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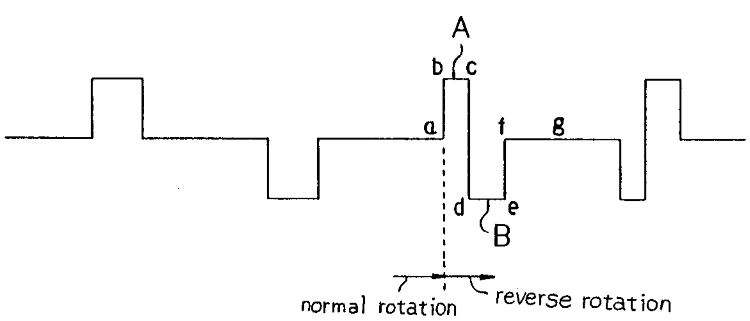
(54) Method for driving a stepping motor in reverse.

(57) [Purpose] It is an object of the present invention to provide a method for driving a stepping motor in reverse wherein the time required for the settlement to the static stable position in the reverse direction is reduced with reduced power consumption.

[Construction] A rotor 1 is rotated in the normal direction with pulses A to an extent that normal stepping is not achieved, and pulses B of the reverse polarity are then applied to reverse the rotor 1 (d). When the magnetic poles of the rotor 1 have passed a dynamic magnetic center line L2, the rotor 1 is rotated by an inertial force (f, g). This causes the rotor 1 to vibrate and settle about a static stable line L1 after the magnetic poles thereof pass a static neutral line (branch line) L3 (g). Since the rotor 1 is rotated by the inertial force after the magnetic poles thereof pass the dynamic magnetic center line L2, the current consumption of the motor can be reduced accordingly. Further, since the drive force of the rotor has already been stopped a predetermined period of time before the magnetic poles of the rotor 1 reach the static stable line L1, the time required by the rotor 1 to settle on the static stable line L1 can be shortened.

FIG. 3



[Detailed Description of the Invention]

[Field of the Invention]

The present invention relates to a method for driving a stepping motor in reverse.

[Description of the Related Arts]

A single-phase pulse motor used for quartz oscillation type clocks and the like is composed of a rotor comprising a permanent magnet magnetized to have two magnetic poles, i.e., N and S poles in the radial direction and a stator having stator magnetic poles for driving the rotor, and rotates the rotor stepwise with drive pulses. Such a single-phase pulse motor is designed so that the rotor is normally driven to rotate only in the normal direction.

In a typical pulse motor configurated for the normal rotation, the angle defined between a static stable position (a static stable line) and a dynamic stable position (a dynamic stable line) of the rotor is about 45 degrees in the reverse direction. The branch point at which the magnetic poles of the rotor start to rotate in either direction to reach the static stable position (hereinafter referred to as "static neutral point") is normally on the vertical bisector of the static stable line.

In a single-phase pulse motor configurated as described above, it has been attempted to allow the stepwise rotation not only in the normal direction but also in the reverse direction using only an electrical means, i.e., only by applying predetermined composite pulses. This makes it possible to cause a pulse motor to rotate stepwise in the the reverse direction without making the mechanical construction of the pulse motor more complicated, thereby allowing it to be used for purposes such as correction of clock needles and driving of the decorative pendulum of a clock for a reciprocate-rotating motion.

Japanese Patent Publication No. S62-43148 is known as one of such prior techniques. The said Patent Publication disclosed a technique wherein stepwise rotation in the reverse direction is achieved using composite pulses which are the combination of three pulses, i.e., pulses A having the polarity which is the reverse of the polarity the pulse for nortmal rotation should have in the said step, pulses B which follow the pulses A and having the reverse polarity, and pulses C which preceed the pulses A, have the same polarity as that of the pulses for normal rotation and have a pulse width which is not large enough to allow normal stepping. According to this, the pulses C having a predetermined pulse width are applied to an extent that the magnetic poles of the rotor do not exceed the position of the static neutral point to rotate the rotor in the normal direction; the return movement of the rotor is absorbed and accelerated by the subsequent pulses A; the pulses B are applied at the time when the magnetic poles of the rotor have come in the vicinity of a dynamic magnetic center position, whereby the rotor repulse to further accerelate in the reverse direction; and the application of the pulses B is stopped when the magnetic poles of the rotor have advanced to a static stable position after passing the static neutral point.

