

Aug. 2, 1966

T. N. LOWRY

3,264,529

MAGNETICALLY CONTROLLED STEPPING SWITCH

Filed Jan. 11, 1963

4 Sheets-Sheet 1

FIG. 1

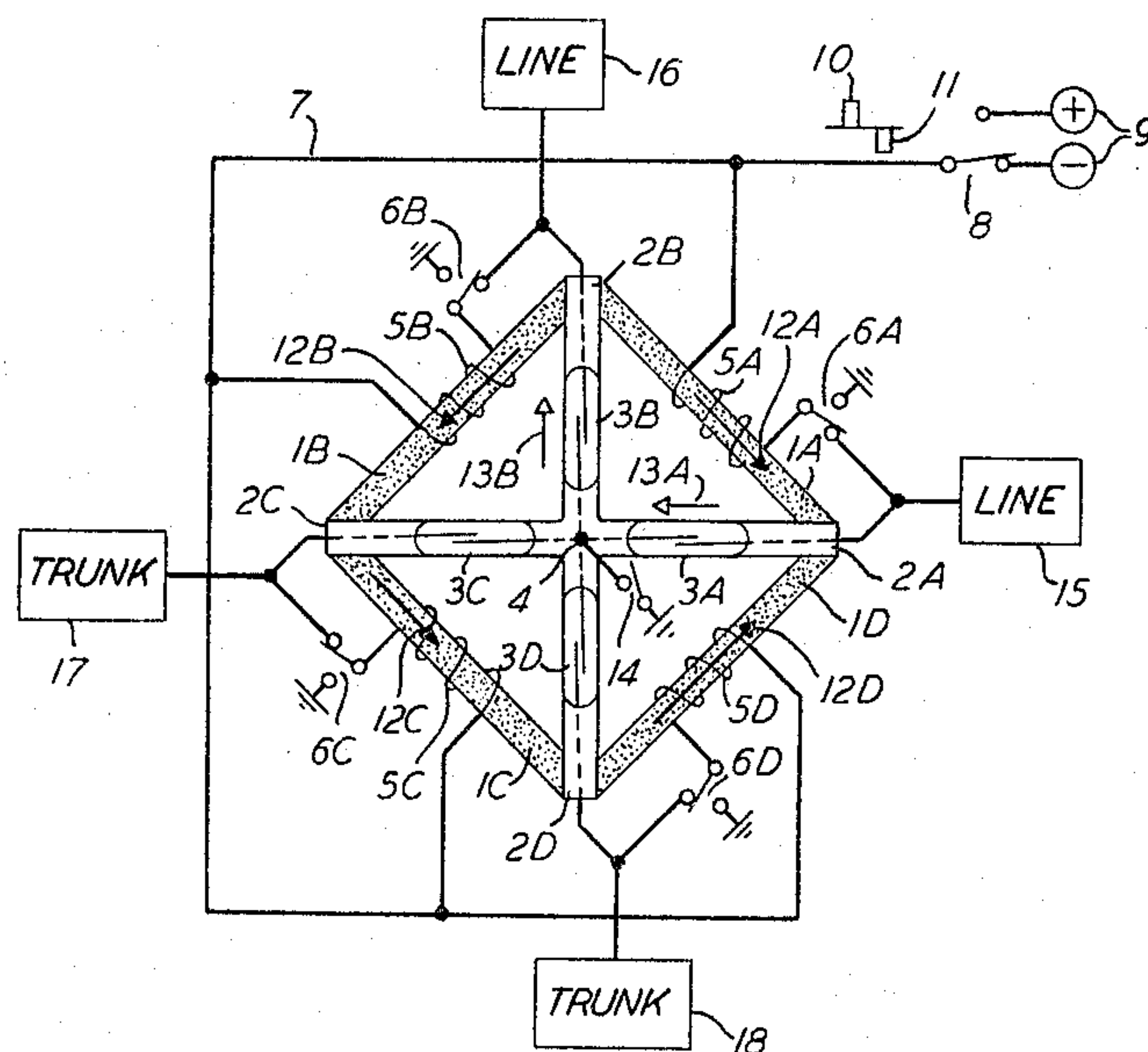


FIG. 3A

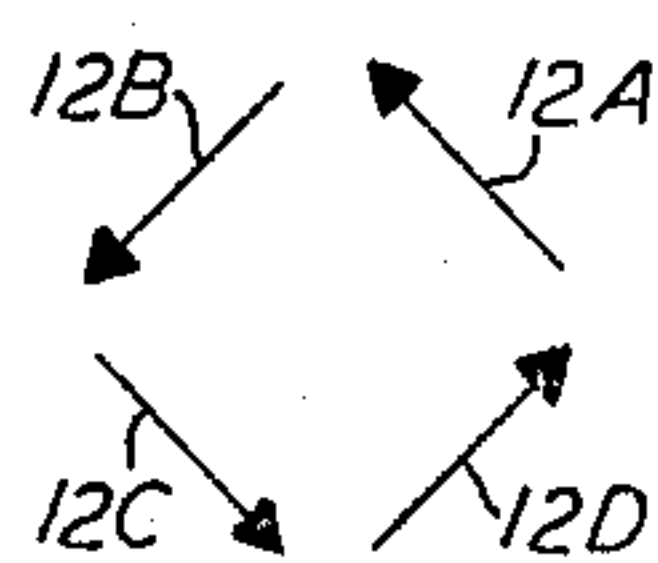


FIG. 3B

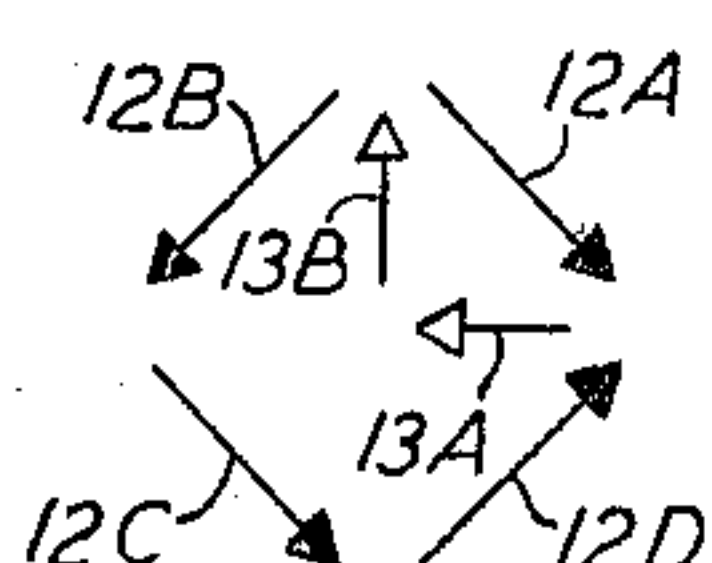


FIG. 3C

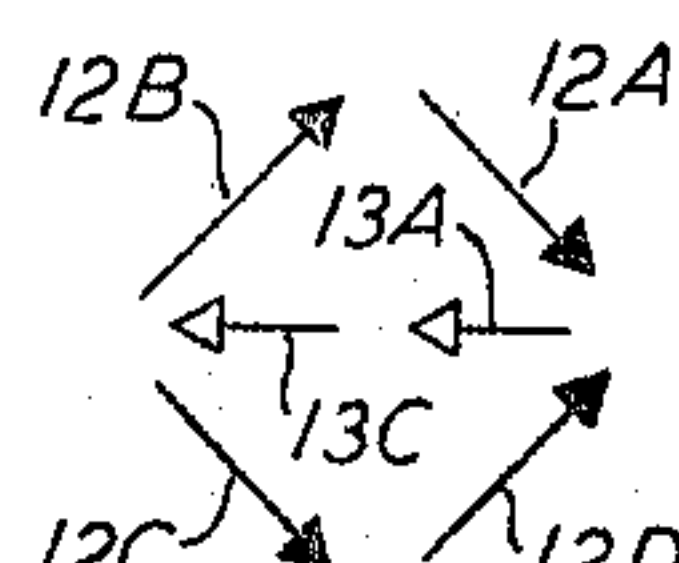


FIG. 3D

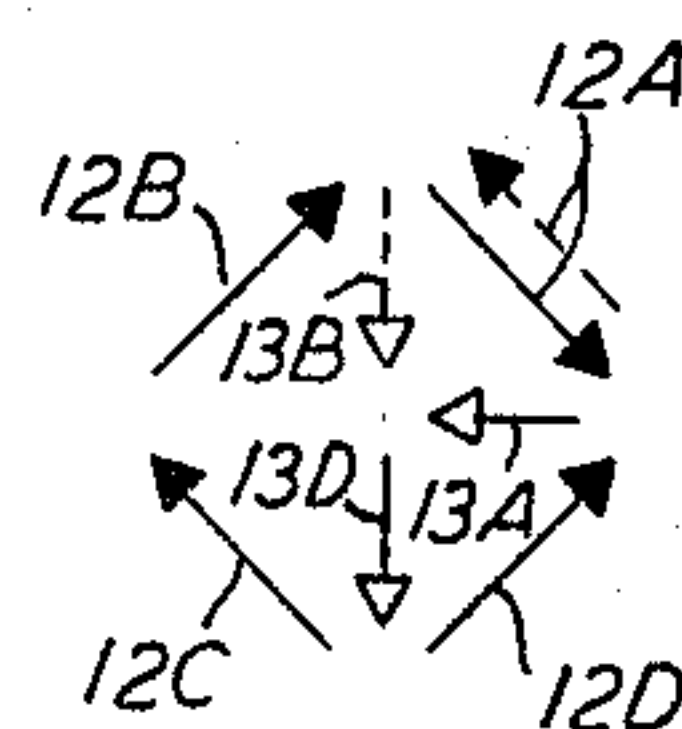


FIG. 3E

