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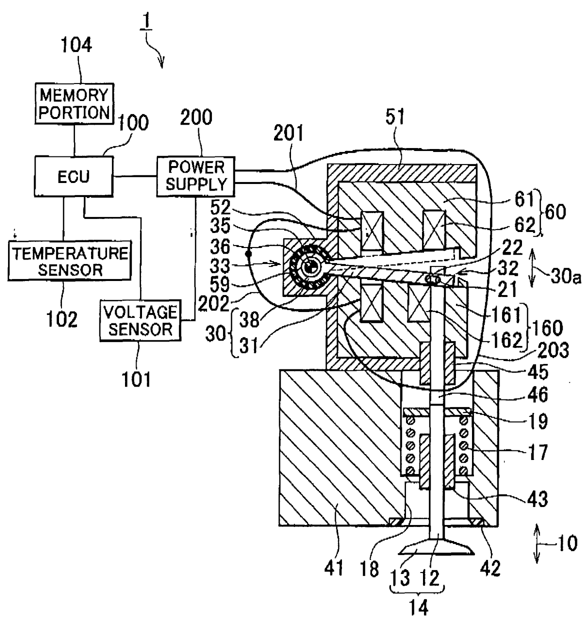
(54) Electromagnetically driven valve and driving method of the same

(57) An electromagnetically driven valve includes a valve element (14) that has a valve stem (12) and moves in reciprocating motion in a direction in which the valve stem (12) extends; a disc (30) that is interlocked with the valve element (14) at a driving end (32), extending to a pivoting end (33), from which a central axis(35) extends and around which the disc (30) oscillates; a coil (62) that oscillates the disc (30); a power supply (200) that supplies electric current to the coil (62); and an ECU (100) that controls the flow of current from the power supply (200) to the coil (62). During the initial period of operation of the disc, the ECU (100) controls the current so that it is supplied from the power supply (200) to the coil (62) in cycles, and in accordance with the voltage and temperature, controls the number of current cycles, the cycle length, and the value of the current.

FIG. 1



EP 1 752 624 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention generally relates to an electromagnetically driven valve, and more particularly, relates to a pivot-type electromagnetically driven valve that is used for an internal combustion engine and driven by electromagnetic force and elastic force and to a means of driving the same.

2. Description of the Related Art

[0002] An electromagnetically driven valve has been disclosed, for example, in the US patent No. 6,467,441.

[0003] The electromagnetically driven valve has a problem in that its sliding resistance at low temperature is different from that at high temperature, so that its controllability also varies, Moreover, when variable lift control is used to hold a disc out of contact with a core, if coil current fluctuates due to load-induced fluctuations in battery voltage, it is impossible to control the holding of the electromagnetically driven valve in a stable manner.

SUMMARY OF THE INVENTION

[0004] The invention aims to provide an electromagnetically driven valve that can be driven in a stable manner.

[0005] A first aspect of the invention relates to an electromagnetically driven valve that is operated by a combined action of electromagnetic force and elastic force. The electromagnetically driven valve includes a valve element that has a valve stem and moves in reciprocating motion in a direction in which the valve stem extends; an oscillating member that is interlocked with the valve element at an driving end, extending to a pivoting end, from which a central axis extends and the oscillating member oscillates around the central axis; a coil that oscillates the oscillating member; a power supply that supplies electric current to the coil; and a control portion that controls the flow of electric current from the power supply to the coil. During the initial period of operation of the oscillating member, the control portion controls the flow of electric current so that electric current is provided from the power supply to the coil in cycles. Specifically, during the initial period of operation, the control portion controls the number of cycles, the cycle length, and the value of the electric current in accordance with the voltage and temperature.

[0006] In an electromagnetically driven valve configured in the above-described manner, a control portion controls the periodic number, the periodic length and the current value in accordance with the voltage and temperature, at the initial drive; therefore it can accelerate heating to improve controllability by applying higher electric current at the low temperature period when sliding resistance is large.

[0007] A second aspect of the invention relates to an electromagnetically driven valve that is operated by a combined action of electromagnetic force and elastic force. The electromagnetically driven valve includes a valve element that has a valve stem and moves in reciprocating motion in a direction in which the valve stem extends; an oscillating member that is interlocked with the valve element at a driving end, extending to a pivoting end, from which a central axis extends and the oscillating member oscillates around the central axis; a core of an electromagnet that oscillates the oscillating member; and a permanent magnet that is located on the outer side of the driving end of the oscillating member and is positioned in such a way that a magnetic flux passing through the oscillating member and the core becomes greater.

[0008] In the electromagnetically driven valve configured as described above, the magnetic flux passing through the oscillating member and the core becomes greater, thereby reducing electric power consumption and making the valve less subject to the effects of voltage when the valve is held at an intermediate lift position. As a result, an electromagnetically driven valve is provided that improves controllability and ensures stable operation.

[0009] According to the invention, an electromagnetically driven valve is provided that ensures stable operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of preferred embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG 1 is a cross-sectional view of an electromagnetically driven valve in accordance with a first embodiment of the invention;

FIG. 2 is a schematic circuit diagram of the electromagnetic valve shown in FIG 1;

FIG. 3 is a graph that shows the relation between electric current and valve lift during the initial period of operation;

FIG 4 is a cross-sectional view of an electromagnetically driven valve that shows a neutral position;

FIG. 5 is a cross-sectional view of an electromagnetically driven valve that shows a closed-valve state;

FIG. 6 is a map of electric current values in relation to different temperatures and voltages;

FIG. 7 is a map of cycle lengths in relation to different temperatures and voltages;

FIG. 8 is a map of the number of cycles in relation to different temperatures and voltages;

FIG 9 is a cross-sectional view of an electromagnetically driven valve in accordance with a second embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] Embodiments of the invention will be explained below with reference to the drawings. Note that in the embodiments below, identical reference symbols are used to represent identical or equivalent elements, and explanations thereof are not repeated.

(First embodiment)

[0012] FIG. 1 is a cross-sectional view of an electromagnetically driven valve in accordance with an embodiment of the invention. An electromagnetically driven valve 1 operates by the combined action of electromagnetic force and elastic force. The electromagnetically driven valve 1 includes a valve element 14 that has a valve stem 12 serving as a valve shaft and moves in reciprocal motion in the direction in which the valve stem 12 extends (arrow 10); a disc 30 serving as an oscillating member that is interlocked with the valve element 14 at driving end 32 and that oscillates around an axis 35, located at pivoting end 33; coils 62 and 162 that drive an upper electromagnet 60 and a lower electromagnet 160 that oscillate the disc 30; a power supply 200 that supplies electric current to the coils 62 and 162; and an electronic control unit (ECU) 100 serving as a control portion that controls the flow of electric current from the power supply 200 to the coils 62 and 162. During the initial period of operation of the disc 30, the ECU 100 controls the flow of electric current so that electric current is supplied from the power supply 200 to the coils 62 and 162 in cycles. Specifically, the ECU 100 controls the number of current cycles, the cycle length, and the current value during the initial period of operation in accordance with the voltage and temperature.