As described above, the rotor is reversed by applying the pulses B after the rotor has been rotated using the pulses C in the normal direction to an extent that the magnetic poles of the rotor do not exceed the static neutral point. As a result, it is possible to apply the pulses A in a period which is the sum of (1) the period during which the rotor starts to return and reaches the static stable position and (2) the period during which the rotor moves from the static stable position to the dynamic magnetic center position, thereby obtaining a reverse drive torque which is larger than that in the case wherein the pulses C are not applied.

[Problems to be Solved by the Invention]

However, since the pulses B are applied until the magnetic poles of the rotor moves from the dynamic magnetic center position to the static stable position and, thereafter, the rotor is stopped at the static stable position as a result of a settling action, the rotor is under a storng inertial force at the time when the application of the pulses B is stopped. This causes the magnetic poles of the rotor to vibrate about the static stable position to finally settle at the static stable position. This phenomenon is referred to as hunting of a rotor, and there has been a problem that it takes too long until the hunting settles. This has resulted in a problem when a rotor is rotated at a high speed.

Further, since the reverse drive is performed using composite pulses comprising three kinds of pulses, there has been a problem that much power must be consumed for driving. Especially, only a very small contribution is made to the increase in the rotation drive torque of the rotor by the pulses B applied when the magnetic poles of the rotor are in the dynamic magnetic center position because the repulsion force resulting from the magnetic field works substantially in the direction of the center of the rotor. Accordingly, while the power consumption increases due to the application of the pulses B, the pulses B make a small contribution to the increase in the torque of the rotor.

It is an object of the present invention to provide a method for driving a stepping motor : in reverse wherein a rotor can be reliably reversed; the magnetic poles of the rotor settle at a static stable position in a short period of time and, therefore, can be rotated at a high speed; and the power consumption is small.

[Means for Solving the Problems]

In order to achieve the above object, according to the present invention, a rotor comprising a permanent magnet magnetized to have two poles, i.e., N and S poles, a stator having a pair of stator magnetic poles magnetically driving the rotor, and a driving coil exciting the stator are provided, and the said rotor is reversed by applying, at a predetermined cycle and for each stepping motion of the rotor in the reverse direction, reversing drive pulses constituted by composite pulses which are the combination of pulses A having the same polarity as the polarity that drive pulses for normal rotation should have in the said step and having a pulse width which is not large enough to allow forward stepping, and pulses B which follow the said pulses A, have reverse polarity, and are applied in the period between the time of the reversal of the rotor and the time at which the rotor reaches a dynamic magnetic center line.

[Operation]

Since the pulses B can be applied within a large angle of rotation at which the rotor which has advanced in the normal direction in a predetermined quantity, is reversed and reaches the dynamic magnetic center line (dynamic stable line), it is possible to cause, through the application of the pulses B, the magnetic poles of the rotor to exceed the static neutral point due to inertia after they have passed the dynamic magnetic neutral position. The values for the voltage and the width of the pulses B are set so that the magnetic poles of the rotor can exceed the static neutral point due to inertia after they have passed the dynamic magnetic neutral position.

[Embodiment]

An embodiment of the present invention will now be described with reference to the drawings.

Fig.1 shows a stepping motor wherein a notched integral stator is used. A rotor 1 is constituted by a disc-shaped permanent magnet magnetized to have two poles, i.e., N and S poles. The normal rotation of the rotor 1 is the counter-clockwise rotation.

A stator 2 comprises left and right portions which are integrally formed and a central portion having a round opening 2a through which the rotor 1 is inserted. On a straight line Y passing the center of the round opening 2a and extending in the vertical direction in Fig. 1, the stator 2 is provided with narrow width portions 2b and 2c on the top and bottom portions thereof. The narrow width portions 2b and 2c provide a small sectional area and a high magnetic resistance at that area. This causes the stator 2 to act as if it is magnetically separated into left and right portions at the straight line Y, forming a pair of stator magnetic poles at the both sides of the opening 2a.