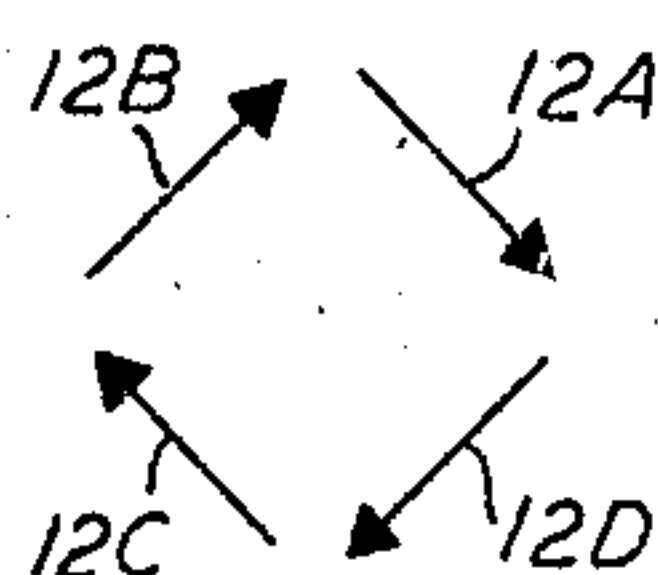


FIG. 3F

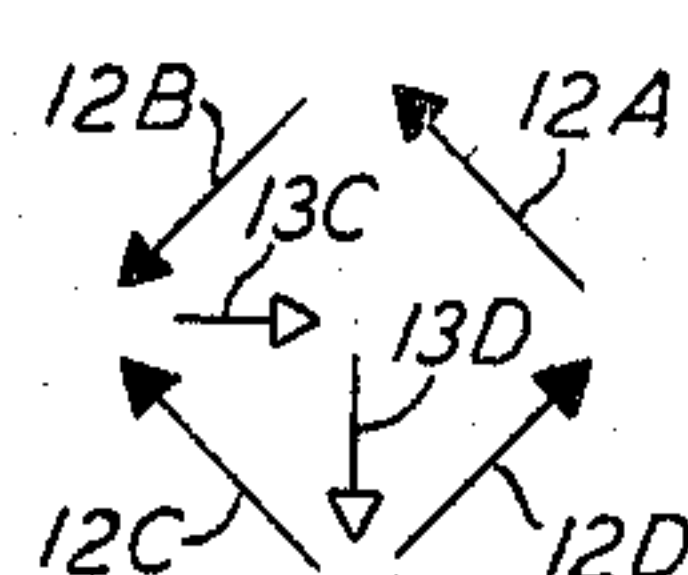


FIG. 3G

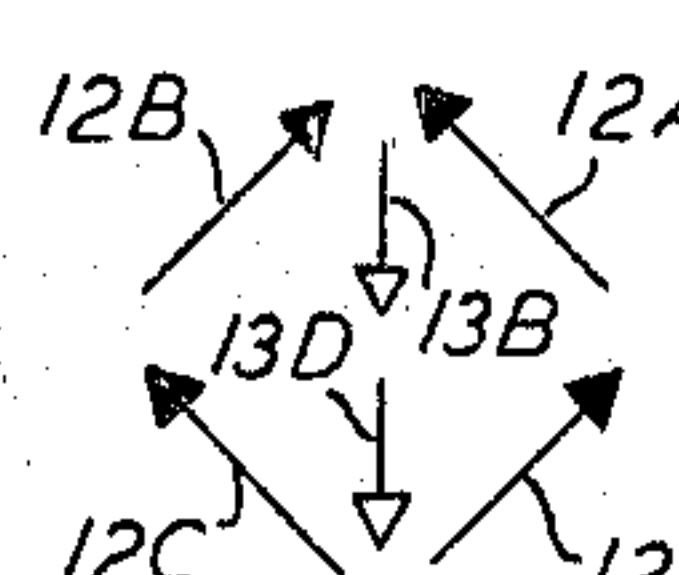
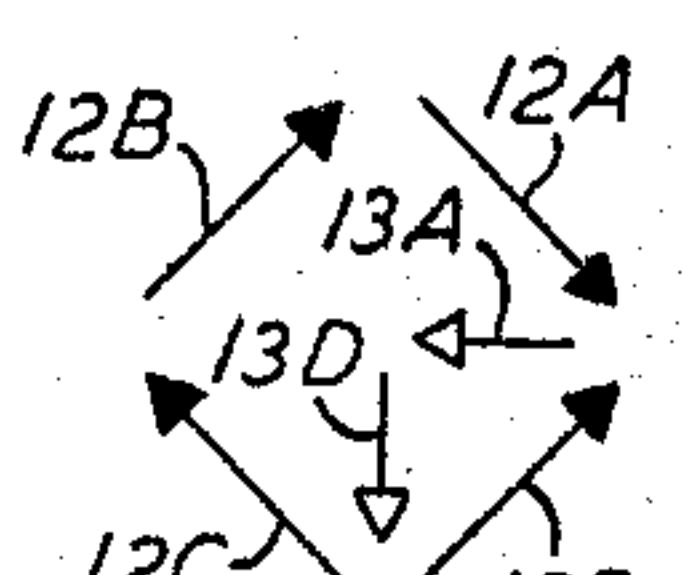


FIG. 3H



INVENTOR
T. N. LOWRY
BY
SE Hollander
ATTORNEY

Aug. 2, 1966

T. N. LOWRY

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FIG. 2

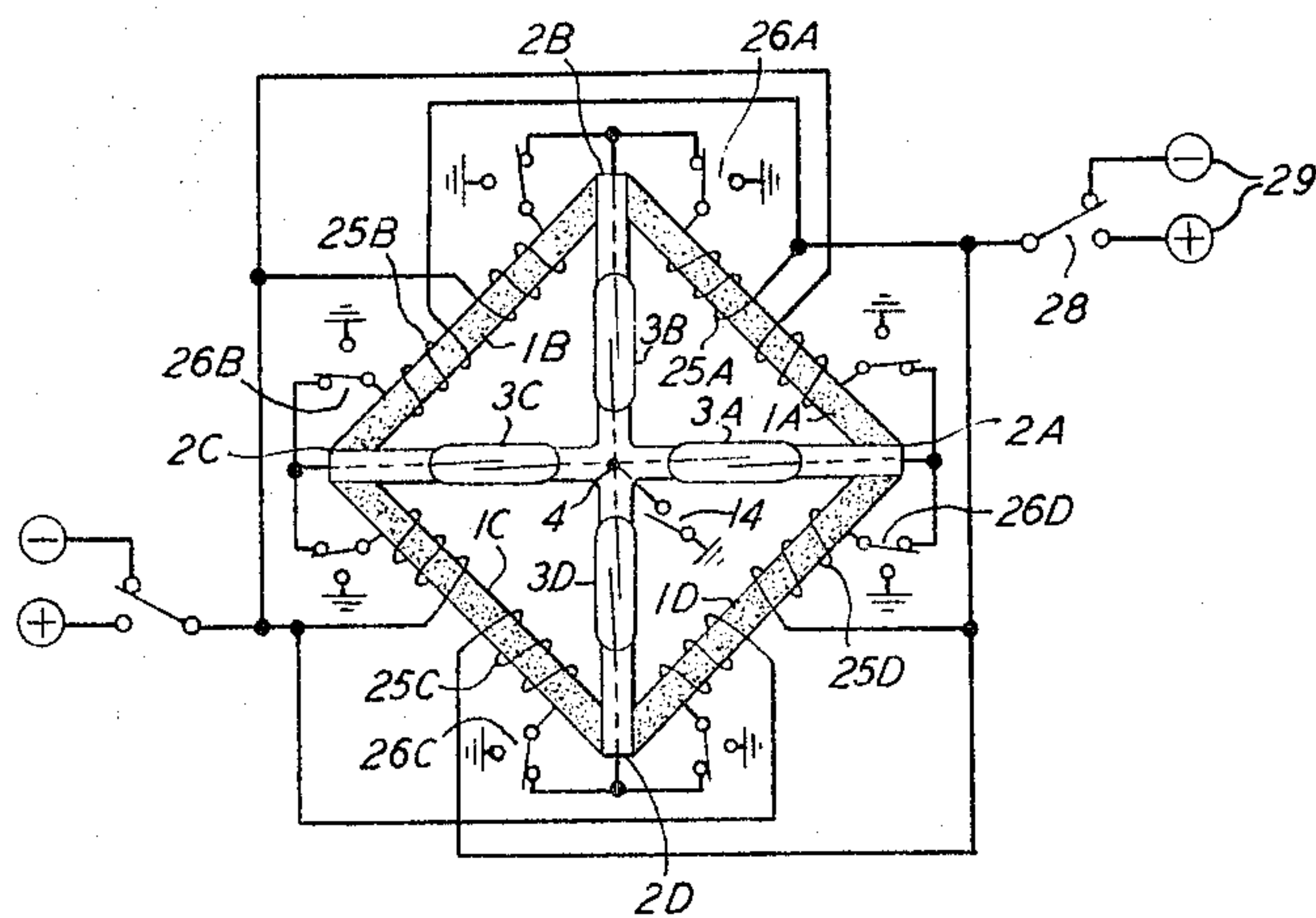
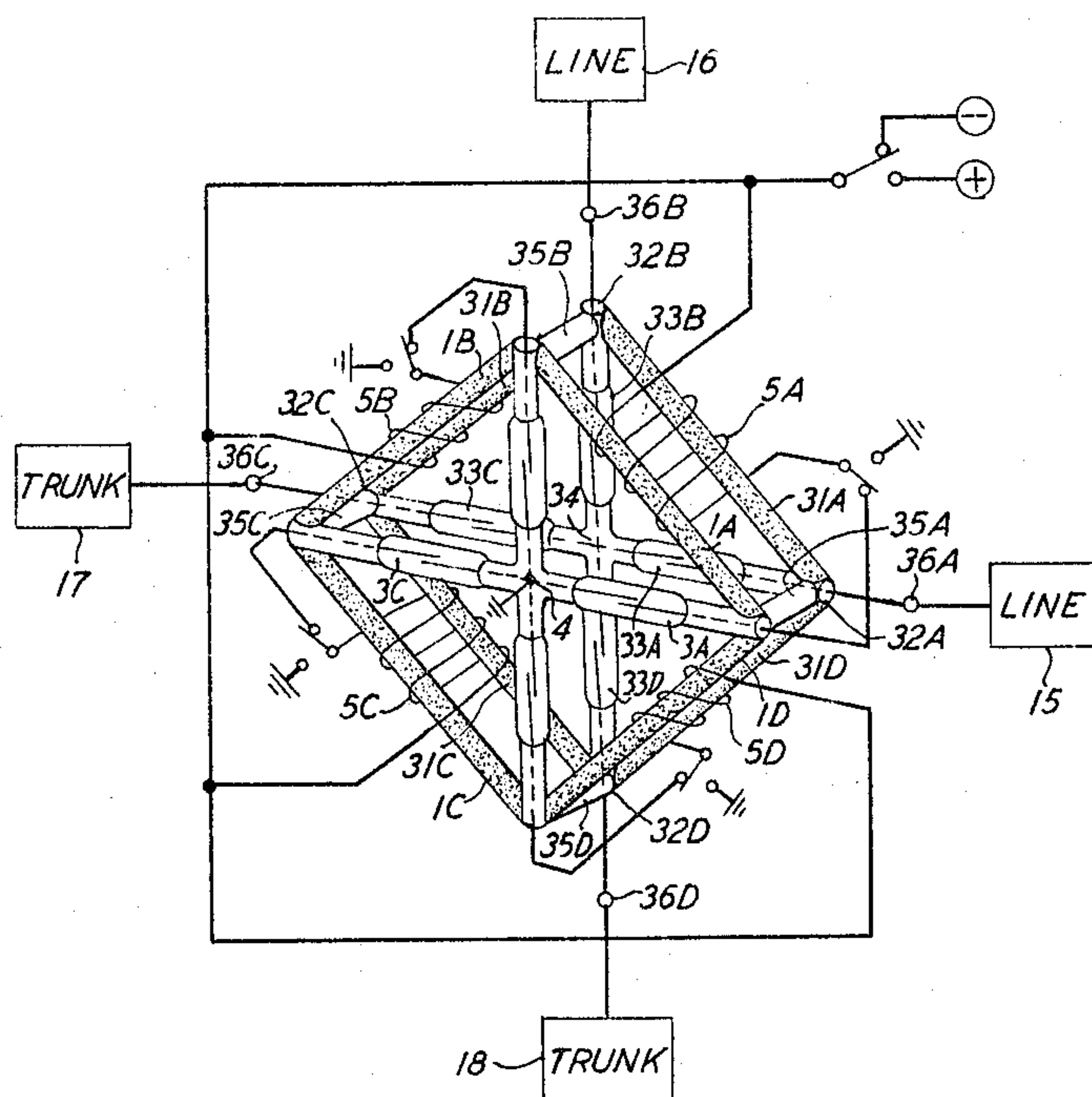


