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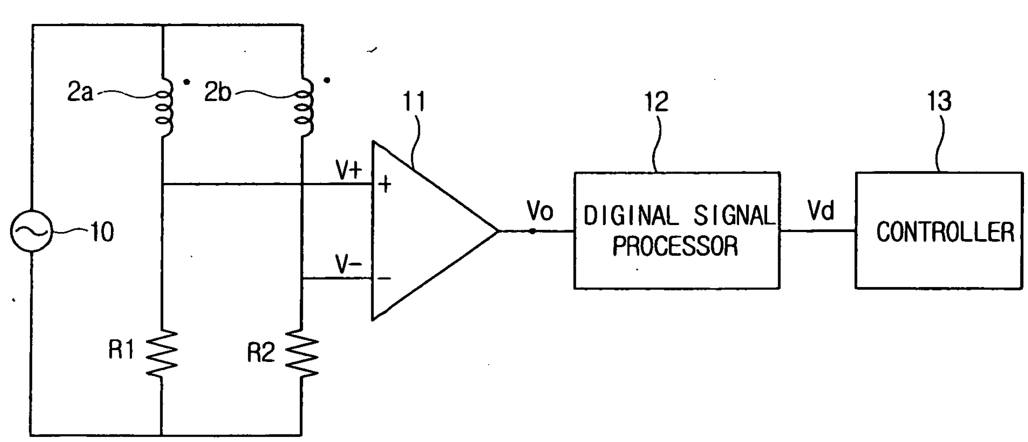
(54) Linear compressor and control method thereof

(57) Disclosed is a linear compressor having a core (4) combined to one end of a piston to detect a position of the piston reciprocally moving up and down. A first sensor coil (2a) and a second sensor coil (2b) detect the position of the core (4). The core has an upper core (4a) having a length shorter than one half of the length of the first sensor coil and a lower core (4b) having a length shorter than one half of the length of the second sensor coil in series. Also disclosed is a method of controlling the operation of the linear compressor including timing the upper core and the lower core driven by the piston through a stroke cycle, receiving the time and calculating a top dead center position based on the time or an offset value respectively, and controlling a piston stroke by varying the power driving the linear compressor according to the calculated top dead center or offset value.

FIG. 5



EP 1 486 670 A2

Description

[0001] The present invention relates to a linear compressor and a control method thereof.

[0002] A linear compressor is widely used to compress coolant in a freezing cycle such as a refrigerator, etc. The linear compressor measures the magnitude of a stroke of a piston, and controls an operation of the piston by applying a current to a driving motor of the linear compressor based on an analysis of the measured magnitude of the stroke of the piston.

[0003] Figure 1 is a cross-sectional view of a position detection sensor of a piston of a conventional linear compressor. As illustrated in Figure 1, the position detection sensor comprises a sensor body 100, a sensor coil 101, a core support 102, and a core 103.

[0004] The sensor body 100 includes the sensor coil 101 inside. The sensor coil 101 has a first sensor coil 101a connected in series to a second sensor coil 101b having the same inductance value, size, and number of turns with those of the first sensor coil 101a. The core support 102 is made of non-magnetic material and supports the core 103 and is combined to the piston (not shown).

[0005] As the core 103 combined to the piston of the compressor moves back and forth along an inner hole of the sensor body 100, a predetermined reactance is generated in the sensor coil 101 according to the reciprocal movement of the piston.

[0006] Figure 2 is a diagram of a position detection circuit of the piston of the conventional linear compressor. As illustrated in Figure 2, two serial sensor coils 101 are connected in parallel with two serial dividing resistors Ra and Rb, and a triangle pulse is inputted as a power source 105. A difference of divided voltages divided by the dividing resistors Ra and Rb is amplified by an amplifier 104 to detect a maximum output voltage according to the piston in which the core 103 moves back and forth starting from a center point between the first sensor coil 101a and the second sensor coil 101b. An analog signal processor 106 receives an output pulse from the amplifier 104 and detects the position of the piston through a predetermined signal process.

[0007] Figure 3 illustrates an output pulse from the amplifier 104 in Figure 2 according to the reciprocal movement of the piston of the linear compressor. As illustrated in Figure 3, the output voltage from the amplifier (line "a") has a linear output property for the reciprocal movement of the piston. The position of the piston can be detected with the output voltage because the output voltage is proportional to the position of the piston.

[0008] However, the sensor circuit of the conventional linear compressor may have the linear property varying an angle of a slope of the graph according to external environment such as a temperature and a pressure. If the sensor circuit of the conventional linear compressor takes the linear property represented by a small angle of the slope like a line "b" due to the external environment, the piston controlled according to a normal operation in a high cooling capacity may have a problem of colliding with a valve of a cylinder. Further variation of cooling capacity may excessively enlarge between a high cooling state and a low cooling state.

[0009] Accordingly, it is an aim of embodiments of the present invention to provide a linear compressor that detects a position of a piston accurately regardless of external environmental conditions.

[0010] Additional aspects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0011] According to a first aspect of the present invention, there is provided a linear compressor having a core combined to one end of a piston to detect a position of the piston reciprocally moving up and down, and a first sensor coil and a second sensor coil detecting the position of the core, wherein the core comprises an upper core having a length shorter than one half of the length of the first sensor coil and the second sensor coil in series.

[0012] Preferably, the core includes an upper core; and a lower core spaced apart from the upper core by a predetermined distance.

[0013] Preferably, a middle point between the upper core and the lower core passes a middle point between the first sensor coil and the second sensor coil when the piston passes a center point of a reciprocal moving path of the piston.

[0014] Preferably, the linear compressor includes a first branch comprising the first sensor coil and a predetermined first dividing resistor connected in series; a second branch comprising the second sensor coil and a predetermined second dividing resistor connected in series; a source power applied to the first branch and the second branch; and a voltage comparator receives voltages applied to the first dividing resistor and the second dividing resistor as inputs.

[0015] Preferably, the voltage comparator receives voltages taken from the opposite terminals of each of the first sensor coil and the second sensor coil as the inputs.