A coil core 5 is provided at the bottom end of the stator 2, and a drive coil 6 is wound around the coil core 5. The drive coil 6 is provided with left and right input terminals 6a and 6b for a drive current. The straight line L2 passing the center of the round opening 2a and extending in the horizontal direction in Fig. 2 is a magnetic center line which is present when energized. When the drive current is applied to the drive coil 6 via the input terminals 6a and 6b, the stator magnetic poles are excited to become N and S poles via the coil core 5. With the stator 2 excited, the rotor 1 receives a force such that the magnetic poles thereof move towards the magnetic center line L2.

A pair of arc-like notches 2d and 2e are provided on the round opening 2a. The notches 2d and 2e are provided on a line L3 passing the center of the round opening 2a(a notch center line), and the notch center line L3 is provided at a position which is at an angle of -45 deg counterclockwise with respect to the dynamic magnetic center line L2. The vertical bisector of the notch center line L3 substantially constitutes the static stable line L1 of the rotor 1 in a non-energized state. The notch center line L3 constitutes the branch line at which the magnetic poles of the rotor start to rotate in either direction to reach the static stable position (a static neutral line).

Hereinafter, L1, L2, and L3 are referred to as "static stable line", "dynamic magnetic center line", and "static neutral line", respectively.

For example, the stepping motor 11 in Fig. 1 is incorporated in a quartz oscillation type clock as shown in Fig. 2. The frequency output from a quartz oscillator 12 is divided by a divider 13 into 1 Hz which is input to a control circuit 14. The control circuit 14 has a normal rotation pulse generating circuit and a reverse rotation pulse generating circuit (not shown) and transmit normal rotation pulses or reverse pulses as a drive signal to a driver 15 at every 1 Hz. The driver 15 generates a drive current corresponding to the drive signal which is supplied to the stepping motor 11. This causes the stepping motor 11 to rotate. Which will the control circuit 14 transmits as the drive signal, the normal rotation pulses or the reverse pulses, depends on a signal for changing the direction of rotation sent to the control circuit 14. The rotation of the stepping motor 11 causes the needles of the clock to rotate via a predetermined gear train and the like. Next, the movement of the rotor caused by the reverse pulses or the reverse pulses will now be described in detail.

Referring now to Fig. 3 and Fig. 4, the magnetic poles of the rotor 1 are positioned on the static stable line L1 with the N pole on the top right side and the S pole on the bottom left side as shown in Fig. 4(a). Further, in the pulse waveform diagram in Fig. 3, the positive pulses (those above the reference line are regarded as positive) cause the stator to be excited to have N pole on the right-hand side and S pole on the left-hand side (the state indicated by Fig. 4(b)), and the negative pulses cause excitation in the reverse way.

The reverse pulses are constituted by composite pulses which are the combination of pulses A having the same polarity as the polarity the drive pulses for normal rotation should have and having a pulse width which is not large enough to allow normal stepping, and pulses B which follow the pulses A, have the reverse polarity, and are applied in the period between the time at which the reversal of the rotor takes place and the time at which the rotor reaches the dynamic stable line.

