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(54) **ELECTROMAGNETIC ACTUATOR APPARATUS.**

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PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 276 (E-215)1421r,9th December 1983; & JP - A - 58 157 104 (MATSUSHITA DENKO)

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Description

The present invention relates to a device which actuates a binary mechanical displacement or holding by electric power in a monostable manner. More particularly, the present invention relates to an electromagnetic actuator which electromagnetically actuates a binary displacement of mechanical operated device such as a valve rod, piston, movable element of switch, locking means, or the like in accordance with a minute electric current in a pulse series.

Conventionally, a holding magnet type electromagnetic actuator has been well known for applying mechanical force to a valve rod, piston or the like.

Referring to Fig. 1, there is shown this holding magnet type electromagnetic actuator which comprises a permanent magnet 2, and a pair of cores 1a and 1b which are respectively wound round with solenoid coils 3a and 3b. These permanent magnet 2, cores 1a, 1b and the solenoid coils 3a and 3b are so arranged as to form a magnetic circuit wherein magnetomotive forces of the electromagnet and the permanent magnet are arranged in series; that is, the magnetomotive force of the solenoid coils 3a and 3b is generated in the counter direction of the coercive force of the permanent magnet 2 when an electric current is flowed through the solenoid coils 3a and 3b. According to this arrangement, a contact element 4 can be reversibly held in either states shown in Fig. 1(a) or Fig. 1(b).

That is, when an electric current is so flowed through the solenoid coil 3a under the condition shown in Fig. 1(a) as to generate the counter magnetomotive force against the coercive force of the permanent magnet 2, the contact element 4 will be attracted to the another core 1b which is connected to the permanent magnet 2 and consists of magnetic material having great coercive force as shown in Fig. 1(b). On the other hand, when an electric current is so flowed through the solenoid coil 3b in the state of Fig. 1(b) as to generate the counter magnetomotive force against the coercive force of the permanent magnet 2, the contact element 4 is returned to the initial state shown in Fig. 1(a).

Although this holding type electromagnet has a self-holding capability for the contact element 4 when an electric current is not flowed, it has essentially following demerits.

(1) This type actuator requires two sets of solenoid coils 3a and 3b for actuating and returning operations so that the structure will be complicated and the size will be enlarged.

(2) An electric current is so flowed through the solenoid coil 3a or 3b as to generate the magnetomotive force in the counter direction of the coercive force of the permanent magnet 2 in order to reduce the coercive force so that the required ampere turn will be increased. Accordingly, an electric power of at least 10 W is required to generate the propulsive force of 0.2 kg and stroke of 2 mm.

(3) This type actuator requires three electric wires to control the actuation.

The British patent specification GB—A—1,466,555 discloses a bistable electromagnetic actuator comprising a magnetic circuit which consists of a stationary element and a movable element, a single electromagnetic coil, and a ring shaped permanent magnet. The permanent magnet is inserted in the magnetic circuit and mounted so that its magnetomotive force is parallel to that of the coil. The movable element is held within a space in the stationary element. Two pole faces in the stationary element are defined so that the movable element can contact one or other pole face.

The use of a spring establishing the monostable condition of the movable element of a magnetic flux shifting ground fault trip indicator is disclosed in the US patent 4,157,520.

It is the primary object of the present invention to provide an electromagnetic actuator of simple, compact and hardy structure which can so operate at high speed and with high sensitivity as to operate under monostable condition.

The electromagnetic actuator as claimed comprises a magnetic circuit consisting of a stationary element and a movable element, and electromagnetic means with a permanent magnet inserted in the magnetic circuit. The permanent magnet is mounted in such a way that magnetomotive force of the permanent magnet is parallel to that of said electromagnetic means, and the movable element is so held within a space in the stationary element that it can be actuated under monostable condition.

The said electromagnetic means comprises a single electromagnetic coil defining two pole faces so that the movable element contacts one or the other pole face. Said stationary element is wound round with the electromagnetic coil and formed into the magnetic circuit containing said space.

According to the present invention, said movable element is composed of said permanent magnet and of two magnetic segments. Each magnetic segment is fixed to each pole face of the permanent magnet. The movable element is so arranged in the space of the magnetic circuit that the magnetic segments face at right angle a yoke of the stationary element through a second gap so as to move alternatively between two positions short circuiting the magnetomotive force of the permanent magnet. A spring is provided for generating and overlapping mechanical bias force between the stationary element and the movable element so as to electromagnetically control a mechanical monostable condition of the actuator.