[0013] A U-shaped housing 51 is a base member, and various elements are installed in the housing 51. The upper electromagnet 60 and the lower electromagnet 160 respectively include cores 61 and 161, which are made of magnetic material, and the coils 62 and 162, which are wound around the cores 61 and 161. The flow of electric current to the coils 62 and 162 generates a magnetic field, which drives the disc 30. The disc 30 is arranged between the upper electromagnet 60 and the lower electromagnet 160, and the disc is attracted to either of them by the attraction force of the upper electromagnet 60 and the lower electromagnet 160. This causes the disc 30 to move in reciprocal motion between the upper electromagnet 60 and the lower electromagnet 160. The reciprocal motion of the disc 30 is transmitted to a stem 46 through a long hole 22 and a pin 21.

[0014] The electromagnetically driven valve 1 in the embodiment constitutes one of an intake valve or exhaust valve in an internal combustion engine such as a gasoline engine and diesel engine. The embodiment section describes the case where a valve element serves as an intake valve fitted to an intake port 18, however the invention is applicable to a valve element that serves as an exhaust valve.

[0015] FIG. 1 shows the pivot-type electromagnetically driven valve 1. The disc 30 is used as a driving mechanism. The housing 51 is installed on a cylinder head 41; and the lower electromagnet 160 is arranged on the side closer to the cylinder head 41, while the upper electromagnet 60 is arranged on the side farther from the cylinder head 41. The coil 62, which configures the upper electromagnet 60, and the coil 162, which configures the lower electromagnet 160, are connected by a wire 202. Moreover, the coil 62 is connected to the power supply 200 by a wire 201, and the coil 162 is connected to the power supply 200 by a wire 203. In other words, the coils 62 and 162 are connected in series to the power supply 200.

[0016] The disc 30 includes an arm portion 31 and a bearing portion 38, and the arm portion 31 extends from driving end 32 to pivoting end 33. The arm portion 31 is a member that is attracted by the upper electromagnet 60 and the lower electromagnet 160; so that it oscillates (or pivots) in the direction indicated by the arrow 30a. The bearing portion 38 is set at an end of the arm portion 31, and the arm portion 31 pivots around the bearing portion 38. It is possible for the upper surface of the arm portion 31 to come into contact with the upper electromagnet 60, and it is possible for the lower surface of the arm portion 31 to come into contact with the lower electromagnet 160.

[0017] The bearing portion 38 is cylindrical, and a torsion bar 36 is accommodated therein, A first end of the torsion bar 36 is fitted into the housing 51 by means of a spline fitting, while the other end is fitted into the bearing portion 38 of the disk 30. Consequently, when the bearing portion 38 pivots, a force in the opposite direction to the rotation is transmitted from the torsion bar 36 to the bearing portion 38. Thus a reaction force is constantly applied to the bearing portion 38 in a neutral direction. At driving end 32 of the disk 30, the stem 46 is provided in such a way that force is imparted to it from the disc 30, and the stem 46 is guided by a stem guide 45. The stem 46 and the disc 30 can oscillate in the direction indicated by the arrow 30a.

[0018] The housing 51 has a projection 52, and pivoting end 33 of the disk 30 is accommodated therein. A bearing 59 is arranged between the bearing portion 38 and the projection 52 of the housing 51.

[0019] The intake port 18 is provided in the lower part of the cylinder head 41. The intake port 18 is a passage for the introduction of intake air into a combustion chamber, and either air-fuel mixture or air passes through the intake port 18. A valve seat 42 is provided between the intake port 18 and the combustion chamber, thereby improving the sealability of the valve element 14.

[0020] The valve element 14 is installed on the cylinder head 41 as an intake valve. The valve element 14 includes the valve stem 12 extending in the longitudinal direction and a bell portion 13 attached at the end of the valve stem 12. The valve stem 12 is guided by a stem guide 43 and is fitted with a spring retainer 19. The spring retainer 19 is energized in the upward direction by a valve spring 17. Thus both the spring retainer 19 and the valve stem 12 are energized by the valve spring 17.

[0021] The ECU 100 controls electric current flowing from the power supply 200 to the coils 62 and 162. The ECU 100 obtains temperature and voltage data from a temperature sensor 102 and a voltage sensor 101. The voltage sensor 101 monitors voltage from the power supply 200. The temperature sensor 102 detects temperature (water temperature, air temperature, or the temperature of the electromagnetically driven valve 1). The ECU 100 is connected to a memory unit 104, in which various map data are stored, including the current cycles and the current values that flows into the coils 62 and 162.

[0022] FIG. 2 is a schematic circuit diagram of the electromagnetically driven valve shown in FIG. 1. As FIG. 2 shows, the two coils 62 and 162 are connected in series to the power supply 200. This embodiment describes an example where the two electromagnets 60 and 160 are arranged on the upper and lower sides respectively, but this example is non-limiting, and more electromagnets may be provided.

[0023] FIG. 3 is a graph that indicates the relationship between the valve lift and electric current during the initial period of operation. FIG. 4 is a cross-sectional view of the electromagnetically driven valve indicating the neutral position. FIG 5 is a cross-sectional view of the electromagnetically driven valve showing a closed-valve state. With reference to FIG. 1 to FIG. 5, motion mechanism of the electromagnetically driven valve is described. In the neutral state, the arm portion 31 on the disc 30 is positioned on the center of the upper electromagnet 60 and the lower electromagnet 160, as shown in FIG 4. This condition continues until a time t10, at which point a electric current I flows to the coils 62 and 162 until a time t11. Because the distance between the arm portion 31 and the upper electromagnet 60 is made slightly shorter than that between the arm portion 31 and the lower electromagnet 160, a large force acts between the arm portion 31 and the upper electromagnet 60, so that at time t11, the valve element 14 moves from the neutral position toward the closed-valve position.

