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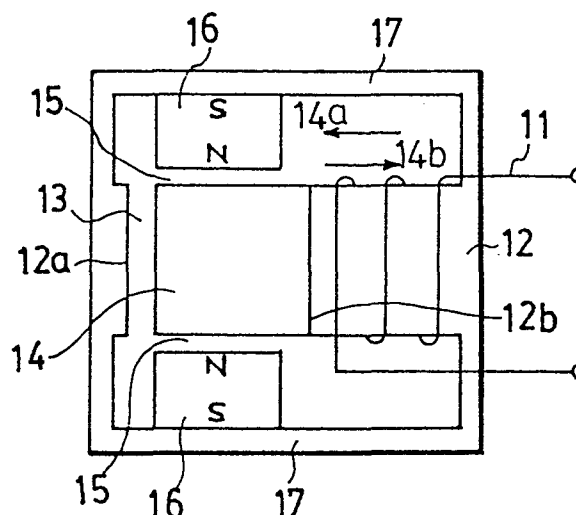
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⑤④ **ELECTROMAGNETIC ACTUATOR APPARATUS.**

⑤⑦ An electromagnetic actuator apparatus is provided with a permanent magnet (16) inserted parallel to a magnetic circuit constituted by a fixed member (12) around which a coil (11) is wound and a movable member (14). The movable member (14) is retained within an air gap inside the fixed member (12) so that it operates in a bistable or monostable manner.



SPECIFICATION

ELECTROMAGNETIC ACTUATOR

Technical Field

The present invention relates to a device which actuates a binary mechanical displacement or holding by electric power in a monostable or bistable 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.

Background Art

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 during 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 10W is required to generate the propulsive force of 0.2kg and stroke of 2mm.

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

Disclosure of The Invention

With these demerits in mind, 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 generate under either monostable or bistable condition.

To accomplish the above object, the electromagnetic actuator according to the present invention mainly comprises a magnetic circuit containing a combination of stationary element and movable element, wherein a permanent magnet is so arranged that the magnetomotive force of the permanent magnet is inserted in parallel to the magnetomotive force of electromagnet in the magnetic circuit so as to actuate under either monostable or bistable condition.

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.

Brief Description of The Drawings

Fig. 1(a) and (b) are schematic illustrations showing a conventional electromagnetic actuator; 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.

Preferred 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 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, all magnetic flux of this actuator 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 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, 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 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, the repulsion force 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 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, all magnetic flux 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 instead of the permanent magnet 16 in the third embodiment shown in Fig. 4. An operation of this embodiment will be conducted in the same manner as the above embodiment shown in Fig. 4.

According to the present invention, the actuator may be also carried out in a monostable operation by employing a mechanical bias force or magnetic bias force; for example 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 30W 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.

Availability for Industry

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.

WHAT IS CLAIMED IS;

1. In an electromagnetic actuator comprising a magnetic circuit consisting of a stationary element and a movable element, the improvement characterized that a permanent magnet is inserted in the magnetic circuit so as to be the magnetomotive force of the permanent magnet in parallel to that of the electromagnet of the circuit; and the movable element is so held within the space in the stationary element as to actuate under either monostable or bistable condition.

2. The electromagnetic actuator according to Claim 1, wherein the stationary element containing the space forming the magnetic circuit is made of a ferromagnetic substance wound round with an electromagnetic coil; the movable element made of magnetic material is so inserted between magnetic pole faces of the stationary element facing the space that the movable element can be reversibly moved with respect to the magnetic pole faces through a first gap; and the permanent magnet is so fixed to either the stationary element or the movable element at the position excluding the first gap that pole faces of the permanent magnet having the different polarity of the above pole faces of the stationary element are faced to either element through a second gap so as to arrange the magnetomotive force of the permanent magnet in parallel to the electromagnetic coil in the magnetic circuit.

3. The electromagnetic actuator according to Claim 1,

wherein the stationary element is a magnetic material wound round with the electromagnetic coil, the magnetic material is fixed to both pole faces of the permanent magnet so as to form the magnetic circuit containing the space; and the movable element made of magnetic material is so arranged as to move alternatively between two positions magnetically short connecting the magnetomotive force caused by the permanent magnet facing the space of the magnetic circuit.