According to the above constitution, the present invention can provide the electromagnetic actuator having a simple and hardy structure and capable of operating with high sensitivity and at high speed.

Fig. 1(a) and (b) are schematic illustrations showing a conventional electromagnetic actu-

ator; Fig. 2(a) and (b) are schematic illustrations showing a first embodiment of the present invention; Fig. 3(a) and (b) are schematic illustrations showing a second embodiment of the present invention; Fig. 4(a) and (b) are schematic illustrations of a third embodiment of the present invention; and Fig. 5(a) and (b) are schematic illustrations showing a fourth embodiment of the present invention.

Hereinbelow, the present invention will be explained in detail according to the embodiments in conjunction with the drawings.

Fig. 2(a) and (b) show a first embodiment of the present invention, wherein the electromagnetic actuator comprises a stationary element 12 as a magnetic circuit having a space energized by a coil 11; a movable element 14 made of a magnetic material which is inserted between a pole faces 12a and 12b of the stationary element 12 through a first gap 13, the movable element 14 can be mechanically moved in the direction represented by the arrow 14a or 14b met with both the pole faces 12a and 12b at right angle; and a permanent magnet 16 fixed to a yoke 17 of the stationary element 12, the pole faces of the same polarity of the permanent magnet 16 are faced to the side surface of the movable element 14 through a fine second gap 15.

An operation on this embodiment will be explained below. As shown in Fig. 2(a), when the movable element 14 is contacted to the pole face 12b of the stationary element 12, the movable element 14 is subjected to the magnetic attractive force towards the pole face 12b due to the magnetic flux 27, 28 of the permanent magnet 16.

Under this condition, when an electric current in a pulse series is flowed through the coil 11 in the positive direction so as to generate the magnetic pole of N-polarity at the pole face 12b and the magnetic pole of S-polarity at the pole face 12a, magnetic flux 26 is generated. So the magnetic flux 26 and the magnetic flux 27, 28 of the permanent magnet will be concentrated to the first gap 13 so that the movable element 14 will be moved with a snap into the state shown in Fig. 2(b). After intercepting the current in a pulse series flowed in the positive direction, the movable element 14 can be held in the contacting state with the pole face 12a owing to the magnetic flux 27, 28 of the permanent magnet 16.

Under the condition shown in Fig. 2(b), when the electric current in a pulse series is flowed through the coil 11 in the reverse direction of the above so as to generate the magnetic pole of N-polarity at the pole face 12a and the magnetic pole of S-polarity at the pole face 12b, magnetic flux 29 is generated. So the magnetic flux 29 and the magnetic flux 27, 28 of the permanent magnet 16 will be concentrated to the first gap 13, so that the movable element 14 is returned to the condition shown in Fig. 2(a).

Fig. 3(a) and (b) show a second embodiment of the present invention, wherein a permanent magnet 16 is so fixed onto the side surface of a movable element 14 as to form a fine second gap 15 between a yoke 17 and the permanent magnet 16.

An operation of this embodiment is carried out in the same manner as the first embodiment shown in Fig. 2(a) and (b).

Fig. 4 shows a third embodiment of the present invention, wherein a movable element 14 capable of mechanically moving in the direction met to both pole faces 12a and 12b of a stationary element 12 at right angle is inserted between a space energized by a coil 11 and pole faces 12a and 12b through a first gap 13, a permanent magnet 16 is connected to the stationary element 12 in series, and contact elements 37 is fixedly connected to both pole faces of the permanent magnet 16 so as to face to the side surfaces of the movable element 14 met to the pole face 12b at right angle through a second gap 15.

As shown in Fig. 4(a), when the movable element 14 contacts to the pole face 12b and faces to the pole face 12a through the first gap 13, the movable element 14 is magnetically attracted to the pole face 12b owing to the magnetic flux 31 caused by the permanent magnet 16. Under this condition, when an electric current in a pulse series is flowed through the coil 11 in the positive direction so as to form N-polarity at the pole face 12b and S-polarity at the contact element 37 connected to the S-pole face of the permanent magnet 16, magnetic flux 30 is generated. The repulsion force caused by the magnetic flux 30 and the magnetic flux 31 of the permanent magnet 16 will be generated at the pole face 12b so that the movable element 14 will be moved with a snap towards and attracted to the pole face 12a as shown in Fig. 4(b). After intercepting the current in a pulse series flowing in the positive direction, it is possible to maintain the attracted state of the movable element 14 to the pole face 12a owing to the magnetic flux 31 of the permanent magnet 16.