The pulses A in Fig. 3 are applied when the magnetic poles of the rotor 1 are in the positions indicated by Fig. 4(a). This causes the rotor 1 to start the normal rotation (the state indicated by Fig. 4(b)). When the rotor 1 has rotated at 45 deg in the normal direction (the state indicated by Fig. 4(c), the pulses B in Fig. 3 are applied. This causes the polarity of the stator magnetic poles to be reversed. The rotor 1 further rotates in the normal direction at a predetermined angle (see Fig. 5) due to inertia and, thereafter, it is absorbed by the stator magnetic pole to rotate in the reverse direction (the state indicated by Fig. 4(d)). Although the rotor 1 further rotates in the normal direction at a predetermined angle due to inertia even afer the pulses B in Fig. 3 are applied, the width and hight of the pulses A are to be set so that the magnetic pole (N pole) does not exceed the static neutral line L3. This is to prevent a phenomenon that when the magnetic pole of the rotor exceeds the notch static neutral line L3, the angular moment acts on the rotor 1 in the normal direction, resulting in an increase in the drive torque required to reverse the rotor 1. Since the pulses B in Fig. 3 are applied when the rotor 1 has rotated at 45 deg in the normal direction, the magnetic field of the stator 2 generated by the pulses B absorbs the magnetic poles of the rotor 1 substantially in the radial direction of the rotor 1. As a result, a strong torque for the reverse rotation can be generated at the rotor 1 to allow more effective utilization of the current consumed. The application of the pulses B is continued until the magnetic poles of the rotor 1 reach the dynamic magnetic center line L2 (the state indicated by Fig. 4(e)) and stopped thereafter (the state indicated by Fig. 4(f)). The rotor 1 then continues to rotate in the reverse direction due to an inertial force. The magnetic poles exceed the static neutral line L3 towards the static stable line L1. They vibrate and settle about the static stable line L1 and then stop at the static stable line L1 (the state indicated by Fig. 4(g)). Since the pulses B can be applied while the rotor 1 which has rotated at 45 deg in the normal direction rotates at 45 deg in the reverse direction, it is possible to provide the rotor 1 with a very large reverse drive torque to generate a very strong inertial force. The width and hight of the pulses B are set so that the rotor 1 is given an inertial force which allows the magnetic poles thereof to pass the peak of the static neutral line L3. The magnetic poles of the rotor 1 rapidly lose their rotational speed after they pass the static neutral line L3 due to the rotational resistance of the gear train connected to the rotor 1 and the like, and overrun after passing the static stable line 1 only in a small quantity. Thus the vibration rapidly settles (See Fig. 5). Therefore, if the setting is made such that the settlement is complete in one second, it is possible to further reduce the rotational speed of the rotor 1 in the period of time during which the pulses A and B are applied. Accordingly, the hight V2 required for the pulses A and B shown in Fig. 5, i.e., the drive voltage applied to the step motor can be reduced to a small amount, and the power consumption can be thus reduced.

When the next signal is input to the control circuit 14 from the divider 13 one second later, a reverse pulse generator generates composite pulses which are the same as the above-mentioned composite pulses except that the overall polarity is reversed. The composite pulses cause the rotor to further rotate half way in the reverse direction, and the magnetic poles of the rotor stop on the next static stable line L1. One second later, the next signal is input to the control circuit 14 again from the divider 13, and pulses having the polarity which is the reverse of that of the said composite pulses, i.e., pulses having the same polarity as that of the above-described composite pulses are generated to cause the rotor 1 to further rotate half way in the reverse direction. This is repeated to keep the rotor 1 reversing.

Although the pulses A are applied until the rotor 1 rotates at 45 deg in the normal direction in the present embodiment, the pulses A are used to cause the rotor 1 to rotate in the normal direction provided that the rotor 1 does not achieve normal stepping. As far as the condition is satisfied, the pulses A may be applied, for example, until the rotor 1 comes in the vicinity of the static neutral line L3.

Further, the pulses B are applied until the magnetic poles of the rotor 1 reach the dynamic magnetic center line L2 in the present embodiment. However, since the angular moment of the rotor 1 received from the magnetic field of the stator becomes small when the magnetic poles of the rotor 1 come in the vicinity of the dynamic magnetic center line L2, the application of the pulses B may be stopped before that.

Further, although the composite pulses generated by the reverse pulse generator have a cycle of one second in the present embodiment, it is possible to employ a configuration wherein, for example, a press on the normal-reverse switch for a predetermined period of time causes a periodic signal from a quick-return signal generator (not shown) having a frequency prepared in advance to be input to the control circuit 14 to generate the said composite pulses at a short cycle which can be used as a quick-return mechanism for the needles of a clock. Since the present invention makes it possible to shorten the time required by the rotor to settle, it is possible to shorten the time required for one stepping motion. As a result, a quich-return mechanism of a high speed can be obtained with small power consumption.

