March 3, 1970 T. W. CUNNINGHAM 3,498,168

DIGITAL COMBINATION ACTION

Filed Dec. 22, 1966 2 Sheets-Sheet 1

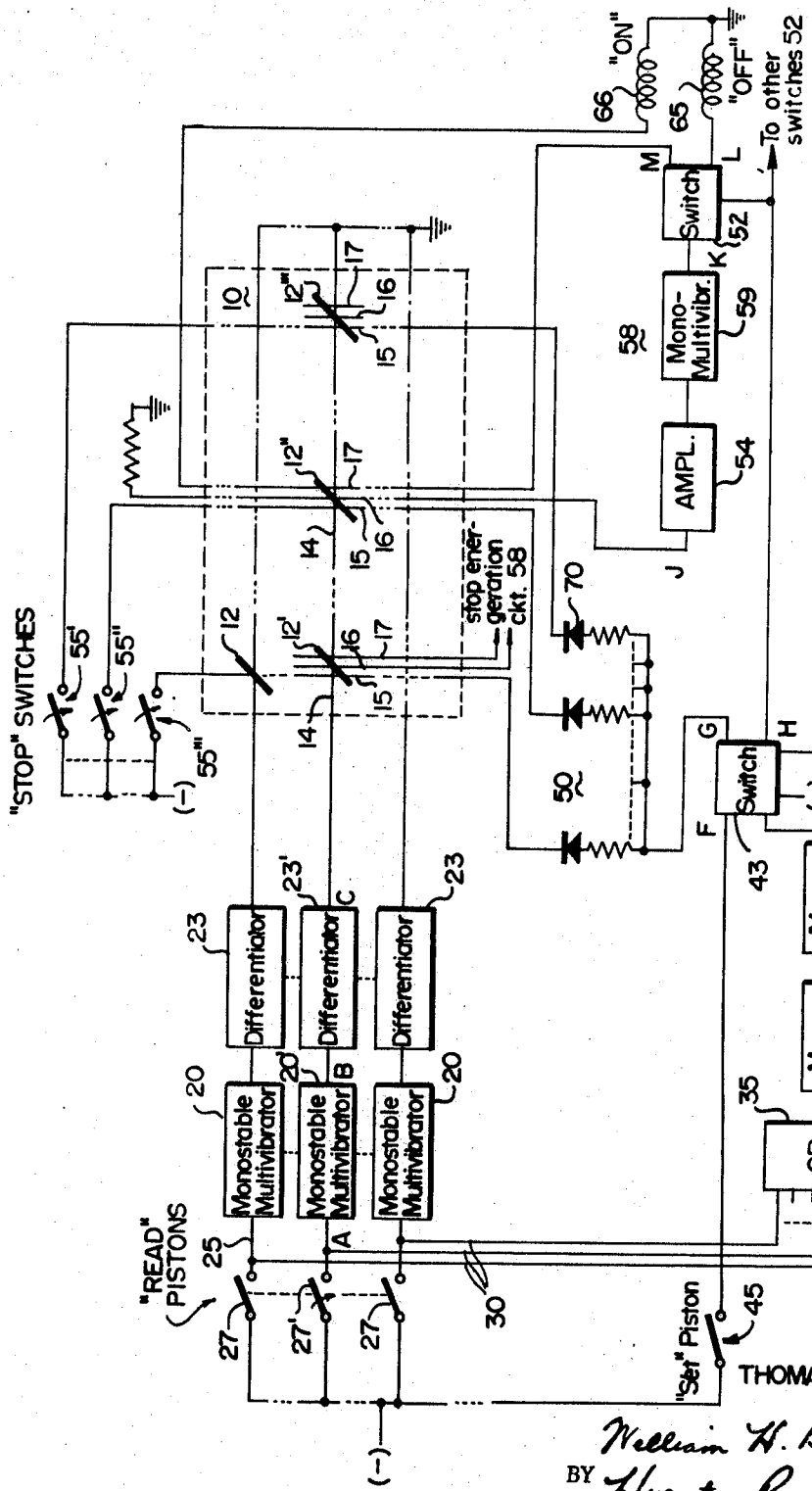


Fig. 1

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WAVEFORMS

FIG. 2

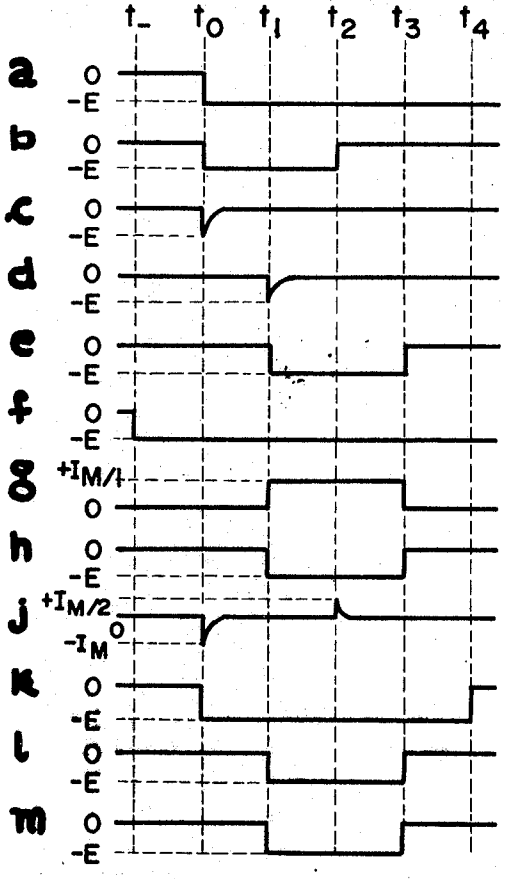


FIG. 3

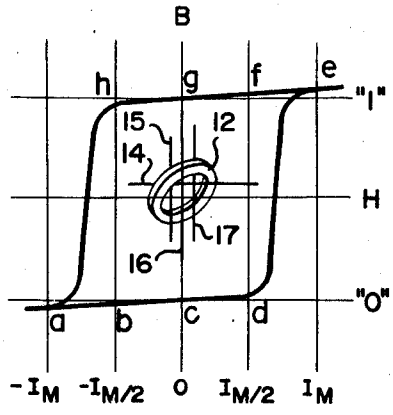


FIG. 5

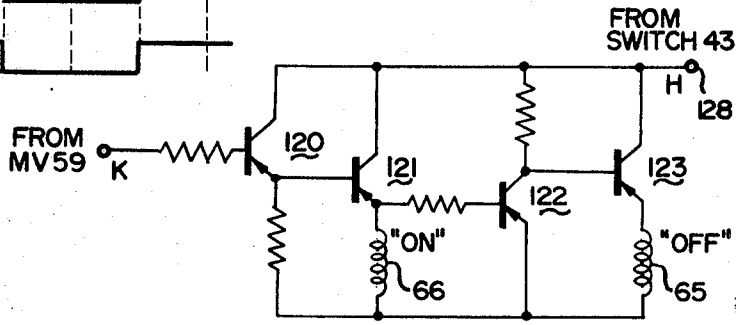
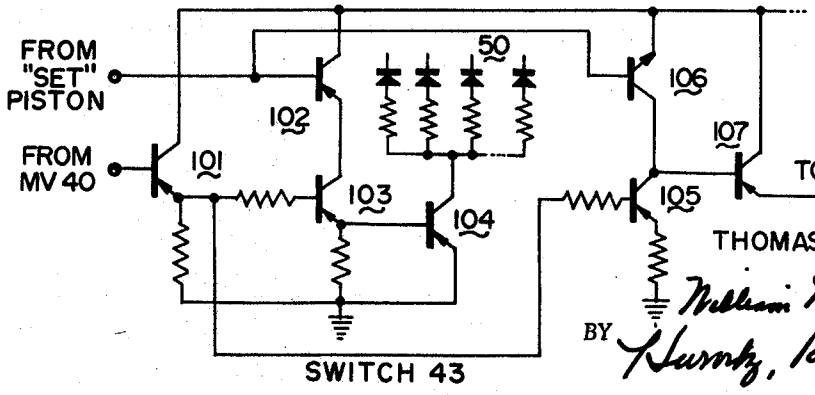


FIG. 4



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3,498,168

DIGITAL COMBINATION ACTION

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Int. Cl. G10b 3/10
U.S. Cl. 84—345 13 Claims

ABSTRACT OF THE DISCLOSURE

An electric organ having a plurality of distinct organ voices that may be called forth by selected operation of switches on an organ keyboard includes an array of binary memory elements arranged in groups, each memory element associated with a respective predetermined organ voice, and in which a binary number is entered into any group of the memory elements in the array to represent the combination of organ voices with which that group of elements is to be associated, for subsequently calling forth that combination upon accessing of the group of memory elements into which that number has been entered. Any group of memory elements in the array is accessed at will, according to the desired combination of organ voices to be brought on, to read out the number that had been entered into the accessed group of memory elements. In response to readout of the number from an accessed group of memory elements the respective combination or organ voices is called forth and simultaneously therewith the number that has been read out is re-entered into the same group of memory elements to permit subsequently calling forth the same combination of organ voices at a later time in the musical selection.

The present invention relates generally to programmable memory control systems, and more particularly to a programmable memory control unit for use as a digital combination action in the presetting and subsequent selection of desired combinations of stops or tabs of electric organs or pipe organs.

Selection of a particular function of the organ for desired voicing or tone color is accomplished by the positioning of stops in the pipe organ, devices for controlling the flow of air through the resonant pipes, or of tabs in electric organs, devices for controlling the output of waveshaping networks (voicing circuits) to simulate control of air flow through resonant pipes. Typically, the tabs or stops are prepositioned or preset in various combinations, as desired to provide the voicing for a particular musical selection or selections, and introduced by the organist at appropriate points during the playing of the selection by operation of pistons, which may be push buttons, switches or other selecting devices, on the front portion of the organ console adjacent the keyboard (or keyboards) of the instrument. Each piston is adapted to "bring on" or "call forth" a different preset combination of stops by operation in conjunction with a control unit, referred to in the art as a combination action."