Under the condition shown in Fig. 4(b), when an electric current in a pulse series is flowed through the coil 11 in the reverse direction of the above so as to form S-polarity at the pole face 12b and N-polarity at the contact element 37, magnetic flux 32 is generated. So the magnetic flux 32 and the magnetic flux 31 of the permanent magnet 16 will be concentrated to the first gap 13 adjacent to the pole face 12b so that the movable element 14 will be returned to the condition shown in Fig. 4(a) and thus attracted to the pole face 12b of the stationary element 12.

Fig. 5 shows a fourth embodiment of the present invention wherein a pair of magnetic pole segments 45, 45 is arranged at both sides of a movable element 46 made of a permanent magnet instead of the permanent magnet 16 in the third embodiment shown in Fig. 4. An operation of this embodiment will be conducted according to magnetic flux 34 caused by the movable element 46 (made of a permanent magnet) and magnetic flux 33, 35 caused by the flow of the electric current through the coil 11 in the same manner as the above embodiment shown in Fig. 4.

According to the present invention, the actuator is carried out in a monostable operation by employing a mechanical bias force by means of a spring, which is a predetermined value smaller than the attractive force of the permanent magnet and applied in the counter direction of the permanent magnet so as to overlap the bias force with the relative movement between the stationary element and the movable element.

As given explanation above, since the embodiment according to the present invention is so designed as to reduce the ampereturn of the coil as possible which supplies operation energy, the insertion of the powerful permanent magnet can result in the following extremely superior effects.

(1) In the operation of the present embodiment, the magnetic flux of energizing current and that of the permanent magnet always act each other in only the inside of the soft magnetic material and thus the magnetomotive force caused by flowing an electric current through the coil does not directly act with that of the permanent magnet having a great coercive force as different from the conventional device shown in Fig. 1. Therefore, it is possible to reduce extremely the required ampere turn for energizing so that two different operation parameters for mechanical strength and mechanical position can be controlled by a minute electric current in a pulse series.

According to an experimental result, the movable element applied with the attractive force of 500 g could be moved in the reverse direction for a stroke of 2 mm with a thrust of 1 kg by supplying the extremely minute operation energy such as an electric current of 6V, 0.5A in a pulse series of several ten m/sec. On the other hand, conventionally used device requires a three wires type for a control cable in addition to the operation electric power of about 30 W for a stroke of 2 mm with a thrust of 1 kg.

(2) The embodiment of the present invention can be achieved by using a coil which can be operated by a two-wires type control cable while the conventional device shown in Fig. 1 requires two coils and a three-wires type control cable. Thus, the present invention can provide a compact, light and low cost device.

(3) The device according to the present invention can be operated by a minute electric current in a pulse series so that it is possible to reduce the cost of wiring equipments for a long distance remote operation.

(4) Since the device according to the present invention can be operated by a small energy such as a low voltage and a minute current, it is possible to use this device for an essential safety and exploding prevention device in factory or mine, and to use a solar cell as an operation power source of this device.

As given explanation above, the present invention can be effectively utilized for an electromagnetic valve, electromagnetic piston, electromagnetic locking device, switch operating mechanism, essential safety and exploding prevention device, abnormal retracting mechanism, or various industry and private usage.

Claims

1. Electromagnetic actuator comprising a magnetic circuit consisting of a stationary element and a movable element, and electromagnetic means with a permanent magnet inserted in the magnetic circuit, the permanent magnet being mounted in such a way that magnetomotive force of the permanent magnet is parallel to that of said electromagnetic means, and the movable element is so held within a space in the stationary element that it can be actuated under monostable condition, the said electromagnetic means comprising a single electromagnetic coil (11) defining two pole faces (12a, 12b) so that the movable element contacts one or the other pole face, said stationary element (12) being wound round with the electromagnetic coil (11), characterized in that said movable element is composed of said permanent magnet (46) and of two magnetic segments (45), each magnetic segment being fixed to one pole face respectively of the permanent magnet, and the movable element is so arranged in the space of the magnetic circuit that the magnetic segments face at right angle a yoke (17) of the stationary element through a gap (15) so as to move alternatively between two positions short circuiting the magnetomotive force of the permanent magnet, and a spring is provided for generating and overlapping mechanical bias force between the stationary element and the movable element so as to electromagnetically control a mechanical monostable condition of the actuator.