[0024] At time t11 the electric current is reduced. Once the arm portion 31 moves upward, downward torsion force is applied to it by the torsion bar 36. As a result, the arm portion 31 moves downward until moves below the neutral position, at which time it stops and then starts to move upward. When it starts moving upward, electric current once more flows to the coils 62 and 162, and the arm portion 31 is strongly drawn upward. This reciprocating motion is repeated from cycle 1 to cycle 3. Through this process, the amplitude of the movements of the valve element 14 gradually becomes greater until the valve element 14 is finally in the closed state. The electric current cycles (cycle 1 to cycle 3 in FIG 3) are controlled during this initial period of operation.

[0025] Once the valve-closed state shown in FIG. 5 is attained, the arm portion 31 can be held by the upper electromagnet 60 as long as a small holding electric current is supplied to the coil 62.

[0026] The cycles shown in FIG 3 are varied according to the voltage and temperature. FIG. 6 shows a map of current values in relation to different temperatures and voltages. FIG. 7 shows a map of cycle lengths in relation to different temperatures and voltages. FIG. 8 shows a map of the number of cycles in relation to different temperatures and voltages. At first, temperature and voltage are measured by the temperature sensor 102 and the voltage sensor 101 shown in FIG 1. Based on the measured temperature and voltage, the ECU 100 calculates an appropriate current value for the initial period of operation, using the FIG. 6 current map stored in the memory unit 104. For example, if the temperature stays between T2 and T3 and the voltage is between V3 and V4, the electric current for the initial period of operation will be calculated from the four current values I23,I33,I24, and I34 on the electric current map. The ECU 100 calculates the length of each cycle based on the FIG. 7 cycle length map. Under the above-mentioned temperature and voltage conditions, the ECU 100 calculates the cycle length based on the cycle lengths L23, L33, L24, and L34 on the cycle length map.

[0027] The ECU 100 also calculates the number of cycles based on the FIG 8 map of the number of cycles. Under the above-mentioned temperature and voltage conditions, the ECU 100 calculates the number of cycles based on the numbers of cycles N23, N33, N24, and N34 on the map. The map data shown in the FIG. 6 through FIG 8 are stored in the memory unit 104, and the ECU 100 can always access the memory unit 104.

[0028] That is, in the embodiment of the invention, the electric current, cycle length, and number of cycles for the initial period of operation are mapped according to the temperature and voltage, and are then controlled to conform to the map based on monitoring values that are input from the temperature and voltage sensors. Particularly, when the temperature is very low and the sliding resistance is high, the normal set value for over-current is momentarily increased. When the temperature is very low, the difference between the measured temperature and the heat-resistance limit temperature of the coils 62 and 162 is greater than under normal operating conditions. The amount by which the electric current is increased is therefore set so that the amount of temperature increase in the coils, due to their heating by the increased electric current, will be equal to the increased temperature difference between the measured temperature and the heat-resistance limit temperature of the coils 62 and 162. The number of cycles for the initial period of operation when the temperature is very low is set so that the temperature of an actuator rises enough to lower the high sliding resistance almost to the sliding resistance level under normal operating conditions. That is, the flow of electric current is controlled so that the upper and lower electromagnets 60 and 160 are heated. In an electromagnetically driven valve configured in this manner, the controllability of the electromagnetically driven valve 1 can be improved by accelerating its heating when the temperature is low and the sliding resistance is high.

(Second Embodiment)

[0029] FIG. 9 is a cross-sectional view of an electromagnetically driven valve in accordance with a second embodiment of the invention. In the electromagnetically driven valve in accordance with the second embodiment of the invention, a permanent magnet 300 is provided on the outer side of driving end 32 of an arm portion 31. The permanent magnet 300 is positioned so that it is apart from a core 161. As a result of this arrangement, the arm portion 31 is held in a position where it is not in direct contact with the core 161. An electromagnetically driven valve 1 in accordance with the second embodiment of the invention is an electromagnetically driven valve that is operated by the combined action of electromagnetic force and elastic force. The electromagnetically driven valve 1 includes a valve element 14 that has a valve stem 12 and moves in reciprocal motion in the direction in which the valve stem 12 extends; a disc 30 that is interlocked with the valve element 14 at driving end 32 and that oscillates around an axis 35, located at pivoting end 33; a core 161 of an lower electromagnet 160 that oscillates the disc 30; a permanent magnet 300 arranged on the outer side of the disc 30 and positioned in such a way that a magnetic flux that passes through the disc 30 and the core 161 in a direction indicated by arrow 301 becomes greater. In the embodiment the amount of lift of the valve element 14 is made variable, and the permanent magnet 300 is arranged on the outer side of the disc 30 in order to reduce electric current (power consumption) when holding the disc 30 out of contact with the core 161. The permanent magnet 300 is positioned apart from the core 161 and close to driving end 32, yet not in direct contact with an arm portion 31. The arrangement of the permanent magnet 300 in this way increases the flow of the magnetic flux generated by the permanent magnet as indicated by the arrow 301. As a result, power consumption can be reduced and the valve can be made less subject to the effects of voltage when the arm portion 31 is held at the intermediate lift position, so that a highly controllable electromagnetically driven valve 1 is provided.

[0030] The first and second embodiments of the invention have been explained above, but numerous variations of the embodiments shown here are possible. The electromagnetically driven valve is not limited to the single-disc driven type, and it may be structured so that an electromagnet is arranged between two parallel disks.

[0031] The embodiments disclosed herein are illustrative examples in every respect and should be considered to be non-limiting. The scope of the invention is indicated not by the explanations above, but by the scope of the claims, and it is intended that the equivalents of the claims and all modifications within the spirit and scope of the claims be included.

[0032] The invention can be used, for example, in the field of electromagnetically driven valves for internal combustion, engines that are mounted in vehicles,

Claims

1. An electromagnetically driven valve that is operated by the combined action of electromagnetic force and elastic force, having:

    a valve element (14) that has a valve stem (12) and moves in reciprocating motion in a direction in which the valve stem extends;
    an oscillating member (30) that is interlocked with the valve element at a driving end (32), extending to a pivoting end (33), from which a central axis extends, and the oscillating member oscillates around the central axis;
    a coil (62, 162) that oscillates the oscillating member;
    a power supply (200) that supplies electric current to the coil; and
    a control portion (100) that controls the flow of electric current from the power source to the coil,
    characterized in that
    during the initial period of operation of the oscillating member (30), the control portion (100) controls at least one of a number of cycles, a cycle length, and a value of an electric current provided in cycles to the coils (62, 162) in accordance with the voltage of the power supply that drives the electromagnetically driven valve (14) and temperature.