The earliest combination actions for organs were entirely mechanical in nature, consisting of linkages including levers, latches and/or cams between piston and stops. More recently, combination actions comprising electromechanical or photoelectric devices have been utilized. In general, however, the prior art combination actions are bulky, complex, difficult to set in advance of a performance and substantially incapable of change in setting with any degree of rapidity, undergo rapid wear, and of even more serious nature, are noisy in operation.

Accordingly, it is a principal object of the present invention to provide an improved combination action for voicing or tone color control in organs.

A more specific object of the invention resides in the provision of a digital combination action in the form of a programmable memory control unit for selectively introducing distinct and different organ functions in the performance of a musical selection.

Another object is to provide a combination action which overcomes one or more of the aforementioned disadvantages of prior art combination actions.

Still another object of the present invention is to provide a digital combination action for pipe organs or electric organs by which the desired combination to be introduced by actuation of each piston is stored in a memory matrix of bistable elements, from which each combination may be called forth during performance of a musical selection, with retention of the original contents of the memory until a change of contents is desired.

A further object of the invention is to provide a digital control circuit by which various combinations of binary controls may be exercised repetitively in any desired sequence after an initial rapidly-effected programming of the circuit.

Briefly, in accordance with the present invention, the control circuit comprises a memory matrix of bistable switching elements arranged in rows and columns, each row (or column) of elements associated with a particular one of a set of switches for exercising various desired combinations of controls on selected ones of a plurality of devices electrically and independently operable to either of two states, and each column (or row) of elements associated with a particular one of said plurality of devices; means including said switches for selectively energizing each element in any row of said elements to either of its bistable states in accordance with the desired combination of controls to be exercised by the switch operatively associated with that row; means for selectively transferring signals generated by those elements restored to the initial stable state, after energization by a respective switch to the other stable state, to the respective ones of said devices associated with those elements; said switches being operable one at a time to restore the energized elements in the associated row to said initial stable state.

In accordance with a preferred embodiment of the invention, for use as a combination action in an organ, each bistable switching or storage element of the memory matrix comprises a magnetic core having at least three windings thereon. One of the windings is common to all cores in any given row of the matrix and is coupled to the control switch (here, a piston) for that row by a pulse forming network. The other two windings are common to all cores in any given column of the matrix and are coupled respectively to any actuated control switch (piston) via a second pulse forming network and to a network for energizing the organ stop associated with the given column.

Preselection of stop combinations for each piston is effected by actuation of the piston in conjunction with operation of the two pulse forming networks to "reset" and then "set" the appropriate cores. Subsequent introduction of a particular combination during performance of a musical selection is accomplished by re-actuating the piston to trigger the operation of the pulse forming networks such that the "set" cores are "reset" and thence trigger the respective stop-energizing network. Writing in of the initial condition ("set" state) of each core of the given row after the stop combination for that row is energized, is achieved by providing a third winding for each column, arranged to be energized by the output of the stop-energizing network. Hence the stop-energizing network is effective to operate a stop to the "on" or "off" condition, and simultaneously therewith, to restore the initial setting of the cores.

Accordingly, it is a further object of the invention to

provide an organ combination action wherein selection of stop combinations is accomplished by control of the states of a plurality of bistable electromagnetic storage elements arranged in a memory plane matrix.

Still another object is to provide an organ combination action for selection of stop combinations in accordance with the preset states of binary storage elements of a memory matrix and wherein selection of any given combination of stops is produced by a change of state of the preset elements and is accomplished by restoration of the elements of changed state to the respective preset states.

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of a preferred embodiment thereof, especially when taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a circuit diagram of a preferred embodiment of the invention;

FIGURE 2 is a chart illustrating the timing and character of waveforms generated at various points in the circuit of FIGURE 1;

FIGURE 3 is an exemplary diagram of a typical hysteresis loop of each of the magnetic cores in the memory plane matrix of the circuit of FIGURE 1;

FIGURE 4 is a circuit diagram of a switch for controlling the initial and subsequent states of the bistable magnetic cores in the memory plane of FIGURE 1; and

FIGURE 5 is a circuit diagram of a switch for controlling the energization of a stop in the selected combination of stops in accordance with the initial state of each core in that portion of the memory plane associated therewith.

Referring now to the drawings, and more specifically to FIGURE 1 thereof, a preferred embodiment of the digital combination action according to the present invention includes a storage unit or memory plane **10** comprising a matrix of magnetic cores **12**, preferably ferrite, each core having four windings, designated **14**, **15**, **16** and **17**. Winding **14** of each core, shown as a line parallel to the X (row) axis of the matrix, is associated with a particular piston **27**, while each set of windings **15**, **16** and **17**, shown as lines parallel to the Y (column) axis, is associated with a particular stop.