2. Electromagnetic actuator according to claim wherein the stationary element (12) is made of a ferromagnetic substance; the movable element made of magnetic material is so inserted between magnetic pole faces (12a, 12b) of the stationary element (12) facing the space that the movable element can be reversibly moved with respect to the magnetic pole faces through a gap (13); and the permanent magnet (46) fixed to the movable element has pole faces of the different polarity of the above pole faces of the stationary element so that the magnetomotive force of the permanent magnet (46) is parallel to the magnetomotive force of the electromagnetic coil (11) in the magnetic circuit.

Patentansprüche

1. Elektromagnetischer Aktuator, der einen magnetischen Kreis, gebildet aus einem stationären Element und einem bewegbaren Element sowie elektromagnetische Mittel mit einem in den magnetischen Kreis eingesetzten Dauermagneten umfaßt, wobei der Dauermagnet in der Weise eingebaut ist, daß die magnetomotorische Kraft des Dauermagneten parallel zu den elektromagnetischen Mitteln verläuft, und das bewegbare Element in der Weise in einem Raum inner-

halb des stationären Elements gehalten wird, daß es unter einer monostabilen Bedingung betätigbar ist, wobei die elektromagnetischen Mittel eine einzige elektromagnetische Spule (11) umfassen, die zwei Polflächen (12a, 12b) bestimmt, so daß das bewegbare Element die eine oder die andere Polfläche berührt, und wobei das stationäre Element (12) mit der elektromagnetischen Spule (11) umwickelt ist, dadurch gekennzeichnet, daß das bewegbare Element aus dem Dauermagneten (46) und zwei magnetischen Segmenten (45) besteht, wobei jedes magnetische Segment an jeweils einer Polfläche des Dauermagneten befestigt ist, und das bewegbare Element in der Weise innerhalb des Raumes des magnetischen Kreises angeordnet ist, daß die magnetischen Segmente im rechten Winkel einem Joch (17) des stationären Elements über einen Luftspalt (15) hinweg zugekehrt sind, so daß es sich wechselweise die magnetomotorische Kraft des Dauermagneten kurzschließend zwischen zwei Stellungen bewegt, und eine Feder vorgesehen ist zum Erzeugen und Überlagern einer mechanischen Vorspannkraft zwischen dem stationären Element und dem bewegbaren Element, so daß eine mechanische monostabile Bedingung des Aktuators elektromagnetisch gesteuert wird.

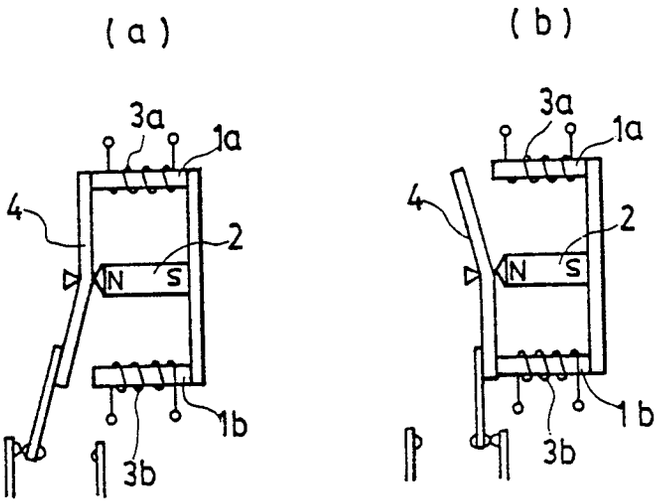
2. Elektromagnetischer Aktuator nach Anspruch 1, bei dem das stationäre Element (12) aus einer ferromagnetischen Substanz gefertigt ist; das aus einem magnetischen Material gefertigte bewegbare Element in der Weise zwischen dem Raum zugekehrten magnetischen Polflächen (12a, 12b) des stationären Elementes (12) eingesetzt ist, daß das bewegbare Element gegenüber den magnetischen Polflächen reversibel durch einen Luftspalt (13) hindurch bewegbar ist und der an dem bewegbaren Element befestigte Dauermagnet (46) Polflächen aufweist, welche eine andere Polarität als die der vorstehend erwähnten Polflächen des stationären Elements aufweisen, so daß die magnetomotorische Kraft des Dauermagneten (46) parallel zur magnetomotorischen Kraft der elektromagnetischen Spule (11) im magnetischen Kreis verläuft.