2. An electromagnetically driven valve according to claim 1, wherein, as the temperature decreases, the control portion (100) increases the value of the electric current that is provided to the coils (62, 162) in cycles during the initial period of operation.

3. An electromagnetically driven valve according to claim 1 or 2, wherein, as the temperature decreases, the control portion (100) increases the number of cycles in which electric current is provided to the coils (62, 162) during the initial period of operation.

4. An electromagnetically driven valve that is operated by the combined action of electromagnetic force and elastic force, **characterized by** comprising:

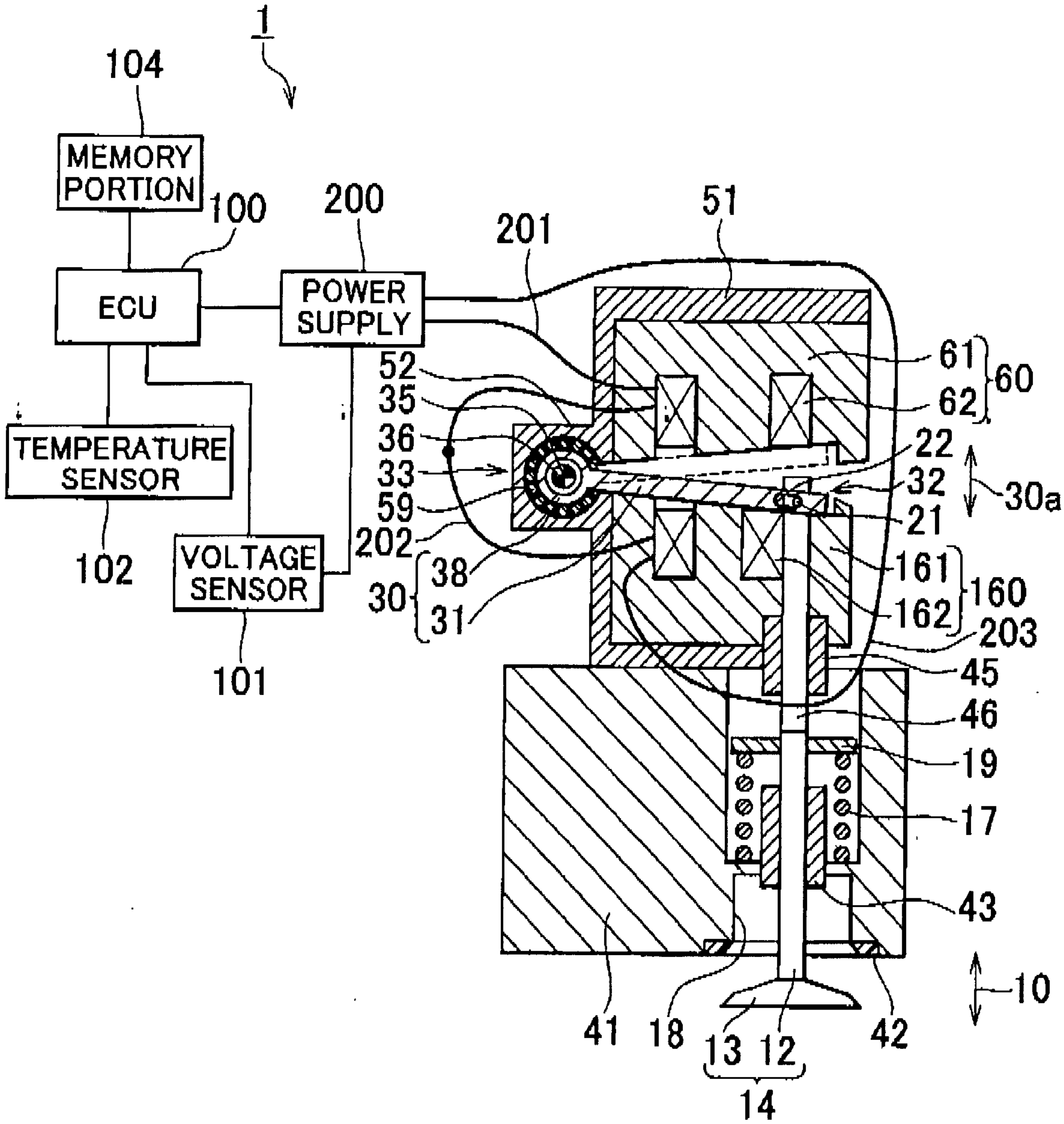
a valve element (14) that has a valve stem (12) and moves in reciprocating motion in a direction in which the valve stem extends;
an oscillating member (30) that is interlocked with the valve element at a driving end (32), extending to a pivoting end (33), from which a central axis extends, and the oscillating member oscillates around the central axis;
cores (61,161) of an electromagnet that oscillates the oscillating member, and
a permanent magnet (300) that is located on the outer side of the oscillating member and arranged in such a position that magnetic flux passing through the oscillating member and the cores becomes greater.

5. The electromagnetically driven valve according to any one of claims 1 to 4, wherein the coil includes an upper coil(62) and a lower coil(162), and the oscillating member(30) is provided between the upper coil and the lower coil.

6. A method of driving an electromagnetically driven valve that is operated by the combined action of electromagnetic force and elastic force, **characterized by** comprising the steps of:

measuring a voltage of a power supply that drives the electromagnetically driven valve and a temperature; and
controlling at least one of a number of electric current cycles, a cycle length, and a value of electric current provided in cycles to a coil in accordance with the measured voltage and temperature, during the initial period of operation of an oscillating member.

FIG. 1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200
201
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ECU
POWER SUPPLY
52
35
36
33
59
202
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62
60
22
32
21
30a
TEMPERATURE SENSOR
102
VOLTAGE SENSOR
101
30
38
31
161
162
160
203
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46
19
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18
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FIG. 2