Each core has a substantially rectangular hysteresis loop, typically of the nature illustrated in FIGURE 3, providing a binary storage function, as is well known. In a conventional manner, the B axis of the curve designates the state of magnetization (flux condition) of the core while the H axis is representative of magnetizing force applied to the core (coercive force of the core). Points *c* and *g* designate reverse directions of flux remaining in the core (remanence or residual flux) when winding currents drop to zero following core saturation. With the core in a "0" state (alternatively termed "off" or "reset" condition), described by point *c* of the B-H curve, the algebraic sum of the currents through the windings must be sufficient to produce positive saturation in order for the core to be switched to the "1" state. Similarly, if the core is in the "1" state (alternatively termed "on" or "set" condition), winding currents short of that sufficient to product negative saturation of the core are ineffective to switch the core to the "0" state.

Assuming, for example, the core condition existing at point *c*, it will be apparent that application of current of magnitude $I_m/2$ to the core windings will simply result in a change in flux to the condition at point *d*, leaving the core in a "0" state but at a point of instability along the curve. Hence, cessation of this current is accompanied by a return of the core to the stable state of remanence at point *c*. Application of "negative" current I_m, while sufficient to produce saturation, will similarly result in a return of the core to the original "0" condition when the current is removed. Continuing with the same assumption of original or initial state "0," a winding current of $+I_m$ or winding currents algebraically totalling $+I_m$ results in a switching of the core to the "1" state at point *e*, and thence to the stable condition at point *g* when the current or currents are removed. Similar considerations are applicable where the core is initially in the "1" state.

It is apparent, then, that each magnetic core constitutes a bistable device or element capable of being switched or triggered from one stable state to the other, or vice versa, upon application of respective binary pulses of predetermined value. Successive application of pulses of the same binary value is ineffective to produce switching if the core state is presently that associated with an input pulse of that value. Similarly, no switching is effected unless the trigger pulse is of sufficient magnitude, i.e., of predetermined value. Accordingly, each bistable element is capable of remembering the last "significant" command and of ignoring commands occurring between those which are "significant." Alternatively, each bistable device may be considered a one-bit memory or storage unit.

Returning now to FIGURE 1, the digital combination action for an organ includes, in addition to the matrix **10** of bistable elements, a separate monostable ("one-shot") multivibrator **20** (operating as a pulse stretcher) and differentiator **23** in the series circuit **25** associated with each organ piston **27** (designated as a switch in the drawing for the sake of simplicity and clarity) and with winding **14** of the set of cores **12** of each row of the matrix. The organ, of course, is provided with several pistons, each associated with the windings **14** of the cores in a distinct and different row of the matrix **10** and each having in series circuit therewith a distinct and different multivibrator **20** and differentiator **23**. For purposes which will subsequently become clear, each of pistons **27** is designated a "read" piston.

When actuated, each "read" piston **27** connects an input terminal of the associated multivibrator **20** to a source of negative potential (designated (−) in the figure). The negative step function (pulse) is also applied to a second circuit path **30**, associated with the respective piston, connected to an input terminal of OR gate **35**. It will be observed that the OR gate is common to all "read" pistons so that a pulse appearing at any one or more of its input terminals is supplied to a monostable multivibrator **38** operating as a pulse delay unit. The output of one-shot multivibrator **38** is applied as an input to a pulse stretcher **40** (another monostable multivibrator) and the output of the latter fed to a switch **43**, a detailed embodiment of which will presently be described. A second input to the switch **43** is supplied in the form of a negative pulse upon actuation of the sole "set" piston **45** of the organ console.

Switch **43** is adapted, when energized by concurrent pulses from one shot multivibrator **40** and "set" piston **45**, to connect a plurality of stop circuits **50**, one circuit associated with each stop, to a point of reference potential, designated as ground potential. On the other hand, switch **43** is responsive to energization by a negative pulse from multivibrator **40** alone to connect an input terminal of a further switch **52** of each of a plurality of stop-energization circuits **58** to a source of negative potential.

Each of the stop circuits **50** includes the windings **15** associated with the cores in a respective column of matrix **10** and a specific one of a plurality of "stop" switches **55**, equal in number to the number of stops or tabs in the organ.

The common lead for the winding **16** of each of the cores in a respective column of the matrix is connected between a point of ground potential and the input terminal of a pulse amplifier **54** in a separate one of the plurality of circuits **58** each associated with a specific stop or tab of the organ. Each circuit **58** further includes a pulse stretching monostable multivibrator **59** to which the amplifier output is applied, and the previously men-

tioned switch **52**. The latter switch is implemented to supply the output from switch **43** to either the "off" coil **65** or the "on" coil **66** of an associated one of the conventional solenoid operated tabs (through winding **17** of the set of cores in the respective column of matrix **10**, in the case of the "on" coil), depending respectively upon the absence or presence of a pulse at its input terminal connected to multivibrator **59**.

