetic state indicated by the point M. Since the magnetic core 12 is saturated, little or no back E.M.F. is induced in the winding 60, and hence it has very low impedance. Thus the voltage in the winding 50 is developed primarily as a large drop across the resistor 58 and a very small or nominal drop across the winding 60. The voltage drop in the collector-emitter circuit of the transistor 54 and the drop across the diode 62 remain negligibly small. The relatively large drop across the resistor 58 is of such a polarity as to oppose the plus 4 volt cutoff bias coupled to this resistor. Consequently the voltage drop across the resistor 58 causes the transistor 88 to become conductive, and current flows from ground to the emitter 94 to a collector electrode 92, and through a winding 90 to a negative voltage source. The current flow in the winding 90 creates a magnetomotive force on the core 12 which changes its magnetization from the point M in Fig. 3 toward the point R and down along the curve to the point S. In the process a signal is induced in the winding 80 which counteracts the positive 4 volt cutoff bias coupled to the resistor 58, tending normally to bias off the transistor 88. A positive feedback action is developed between the windings 90 and 80 on the core 12 which maintains the transistor 88 conductive after the termination of the signal induced on the winding 50 in substantially the same manner in which the positive feedback action of the windings 36 and 20 on the core 10 maintained current conduction in the transistor 28 after the termination of an input pulse to the terminal 16. The pulse induced across the winding 50 must terminate before the reset action of the core 12 is completed. Hence the relatively large drop developed across the resistor 58 by the tenth pulse serves merely to overcome the positive 4 volt cutoff bias applied to the base electrode 86 through the resistor 58 and thereby initiate current conduction in the transistor 88. The feedback action between the windings 90 and 80 maintains the transistor 88 current conductive. Thus conduction of the transistor 88 is insured and current continues to flow through the winding 90 while the magnetic core 12 changes its magnetic state from that indicated by point M to that indicated by the point S of the curve in Fig. 3. As the magnetization of the core 12 approaches the point S, the feedback signal from the winding 90 to the winding 80 commences to decrease in the manner explained above with respect to the windings 36 and 20 on the core 10. This decrease in the feedback signal continues until the positive 4 volt cutoff bias coupled to the resistor 58 assumes control and cuts off current conduction in the transistor 88. When this occurs current

ceases to flow in the winding **90**, and the state of magnetization of the core **12** changes from that indicated at point S to the condition indicated at point E which is the initial state of magnetization of the core **12**.

It is appropriate at this point to compare the operation of the transfer circuit **14** with and without the transistor **54**. Assuming first that this transistor is omitted and the lower end of the winding **50** and the resistor **58** are directly connected, the transfer circuit **14** is not capable of being opened during the period when the magnetic core **12** is changing its magnetic state from that indicated by the point M in Fig. 3 to that indicated by the point E, and a large signal is induced in the winding **60** and applied across the diode **62** in a forward direction. Consequently the transfer circuit **14** tends to conduct a heavy current, and since the energy for this current is supplied ultimately by the negative voltage source connected to the winding **90**, a relatively heavy current flows through the transistor **88**. The transistor **88** is operated in the saturated condition during this period. However, when the core **12** reaches the magnetic state indicated by the point S in Fig. 3, little or no signals are induced in the windings **80** and **90**. Accordingly, the positive bias source connected through the resistor **58** to the base electrode **86** tends to cut off current conduction from the emitter **94** to the collector **92** of the transistor **88**. Current conduction in this transistor does not cease abruptly. Instead, it gradually decays to zero. Since the core **12** undergoes only a slight change in magnetic state as it changes from the point S in Fig. 3 to the point E, there is little voltage induced in the winding **90**. Thus the voltage applied between the emitter **94** anud the collector **92** of the transistor **88** is substantially equal to the negative voltage source connected to the winding **90**, and the dissipated power in the transistor **88** is extremely high, sometimes as high as one hundred times the average rated power dissipation, during this period. Briefly summarizing the foregoing, the transistor **88** is saturated and conducts a heavy current when the core **12** changes from point M to R to S in Fig. 3. But there is very little voltage drop across the transistor at this time, and the power dissipation is low. As the core **12** changes from point S to E in Fig. 3, current conduction in the transistor **88** gradually decays to zero. But the voltage from the negative 10 volts source connected to the winding **90** is almost entirely across the transistor **88** because very little drop is developed across the winding **90** as the core **12** has been switched. Consequently, with current conduction in and relatively high voltage drop across the transistor **88**, the power dissipation is very high, reaching as much as one hundred times the rated power dissipation during the brief period the transistor is being turned off. This high dissipation tends to shorten the life of the transistor **88**, and consequently it is rendered less reliable in operation. In addition, a heavy current in the transfer circuit during a reset operation of the core **12** makes the period of time relatively long to change the condition of the magnetic core **12** from point M in Fig. 3 to point E.