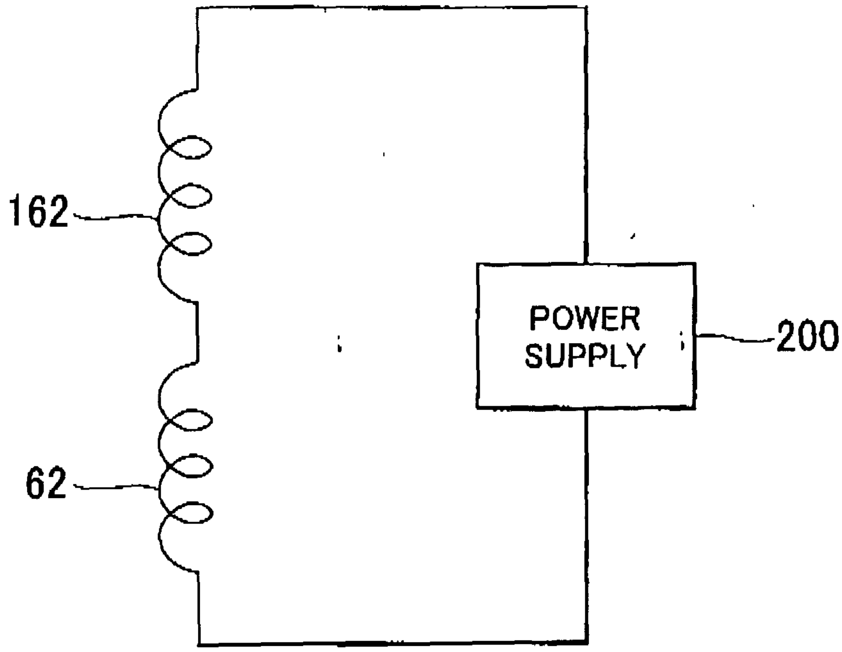
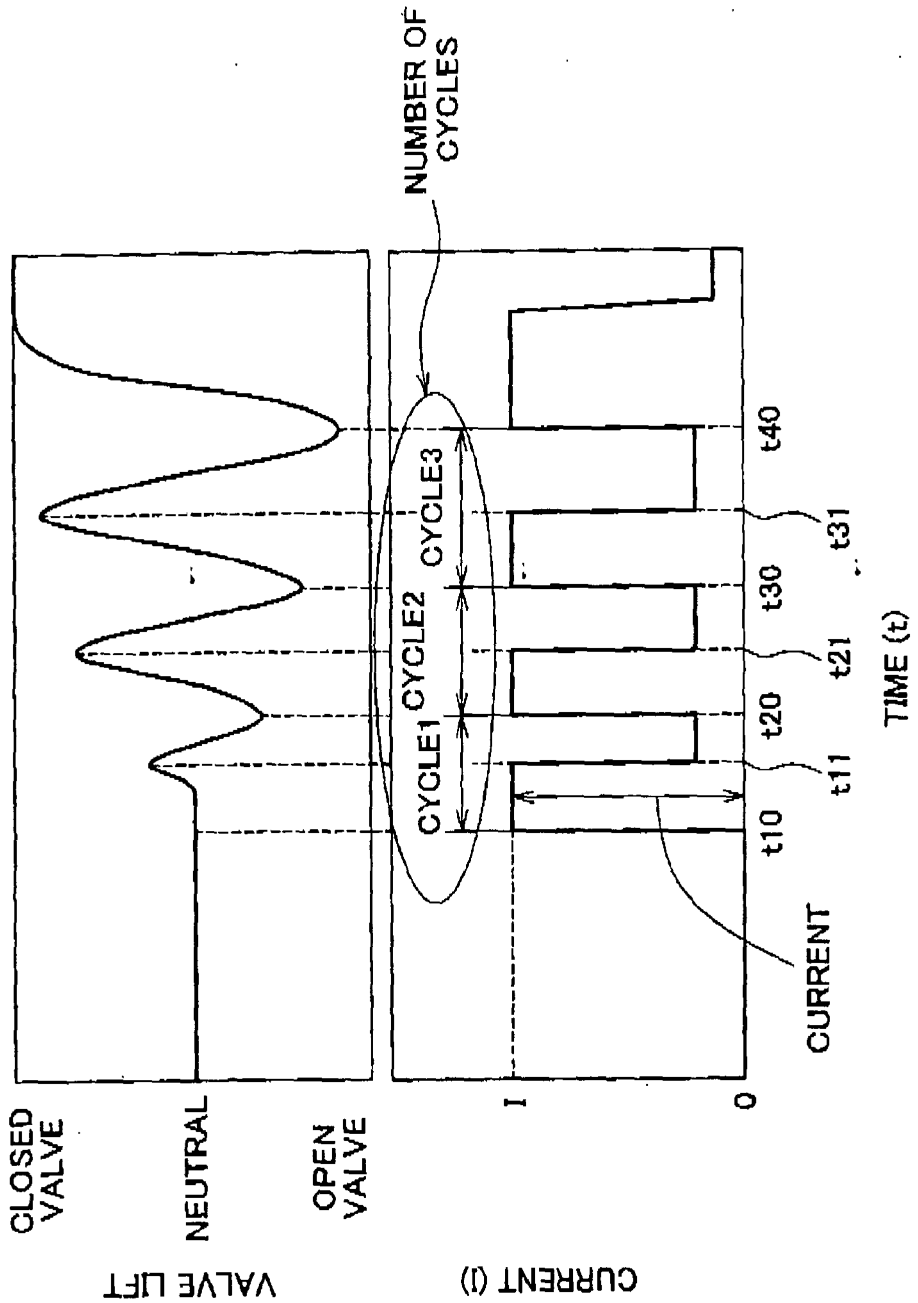