FIG. 4



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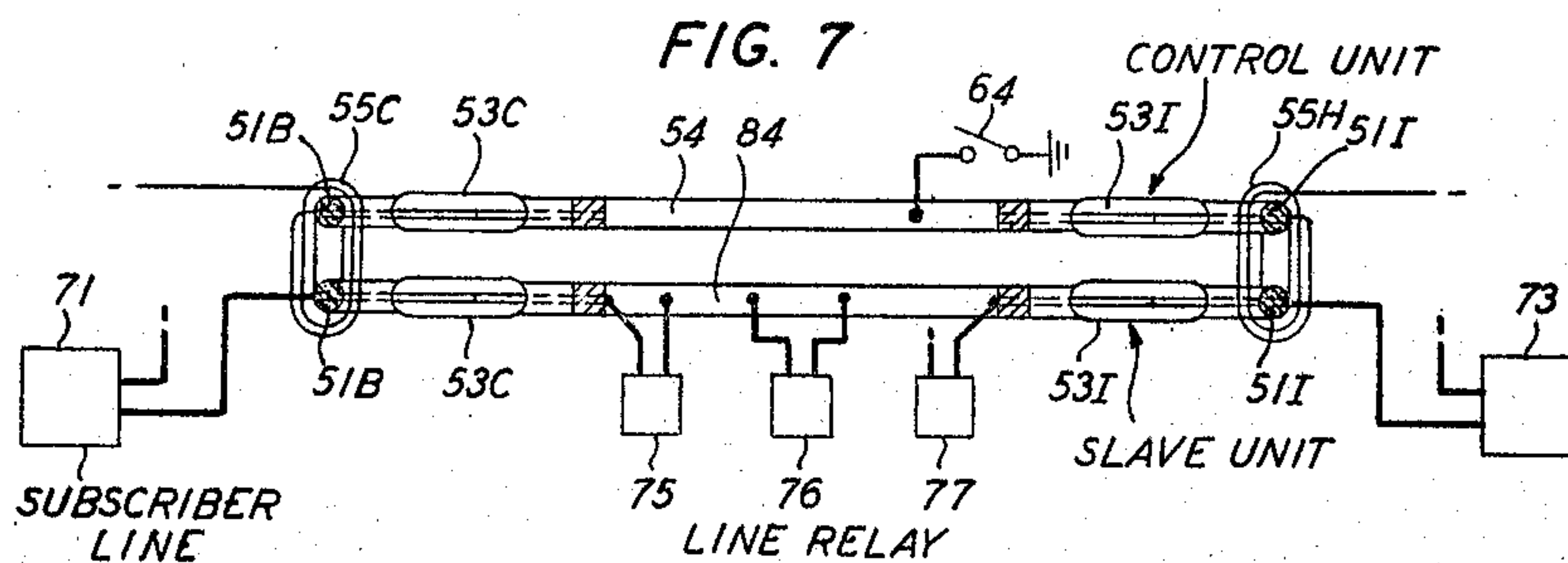
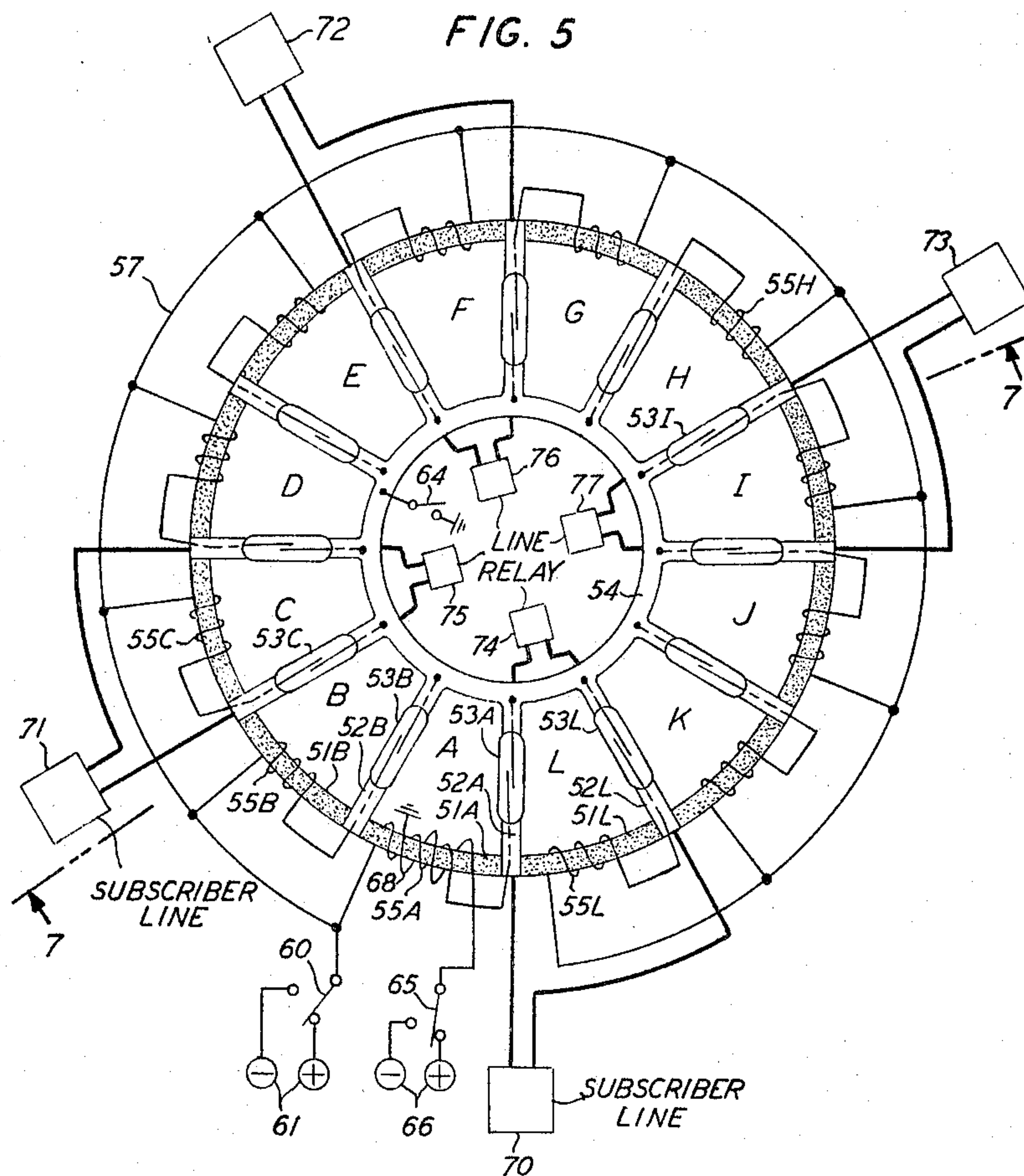
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FIG. 6A