Each of one-shot multivibrators **20**, **38**, **40** and **59**, differentiator **23**, OR gate **35**, and amplifier **54** may be of any conventional design suitable for the intended purpose. Since each of these components is of a type well known in the art and readily implemented by reference to any standard text, it is unnecessary to supply a detailed description thereof to the ordinarily skilled person to whom this specification is addressed. Monostable multivibrators, for example, may be implemented to operate as pulse stretchers or pulse delay devices by appropriate adjustment of elements determining time duration of the quasi-stable state or determining time interval between application of trigger pulse and assumption of quasi-stable state, respectively. Millman et al., Pulse and Digital Circuits (McGraw-Hill 1956), is representative of the multitude of texts available on the subject. It will further be apparent to those skilled in the pertinent art that other components capable of performing the same function may be utilized in place of the multivibrators. Embodiments of switches **43** and **52**, while admitting of a wide variety of possible modifications and different implementations, will be described in detail presently.

Since the number of cores in any row of matrix **10** corresponds to the number of stops available in the organ, i.e., each core of a row associated with a particular stop, and the number of cores in any column of the matrix corresponds to the number of "read" pistons available in the organ, i.e., each core of a column associated with a particular piston, it is a simple matter for the organist to rapidly select the voice combination desired for each piston. Assuming, for example, that piston **27'** is to bring on the combination of stops associated with cores **12'**, **12''**, and **12'''** of matrix **10** during the performance of a musical selection, the procedure for presetting the cores is as follows (concurrent reference being made to FIGURE 2).

Initially, "set" piston **45** is actuated (i.e., depressed in the case of a push button) at a time which will arbitrarily be designated t—, thereby supplying a negative step function of magnitude —E (the level of potential of the negative voltage source to which piston **45** is connected) to an input terminal of switch **43**. The "set" piston is maintained in the actuated position throughout the preselection of voice combinations to be introduced by actuation of each "read" piston **27**. The negative voltage step resulting from closure of switch **45** is shown as waveform F in FIGURE 2.

Each stop switch **55** associated with a stop or tab to be brought on by a particular "read" piston during performance of a musical selection is closed, thus connecting common winding **15** of the matrix column associated with that stop switch to a point of negative potential (also having a voltage level —E). The mere application of step function F to switch **43** is ineffective to actuate that switch, as will presently be explained, so that as yet no energized circuits are established through the total combination action circuit.

The "read" piston **27** of interest, assumed above to be **27'**, is now actuated, at a time designated t_0, so that a negative voltage step, shown as waveform A in FIGURE 2, is applied in parallel to monostable multivibrator **20'** and OR gate **35**. The output of the OR gate is, of course, simply the negative voltage step A, which is applied to monostable multivibrator **38**. Multivibrator **20'** is, as previously stated, a pulse stretcher, operating when triggered by voltage step A to produce a pulse of duration (width) t_2-t_0 (waveform B, FIGURE 2). Multivibrator **38**, on the other hand, is employed as a pulse delay device and assumes, a predetermined interval following application of triggering voltage thereto, its quasi-stable state for only a fraction of the duration of the pulse B generated by multivibrator **20'**. Specifically, the output of multivibrator **38** is illustrated as waveform D of FIGURE 2, occurring at a time t_1.

Differentiation of pulse B by differentiator **23'** produces a pulse train designated by C of FIGURE 2, a negative pulse of current amplitude $-I_m$ occurring at time t_0, coincident with the start of pulse B, and a positive pulse of current amplitude $+I_m/2$ occurring at time t_2, coincident with the termination of pulse B. The $-I_m$ pulse sets all cores **12** in that row of the matrix **10** associated with piston **27'** to the "0" or "off" state (FIGURE 3), in the manner previously explained.

Triggering of monostable multivibrator (pulse stretcher) **40** by pulse D results in a negative output pulse E (FIGURE 2) therefrom, extending from t_1 to t_3. Application of pulse E to switch **43** concurrently with negative voltage step F is effective to energize the switch to supply a ground connection to the parallel coupled terminals of stop circuits **50**. The ground connection is supplied over the interval from t_1 to t_3 in accordance with the timing and width of pulse E. Hence, each stop circuit **50** having a closed stop switch **55** (assumed, in this example, to be switches **55'**, **55''**, **55'''**), conducts a current pulse G of equal duration and coincident timing through the winding **15** thereof in a respective column of matrix **10**. Since current pulse $I_m/2$ of pulse train C flows through the common winding **14** for the row of cores **12** associated with piston **27'** during a portion of the time interval over which current pulse G, also of magnitude $I_m/2$, flows through a winding **15** of each column associated with a respective stop switch **55'**, **55''**, and **55'''**, each of cores **12'**, **12''** and **12'''** is switched to the "1" or "on" state. That is, the algebraic sum of the currents through the windings of each of these cores is I_m, sufficient to produce positive flux saturation and thus a change of state of the core.

Each of the cores associated with a respective stop or tab of the organ which is to be brought on by piston **27'** during the organ recital is now set to produce a particular voice combination. The same procedure is followed for the selection of a combination for each "read" piston. In each case, the desired ones of stop switches **55** are closed and undesired ones opened prior to proceeding with the advance selection of combination action for a given "read" piston.

During the advance selection of combinations each of circuits **58** is ineffective to produce any variation in the operation which has thus far been described, because of the absence of energizing voltage for switch **52** from switch **43**. After the advance selection has been completed, the calling forth of any particular combination merely requires that the "read" piston for which that combination has been preset be actuated, all stop switches **55** having been opened and the "set" piston **45** remaining unactuated.