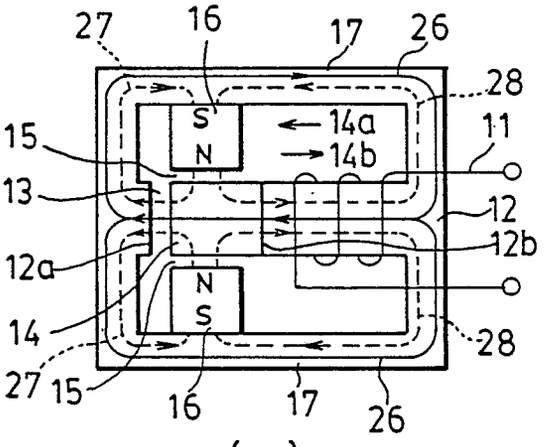
Revendications

1. Actionneur électromagnétique comportant un circuit magnétique constitué d'un élément stationnaire et d'un élément mobile, et de moyens électromagnétiques avec un aimant permanent inséré dans le circuit magnétique, l'aimant permanent étant monté de telle sorte que la force magnétomotrice de l'aimant permanent soit parallèle à celle desdits moyens électromagnétiques, l'élément mobile étant maintenu à l'intérieur d'un espace dans l'élément stationnaire de façon qu'il puisse être actionné dans un état monostable, lesdits moyens électromagnétiques comportant un enroulement électromagnétique unique (11) définissant deux faces polaires (12a, 12b) de sorte que l'élément mobile vienne en contact avec l'une ou l'autre face polaire, ledit élément stationnaire (12) étant entouré par l'enroulement électromagnétique (11), caractérisé en ce que ledit élément mobile est constitué dudit aimant permanent (46) et de deux segments magnétiques (45), chaque segment magnétique étant fixé à une face polaire de l'aimant permanent respectivement, l'élément mobile étant disposé de telle façon dans l'espace du circuit magnétique que les segments magnétiques fassent face à angle droit à une culasse (17) de l'élément stationnaire à travers un entrefer (15) de façon à se déplacer alternativement entre deux positions court-circuitant la force magnétomotrice de l'aimant permanent, et en ce qu'un ressort est prévu pour générer et récouvrir une force mécanique de sollicitation entre l'élément stationnaire et l'élément mobile de façon à commander de façon électromagnétique un état monostable mécanique de l'actionneur.

2. Actionneur électromagnétique selon la revendication 1, caractérisé en ce que l'élément stationnaire (12) est en matériau ferromagnétique; en ce que l'élément mobile en matériau magnétique est inséré entre les faces polaires magnétiques (12a, 12b) de l'élément stationnaire (12) faisant face audit espace, de telle sorte que l'élément mobile puisse être déplacé de façon réversible par rapport aux faces polaires magnétiques à travers un entrefer (13); et en ce que l'aimant permanent (46) fixé à l'élément mobile présente les faces polaires d'une polarité différente de celle des faces polaires de l'élément stationnaire, de telle sorte que la force magnétomotrice de l'aimant permanent (46) soit parallèle à la force magnétomotrice de l'enroulement électromagnétique (11) dans le circuit magnétique.

FIG. 1

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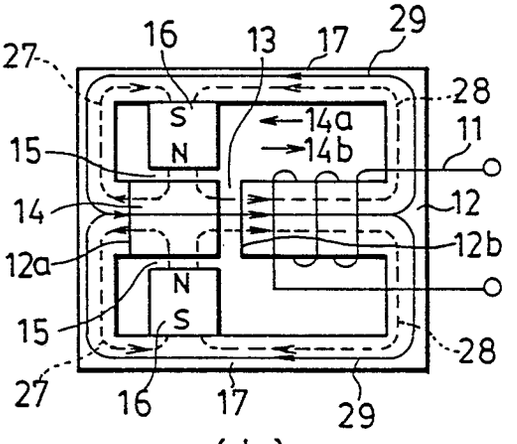
(a)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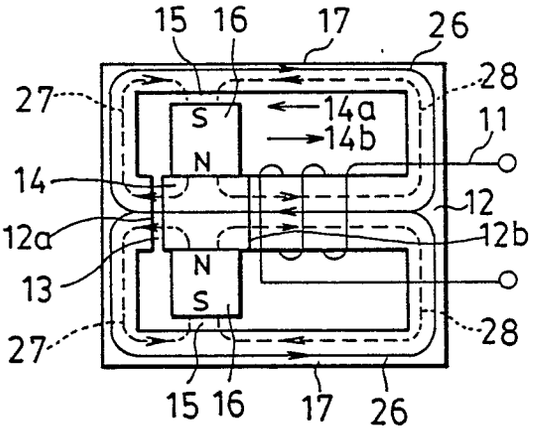
(b)