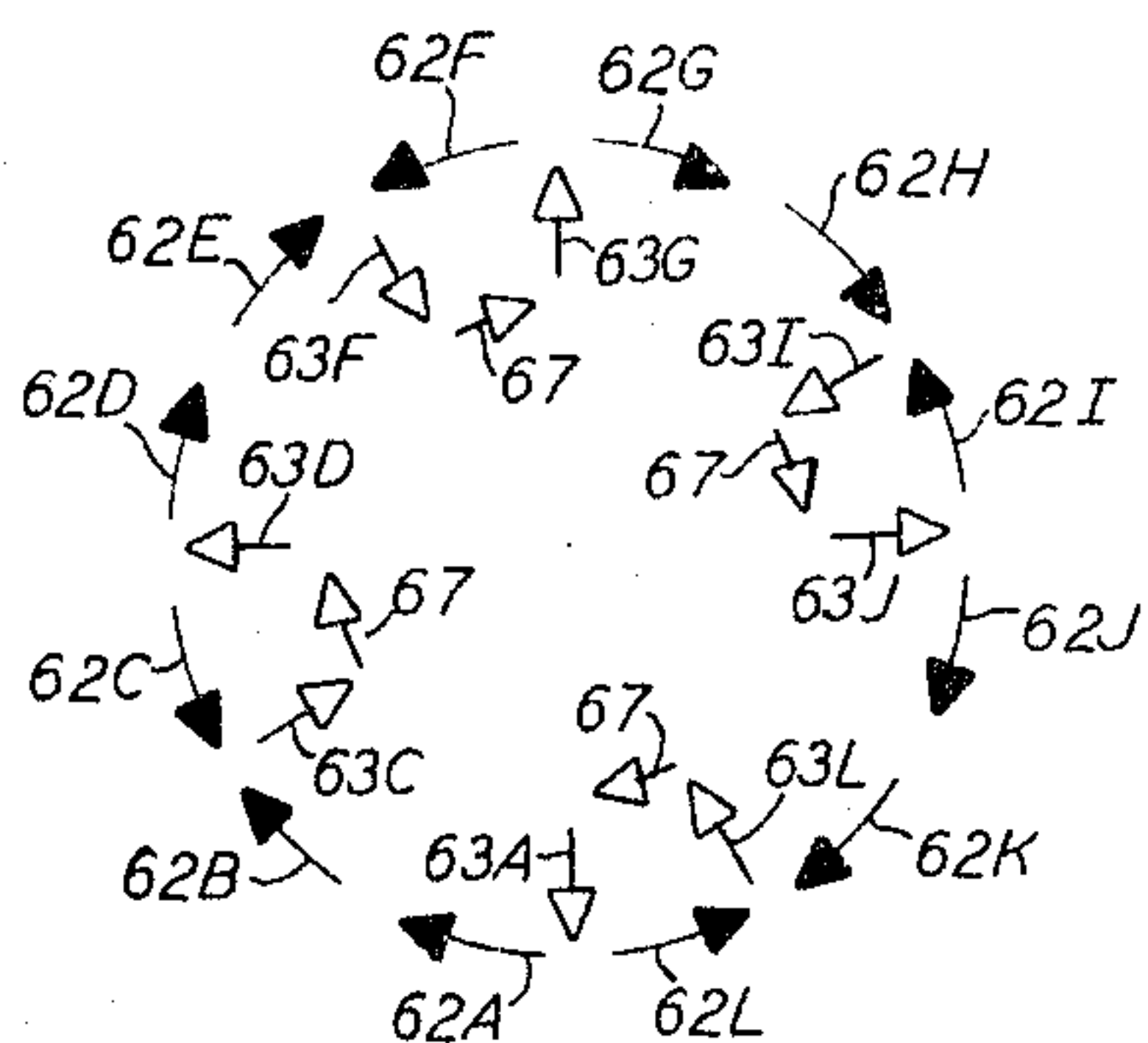


FIG. 6B

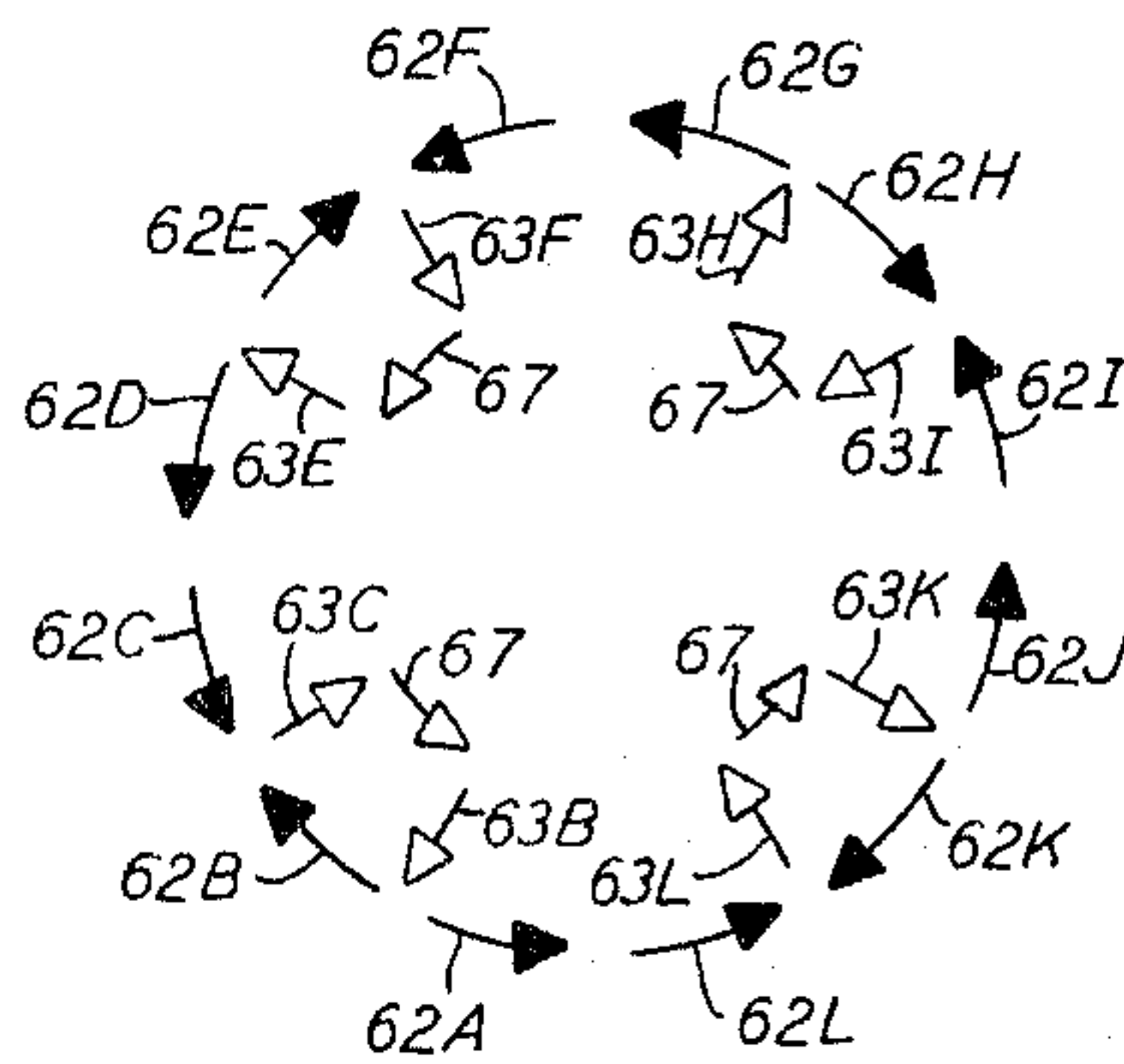


FIG. 6C

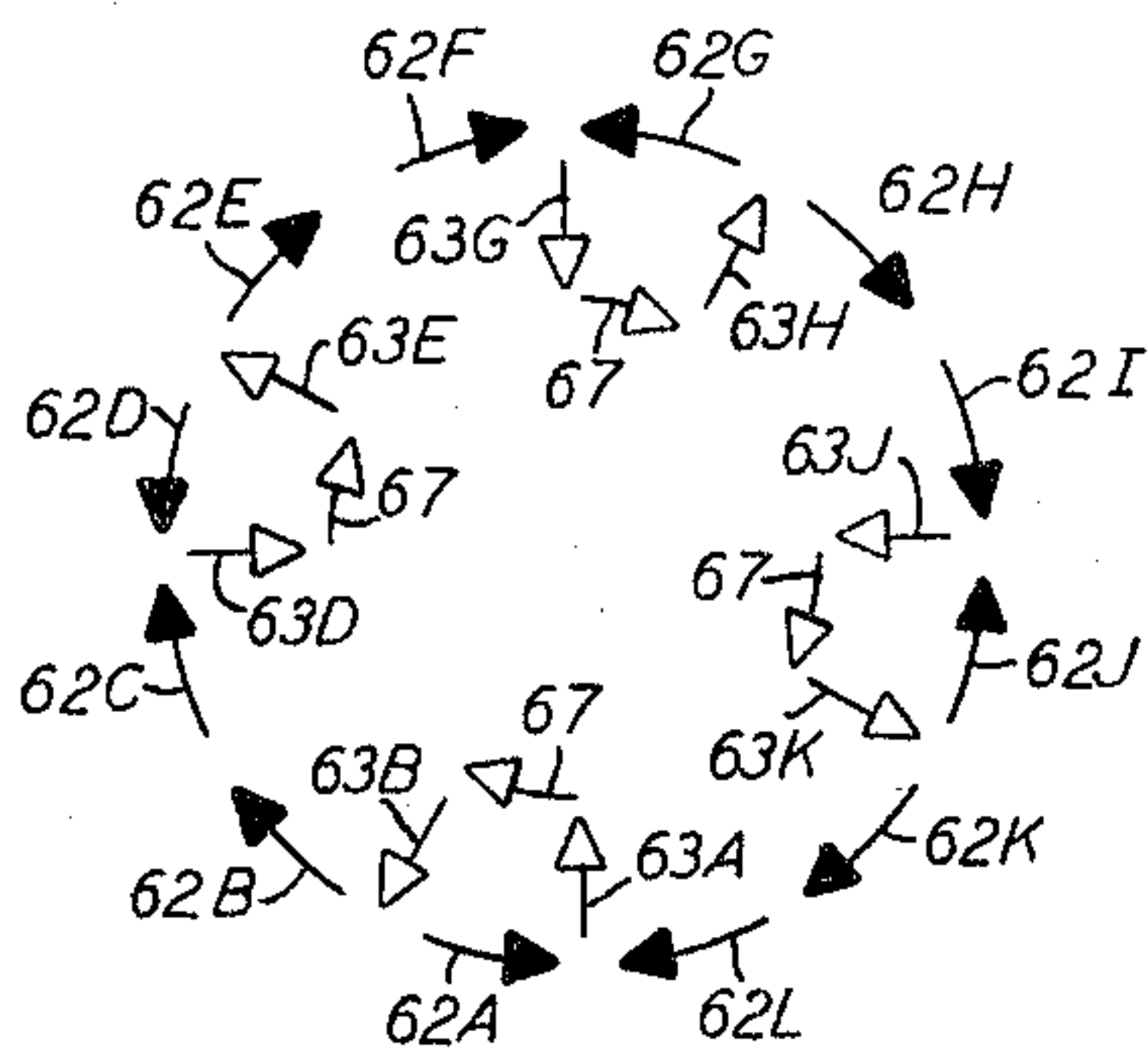
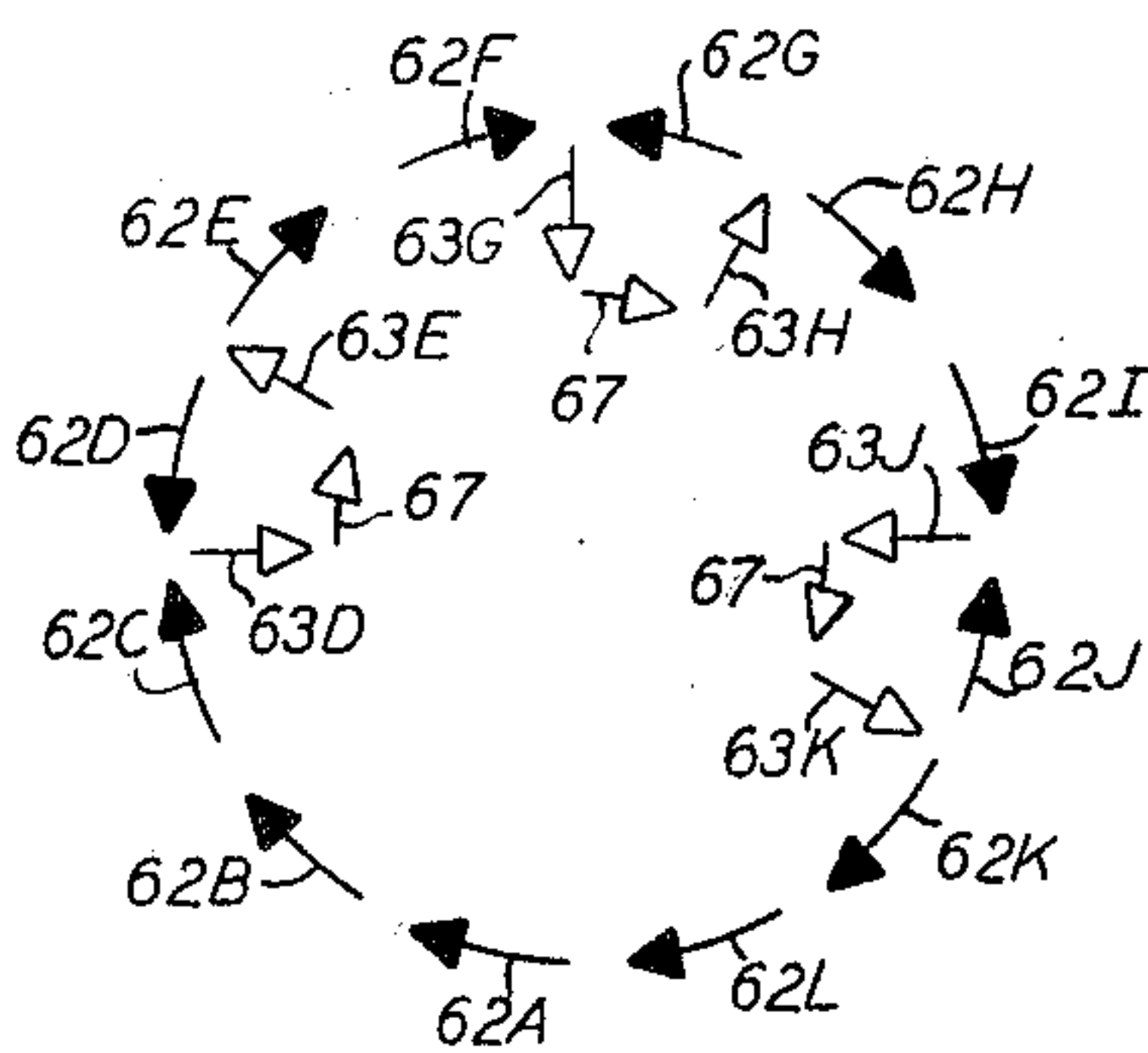