[0016] Preferably, the linear compressor further includes a controller controlling the position of the piston based on a top dead center detected by measuring a difference of time taken for a center point of the upper coil to pass a coil origin, or a middle point between the first sensor coil and the second sensor coil, according to reciprocal movement of the piston.

[0017] Preferably, the linear compressor includes a controller controlling the position of the piston by detecting a top dead center on a basis of a difference of time taken for an output of the voltage comparator to become 0 twice as the piston is positioned near the top dead center.

[0018] Preferably, the linear compressor includes a controller controlling the position of the piston by detecting a top dead center on a basis of a difference of time taken for the output of the voltage comparator to become 0 as the piston is positioned near the top dead center.

[0019] Preferably, the linear compressor includes a controller detecting an offset value indicating the degree of how far a center point of reciprocation movement of the piston is off from a predetermined center point by measuring a difference of time taken for a center point of the upper core to pass a coil origin positioned at a middle point between the first sensor coil and the second sensor coil, and by measuring a difference of time taken for a center point of the lower core to pass the coil origin according to the reciprocal movement of the piston.

[0020] According to a second aspect of the present invention, there is provided a control method of a linear compressor having a core combined to one end of a piston moving up and down, and a first sensor coil and a second sensor coil detecting a position of the core, including forming the core comprising an upper core and a lower core being spaced from each other; detecting a top dead center of the piston by measuring a time taken for a center point of the upper core to pass a middle point between the upper coil and the lower coil according to reciprocal movement of the piston; and controlling a position of the piston on a basis of the top dead center.

[0021] According to a third aspect of the present invention, there is provided A method for controlling an operation of a linear compressor having an upper core and a lower core combined to a shaft of a piston, and a first sensor coil and a second sensor coil detecting a position of the piston, comprising: timing the upper core driven by the piston through a stroke cycle; receiving the time and calculating a top dead center position based on the time; and controlling a piston stroke according to the calculated top dead center, by varying the power driving the linear compressor.

[0022] According to a fourth aspect of the present invention, there is provided a linear compressor piston control device, comprising: a sensor body having an annular shape defining an aperture; a sensor coil disposed in the sensor body; a core having a lower part and an upper part attached to a piston disposed coaxially in the aperture of the sensor body, wherein the lower part and the upper part are less than one half the length of the sensor coil; a controller controlling a position of the piston by determining a top dead center based on signals from the sensor coil sensing the position of the lower part of the core and the upper part of the core.

[0023] For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 is a cross-sectional view of a position detection sensor for a piston of a conventional linear compressor;

Figure 2 is a diagram of a position detection circuit for the piston of the conventional linear compressor;

Figure 3 is a waveform of an amplifier according to reciprocal movement of the piston of the conventional linear compressor in Figure 2;

Figure 4 is a cross-sectional view of a position detection sensor for a piston of a linear compressor according to an embodiment of the present invention;

Figure 5 is a block diagram of a position detection circuit for the piston of the linear compressor according to the embodiment of the present invention;

Figures 6A-6C and 7A-7C are waveforms of a voltage comparator according to reciprocal movement of the piston of the linear compressor;

Figure 8 is an output waveform of the voltage comparator according to the position of the piston of the linear compressor according to the embodiment of the present invention;

Figures 9A and 9B illustrate the position of the piston according to the embodiment of the present invention corresponding to passage of time.

[0024] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout.

[0025] The embodiments are described below to explain the present invention by referring to the figures.

[0026] Figure 4 is a cross-sectional view of a position detection sensor for a piston of a linear compressor according to an embodiment of the present invention. As illustrated in Figure 4, a position detection sensor comprises a sensor body 1, a sensor coil 2, a core support 3, and a core 4.

[0027] The sensor body 1 includes a sensor coil 2 inside. The sensor coil 2 comprises a first sensor coil 2a connected in series with a second sensor coil 2b. The first sensor coil 2a and second sensor coil 2b have the same inductance value, size, and number of turns. The core support 3 is made of non-magnetic material that supports the core 4 and is combined to the piston (not shown).

[0028] The core 4 comprises an upper core 4a and a lower core 4b respectively having a short predetermined length. The upper core 4a and lower core 4b are spaced apart from each other by a predetermined distance. The length of each of the upper core 4a and the lower core 4b should be preferably less than one half of the length of the sensor coil 2 comprising the first sensor coil 2a and the second sensor coil 2b. The upper core 4a is connected to the lower core 4b by the core support 3.

[0029] As the core 4 combined to the piston of the compressor moves back and forth along an inner hole of the sensor body 1, a predetermined reactance is generated in the sensor coil 2 according to the movement of the core 4 within the inside of the sensor coil 2.

[0030] Figure 5 is a block diagram of a position detection circuit for the piston of the linear compressor according to an embodiment of the present invention. As illustrated in Figure 5, the position detection circuit comprises the first sensor coil 2a, the second sensor coil 2b, a first dividing resistor R1, a second dividing resistor R2, a power source 10, a voltage comparator 11, a digital signal processor 12, and a controller 13.

[0031] The power source 10 applies power to a first branch having the first sensor coil 2a and the first dividing resistor R1 connected in series, and to a second branch having the second sensor coil 2b and the second dividing resistor R2 connected in series.

[0032] The voltage comparator 11 receives voltages taken from a corresponding terminal of each of the first dividing resistor R1 and the second dividing resistor R2 as a comparison signal V+ and a comparison signal V-, respectively. Also, the voltage comparator 11 may receive voltage taken from a terminal of each of the first sensor coil 2a and the second sensor coil 2b.

[0033] The digital signal processor 12 transmits a rectangular pulse to the controller 13 according to an output of the voltage comparator 11, and then the controller 13 controls a driving motor (not shown) of the linear compressor based on the rectangular pulse.

[0034] Figures 6A through 6C and 7A through 7C are input waveforms of the voltage comparator 11 according to reciprocal movement of the piston of the linear compressor.