Assuming actuation of piston **27'** during the performance of a musical selection, after the advance setting as in the above example, the operation of circuit **25** is that previously described. Similarly, there is no change in the aforementioned operation of the branch circuit including OR gate **35** and multivibrators **38** and **40**. In the absence of the negative step function F from "set" piston **45** (unactuated), however, switch **43** is operative to supply negative voltage to switch **52** coinciding with the timing and duration of pulse E from multivibrator **40**, as troduced by multivibrator **38**, current pulse $-I_m$ of pulse tion of pulse H is at time t_1 owing to the time delay introduced by multivibrator **38**, current pulse $-I_m$ of pulse train C, having occurred at time t_0, has previously

switched cores 12', 12'', 12''' from the "1" to the "0" state. Switching of these cores is accompanied by a pulse of current through each of windings 16 associated therewith, as indicated by the pulse occurring at time t_0 in waveform J of FIGURE 2. After amplification by pulse amplifier 54, each of these pulses triggers a monostable multivibrator (pulse stretcher) 59 in a respective circuit 58 to produce a negative voltage pulse K (FIGure 2) extending from approximately t_0 to t_4. Slight comparison of the timing and duration of pulses H and K will readily reveal that they are concurrently applied to switch 52 during a portion of the interval from t_0 to t_4 (specifically, from t_1 to t_3). Accordingly, switch 52 is energized to pass current, shown as pulse M of magnitude —I in FIGURE 2, through the respective winding 17 and the "on" coil 66 of the associated solenoid-actuated stop or tab.

Absent application of pulse K to a particular switch 52, because the associated core 12 had not previously been set (to the "1" state), the switch receives only an enabling pulse H of negative voltage from switch 43, effective to permit flow of negative current pulse L (FIGURE 2) through the "off" coil of the respective stop or tab. Hence, the desired combination, and only the desired combination, is brought on by actuation of a given "read" piston once the presetting of cores has been accomplished for that piston.

All cores are automatically reset to the condition existing at t_0, after actuation of the associated "read" piston, because current pulse M of magnitude $I \geq I_m/2$ passes through path 17 of the respective column of the matrix and adds a magnetizing force to that resulting from pulse C, also of magnitude $I_m/2$, to return the associated core to its preset state ("1" or "on"). Those cores which were initially in the "0" state are, of course, unchanged since no current pulse M flows through the associated windings 17.

All core coils are wound to effect the aforementioned proper switching of the cores, assuming currents of sufficient magnitude, irrespective of the arbitrary signs indicating direction of current flow in FIGURE 2. All voltage pulses (other than those which have been mentioned) induced in the core windings as a result of switching are of such polarity and magnitude that they are either blocked (as by diodes 70 of stop circuits 50) or are incapable of energizing the circuit.

It will be observed that rapid changes of combinations may be effected between musical pieces in the previously described manner by use of digital combination actions in accordance with the present invention. While each change of combination for a particular piston will initially result in switching of those cores in the "1" state (for the previous combination) to the "0" state and this effects application of a pulse to the associated amplifier, the respective switch 52 is unaffected since it requires an input pulse H before it can operate. No such pulse is forthcoming, of course, because switch 43 has pulses E and F concurrently applied thereto during presetting of the cores and can, under such conditions, only supply a ground connection to stop circuits 50.

Suitable embodiments of switches 43 and 53 are shown in FIGURES 4 and 5, respectively.

Referring to FIGURE 4, switch 43 comprises an input transistor 101 to which pulse E is to be applied, and an input transistor 102 to which pulse F is to be applied. The output circuit of transistor 102 is connected in series with the output circuit of a transistor 103, cascaded with transistor 101. A fourth transistor 104 receives an input from transistor 103 and has its collector electrode connected to the lead coupling terminals of stop circuits 50 in parallel. A further transistor 105 is cascaded with transistor 101 for parallel application, with transistor 103, of voltage therefrom. Transistor 105 has its output circuit series connected with the output circuit of a transistor 106, to which pulse F is also to be applied. The last transistor 107 has its base electrode connected to the emitter electrode of transistor 105 and its emitter electrode connected to an input terminal of switch 52.

Each of the transistors is of the PNP type, except for NPN transistor 106. Power is supplied to the switch from a voltage source designated —V and all transistors are normally biased to the non-conductive state (i.e., cut off) except for normally conductive transistor 106.

In operation, application of negative voltage step F to transistors 102 and 106 (upon actuation "set" piston 45) renders the former highly conductive and the latter non-conductive. Simultaneous application of negative pulse E to transistor 101 causes saturation thereof so that negative voltages are supplied to transistors 103 and 105 tending to switch them to the conductive state. Transistor 103 is connected to the source of power —V by conductive transistor 102, thereby placing its emitter (as a result of its similarly conductive state) at negative potential close to that of source —V. Transistor 105, however, is removed from voltage source —V by non-conductive transistor 106, so that it is ineffective to switch on transistor 107. Application of negative voltage to the base electrode of transistor 104 turns that transistor "on" to supply the desired ground connection to stop circuits 50.