FIG. 3


NUMBER OF CYCLES
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CYCLE2
CYCLE3
CLOSED VALVE
NEUTRAL
OPEN VALVE
VALVE LIFT
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I
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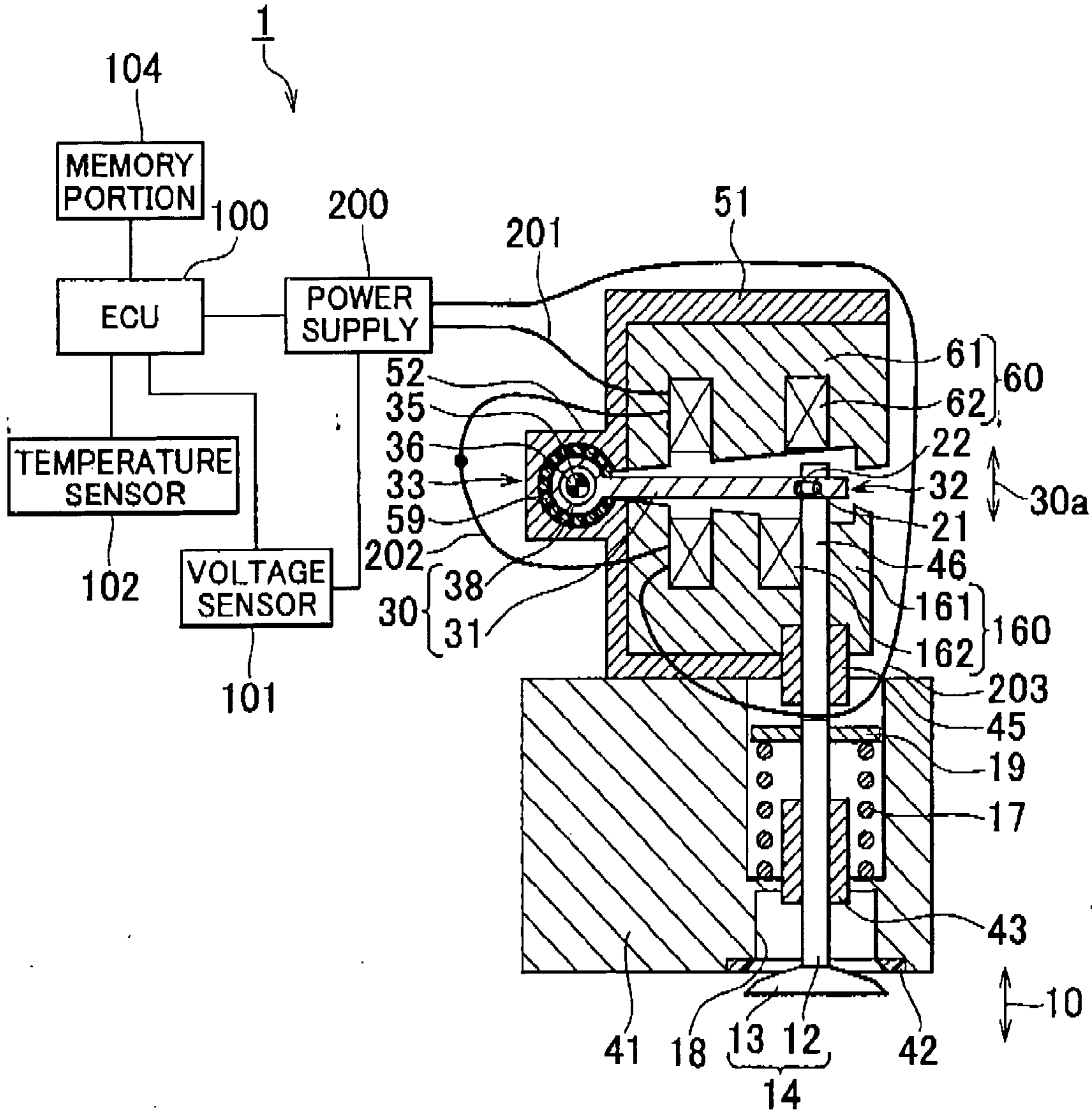
t10
t11
t20
t21
t30
t31
t40
TIME (t)
CURRENT

FIG.4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202
38
30
31
61
62
60
22
32
30a
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161
160
162
203
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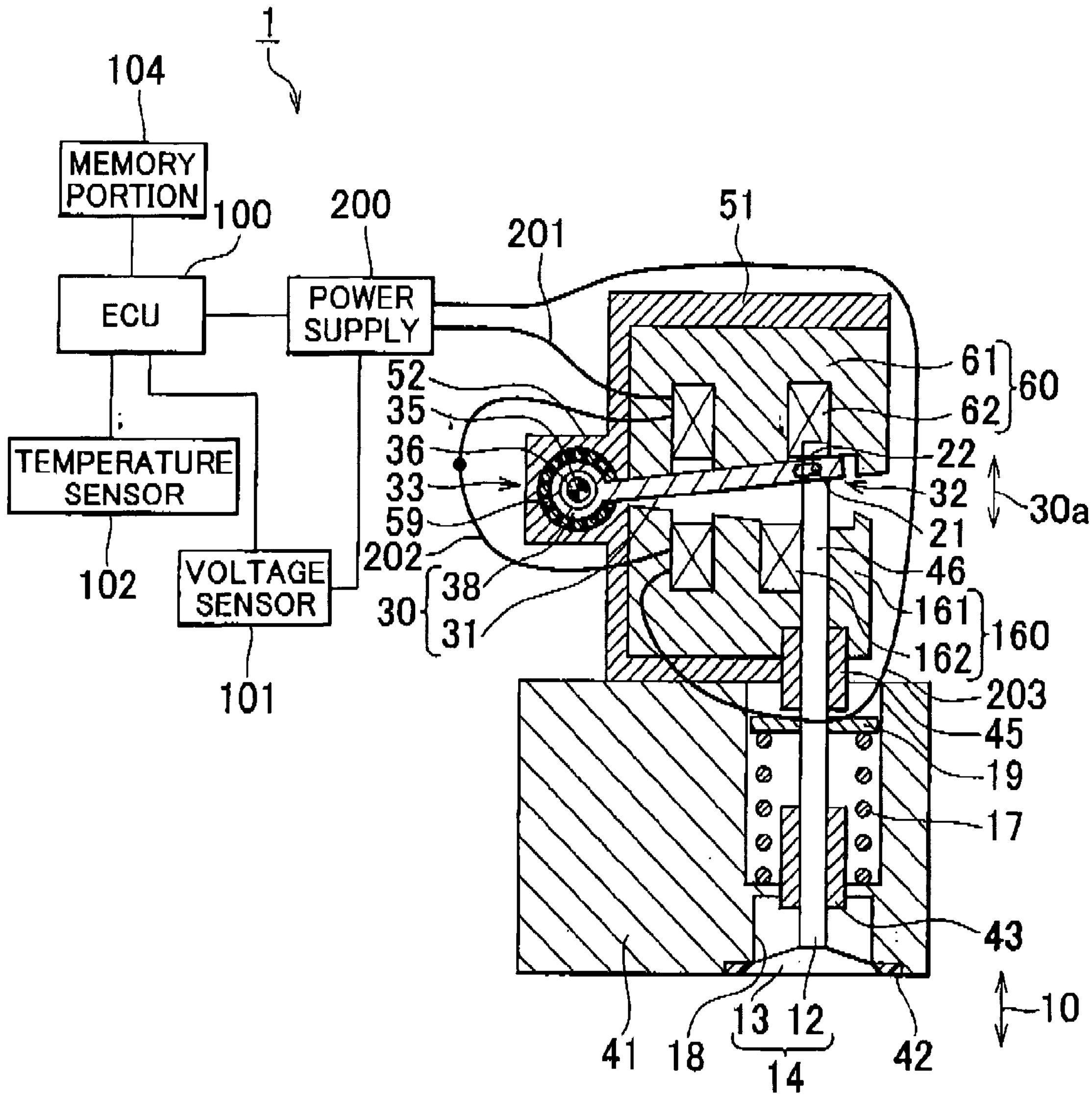
19
17
43
10
41
18
13
12
14
42