[0035] Figure 6A represents a triangle pulse from the power source 10, and Figure 6B represents waveforms inputted to a positive terminal and a negative terminal of the voltage comparator 11.

[0036] Figure 6B represents the input waveform of the voltage comparator 11 when a center point (will be referred to as an upper core origin) of the upper core 4a passes a middle point (will be referred to as a coil origin) between the first sensor coil 2a and the second sensor coil 2b, or compression when the piston reaches near a top dead center during a compression stroke. If the triangle pulse is applied from the power source 10, an inductance L2 of the second sensor coil 2b becomes greater than an inductance L1 of the first sensor coil 2a during the negative portion of the triangle pulse input. Accordingly, the input waveform V- input into the negative terminal of the voltage comparator 11 has a longer time delay than the time delay of the input waveform V+ input into the positive terminal of the voltage comparator 11.

[0037] As illustrated in Figure 6C, the digital signal processor 12 generates a rectangular waveform Vd having a high level when the input waveform V+ of the positive terminal of the voltage comparator 11 is greater than the input waveform V- of the negative terminal.

[0038] Figure 7A through 7C are waveforms when the upper core origin is inclined toward the first sensor coil 2a from the coil origin. In this case, the inductance L1 of the first sensor coil 2a becomes greater than the inductance L2 of the second sensor coil 2b during the negative cycle of the triangle input. Accordingly, the input waveform V+ input into the positive terminal of the voltage comparator 11 has a longer time delay in comparison with the input waveform V- as shown in Figure 7B. Figure 7C illustrates a rectangular waveform Vd output from the digital signal processor 12 corresponding to the waveforms in Figure 7B.

[0039] Figure 8 is a waveform that is output from the voltage comparator 11 according to a position of the piston of the linear compressor according to an embodiment of the present invention. As illustrated in Figure 8, a waveform "c" has three zero points and corresponds to the input waveforms illustrated in Figures 6B and 7B.

[0040] The output waveform of the voltage comparator 11 passes through a first zero point as a middle point (will be referred to as a core origin), between the upper core 4a and the lower core 4b, passes the coil origin.

[0041] An output V_0 of the voltage comparator 11 has a second zero point in a top area if the upper core origin of the upper core 4a passes the coil origin, and the output V_0 of the voltage comparator 11 has a third zero point in a bottom area if the center point of the lower core 4b passes the coil origin.

[0042] When the output V_0 of the voltage comparator 11 is at the second zero point during the compression stroke of the piston, the piston is at a top origin position. The top origin position is also passed during an extension stroke. The top origin is a fixed position, and an exact position of the top dead center can be estimated by measuring the amount of time that the piston takes to pass the top origin twice, once during the compression stroke and once during the extension stroke.

[0043] Also, the position of the top dead center can be estimated based on the duration of time that passes before the output V_0 of the voltage comparator 11 passes the second zero point having a zero output in the top area twice.

[0044] A waveform "d" in Figure 8 is the output waveform V_0 of the voltage comparator 11 when the external environmental conditions of the sensor such as a temperature, and pressure have changed. The waveform "d" illustrates that the zero points do not vary regardless of changes to the external environment. Accordingly, the top dead center can be found accurately on the basis of the top origin that is not affected by the external environment, and the position of the piston can be controlled based on the aforementioned.

[0045] Figures 9A and 9B illustrate magnitude of a stroke of the piston of the linear compressor according to an embodiment of the present invention corresponding to passage of time. As illustrated in Figure 9A, the stroke of the piston appears as a sine waveform according to the passage of the time. The magnitude of the stroke of the piston appears as a sine waveform "F", in a case where the core origin does not match to the coil origin and gets inclined to the top dead center, that is, an offset occurs, when the piston is in a middle point of a reciprocal moving path.

[0046] Even for such cases, the stroke of the piston can be controlled because the top dead center can be measured based on a measured time that the piston takes to pass the top origin twice.

[0047] If the position of the lower core 4b is inclined near to the coil origin, the bottom origin is adjusted upward to the coil origin in Figure 9A. With such a configuration, an offset value indicating the degree that the center point of the reciprocal moving path of the piston is off from a predetermined center point can be detected by measuring an elapsed time that the piston takes to pass the altered bottom origin twice and by measuring the time that the piston takes to pass the top origin twice.

[0048] Figure 9B illustrates the output waveform Vd of the digital signal processor 12 corresponding to curved lines E and F in Figure 9A.

[0049] Also, even if the core 4 includes only the upper core 4a, the output waveform V_0 of the voltage comparator 11 has the second zero point in the top area, and the top dead center can be estimated in the same manner on a basis of duration for passing the top origin.

[0050] The position of the piston of the linear compressor can be measured and controlled according to this embodiment of the present invention.

[0051] Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in this embodiment without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.

[0052] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0053] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0054] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0055] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A linear compressor having a core (4) combined to one end of a piston to detect a position of the piston reciprocally moving up and down, and a first sensor coil (2a) and a second sensor coil (2b) detecting the position of the core, wherein the core comprises:

an upper core (4a) having a length shorter than one half of the length of the first sensor coil and the second sensor coil (2b) in series.

2. The linear compressor according to claim 1, wherein the core further comprises:

a lower core (4b) being spaced from the upper core (4a) by a predetermined distance.

3. The linear compressor according to claim 2, wherein a middle point between the upper core and the lower core passes a middle point between the first sensor coil and the second sensor coil when the piston passes a center point of a reciprocal moving path of the piston.

4. The linear compressor according to any one of the preceding claims, comprising:

a first branch comprising the first sensor coil (2a) and a predetermined first dividing resistor (R1) connected in series;

a second branch comprising the second sensor coil (2b) and a predetermined second dividing resistor (R2) connected in series;

a power source (10) applied to the first branch and the second branch; and

a voltage comparator (11) that receives voltages applied to the first dividing resistor and the second dividing resistor as inputs.

5. The linear compressor according to claim 4, wherein the voltage comparator receives voltages taken from the opposite terminals of each of the first sensor coil and the second sensor coil as the inputs.