As is apparent, application of negative voltage F alone to switch 43 is ineffective to actuate the switch.

Application of pulse E alone, however, as before, triggers transistor 101 to the conductive state so that its emitter is at approximately —V. Absence of the negative voltage step at the base electrodes of transistors 102 and 106 results in those transistors being in their normal conditions of cut off and saturation, respectively. Hence, transistor 105, switched to the conductive state by the negative voltage appearing at the emitter of transistor 101, supplies negative voltage to transistor 107 to trigger it to a conductive state and thereby supply negative voltage to switch 52 for the duration of these conditions. Transistor 103 is ineffective to supply switching voltage to transistor 104 because of the "open" condition of transistor 102.

Referring to FIGURE 5, each of switches 52 comprises four cascaded transistors (all PNP) designated 120, 121, 122, and 123. The emitter of transistor 121 is connected to the "on" coil 66 (through respective winding 17 of the cores) of the solenoid-actuated stop or tab, while the emitter of transistor 123 is connected to "off" coil 65. Transistors 120, 121, and 122 are normally biased "off" (non-conductive) and transistor 123 normally biased "on," when the switch is supplied with operating power. The operating power is supplied to terminal 128 in the form of negative voltage H (when the appropriate connection is provided by switch 43, of course). Consequently, application of pulse H alone is effective to produce a transfer of current to "off" coil through normally conductive transistor 123.

Absent a negative pulse H at terminal 128, of course, switch 52 is non-energized and incapable of operation.

Application of negative pulse K to the base electrode of transistor 120 concurrently with energization of the entire switch by pulse H is effective to render transistors 120, 121, and 122 conductive, and transistor 123 (having its base electrode grounded) non-conductive. Thus, current flows through "on" coil 66.

It is to be understood that the organ stops or tabs need not be solenoid-actuated but may be of any design suitable for actuation to either an "on" or an "off" condition by selective application of energizing voltages or currents from switch 52. For example, each stop may be an electro-pneumatic device such as an electromagnetic valve for permitting or blocking the passage of air into a bellows, or an electrically or electromagnetically operated diaphragm.

Moreover, while control circuits in accordance with the present invention are particularly suited for use as digital combination actions in organs, they may also be

used for any application requiring combinations of binary control by actuation of each of a set of switches.

For organ use, the following components (FIGURE 1) are required:

One per "read" piston:
- Pulse stretcher **20**
- Differentiator **23**

One per organ:
- OR gate **35**
- Pulse delay unit **38**
- Pulse stretcher **48**
- Switch **43**
- Memory plane **10**

One per stop or tab:
- Pulse amplifier **57**
- Pulse switcher **59**
- Switch **52**

I claim:

1. A circuit for controlling the combined operating states of desired groups of a plurality of electrically actuable devices each having at least two possible operating states, said circuit comprising

a matrix of bistable magnetic cores, each core characterized by a substantially rectangular hysteresis loop,

a plurality of actuable switches each for selecting a particular combination of operating states for a group of said devices,

said matrix comprising

rows and columns of said cores,

each row operatively associated with a distinct and different one of said switches, each of the cores in any given row of said matrix having a winding connected in series with the corresponding winding of each of the other cores in said given row,

each column operatively associated with a distinct and different of said devices, each of the cores in any given column of said matrix having at least a pair of further windings respectively connected in series with corresponding ones of the pair of further windings of each of the other cores in said given column,

means responsive to actuation of a switch for energizing all of the cores in the respective row associated therewith to a predetermined one of the stable states, coupling the series-connected windings of the cores in each row of the windings to a distinct and different one of said switches,

means coupled to each of said columns or cores for selectively energizing the cores in desired ones of the columns to the other of said stable states, for each row of said cores, including means for controlling the presetting of each of the cores in selected ones of said columns to an initial state corresponding to said other stable state, and means connecting said means for controlling one of said pair of series-connected further windings of cores in each column of said matrix and to each of said switches, and

means responsive to restoration of the cores of a row from said other stable state to said one stable state for energizing the devices associated with the restored cores in the row to a preselected one of said at least two operating states, and means connecting said means for energizing said devices to the other of said pair of series-connected further windings of cores in each column of said matrix.

2. The invention according to claim **1** wherein said means for energizing is further responsive to said restoration for returning each restored core to said other stable state upon energization of said devices associated with the restored cores.

3. The invention according to claim **1** wherein

each of said cores in any given column of said matrix has a third further winding connected in series with the third further winding of each of the other cores in said given column,

said series-connected third further windings connecting said means for energizing said devices to said devices.