FIG.5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38
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102
VOLTAGE SENSOR
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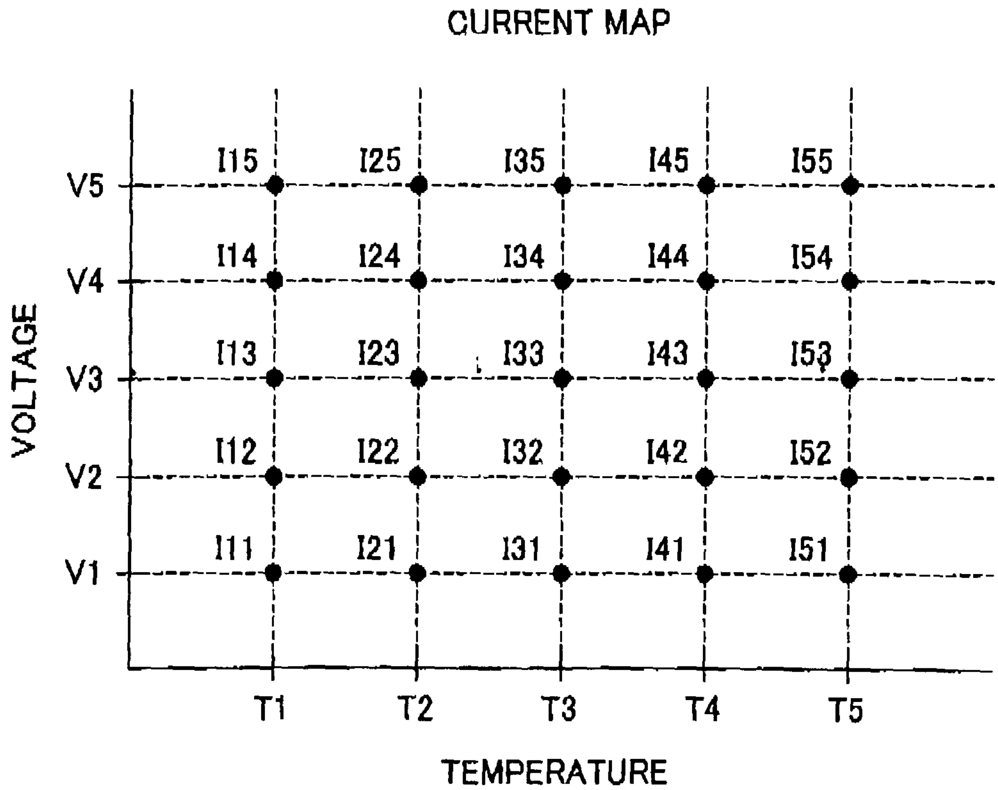
12
14
42

FIG. 6


CURRENT MAP
VOLTAGE
V5
V4
V3
V2
V1
I15
I25
I35
I45
I55
I14
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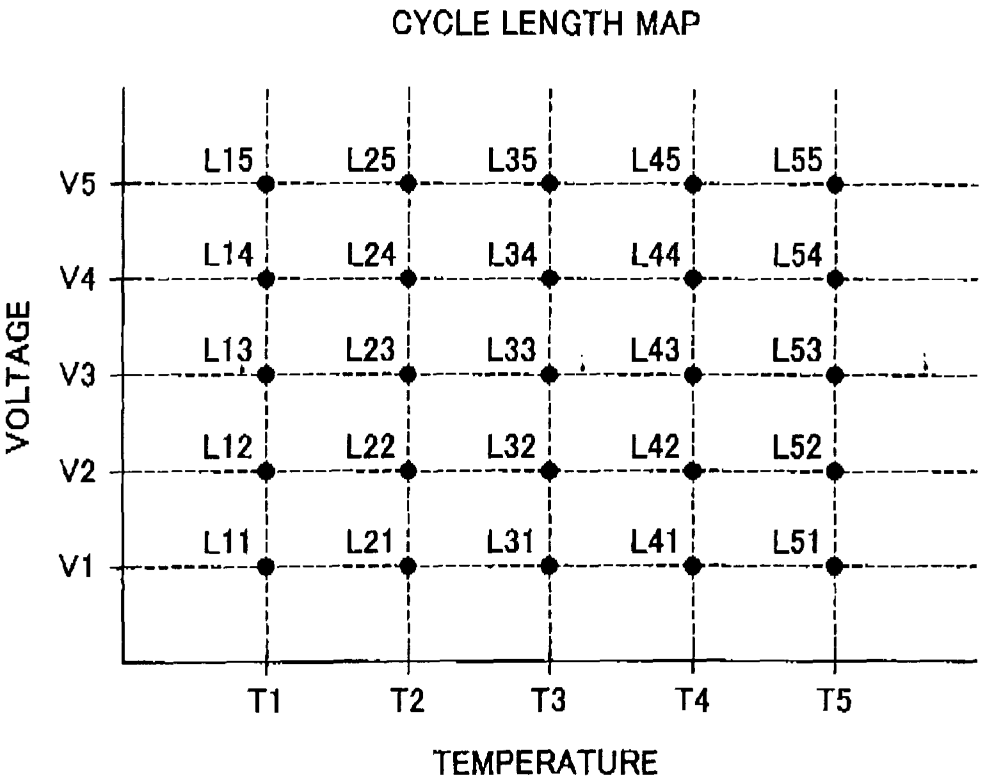
I54
I13
I23
I33
I43
I53
I12
I22
I32
I42
I52
I11
I21
I31
I41
I51
T1
T2
T3
T4
T5
TEMPERATURE