6. The linear compressor according to any one of the preceding claims, further comprising a controller (13) controlling the position of the piston based on a top dead center detected by measuring a time that a center point of the upper core takes to pass a coil origin, or a middle point between the first sensor coil and the second sensor coil, according to reciprocal movement of the piston.

7. The linear compressor according to any one of claims 4-6, further comprising a controller (13) controlling the position of the piston by detecting a top dead center based on the time taken for an output of the voltage comparator to become 0 twice as the piston is positioned near the top dead center.

8. The linear compressor according to any one of claims 5-7, further comprising a controller (13) controlling the position of the piston by detecting a top dead center based on a time taken for the output of the voltage comparator to become 0 as the piston is positioned near the top dead center.

9. The linear compressor according to any one of claims 2-8, further comprising a controller (13) detecting an offset value indicating the degree a center point of reciprocation movement of the piston is off from a predetermined center point by measuring a difference of time that a center point of the upper core takes to pass a coil origin positioned at a middle point between the first sensor coil (2a) and the second sensor coil (2b), and by measuring an elapsed time that a center point of the lower core takes to pass the coil origin according to the reciprocal movement of the piston.

10. A control method of a linear compressor having a core combined to one end of a piston moving up and down, and a first sensor coil (2a) and a second sensor coil (2b) detecting a position of the core, comprising:

forming the core (4) comprising an upper core (4a) and a lower core (4b) separated from each other;

detecting a top dead center of the piston by measuring a time that a center point of the upper core takes to pass a middle point between the first sensor coil and the second sensor coil according to reciprocal movement of the piston; and

controlling a position of the piston on a basis of the top dead center.

11. A method for controlling an operation of a linear compressor having an upper core (4a) and a lower core (4b) combined to a shaft of a piston, and a first sensor coil and a second sensor coil detecting a position of the piston, comprising:

timing the upper core driven by the piston through a stroke cycle;

receiving the time and calculating a top dead center position based on the time; and

controlling a piston stroke according to the calculated top dead center, by varying the power driving the linear compressor.

12. The method of claim 11, wherein the calculating the top dead center is based on the elapsed time of the upper core passing a mid point, of the first sensor coil and the second sensor coil, during a compression stroke and passing the mid point, of the first sensor coil and the second sensor coil, during an extension stroke of the piston.

13. The method of claim 11 or 12, further comprising determining an offset value based on a difference between a predetermined center point and an actual center point of the piston stroke, wherein the offset value is determined by measuring a time that elapses when a center point of the lower core passes the mid point, of the first sensor coil and the second sensor coil, a first time and then passes the mid point, of the first sensor coil and the second sensor coil, a second time during a stroke.

14. A linear compressor piston control device, comprising:

a sensor body (1) having an annular shape defining an aperture;

a sensor coil (2) disposed in the sensor body;

a core (4) having a lower part (4b) and an upper part (4a) attached to a piston disposed coaxially in the aperture of the sensor body, wherein the lower part and the upper part are less than one half the length of the sensor coil;

a controller (13) controlling a position of the piston by determining a top dead center based on signals from the sensor coil sensing the position of the lower part of the core and the upper part of the core.

15. The control device according to claim 14, wherein the controller measures a time that elapses when the upper part passes a mid point of the sensor coil during a compression stroke and then passes the mid point of the sensor coil during an extension stroke of the piston.

16. The control device according to claim 14 or 15, further comprising the controller determining an offset value based on a difference between a predetermined center point and an actual center point of a piston stroke, wherein the offset value is determined by measuring a time that elapses when a center point of the lower part passes the mid point of the sensor coil a first time and then passes the mid point of the sensor coil a second time during a stroke.

17. The control device according to any one of claims 14-16, wherein the sensor coil includes a first sensor coil and a second sensor coil.

18. The control device according to claim 17, wherein the first sensor coil and the second sensor coil have the same number of turns, size and inductance value.

19. The control device according to claim 18, wherein the control device further comprises:

a first branch having a first predetermined dividing resistor (R1) connected in series with the first sensor coil (2a);

a second branch having a second predetermined dividing resistor (R2) connected in series with the second sensor coil (2b).

20. The control device according to claim 19, further comprising:

a voltage comparator (11) that receives voltage inputs from the first branch and the second branch and outputs a comparator signal;

a digital signal processor (12) that receives the comparator signal and sends an output signal to the controller (13) based on the comparator signal.

21. The control device according to claim 20, further comprising:

the controller determining the top dead center by measuring the time that elapses between the comparator signal equaling 0 a first time during a compression stroke and the comparator signal equaling 0 a second time during an extension stroke.

FIG. 1
(PRIOR ART)