4. Apparatus for selectively controlling the actuation of a plurality of electrically actuable devices, each capable of assuming either of at least two operating conditions, to any desired combination of said conditions, said apparatus comprising

means for electrically energizing each of said devices to either of said two operating conditions;

a matrix of bistable storage elements for selectively controlling the operation of said means for electrically energizing to govern the respective operating condition to which each of said plurality of devices is actuated, in accordance with the states of the elements in predetermined groups of elements of said matrix, said matrix comprising

a plurality of magnetic cores each having a substantially rectangular hysteresis loop, each core having a pair of windings for alternately switching the state thereof when pulsed by respective currents of predetermined magnitude and polarity, one winding of each core connected in series circuit with the corresponding winding of a group of said cores, each group consisting of a like number of cores, the other winding of each core connected in series circuit with the other winding of a distinct and different core in every group of said cores;

means for presetting elements in each group to the stable state required to effect said selective control of the operation of said energizing means, including

means for supplying energizing current pulses to the series circuit including said one winding of each core of a group of said cores, and means for selectively supplying energizing current pulses to the series circuit including said other winding of one or more cores in the last-named group of cores; and

means for changing the state of predetermined ones of said elements in each group from the preset stable state to the other stable state as desired combinations of operating conditions of said plurality of devices are to be produced;

said means for electrically energizing said devices comprising

a third winding for each of said cores, a plurality of normally open switch means coupled to respective ones of said devices, means connecting each of said switch means to the third winding of a distinct and different core in each group of said cores, and a source of current, each of said switch means responsive to a current pulse of predetermined magnitude in the respective third winding to couple said current source to a respective device.

5. The invention according to claim **4** wherein is further included means for restoring said predetermined ones of said elements in each group to said preset stable state from said other stable state during actuation of said plurality of devices to a combination of operating conditions governed by the respective group,

6. The invention according to claim **4** wherein

said means for changing state comprises the first-named means for supplying energizing current pulses, and

means for disabling the second-named means for supplying energizing current pulses,

said change of state of predetermined ones of said elements effected in accordance with the selective energization of said other winding of one or more cores in said last-named group by said second-named means for supplying energizing pulses prior to ener-

gization of said series circuit including said one winding of each core of said last-named group by said first-named means for supplying energizing current pulses,

said change of state producing said current pulse in the third winding of said predetermined ones of the cores.

7. The invention according to claim **6** wherein is further included

means for restoring said predetermined ones of said cores in each group of said preset state, comprising

a fourth winding on each core,

said fourth winding coupling one of said plurality of switch means to a respective device.

8. In an organ, a circuit for actuating any desired combination of a plurality of organ stops in accordance with the selective activation of organ pistons, said circuit comprising

a matrix of bistable storage elements, said matrix including

rows and columns of said elements,

each row operatively coupled to a distinct and different one of said pistons,

each column operatively coupled to a distinct and different one of said stops,

means responsive to activation of a piston for energizing all of the elements in the row coupled thereto to an initial one of the two stable states,

switch means coupled to each column of elements for selectively energizing a column or columns of elements to the other of said two stable states in delayed response to said activation of said piston, and

means responsive to restoration to the initial state of the elements in a row associated with said selectively energized columns, upon subsequent activation of the piston coupled to the last-named row, for actuating the stops coupled to the last-named columns.

9. The invention according to claim **8** wherein the last-named means is further responsive to said restoration to drive each element whose initial stable state is restored to said other stable state, in readiness for further activation of the piston coupled to said last-named row.

10. The invention according to claim **8** wherein

each of said elements comprises

a magnetic core having a substantially rectangular hysteresis loop,

each core having three windings,

means coupling one winding of each core in a row of cores to one of said pistons,

means coupling a second winding of each core in a column of cores to said switch means, and

means coupling the third winding of each core in a column of cores to said restoration-responsive means.

11. The invention according to claim **8** wherein

said restoration responsive means includes

a plurality of normally non-conductive switches each having a pair of input terminals and a pair of output terminals,

means respectively coupling each output terminal of a switch to the on and off selectors for a stop,

means coupling one input terminal of said switch to a separate and distinct column of said element, and

means responsive to said subsequent activation of said piston for supplying energizing voltage to the other input terminal of said switch;

each switch comprising

means responsive to energizing voltage at said other input terminal only for energizing one of said on and off selectors of the respective stop, and

means responsive to said energizing voltage and to signal indicative of restoration of initial state of an element in the column coupled to said one input terminal for energizing the other of said on and off selectors of the respective stop.

12. In an electric organ having a plurality of distinct organ voices that may be called forth by selective operation of switches on an organ keyboard,

an array of binary memory elements arranged in groups, each memory element associated with a respective predetermined one of said organ voices,

means responsive in part to operation of said switches for entering a binary number into a selected group of the memory elements in said array, representative of the combination of organ voices with which said group of elements is associated and which is to be called forth upon subsequent accessing of said group memory elements,

means responsive in part to further selective operation of said switches for accessing any selected group of memory elements within said array for destructive read out of the number that has been entered therein, and

means responsive to the number read out of an accessed group of memory elements to call forth the respective combination of organ voices associated with that group of memory elements, and simultaneously therewith to re-enter the last-named number back into the group of memory elements from which it has been read.

13. The invention according to claim **12** wherein each of said memory elements is a magnetic core, and wherein said means for entering and said means for accessing each include windings on each said core, and wherein said array of memory elements comprises a memory plane, said memory elements being arranged in groups along one of two coordinate axes of said memory plane.

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