FIG. 6D



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MAGNETICALLY CONTROLLED STEPPING SWITCH

Terrell N. Lowry, New York, N.Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

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18 Claims. (Cl. 317-140)

This invention relates generally to magnetically controlled switches and more particularly to such switches employing magnetically actuated stepping actions, as priorly exemplified by rotary stepping switches.

Most of the prior art rotary stepping switches are characterized by a central wiping arm which makes selective and rubbing contact with a plurality of stationary contacts. Employment of the wiping arm offers many advantages, such as simplicity of access to and storage of information, and metallic output connections which enable high quality transmission of signals. Other advantages are apparent; for example, performance of many diverse functions such as selective switching, counting, registering; simplicity of structure and operation, et cetera.

Despite these advantageous characteristics, in many instances these prior art switches also include a number of inherent limitations. As examples, operation is sluggish, noisy and inefficient; rubbing action between the arm and contacts causes wear and tear and reduces the reliability; and moreover, access to stored information and means for providing circuitual interconnections are limited to a single link through the arm. To illustrate this latter point, in a telephone system a single step-by-step switch can be used to interconnect one line to any one of a plurality of trunks or one trunk to any one of a plurality of lines, but in no event can there be selectivity in connecting any line to any trunk (i.e., one of a plurality of lines to one of a plurality of trunks). A cursory consideration of these limitations will make it apparent that they are caused mainly by the employment of the central wiping arm.

Accordingly, an object of my invention is to improve rotary stepping switches by providing a scheme for causing rotary and stepwise actuation of stationary contacts without any mechanical or wiping arm movement therebetween.

A further object of my invention is to provide a rotary stepping switch wherein any of a plurality of contacts can be selectively connected to any of another plurality of contacts.

Additional objects of my invention are to reduce or substantially eliminate the mentioned restrictions such as sluggish operation, etc.; and to retain as much as possible the mentioned advantages, such as simplicity of operation, metallic contacts, etc., by eliminating the central wiping arm.

These and other objects of my invention are attained in an illustrative embodiment thereof having a plurality of sealed reed switches, of the type disclosed in W. B. Ellwood Patent 2,289,830, of July 14, 1942, interconnected at and radiating from a common point. In accordance with the principles of my invention, I provide means for initially producing a magnetic flux pattern having a plurality of legs in positions which are in alignment with particular ones of the switches. Further means is provided for subsequently causing at least one leg of the magnetic flux pattern to be selectively and stepwisely rotated in either of two directions from the initial position to positions in alignment with different switches. The switches are operative when the legs of the flux pattern are in corresponding alignment therewith. Accordingly, the stepwise rotation of the leg or legs of the magnetic flux pattern cause stepwise closures of correspondingly aligned

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switches, with no physical movement of the switch bodies.

Thus, advantageously, I have in essence a stationary rotary stepping switch which employs rotating magnetic flux patterns to cause stepping action instead of the priorly used rotating central wiping arm. Furthermore, advantageously, one or more communications paths can be established through any two or more of the reed switches; multiple access may be simply attained between any two of the reed switches. For example, in a telephone system having a plurality of lines and a plurality of trunks connected to the respective reed switches of my device, I can selectively interconnect any line to any trunk through a pair of reed switches by selectively rotating the leg or legs of the magnetic flux pattern into positions which are in alignment with the corresponding reed switches.

A feature of my invention is a stationary rotary stepping switch having rotary stepping action produced by a magnetic flux pattern aligned with stationary reed switches and stepwisely rotatable through different ones thereof.

Another feature is the provision of means for causing stepped rotation of the magnetic flux pattern in both the clockwise and counterclockwise directions.

A further feature of my invention is the provision of a control unit and at least one slave unit, both operative in unison by the rotative flux patterns, and one employable for selectively interconnecting electrical circuits and the other employable for controlling the operation of both units.

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

FIG. 1 depicts one specific illustrative embodiment of my invention;

FIG. 2 depicts another illustrative embodiment of my invention wherein two windings are disposed on each member;

FIGS. 3A, 3B, 3C, 3D, and 3E depict the rotative flux patterns aligned with the correspondingly lettered elements of and resulting from the operation of the embodiment of FIG. 1;

FIGS. 3F, 3G, and 3H depict the rotative flux pattern resulting from the operation of the embodiment of FIG. 2;

FIG. 4 depicts two units similar to the embodiment of FIG. 1, one used as a control unit and the other as a slave unit, which slave unit employs its switches for electrical interconnection purposes;

FIG. 5 depicts a plan view of another embodiment of my invention having numerous switches on a control and a slave unit, and illustrating a technique for erasing a particular flux pair;

FIGS. 6A, 6B, 6C and 6D depict the rotative magnetic flux patterns resulting from the operation of the embodiment of FIG. 5 and FIG. 7; and

FIG. 7 depicts an elevation view of the embodiment of FIG. 5, taken along section line 7-7 thereof.

Description of the basic structure having single windings

Turning now to the drawing, in FIG. 1, I depict a plurality of remanently magnetic members 1A through 1D, interconnected by soft magnetic joints 2A through 2D, and, magnetically coupled to and physically attached to the respective joints, a plurality of sealed reed switches 3A through 3D. The switches may be employed to selectively interconnect external circuits such as lines 15 and 16 and trunks 17 and 18. The sealed reed switches are also joined commonly to a soft magnetic center core 4 which is groundable through switch 14. Each of the members is provided with a respective winding 5A through 5D wound in magnetically appropriate directions. One terminal of each winding is connected to an outer or ter-

minal reed of an adjacent sealed reed switch and is connectable through a respective switch 6A through 6D to ground. The other terminal of each winding is connected via conductor 7 and switch 8 to bipolar pulse source 9. Source 9 is capable of producing positive pulses, e.g., 10, and negative pulses, e.g., 11. The closed arrows 12A through 12D superimposed against the respective remanent members represent their respective remanent states. The open arrows 13A and 13B represent magnetic flux flow through the respective switches 3A and 3B.

General principles of operation

The remanent members can be of any known type of magnetic material which possesses the characteristics of a substantially rectangular hysteresis loop and of ability to attain bistable states of magnetic remanence. When any of the windings 5A through 5D is energized by a pulse of appropriate magnitude and polarity, an appropriate remanent state of the associated remanent member will be effected. When two adjacent members, e.g., 1A and 1B, are in opposite states or directions a remanent magnetic pole will be induced at the joint therebetween, e.g., 2B. Since a switch, e.g., 3B, is magnetically coupled to that joint, the magnetic pole will be induced on the outer reed thereof. When at the same time, the remanences of another pair of adjacent remanent members cause the induction of a remanent pole at another joint, e.g., 2C, the reed switch magnetically coupled thereto, e.g., 3C, will also have induced thereon a remanent pole. Thus, if the poles are of opposite polarity magnetic flux will be caused to flow from one joint to the other through the two switches connected thereto, e.g., through switches 3B and 3C, causing both of the switches to close.