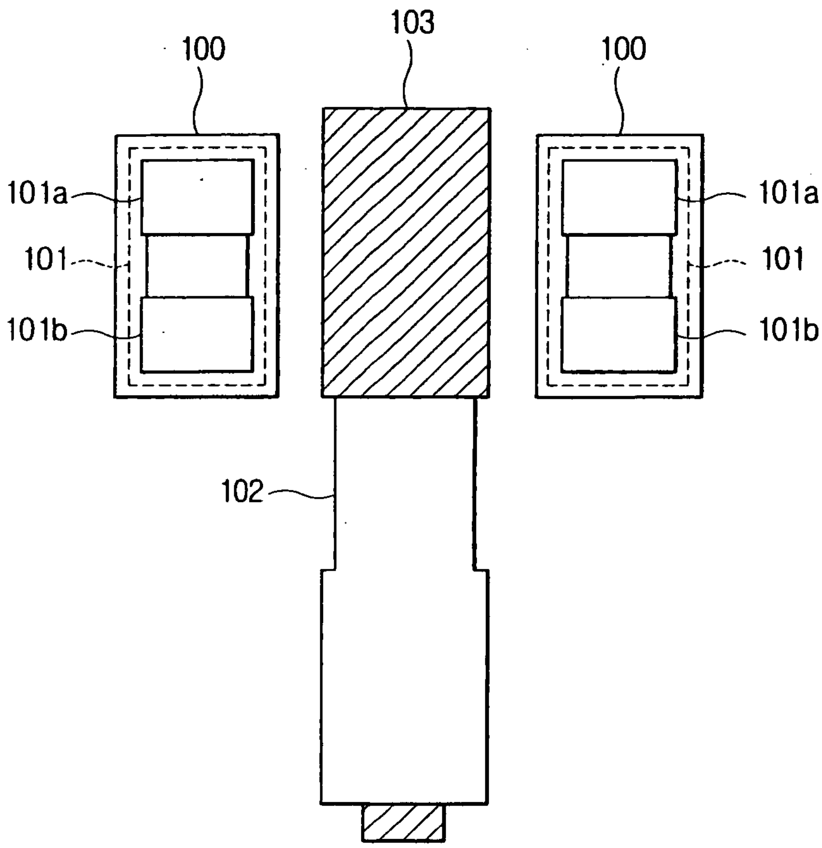


FIG. 2
(PRIOR ART)

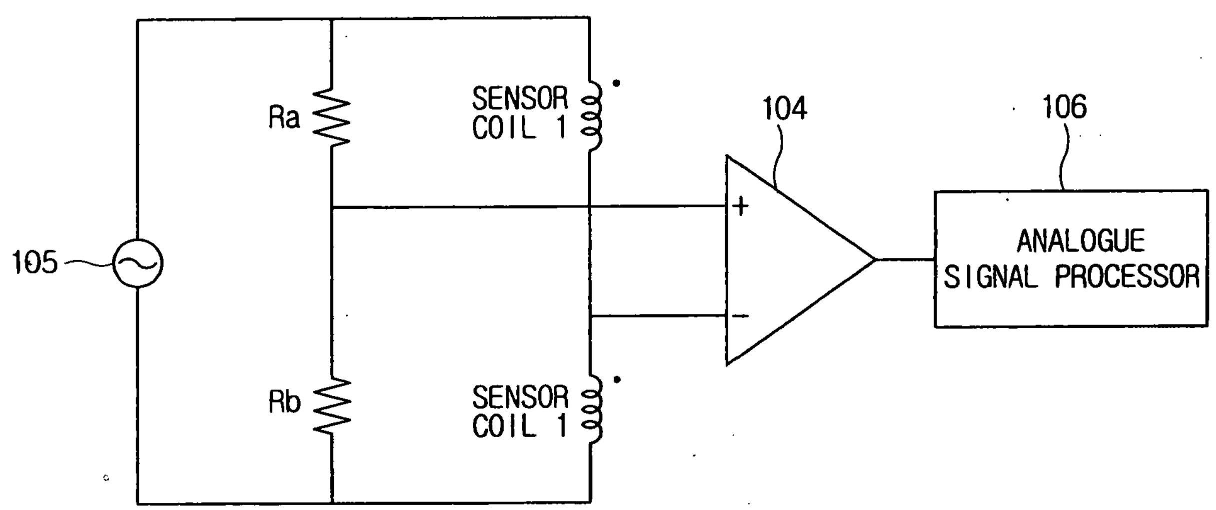


FIG. 3
(PRIOR ART)