In addition, the present invention may be applied to a drive mechanism for rotating the decorative pendulum of in a clock, and the like. Since a great reverse drive torque can be obtained, it is possible to reverse-rotate substances having big rotational resistance such as a decorative pendulum. Further, since the settling time in the case of the reverse rotation is short, the reverse rotation can be performed at a high speed, and it is possible to provide large movement in a variety of forms with small power consumption by combining the normal rotation and the normal rotation at a high speed.

[Advantage of the Invention]

The present invention reduces the time required by a rotor to settle on a static stable line at the reverse rotation thereof (hunting) and, as a result, it is possible to provide a quick-return mechanism of a high speed.

Further, since no pulse is applied after the magnetic poles of a rotor pass a dynamic magnetic center line and the reverse drive is performed with two pulses, the power consumption for the motor can be reduced.

In addition, since the settling time of a rotor is shortened, the speed of the rotation of the rotor due to the pulses A and B can be reduced extending the time required for the rotation. Accordingly, the drive voltage can be reduced to thereby reduce the power consumption. This allows efficient utilization of the power.

[Brief Description of the drawings]

[Fig. 1]

Fig. 1 shows the configuration of a stepping motor.

[Fig. 2]

Fig. 2 is a block diagram illustrating the driving of a stepping motor.

[Fig. 3]

Fig. 3 is a waveform diagram of composite pulses applied according to the present invention.

[Fig. 4]

Fig. 4 illustrates the states of the rotation of a rotor taken on various positions of the composite pulses.

[Fig. 5]

Fig. 5 is a graph showing the angle of the rotation of a rotor relative to time t when the composite pulses are applied.

[Reference Numerals]

1 :	rotor
2 :	stator
6 :	drive coil
11 :	stepping motor

Claims

1. A method for driving a stepping motor in reverse which is equipped with a rotor comprising a permanent magnet magnetized to have two poles, i.e., N and S poles, a stator having a pair of stator magnetic poles magnetically driving the rotor, and a driving coil exciting the stator, characterized in that the said rotor is reversed by applying, at a predetermined cycle and for each stepping motion of the said rotor in the reverse direction, reversing drive pulses constituted by composite pulses which are the combination of pulses A having the same polarity as the polarity that drive pulses for normal rotation should have in the said step and having a pulse width which is not large enough to allow forward stepping, and pulses B which follow the said pulses A, have the reverse polarity and are applied in the period between the time of the reversal of the rotor and the time at which the rotor reaches a dynamic magnetic center line.