Closures of any pair of switches permits interconnection of external circuits, e.g., closures of switches 3B and 3C permit connection of line 16 to trunk 17. The remanent poles can be transferred from one joint to another to cause magnetic flux to flow through different pairs of switches. Hence, by rotating the magnetic pole locations the magnetic flux pattern is rotated and the reed switches are rotationally closed, in the manner caused heretofore by a rotative mechanical arm.

The remanent states of the members can be switched in the order of microseconds and the energizing pulse need only be sufficient in magnitude and duration to cause the switching of the remanent state. The magnetic flux resulting from the remanent state, independently of the pulse duration, causes operation of the sealed reed switches in their natural response times which are in the order of tenths of milliseconds. Thus, advantageously, the energizing pulse need not occur at the time of switch closure and its duration can be independent of the switch response time.

Description of the operation of the basic device

The principles of operation of my invention are best explained by referring concurrently to FIGS. 1 and 3A, 3B, 3C, 3D and 3E.

In a quiescent state of the FIG. 1 embodiment, all of the sealed reed switches are open and no interconnection exists between any of the lines and trunks. All of the remanent members 1A through 1D have their remanent states in the same direction, as depicted in FIG. 3A with closed arrows 12A through 12D pointing counterclockwise. No remanent magnetic pole is induced at any of the joints. Magnetic flux is caused to substantially circumvent all of the switches.

Initially, a pair of opposite magnetic poles are induced at next adjacent joints to cause a magnetic flux pattern having at least a pair of magnetic flux legs in positions aligned with and flowing through at least a pair of switches coupled to the joints. For example, as illustrated in FIG. 3B, opposite poles are induced at joints 2A and 2B of FIG. 1, to cause flux legs 13A and 13B which flow through respective switches 3A and 3B. Flux flowing

through the switches, of course, causes their closures. This initial production of a pair of flux legs is accomplished by momentarily grounding switch 6A and transmitting a positive pulse from source 9 through closed switch 8, through winding 5A to ground. The remanent state of member 1A is reversed from the counterclockwise direction depicted in FIG. 3A to a clockwise direction depicted in FIG. 3B by closed arrow 12A. Closure of switches 3A and 3B enables connection of line 15 to line 16, provided switch 14 is opened to prevent passage of current to ground.

In accordance with the principles of my invention, either of the remanent poles can be rotated to other joints to cause rotation of either flux leg of the flux pattern from their initial positions to other positions which are in alignment with other switches. For convenience of explanation, flux leg 13B of FIG. 3B will be called the front leg and flux leg 13A will be called the back leg. Assume it is desired to connect line 15 to trunk 17. This is accomplished by rotating in a counterclockwise direction the front leg from a position initially aligned with switch 3B to a position aligned with switch 3C; at the same time the back leg is caused to remain stationary and in alignment with switch 3A. With switches 3A and 3B closed, a second positive pulse from the pulse source 9 is caused to flow via conductor 7 through windings 5A and 5B, through respective switches 3A and 3B, through center core 4, and through closed switch 14 to ground. The remanences of members 1A and 1B are caused to be in clockwise directions as depicted in FIG. 3C by arrows 12A and 12B. Opposite remanent poles are induced at joints 2A and 2C, one remanent pole being rotated from joint 2B to joint 2C. Thus, magnetic flux is caused to flow through switches 3A and 3C as illustrated in FIG. 3C by open arrows 13A and 13C to cause their closures. No remanent pole being present at joint 2B, magnetic flux circumvents switch 3B, to cause its opening. In this manner, link connection has been step-rotated from a position between line 15 and line 16 to a position between line 15 and trunk 17. When the connection is established between line 15 and trunk 17, switches 6 and 14 are opened to prevent shunting of the connection path.

In a similar manner, a third pulse may cause to be established the flux pattern depicted by open and closed arrows in FIG. 3D, that is, with remanent poles induced at joints 2A and 2D magnetic flux is caused to flow through switches 3A and 3D, the front leg having been rotated from switch 3C to switch 3D. In this position line 15 may be connected through closed switches 3A and 3D to trunk 18. The fourth pulse may cause the front leg to be further rotated into coincidence with the back leg and thus to be destroyed as depicted in FIG. 3E. The destruction or erasure of any flux pair is accomplished by the destruction of the remanent magnetic poles at the associated joints. Here, one pole is caused to coincide with another to cause their disappearance. Magnetic flux is caused to circumvent in the clockwise direction all of the switches, and thus cause the openings thereof. The stepping operation can be repeated by changing the remanent states of the members from that as depicted in FIG. 3E to be as depicted in FIG. 3A, and by subsequently repeating the just described steps.

The back leg can also be rotated in a counterclockwise direction. Assume that line 15 is connected to trunk 18 as above described, and it is desired to connect trunk 18 of FIG. 1 to line 16. This is accomplished by transferring the other remanent pole at joint 2A to joints 2B, etc. and thereby rotating the back leg in a counterclockwise direction. The rotation of the back leg is done by applying negative pulses, instead of positive pulses as just described, to the windings. For example, with the embodiment of FIG. 1 in a state having the open and closed arrow flux pattern depicted in FIG. 3D and with line 15 connected to trunk 18, a negative pulse is caused to travel from source 9 via closed switch 8, and conductor 7

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through windings 5A and 5D, closed switches 3A and 3D, through center core 4 and through closed switch 14 to ground. The remanences of members 1A and 1D will be caused to be in directions as represented in FIG. 3D by closed arrow 12D and dotted arrow 12A. Opposite remanent poles will be induced at joints 2B and 2D, one remanent pole being moved from joint 2A to joint 2B, causing magnetic flux to flow therebetween through switches 3B and 3D as represented by dotted arrow 13B and open arrow 13D.

The remanent poles and resulting flux legs can also be rotated in a clockwise direction. This can be done either by disposing an additional winding on each member or by using the same winding and, in either case, connecting one terminal of the winding to the switch located away from the desired direction of rotation. For example, in the embodiment of FIG. 1, the desired direction of rotation was counterclockwise. Each of the windings had one terminal thereof connected to a respective adjacent switch located toward the clockwise end of the associated member (e.g. winding 5A is connected to switch 3A on joint 2A at the clockwise end of member 1A). Accordingly, to get clockwise rotation of the remanent poles and resulting flux legs, the winding terminal should be connected to a switch located toward the counterclockwise end of the member (e.g. winding 5A should be connected to switch 3B).

Descriptions of the basic structure having double windings

In FIG. 2, I employ the first alternative, that is to say, I employ a second winding on each member to attain clockwise rotation as well as counterclockwise rotation of the remanent poles and consequently caused flux legs. The embodiment of FIG. 2 is similar to the embodiment of FIG. 1 with the exception of the additional windings 25A through 25D, switches 26A through 26D, switch 28 and bipolar pulse source 29. The external circuit connections of lines and trunks are not shown, in order to simplify the discussion, but obviously can be employed. Only the additional elements pertinent to a discussion of the operation are numbered for the sake of clarity.

Description of the operation of the double winding device

To explain the clockwise rotation of a remanent pole and the resulting flux leg, assume in the embodiment of FIG. 2, that switches 3C and 3D are initially closed, remanent poles being at joints 2C and 2D, and that the magnetic flux pattern aligned with the switches is as depicted in FIG. 3F. This is caused by initially closing switch 26C to ground and by applying a positive pulse through winding 25C to ground (if all conditions were initially as shown in FIG. 3A).

Subsequently, a positive pulse from source 29 may travel through closed switch 28, through windings 25B and 25C, through respective switches 3C and 3D, through center core 4 and closed switch 14 to ground. This causes the change of remanence of members 1B and 1C to be as illustrated in FIG. 3G by closed arrows 12B and 12C. Opposite remanent poles are induced at joints 2B and 2D thereby causing magnetic flux to flow therebetween and through respective switches 3B and 3D as illustrated by open arrows 13B and 13D. The remanent pole has been transferred from joint 2C to joint 2B to cause rotation of flux leg 13C in a clockwise direction from a position in alignment with switch 3C to a position in alignment with switch 3B. Similarly, responsive to the next pulse, the remanent pole of joint 2B will be rotated to joint 2A to cause clockwise rotation of flux leg 13B to be in alignment with switch 3A as illustrated by FIG. 3H. The next following pulse would, in a manner similar to that as discussed for the FIG. 1 embodiment, cause the two remanent poles to coincide and thus be destroyed or erased by causing the front leg 13A to be rotated into the back leg 13D causing their mutual destruction.

Here again, when a connection is completed between

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two reed switches, the switches 26 and 14 are opened to prevent shorting of the communications path.

Description of the slave unit

A different set of switches other than that employed for passage of current to control the device can be employed for interconnecting external electrical circuits. In FIG. 4, I provide a second unit having such an additional set of sealed reed switches for such interconnection purposes. This second unit is depicted as the backmost unit and is structurally similar to the embodiment of FIG. 1. The forwardmost unit is similar to FIG. 1 and may be called the control unit. The backmost unit may be called the slave unit; its operation being directly dependent upon the control unit. For clarity, only the slave unit and elements of the control unit pertinent to the following discussion are numbered.

The slave unit is connected in element-to-element correspondence with the control unit by means of attachment pieces 35A through 35D, which pieces are of electrically insulating material. The slave unit comprises remanently magnetic members 31A through 31D, interconnected by joints 32A through 32D, and having sealed reed switches 33A through 33D connected thereto and terminated at a soft magnetic center core 34. The center core 4 of the control unit provides electrical connections to ground for the control windings, while the center core 34 of the slave unit may provide electrical connections between the reed switches. Of course, the reed switches of the slave unit can, in desired cases, be insulated from the core 34. The terminals 36A through 36D of the slave unit switches are connectable to external circuits; for example, terminals 36A, 36B may be connected to lines 15, 16 and terminals 36C, 36D may be connected to trunks 17 and 18. The windings 5A through 5D embrace both the remanent members 1A through 1D of the control unit and the respective corresponding members 31A through 31D of the slave unit, and are connected to the switches of the control unit, in the manner shown.