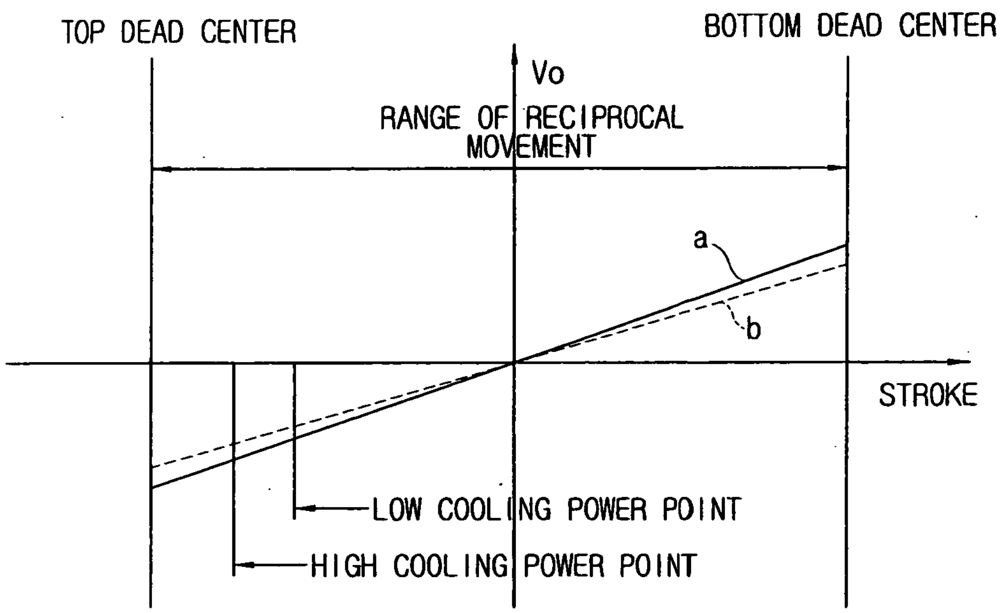


FIG. 4

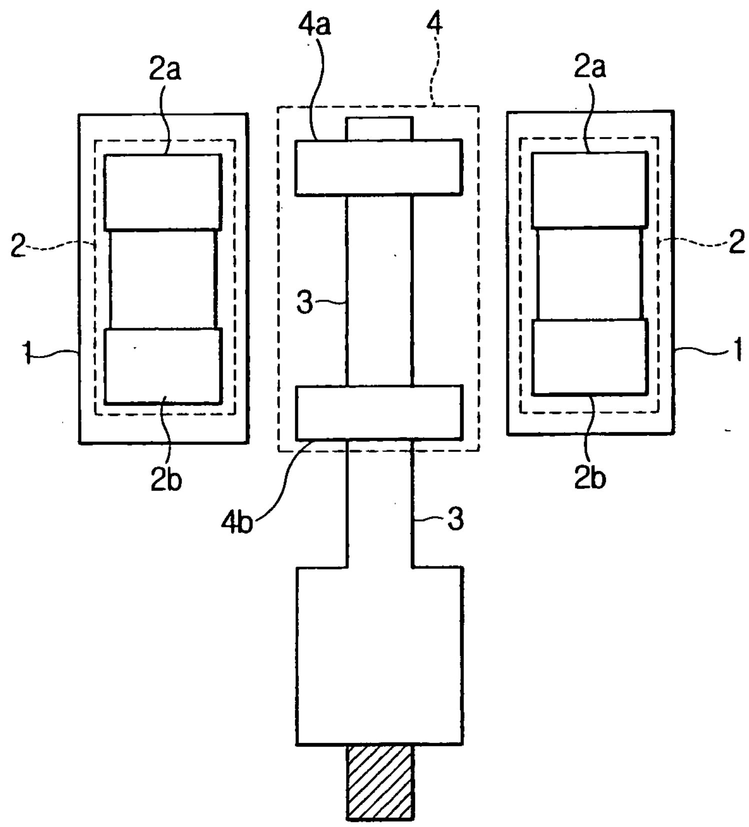


FIG. 5

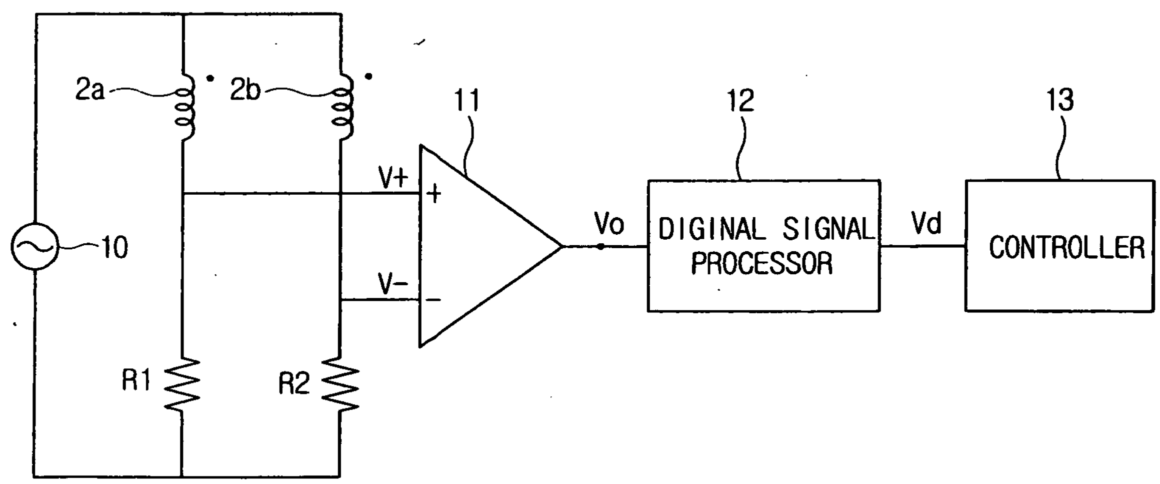

2a
2b
11
12
13
10
V+
V−
+
−
Vo