FIG. 2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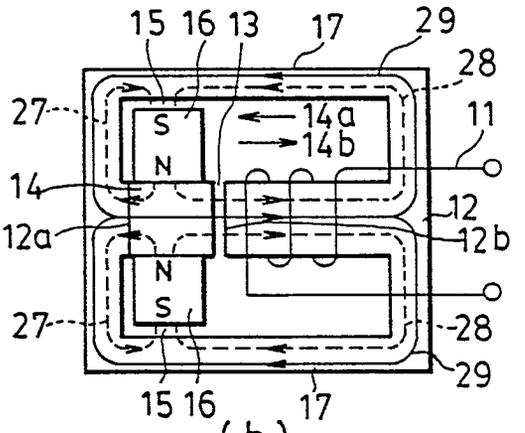
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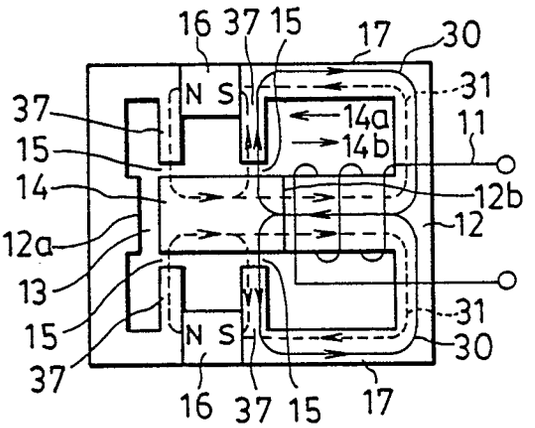
(b)

FIG. 3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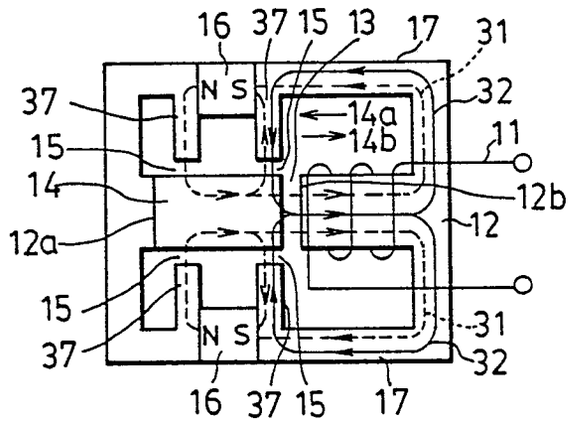
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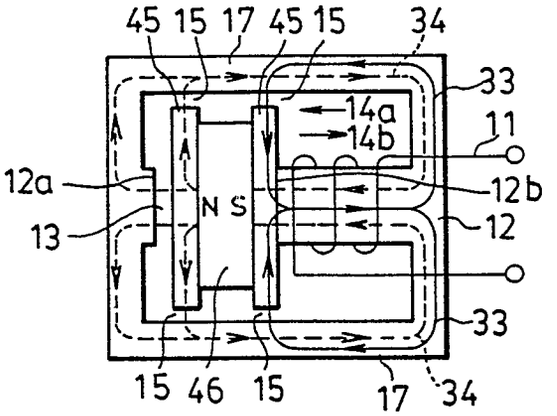
(b)

FIG. 4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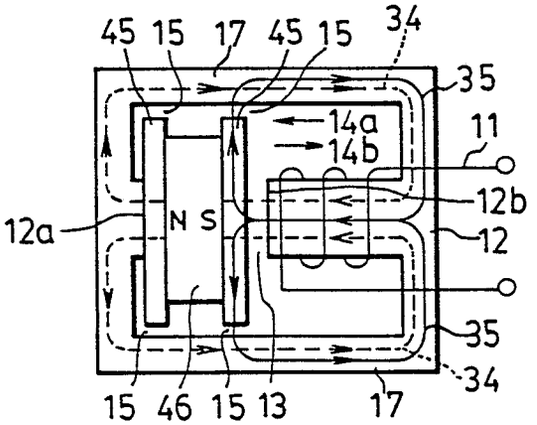
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(b)

FIG. 5