Description of the operation of the slave unit

The operation of the embodiment of FIG. 4 is similar to the operation of the embodiment of FIG. 1, but due to the windings commonly coupling the corresponding members of both units, the slave unit is operated in unison with the control unit. Accordingly, to interconnect a particular line to a particular trunk, for example, line 15 to trunk 17, the control unit is step-operated in the manner as described above in FIG. 1 to cause switch 3A and 3C to be operated. Since the slave unit is operated in unison with the control unit, switches 33A and 33C will be operated in unison with switches 3A and 3C and since line 15 is connected to switch 33A and trunk 17 is connected to switch 33C, the interconnection will be completed there-through. Of course, more than one slave unit can be employed. Furthermore, the embodiment of FIG. 2 just described, may have one or more slave units although such slave units are not shown therein.

Description of operation in providing cut-off function

FIGS. 5 and 7 depict an embodiment having a control unit and a slave unit, each unit comprising a set of 12 switches, 53A through 53L, 12 remanent members 51A through 51L interconnected by 12 joints 52A through 52L, and 12 windings 55A through 55L. One member 51A is employed for purposes of erasing or destroying a flux pair and of reinstating a destroyed flux pair, as will be explained further below. The center core 54 and switch 64 of the control unit are similar to the corresponding elements of the embodiment of FIG. 1; the center core 84 of the slave unit, however, is insulated from the terminals of the reed switches 53 in order to prevent short circuits between the lines and does not have a grounding switch. Although in the plan view of FIG. 5 the subscriber lines may appear to be connected to the winding 55, it is to be understood that the windings 55 are con-

connected to the reed switches of the control unit only, and the subscriber lines are connected to the reed switches of the slave unit only, as depicted in FIG. 7. To distinguish in the drawing, the conductors interconnecting the slave unit switches are shown in heavier outline than those interconnecting the control unit switches. The reed switches 53 of the slave unit (bottom unit in FIG. 7) may be used as cut-off relays between subscriber lines 70 through 73 and line relays 74 through 77. In this embodiment, the direction of rotation is desired to be in the clockwise direction. Accordingly, each of the windings is connected to a respective control unit (upper unit in FIG. 7) switch 53 located toward the counterclockwise end of its associated remanent member 51. The windings 55A through 55L are connected to a common conductor 57. The conductor 57 is connectable through switch 60 to bipolar pulse source 61. The erase member is provided with an additional winding 68 of magnetically appropriate direction, which is grounded at one terminal and connectable at the other terminal through switch 65 to bipolar source 66.

Description of the cut-off operation

In some cases, it may be desired to have a plurality of pairs of switches which can be selectively opened and closed. For example, in a telephone system, a plurality of subscriber lines (depicted in FIGS. 5 and 7 as boxes 70 through 73), each having a pair of wires, are connected to respective line relays (depicted in FIGS. 5 and 7 as boxes 74 through 77) to enable detection of a service requesting line.

When the telephone sets are on hook, all of the lines are normally connected to the respective line relays over the respective pairs of reed switches of the slave unit connected thereto. Closures of these switches are accomplished by establishing the flux pattern shown in FIG. 6A, which flux pattern is aligned with the correspondingly lettered elements of the control and slave units of the embodiment of FIGS. 5 and 7. The open arrows 67 represent magnetic flux flow through the center cores 54 and 84 of both units. This flux pattern is attained, advantageously, by initially setting the remanences of all the members, to be similar in direction, then energizing the erase winding 68 to reverse the remanence of the erase member 51A, to cause opposite remanent poles at joints 52A and 52B and a flux pair in switches 53A and 53B, and then rotating this flux pair to other switches in a manner to be explained. Repetition of this step will cause the entire flux pattern to be produced. Of course, if one or more pairs of flux legs already exist, the same procedure need not be repeated as many times.

Assume that subscriber line 70, connected to reed switches 53A and 53L of the slave unit, is off hook and is now engaged in conversation; it is desired that the line relay be disconnected therefrom to prevent shunting of unnecessary current from the communications path. This is done by opening switches 53A and 53L of both units; opening of these switches is accomplished by erasing, i.e., destroying, the remanent poles at the joints to which the switches are coupled and hence destroying flux legs aligned therewith, which flux legs are represented in FIG. 6A by open arrows 63A and 63L.

Erasing of the flux pair is caused by rotating the remanent poles and resulting flux pair 63A and 63L from their present positions enclosing member 51L to a position enclosing the erase member 51A and then changing the magnetic remanence of the erase member 51A to destroy the remanent poles. As a result magnetic flux will circumvent the switches 53A and 53L to which the legs were aligned.

The rotation of the remanent poles and resulting flux pair 63A and 63L is done in the manner as discussed above in the embodiment of FIG. 1, that is to say, one remanent pole is rotated from joint 52A to joint 52B to cause the front leg, 63A, to be rotated from a position

aligned with switch 53A to a subsequent position aligned with vacant switch 53B next adjacent thereto. Subsequently, another remanent pole at joint 52L is rotated to joint 52A to cause the back leg 63L to be rotated from a position in alignment with switch 53L to a position in alignment with the switch 53A.

The front leg 63A is caused to be moved by applying in the embodiment of FIG. 5 a positive pulse from source 61, through closed switch 60, conductor 57, winding 55A, closed switch 53A, center core 54 of the control unit, and closed switch 64 of the control unit to ground. The back leg 63L is caused to be moved by applying a negative pulse from source 61, through closed switch 60, conductor 57, winding 55L, closed switch 53L, center core 54 of the control unit, and closed switch 64 of the control unit to ground. The corresponding reed switches of both control and slave units are, of course, operated in unison. The appropriate remanent states of the involved members 51A and 51L which enable the front and back legs to be rotated are shown in respective FIGS. 6B and 6C.

Since windings 55A through 55L are connected to the common conductor 57, energization thereof causes similar rotative action of the other fluxes, that is to say, the remanent poles and the resultant front legs 63D, 63G and 63J of FIG. 6A will also be caused to be rotated through one switch position, from positions depicted by the open arrow flux legs of FIG. 6A to that depicted in FIG. 6B. Similarly, when conductor 57 is energized by a negative pulse, the remanent poles and the resultant back legs 63C, 63F and 63I are also caused to be rotated one step from positions depicted by the open arrow flux pattern of FIG. 6B to that depicted in FIG. 6C. In this manner, the flux pattern can be rotated in a wavelike motion from one switch to another, always ending in flux pairs with a vacant switch between each pair. Any flux pair can hence be rotated to positions enclosing the erase member and be caused to be erased.

Once the remanent poles and resultant flux pair 63A and 63B are in positions enclosing the erase member 51A (as represented in FIG. 6C by closed arrow 62A), such poles and flux pair can be erased by closing switch 65 of FIG. 5 and by applying a positive pulse from source 66, through winding 68 to ground. The magnetic remanence of member 51A is caused to be reversed as illustrated in FIG. 6D by closed arrow 62A. No independent remanent magnetic pole is present at the joints 52A and 52B. Thus, magnetic flux is caused to circumvent the switches 53A and 53B to which the flux legs 63A and 63L were aligned and causes the erasure of the magnetic flux legs 63A and 63L.

At this time, the unerased or remaining flux pairs should again be brought back to their original positions. This process of returning the flux pairs to their original positions is accomplished either by continuing the clockwise rotation of the remaining remanent poles and resultant flux pairs to their original positions or by reverse rotating in a counterclockwise direction the remaining remanent poles and resultant flux pairs to their original positions. This reverse rotation may be accomplished with the use of a second winding on each of the members as taught in FIG. 2 but which is not shown in this embodiment in order to preserve clarity. In either manner the result is that the reed switches 53A and 53L are unexcited by the flux pair 63A and 63L and hence are open, accomplishing thereby cut-off of the subscriber line 70 from line relay 74. The other subscriber lines 71 through 73 are again connected to their respective line relays 75 through 77.

When it is desired to reinstate the erased flux pair, for example when the conversation is over, and line 70 is desired to be reconnected to line relay 74, that absent pair or, to be specific, the positions the erased pair is to take are rerotated until they enclose the erase member 51A (illustrated by the flux pattern of FIG. 6D). The remanence of that member is again changed to cause

reinstatement of opposite remanent magnetic poles at joints 52A and 52B to which are connected the switches 53A and 53B and to which the flux legs will be reinstated. The rerotation is accomplished in the same manner as prior to erasure; the reinstatement is accomplished by applying an opposite, i.e., negative, polarity pulse to winding 68 of member 51A to cause change of the remanence thereof to be as depicted in FIG. 6C by closed arrow 62A.

The time required to accomplish the rotation of the flux pairs is dependent upon the response time of the control unit reed switches, and can be in the order of milliseconds, multiplied by the number of switches stepped. Thus, advantageously, the total time for the erasing or opening of a particular switch pair, may be far more rapid than is the case for mechanical stepping switches.

The stepped rotation of the magnetic flux legs through the closed reed switches interconnecting the line relays to the subscriber lines is accomplished with such rapidity that the interconnections are not disturbed to any substantial degree. Any contact chatter that may result can be substantially eliminated by adjusting the release times of the line relays.

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

What is claimed is:

1. A magnetically controlled rotary stepping switch comprising

a plurality of radially positioned contact switches, and means for establishing a magnetic flux pattern which is in alignment with selected ones of said switches and for causing selected rotation of said flux pattern to subsequent positions which are aligned with different ones of said switches, said last-mentioned means comprising

a plurality of remanently magnetic members each magnetically coupled between one terminal of each pair of adjacent switches,

means for initially selectively remanently magnetizing said members to cause said magnetic flux pattern having magnetic flux flowing through at least a pair of said switches to cause their consequent closures, and

means including part of said initial means for subsequently selectively remanently magnetizing said members to cause selective rotation in a particular direction of at least one leg of said flux pattern through different ones of said switches and to cause consequent stepped closures thereof.

2. The invention defined in claim 1 wherein said initial and said subsequent means in common comprise

a plurality of windings each magnetically coupled to a respective member,

at least one pulse source, and

means for connecting one terminal of each of said windings to said pulse source, and

said initial means further comprises means for momentarily grounding the other terminal of at least one of said windings, and

said subsequent means further comprises

means for connecting each of said windings to a respective switch next adjacent the member associated with that winding, and

means for grounding the other terminal of each of said switches.