FIG.1

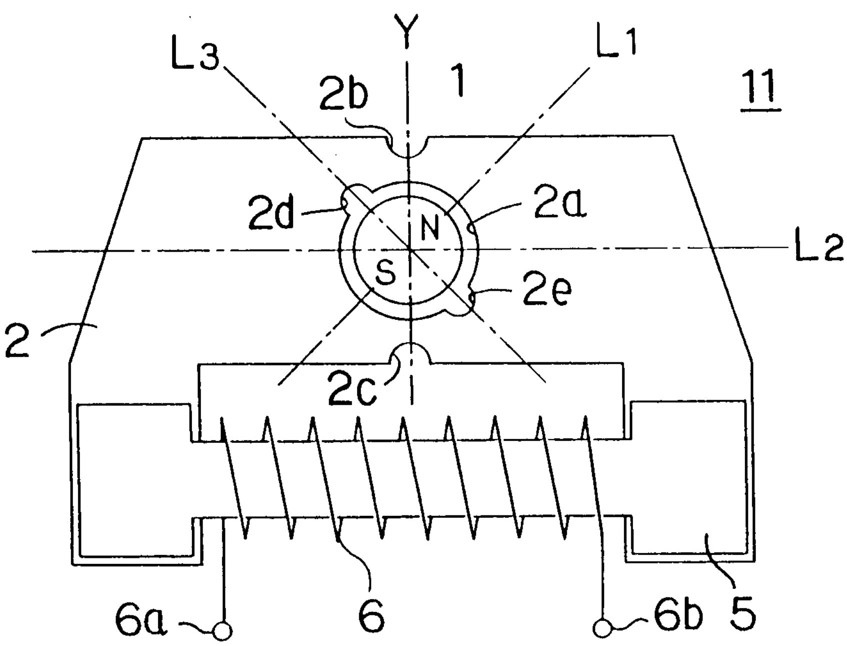


FIG. 2

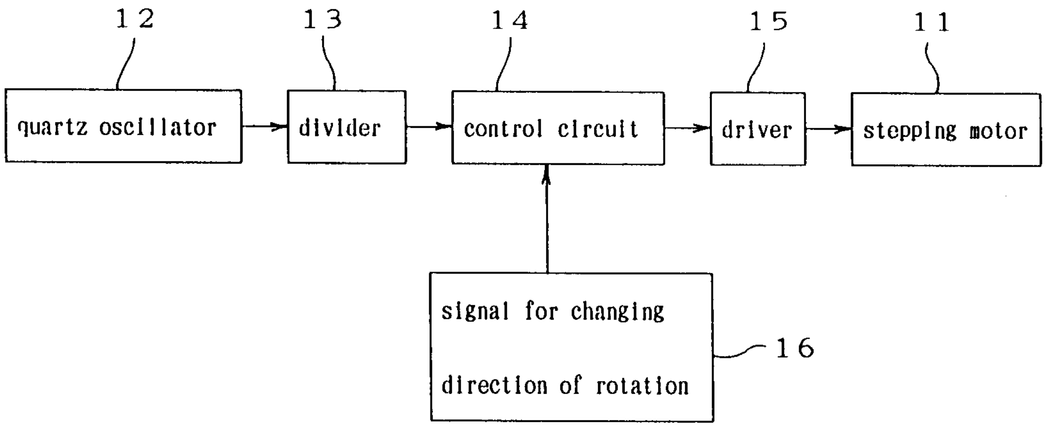
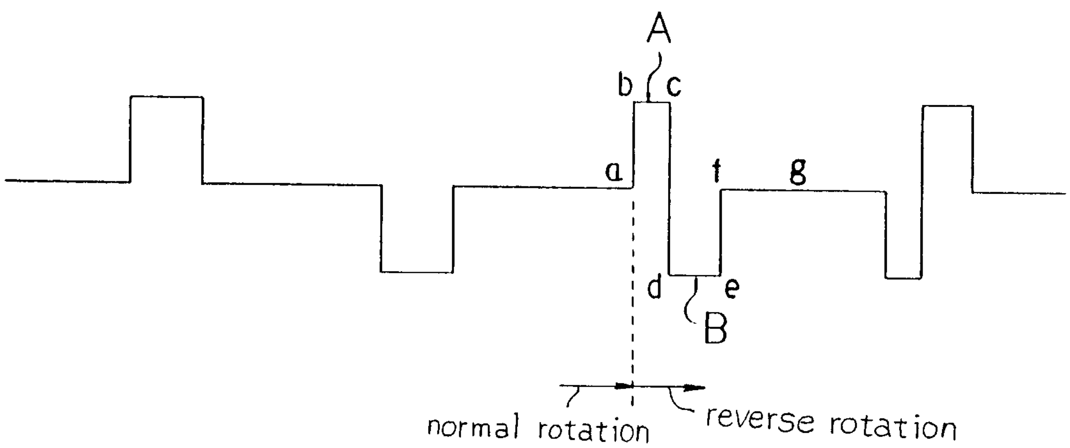

12
13
14
15
11
quartz oscillator
divider
control circuit
driver
stepping motor
signal for changing direction of rotation
16