4. The electromagnetic actuator according to Claim 1, wherein the stationary element is wound round with the electromagnetic coil and formed into the magnetic circuit containing the space; and the movable element is composed of the permanent magnet and two magnetic segments, each magnet 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 magnet segments face to a yoke of the stationary element through a second gap so as to move alternatively between two positions shortly connecting the magnetomotive force of the permanent magnet.

5. The electromagnetic actuator according to any one of Claims 1 to 4 further comprising means for generating and overlapping magnetic bias attractive force or mechanical bias force between the stationary element and the movable element so as to electromagnetically control a mechanical monostable condition of the actuator.

FIG. 1

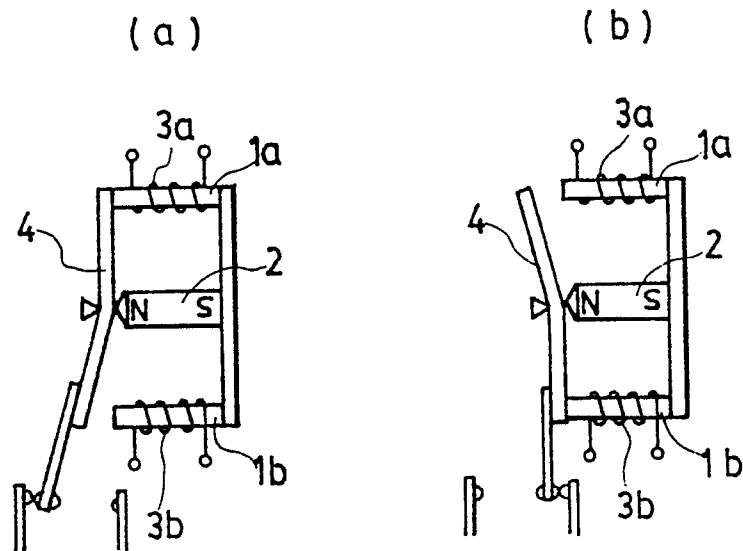


FIG. 2

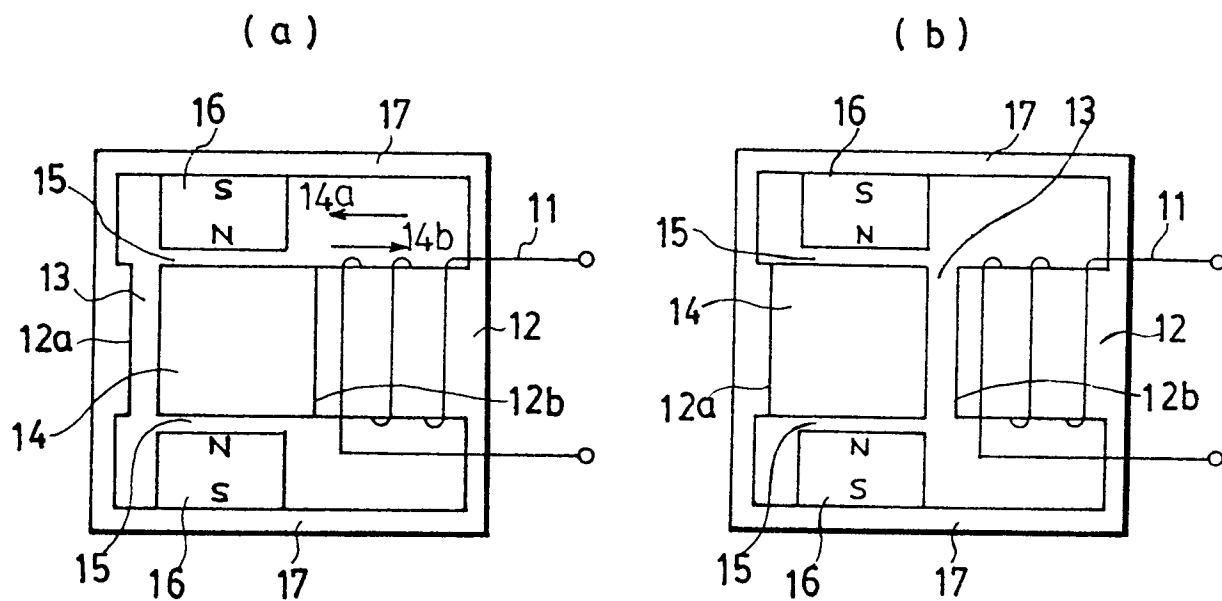


FIG. 3

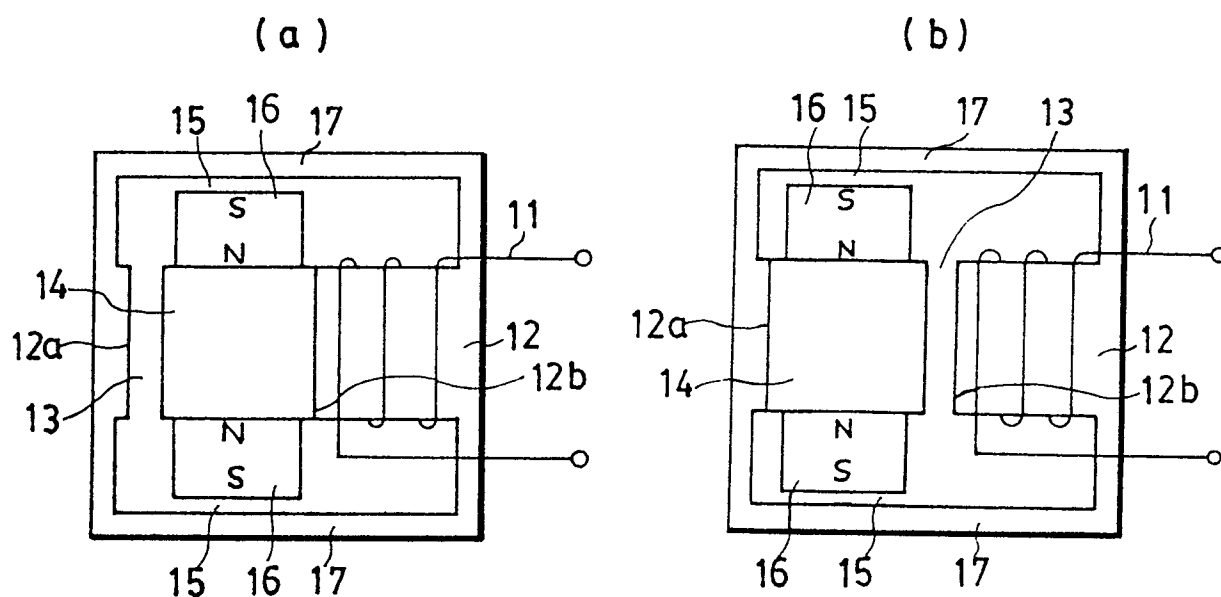


FIG. 4

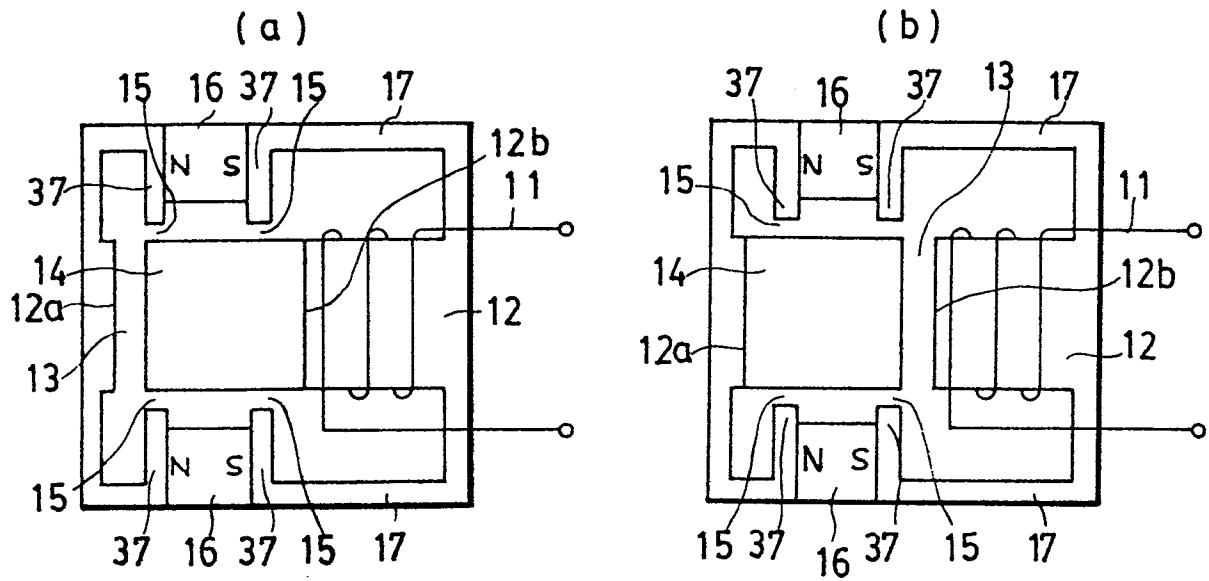
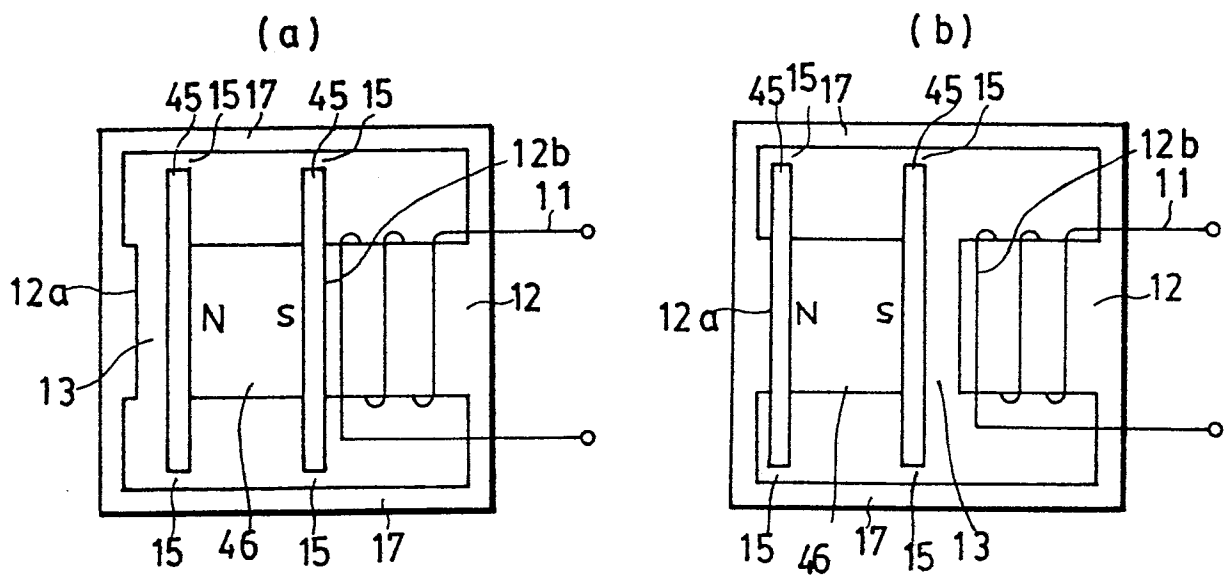


FIG. 5



INTERNATIONAL SEARCH REPORT

International Application No.

PCT/JP84/00084 0179911

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl ³ H01F7/08, 7/16		
II. FIELDS SEARCHED		
Minimum Documentation Searched *		
Classification System	Classification Symbols	
IPC	H01F7/08, 7/16	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched *		
	Jitsuyo Shinan Koho	1956 - 1984
	Kokai Jitsuyo Shinan Koho	1971 - 1984
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category*	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
A	GB, A, 1,047,848 (H. E. & B. S. Benson Ltd.) 17 July 1963 (17. 07. 63) Fig. 1	1
A	GB, A, 1,347,854 (Anker-Werke A. G.) 6 July 1970 (06. 07. 70)	1
A	JP, A, 56-168315 (Matsushita Electric Works, Ltd.) 24 December 1981 (24. 12. 81) Fig. 5	1 - 4
A	JP, U, 59-18411 (Omron Tateisi Electronics Co.) 4 February 1984 (04. 02. 84) Fig. 2	1 - 4
* Special categories of cited documents: ¹⁵ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ²	Date of Mailing of this International Search Report ²	
May 14, 1984 (14. 05. 84)	May 28, 1984 (28. 05. 84)	
International Searching Authority ¹	Signature of Authorized Officer ²⁰	
Japanese Patent Office		