Considering next the operation of the transfer circuit **14** with the transistor **54** connected therein, assume that the core **12** undergoes a change in magnetic condition from the point M through the points R and S to the point E in Fig. 3. The transistor **54**, the winding **74** and the diode **76** are employed to open the transfer circuit **14**. It is recalled that the diode **76** is normally nonconductive because the drop across the emitter-base circuit of the transistor **54** is less than the forward threshold or breakdown voltage of the diode **76**. However, a signal is induced in the winding **74** as the core **12** changes its magnetic condition during a reset operation from the point M in Fig. 3 to the point E. This signal is sufficient in magnitude and of the proper polarity to cause conduction of the diode **76**. Thus the signal induced in the winding **74** is applied between the base electrode **72** and the emitter **56** of the transistor **54**. It is sufficiently negative to terminate current conduction in this transistor. The transistor **54** acts as a switch which is normally closed but is opened when a signal is induced in the winding **74** as the magnetic core **12** changes from the magnetic condition indicated at point M in Fig. 3 through the points R and S to the point E. Since the transfer circuit **14** conducts no current during this change in state of the magnetic core **12**, considerably less current flows through the winding **90** and the transistor **88** than in the previously described instance. Like the above described operation, the positive bias connected through the resistor **58** to the base electrode **86** gradually assumes control and terminates current conduction from the emitter **94** to the collector **92** of the transistor **88**, and during the process the negative voltage source connected to the winding **90** is applied almost entirely across the transistor **88**. However, because the maximum current flow through this transistor is much less in this instance, the dissipated power in the transistor **88** is reduced considerably to a value within safe limits. Hence the reliability of the transistor **88** is increased because its useful life is extended. Also, the time required to reset the core **12** may be substantially decreased, and this may serve to shorten the basic time cycle required to count the core **12** through a complete cycle of 10 pulses one of which causes a reset operation. Accordingly, the repetition rate of pulse applied to the input terminal **16** may be increased.

What is claimed is:

1. In combination, a first magnetic core having an input winding and an output winding coupled to the core, said input winding including a pair of windings coupled to said core in a positive feedback arrangement and serially connected by means of a switching element, a source of pulses coupled to the input winding whereby the pulses switch the magnetic state of said core, a second magnetic core having an input winding and a reset winding, said reset winding including a pair of windings coupled to the second core in a positive feedback arrangement and serially connected by means of a switching element, a unilateral transfer loop coupled between the output winding of the first magnetic core and the input winding of the second core arranged to deliver only pulses of a preselected polarity to the second core, the output winding of the first core is defined to provide pulses for changing the magnetic condition of the second core along its hysteresis characteristic from one magnetic remanent point to the other remanent point, and circuit means including a switching winding coupled to the second core switchable between two conductive conditions and coupled to the transfer loop to control the conductivity thereof and arranged in one conductive condition to deliver pulses from the first core to the second core, said switching winding is arranged to be responsive to the switching of the second core from said other remanent point to said one remanent point for changing its conductive condition during this switching interval whereby the feedback arrangement of said reset winding maintains this changed conductive conditon for a preselected interval after the termination of the pulse effective to switch the second core from the said other remanent point to said one remanent point.

2. In combination, a first magnetic core having an input winding and an output winding coupled to the core, a source of pulses coupled to the input winding whereby the pulses switch the magnetic state of said core, a second magnetic core having an input winding and a reset winding, said reset winding including a pair of windings coupled to the second core in a positive feedback arrangement and serially connected by means of a switching element, a unilateral transfer loop coupled between the output winding of the first magnetic core and the input winding of the second core arranged to deliver only pulses of a preselected polarity to the second core, the output

winding of the first core is defined to provide pulses for changing the magnetic condition of the second core along its hysteresis characteristic from one magnetic remanent point to the other remanent point, and circuit means switchable between two conductive conditions and coupled to the transfer loop to control the conductivity thereof and arranged in one conductive condition to deliver pulses from the first core to the second core, said circuit means comprising a normally conductive switching element serially connected with an impedance device and a switching winding coupled to the second core, said reset winding is coupled to said circuit means intermediate the impedance device and the input winding of said second core to control the switching element for said reset winding and thereby the switching of the second core from said other remanent point to said one remanent point, said switching winding is arranged to be responsive to the latter mentioned switching of the second core for changing the conductive condition of the switching element for the circuit means during this switching interval whereby the feedback arrangement of said reset winding maintains this changed conductive condition for a preselected interval after the termination of the pulse from the first core effective to switch the second core from the said other remanent point to said one remanent point.

3. A counter comprising a quantizing magnetic core having at least an input winding and an output winding coupled to the core, a source of pulses to be counted coupled to the input winding, a counting magnetic core having at least an input winding and a reset winding, each of said magnetic cores having a substantially rectangular hysteresis loop, a unilateral transfer loop coupled between the output winding of the quantizing magnetic core and the input winding of the count core arranged to deliver only quantized pulses to be counted to the count core, the output winding of the quantizing core as defined to provide pulses to be counted for stepping the count core along its hysteresis characteristic from one magnetic remanent point to the other remanent point in preselected increments, and a circuit means connected to the transfer loop for controlling the conductive condition thereof and arranged in one conductive condition to deliver the quantized pulses to be counted to the count core, said circuit means including a switching winding coupled to said count core and arranged to be responsive to the switching of the count core from said other remanent point to said one remanent point for changing the one conductive condition of said circuit means to its other conductive condition during this latter mentioned switching interval, said circuit means further including impedance means connected to the reset winding for the count core and providing a signal to said reset winding when the count core is at the other remanent point effective to switch the count core to said one remanent point.

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