FIG. 3



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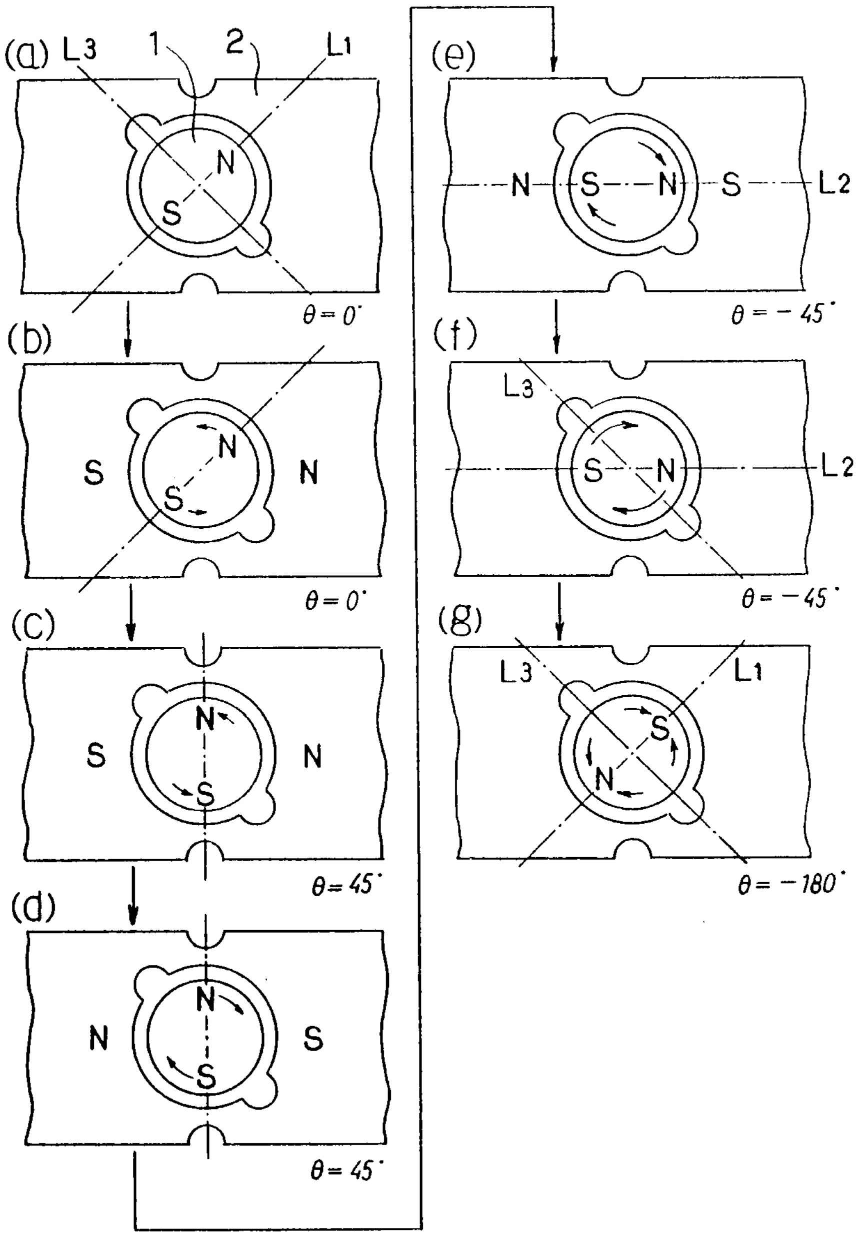
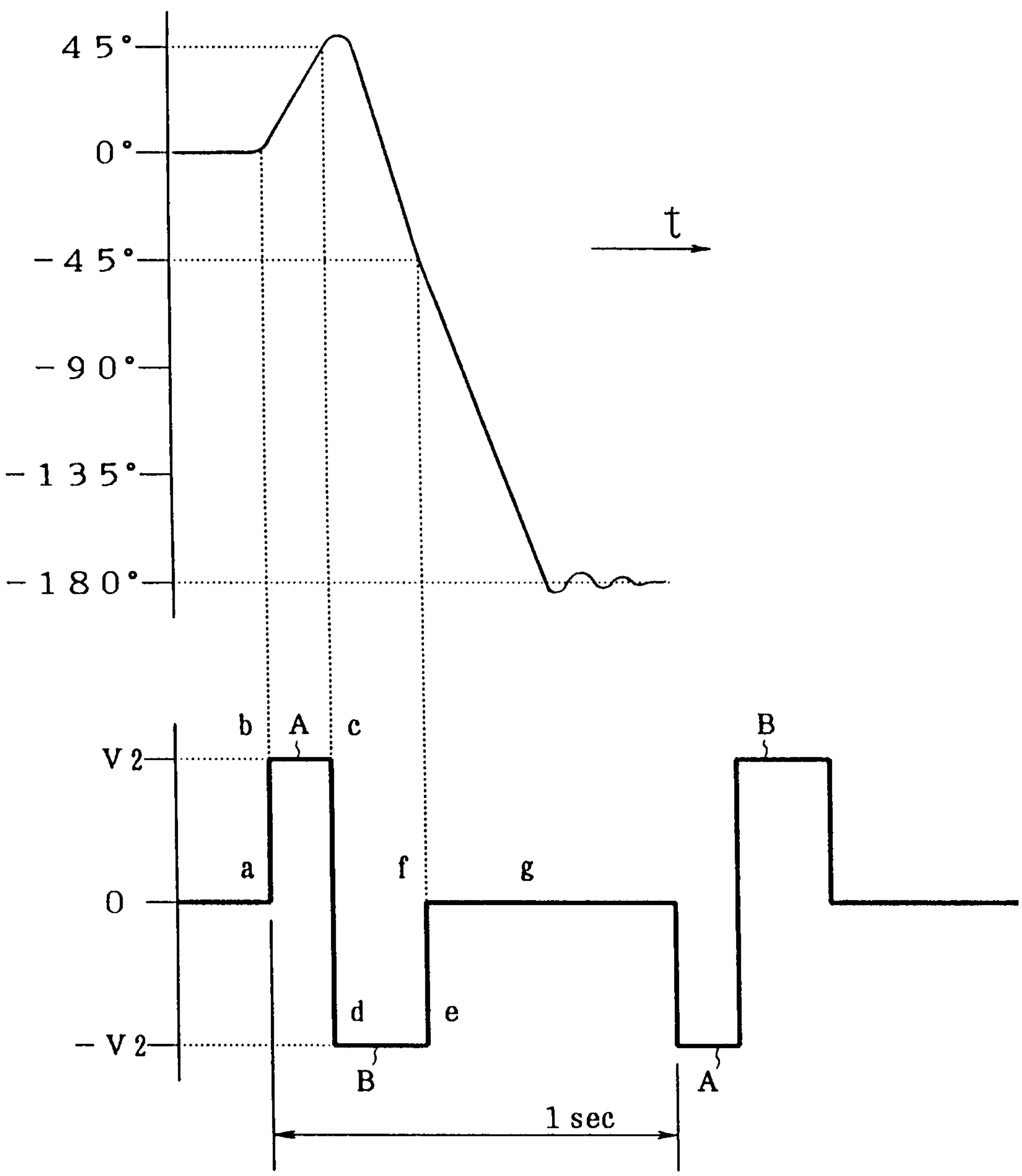

(a)
L3
1
2
L1
N
S
θ = 0°
(b)
S
N
N
S
θ = 0°
(c)
S
N
N
S
θ = 45°
(d)
N
S
N
S
θ = 45°
(e)
N
S
N
S
L2
θ = − 45°
(f)
L3
S
N
L2
θ = − 45°
(g)
L3
L1
S
N
θ = − 180°

FIG. 5



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EUROPEAN SEARCH REPORT

Application Number

EP 92105727.9

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	GB - A - 2 084 819 (TIMEX CORPORATION) * Abstract; page 1, lines 3-102; page 3, lines 102-127; fig. 6 * --	1	H 02 P 8/00 G 04 C 3/14
A	EP - A - 0 026 002 (SOCIETE SUISSE POUR L'INDUSTRIE HORLOGERIE) * Abstract; page 1, lines 1-35; fig. 10 * --	1	
A	EP - A - 0 341 582 (ASULAB S.A.) * Column 6, line 18 - column 11, line 17; fig. 1,2 * ----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H 02 P G 04 C H 02 K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	25-08-1992	HAJOS

CATEGORY OF CITED DOCUMENTS

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