3. The invention defined in claim 2 wherein said source is capable of generating positive and negative polarity pulses and wherein each of said windings of said members is connected to a respective switch located at the end of that member opposite said particular direction of rotation such that positive pulses applied to said windings

will cause one leg of said flux pattern to rotate in said particular direction and such that negative pulses applied to said windings will cause another leg of said flux pattern to rotate in said particular direction.

4. The invention defined in claim 3 wherein further is provided

a second pulse source capable of generating positive and negative polarity pulses and second plurality of windings each coupled to a respective said member and each connected to a respective switch located at the end of that member in said particular direction of rotation such that positive pulses applied from said second source to said second plurality of windings will cause rotation of one leg of said flux pattern in a direction opposite said particular direction and such that negative polarity pulses applied from said second source to said second plurality of windings will cause rotation of another leg of said flux pattern in said opposite direction.

5. A magnetically controlled rotary stepping switch comprising

a control unit and at least one slave unit, each of said units comprising

a plurality of contact switches,

magnetic permeable means for interconnecting one terminal of each of said switches;

and means for causing a magnetic flux pattern which is in alignment with different ones of said switches and for causing selective rotation of said flux pattern to subsequent positions which are aligned with selected others of said switches, said last-mentioned means comprising

in each said unit a plurality of remanently magnetic members, each disposed between and magnetically coupled to the other terminals of respective adjacent pairs of said switches,

a plurality of windings each magnetically coupled commonly to a respective corresponding member of each of said control and slave units and each connected to a respective adjacent switch of the control unit, and

a source of pulses connectable to said windings to selectively remanently magnetize said members to cause initial induction of flux into at least a pair of corresponding switches of both said control and slave units and to cause their consequent closures, said source also being connectable to said windings to selectively remanently magnetize said members to cause stepwise rotational transferring of flux from one switch of both said units to other different ones of said switches thereof and to cause their consequent step-by-step closures.

6. A magnetically controlled rotary stepping switch comprising

a plurality of contact switches;

a magnetically permeable means for magnetically coupling in common one terminal of each of said switches; and means for causing a magnetic flux pattern which is in alignment with pairs of said switches and for subsequently causing rotation of said flux pattern to be in alignment with different pairs of said switches,

said last-mentioned means comprising

a plurality of remanently magnetic members, each magnetically coupled to a different respective pair of adjacent switches,

means for initially causing said magnetic flux pattern having a plurality of pairs of magnetic fluxes in positions aligned with a plurality of pairs of said switches, said aligned plurality of switch pairs each being separated by an open switch,

said initial means comprising

a first pulse source,

a plurality of windings, each magnetically coupled to a respective member,

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means for commonly connecting one terminal of each of said windings to said first source, means for connecting the other terminal of each first winding to a switch adjacent the associated member, and

means for momentarily grounding said other terminals of said first windings to cause appropriate remanent magnetization of members associated therewith and to cause said magnetic flux pairs which are in alignment with said pairs of switches, which switches enclose said associated members thereby causing their closures; and

means for subsequently causing sequential and wave-like rotation of one flux of each of said flux pairs in one step and the other flux of each of said flux pairs in a subsequent step from positions aligned with closed switches to positions aligned with open switches to effect opening of the previously closed switches and closing of the previously opened switches, said last-mentioned means comprising

in common with said initial means said first source and said plurality of windings, and means for controllably connecting said first source in step-by-step sequence to said one terminals of said windings thereby to selectively change the remanent magnetizations of the members associated with said windings to cause said wave-like rotation of said flux pairs.

7. The invention defined in claim 6 wherein further is provided means for destroying and for subsequently reinstating any one of said pairs of fluxes, said destroying and reinstating means comprising a second bipolar pulse source, and a further winding disposed on at least one of said members, said second source being connectable to said further winding to enable energization thereof with a particular polarity pulse to cause selective change of the remanence of said one member and to cause destruction of said desired pair of fluxes, and to enable energization of said further winding with an opposite polarity pulse to cause selective change of said remanence of said one member and to cause reinstatement of said desired pair of fluxes.

8. A magnetically controllable rotary stepping switch comprising

a closed magnetic structure having a plurality of remanently magnetic parts interconnected by a plurality of soft magnetic portions;

a plurality of two terminal magnetic switches of like permeability, one terminal of each magnetically coupled respectively to different said portions of said structure; a plurality of windings, each inductively disposed on respective said parts of said structure and each connected to a respective said switch adjacent thereto;

means for magnetically coupling together the other terminal of each of said switches;

a source of energizing pulses;

means for connecting said source to one terminal of each of said windings;

means for initially grounding the other terminal of at least one of said windings to permit energization of said windings by pulses from said source to cause a particular remanent magnetic pattern in said parts of said structure and to cause magnetic flux flow through at least one pair of said switches;

and means for controllably applying energizing pulses from said source to all of said windings to cause appropriate pulses to selectively travel through both initially closed switches and to cause changes in the remanent magnetic pattern of said parts of said structure, said changed remanent magnetic pattern causing magnetic flux to be rotated from a position aligned with at least one switch of said closed switch pair to another position aligned with an adjacent open switch to cause its closure.

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9. A switching device comprising a closed magnetic element comprising remanent magnetic means, a plurality of contact means magnetically coupled to said element and distributed along the periphery of said element, a plurality of control windings coupled to said element intermediate said contact means, and means for selectively energizing said control windings to orient said element in a magnetic condition for providing flux flow through selected pairs of said contact means to interconnect said selected pairs of actuated contact means.

10. A magnetic stepping switch comprising a closed magnetic element comprising remanent magnetic material, a plurality of contact switches magnetically coupled to said element and distributed along the periphery of said element, a plurality of control windings individually coupled to said element intermediate said contact means, means for selectively electrically connecting said contact means to adjacent ones of said windings, and pulse source means for sequentially energizing said windings to selectively magnetically orient said element to drive magnetic flux through and operate selected pairs of said contact means sequentially under control of said pulse means.

11. A magnetic stepping switch comprising a closed magnetic element comprising remanent magnetic material, a plurality of contact means having proximal and distal ends, means for magnetically coupling said distal ends to said element, additional means for magnetically intercoupling said proximal ends of said contact means, a plurality of control windings magnetically coupled to said element and individually disposed intermediate said contact means, and pulse source means for sequentially energizing said control windings to deliver a magnetic flux flow through selected pairs of said contact means to actuate said selected pairs step-by-step under control of said pulse source means.

12. A magnetically controlled stepping switch comprising an outer element of remanently magnetic material disposed in a closed path, an inner element of magnetic material, a plurality of contact means magnetically coupled to said outer and inner elements and disposed intermediate said outer and inner elements, a plurality of control windings magnetically coupled to said outer element and individually disposed intermediate said contact means, means for electrically connecting said contact means to selected adjacent control winding means, and means for periodically and sequentially energizing said control winding means to magnetically orient said outer element in varying magnetic conditions for driving magnetic flux through selected pairs of adjacent contact means to actuate said contact means on a step-by-step basis over a path including said control windings and previously actuated contact means.

13. A magnetically actuated stepping switch comprising a closed magnetic structure including remanent magnetic means and having a plurality of terminals disposed at different peripheral locations thereon, a plurality of magnetically operable switches each magnetically coupled to each said terminal, a plurality of windings, each disposed about said structure between said locations and connected to each switch, and means under the control of closed said switches for energizing said windings to establish particular remanent states of said structure and to effect closure of any selected pair of said switches and electrical connection between any pair of said terminals by causing magnetic flux to flow through said pairs.

14. A magnetically operated switch comprising a closed magnetic structure having defined thereon a plurality of terminal locations, means bridging said locations comprising a plurality of magnetic switches, each connected to each said location, means interconnecting said switches, a plurality of windings, each inductively coupled to portions of said structure between said locations, an energizing source, first means including said

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source for initially effecting a magnetic flux pattern through at least a particular pair of said switches by establishing particular remanent states of said structure to cause closure of said pair, and second means including said source and under the control of said closed switches for subsequently causing transfer of said flux pattern to any other pair of said switches to cause closure thereof and to effect electrical connection between any pair of corresponding terminal locations.

15. A magnetically actuated stepping switch comprising an outer concentric ring of remanent magnetic material, an inner concentric ring of magnetizable material, a plurality of magnetizable switches bridging said rings at different locations to form electrical terminals on the periphery of said outer ring, winding means disposed on said outer ring portions between said locations and connected to said switches, a pulse source, first means including said source and connectable to said winding means for initially establishing particular remanent states of said outer ring to cause a magnetic flux pattern having legs flowing through a particular pair of switches and a portion of said inner ring connected therebetween to cause closure of said particular pair of switches, and second means including said source and connectable to said winding means and under the control of said closed switches for changing said remanent states to cause transfer of said flux pattern to any other selected pair of said switches and closure thereof to complete an electrical circuit between a pair of said terminals correspondingly connected to said other pair of switches.

16. In a magnetically controlled switching arrangement having a plurality of magnetically responsive switch elements arranged in an array, the combination for causing magnetic flux to step along said array sequentially to close said switches comprising an outer closed magnetic member including at least remanent portions, each of said switches having one terminal thereof magnetically

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coupled to said outer member between adjacent said portions, winding means on each of said portions, means series connecting each said winding means with said one terminal of an adjacent switch, means commonly connecting the other terminals of said switches together, means for establishing an initial state of remanence in at least one of said portions to cause closure of at least one of said switches, and pulse means for applying pulses in parallel to all said windings to cause alteration of the states of remanence of said portions to effect a stepping of flux through successive ones of said switches in said array.

17. In a magnetically controlled switching arrangement in accordance with claim 16, the combination further comprising a second outer closed magnetic member including at least remanent portions and a second plurality of magnetically responsive switch elements, each of said second switches having one terminal thereof magnetically coupled to said second outer member between adjacent said portions and each said winding means encompassing one of said portions of both said first mentioned and said second outer members.

18. In a magnetically controlled switching arrangement in accordance with claim 16, the combination further comprising an inner closed magnetic member, the other terminals of each of said switches being magnetically coupled to said inner member.

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STEPHEN W. CAPELLI, *Primary Examiner*.

SAMUEL BERNSTEIN, *Examiner*.

D. YUSKO, *Assistant Examiner*.