DIGINAL SIGNAL PROCESSOR
Vd
CONTROLLER
R1
R2

FIG. 6

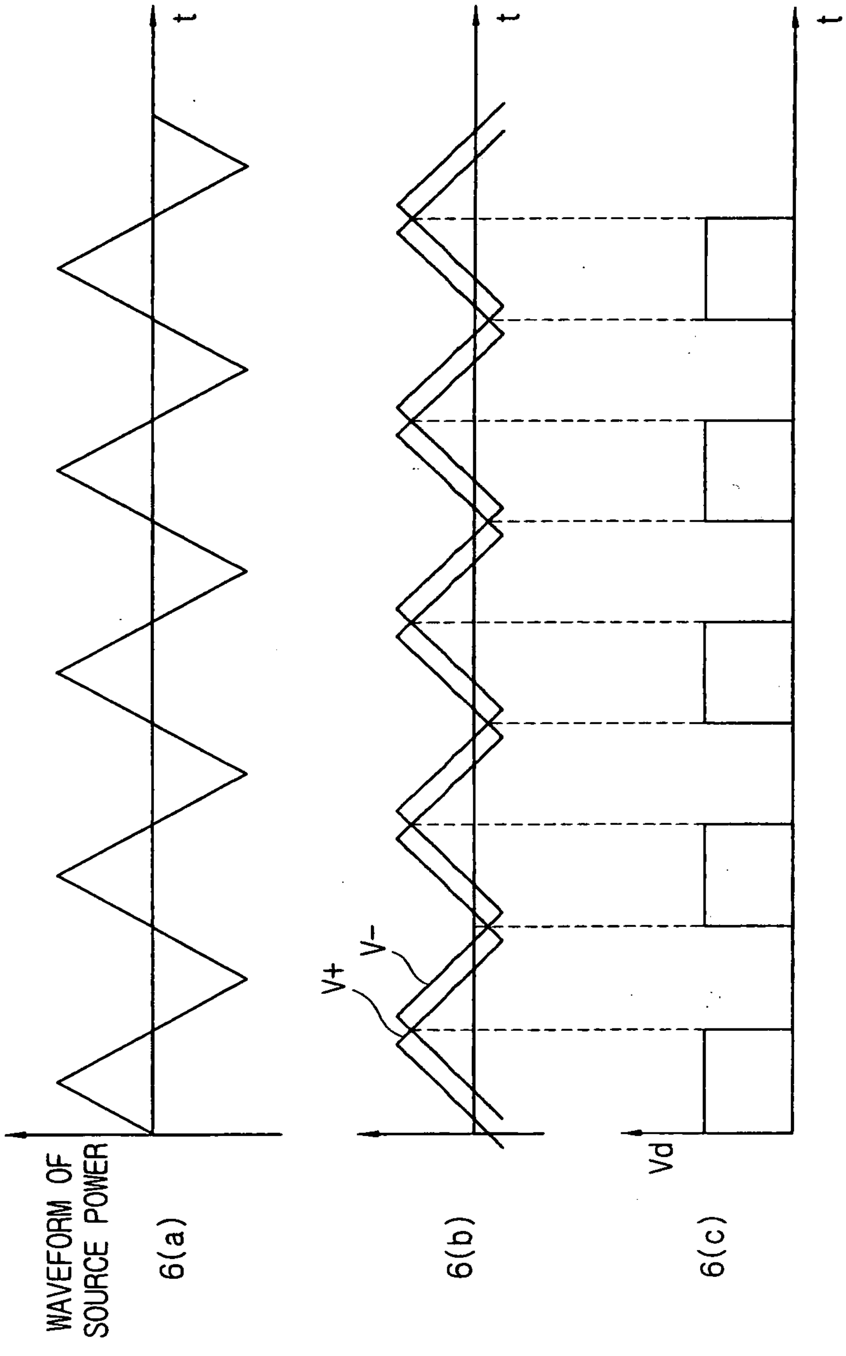


FIG. 7

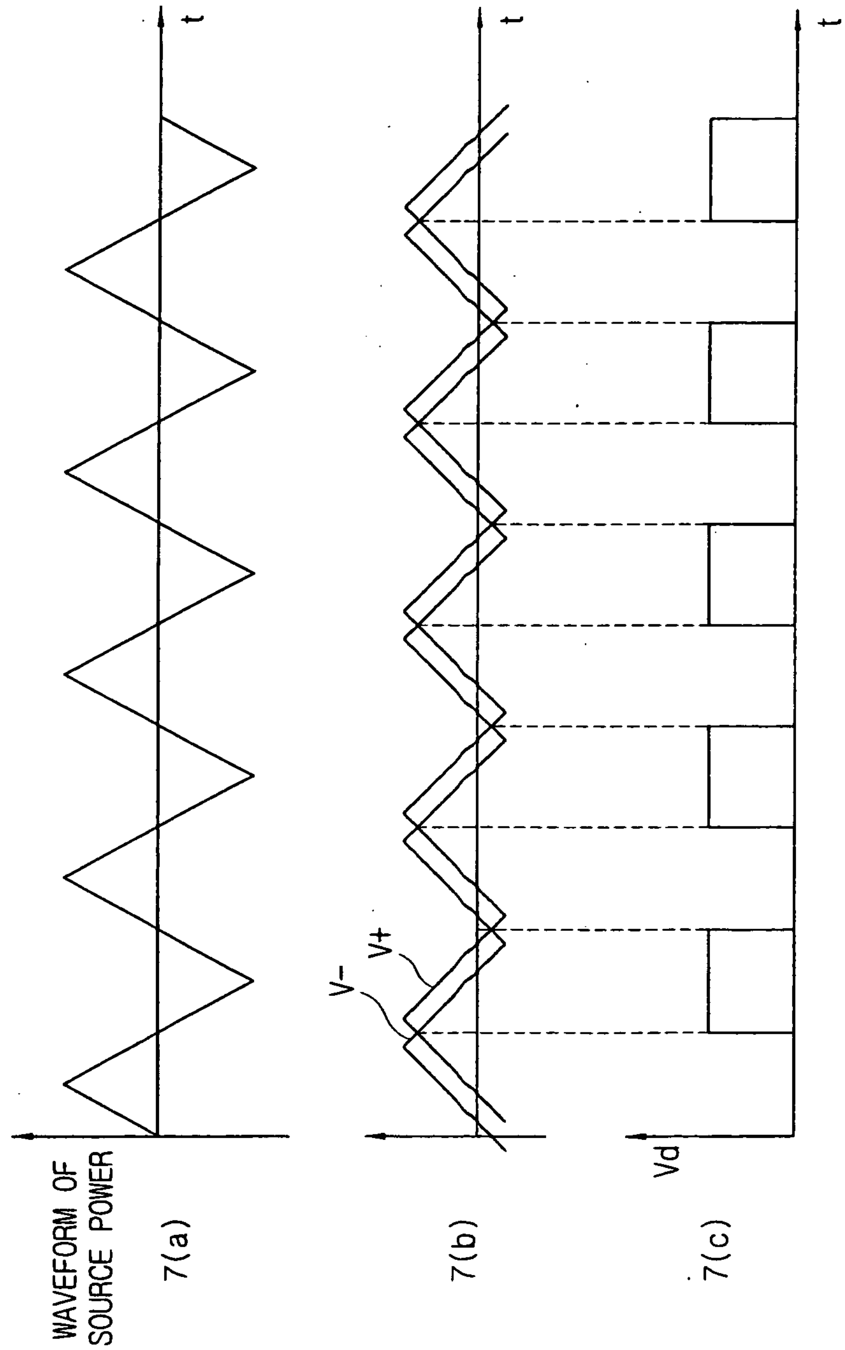


FIG. 8