FIG. 7


CYCLE LENGTH MAP
VOLTAGE
V5
V4
V3
V2
V1
L15
L25
L35
L45
L55
L14
L24
L34
L44
L54
L13
L23
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L53
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L22
L32
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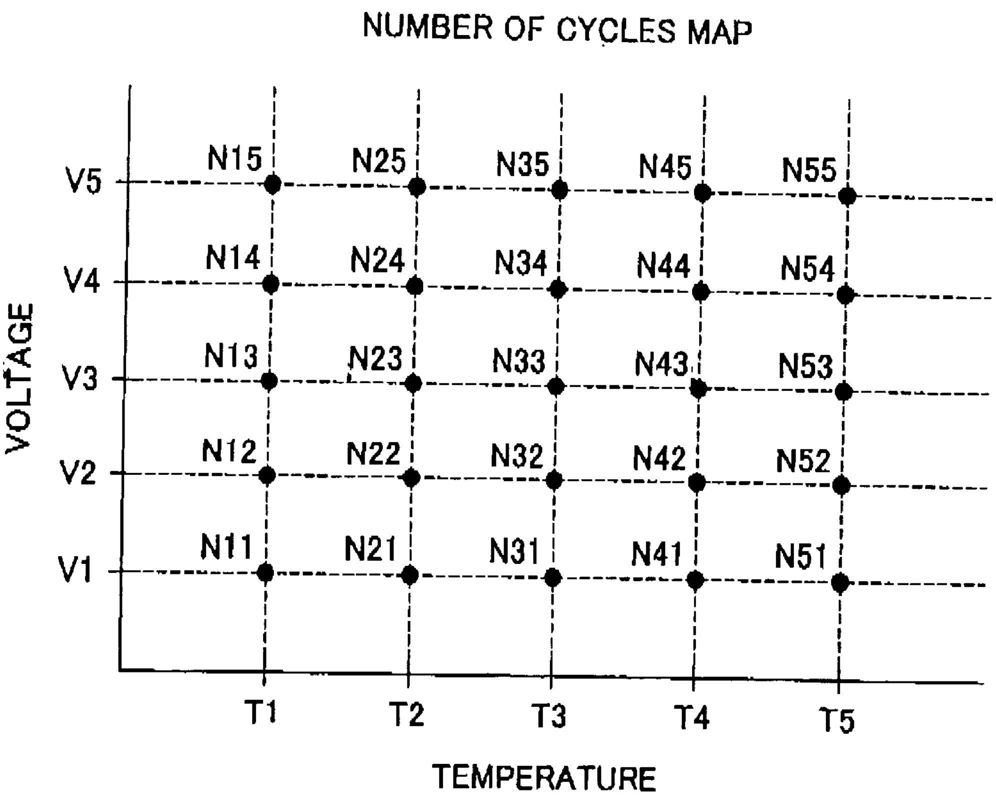
TEMPERATURE

FIG. 8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V2
V1
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N44
N54
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N53
N12
N22
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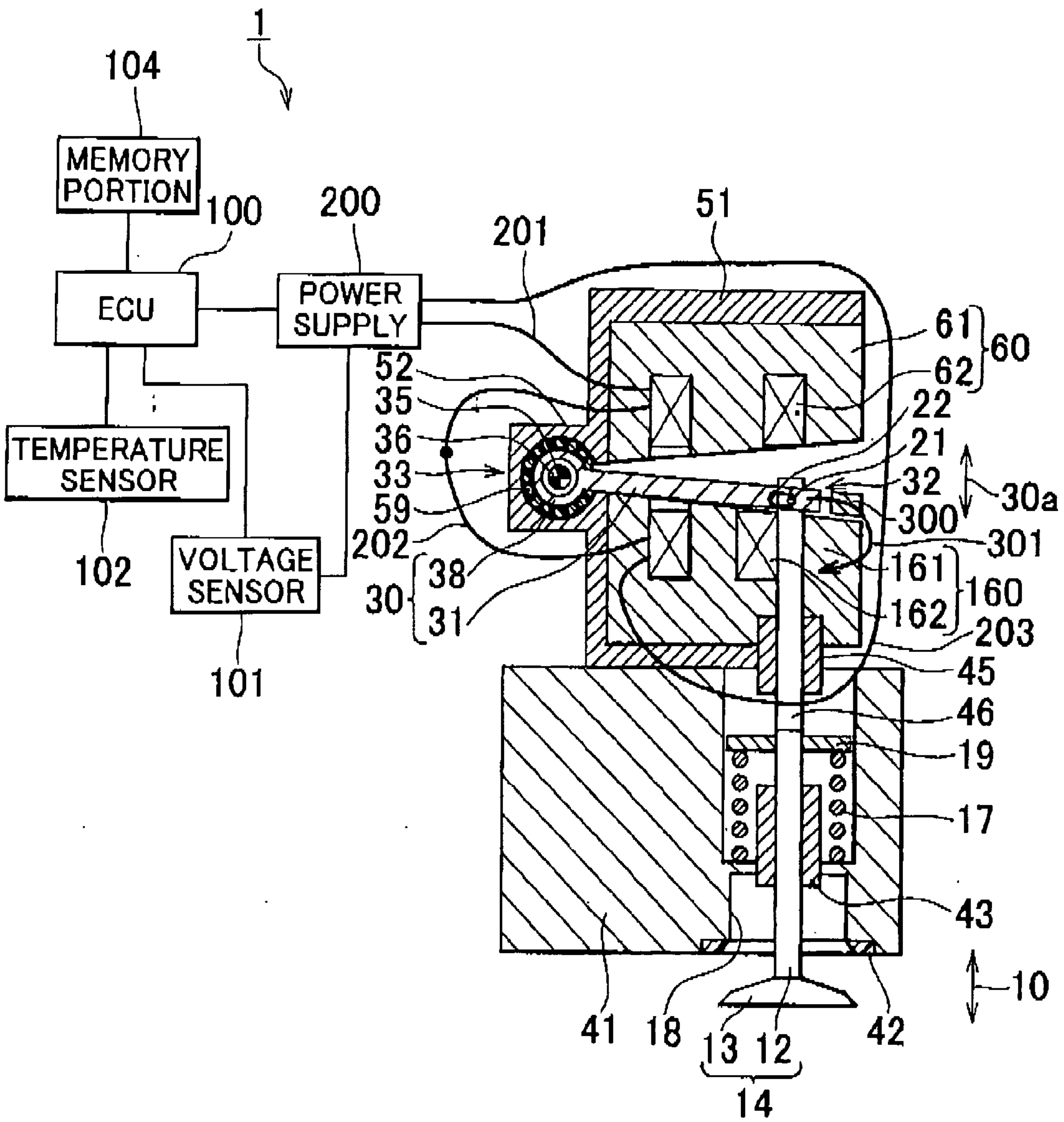
TEMPERATURE

FIG.9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160
162
203
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TEMPERATURE SENSOR
102
VOLTAGE SENSOR
101
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46
19
17
43
10
41
18
13
12
42
14

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 01 5546

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,Y	EP 1 209 328 A2 (MAGNETI MARELLI POWERTRAIN SPA [IT]) 29 May 2002 (2002-05-29) * abstract * * figure 1 * * paragraphs [0012], [0036] * -----	1,4	INV. F01L9/04
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	28 November 2006	Paulson, Bo

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