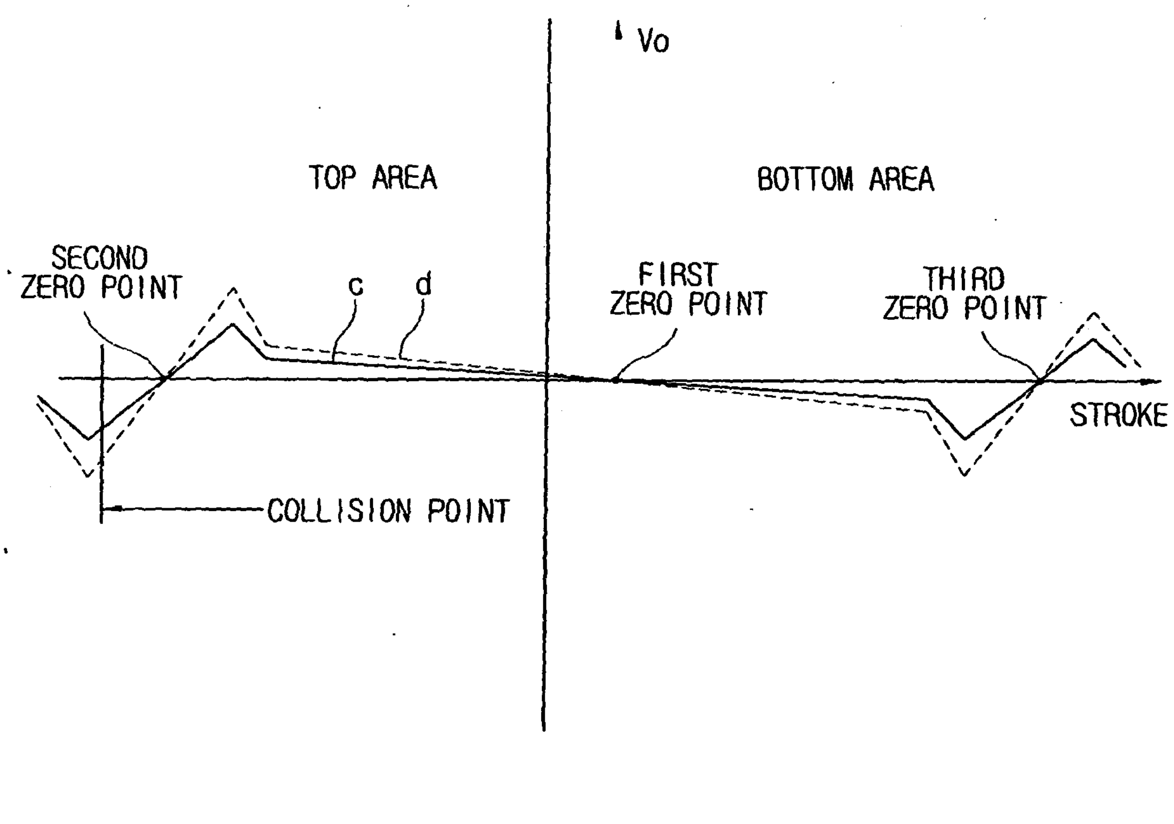

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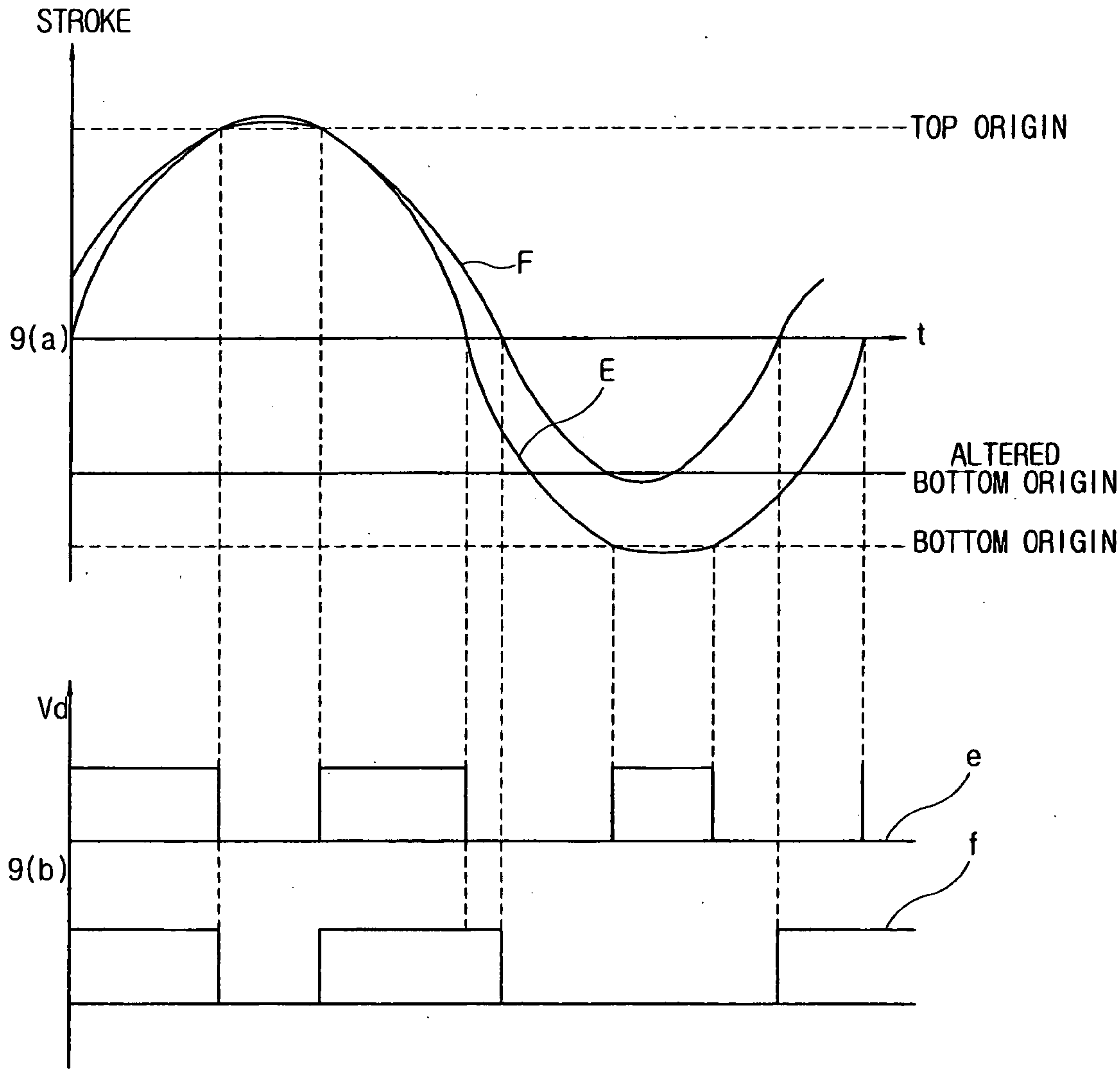
FIG. 9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