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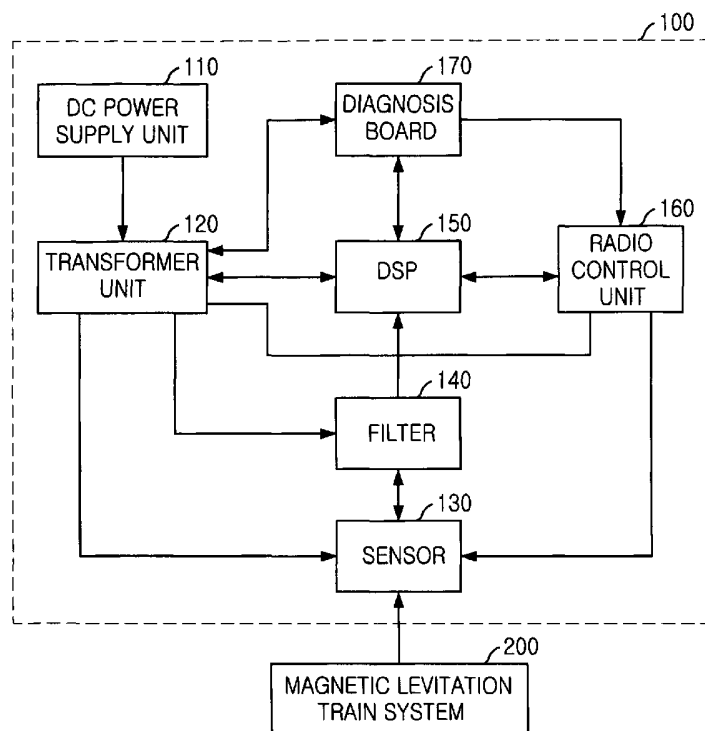
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[Continued on next page]

(54) Title: LEVITATION CONTROL APPARATUS FOR MAGNETIC LEVITATION TRAIN AND METHOD THEREOF



(57) Abstract: The present invention provides an apparatus for controlling levitation of a magnetic levitation train and method thereof, by which the algorithm of the DSP instead of developing that of the magnetic levitation train is provided to enhance an economical effect, by which in developing the algorithm, the risk factors with which the real train test is accompanied are lowered, and by which adaptation to the risk factors is made quick to enable the development of the improved algorithm to proceed efficiently. The present invention, which controls a levitation controller of a magnetic levitation train, includes a DC power supply unit supplying power to the levitation controller, a transformer unit transforming a supply voltage supplied from the DC power supply unit to supply to the levitation controller, a sensor sensing a gap indicating a levitation distance of the magnetic levitation train from a railway and acceleration information of the magnetic levitation train, a filter removing noise of the gap and acceleration information sensed by the sensor, a DSP receiving magnetic levitation train system information transferred via the sensor and the filter to

perform a levitation control, a radio control unit controlling to enable the sensor to detect/receive the gap and the acceleration information by wireless, and a diagnosis board analyzing data computed by the DSP to check whether the magnetic levitation train normally operates.



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**Levitation Control Apparatus for Magnetic Levitation Train
and
Method Thereof**

5 TECHNICAL FIELD

 The present invention relates to an levitation control apparatus for magnetic levitation train and method thereof, in which the same system of the magnetic levitation train is employed overall, in which a structure
10 failing to essentially match with that of the real magnetic levitation train is configured to fit the characteristics of the magnetic levitation train, and by which a test can be performed with the same performance of the magnetic levitation train.

15 BACKGROUND ART

 Generally, a rapid transit railway is opened for traffic to develop a public traffic means with the purpose of supporting the national economy base. A life pattern has
20 been changed as well as a life paradigm. For instance, the National Capital region ix expanded. And, in case of using the rapid transit railway, it takes only 30 minutes to travel a distance between Seoul and Cheonan. Thus, a traffic revolution occurs to correct the concept of a
25 locality.

 The rapid transit railway, which employs a wheel system, reduces its contact and the like in aspect of operating the wheel system, prepares various systems including a railway, a train, and the like such as a
30 rotation of the train to fit its speed, and operates its control system to fit its high speed. Yet, limitation is put on the high-speed train using the wheel system and there are various problems caused by the rapid transit service. Moreover, to overcome the problems, various kinds
35 of technical know-how and operational know-how are needed.

 A magnetic levitation train is expected as one of the

next generation solutions but needs its own problems for test such as an excessive expense, wide test area occupancy, and the like. Currently, the magnetic levitation train system is operated by such an advanced country as Japan, 5 U.S.A., Germany, China, and the like for test equipments and limited regions only. And, it is still regarded as reckless to commercialize the magnetic levitation train system despite the excessive expense and the risk proportional to a national-wide scale that combines the 10 entire country as a one-day life zone. This is attributed to the difficulty in testing the magnetic levitation train system and its overall system.

In order to secure the performance and reliability, a levitation control and propulsion system configuring the 15 magnetic levitation train system needs to be sufficiently tested to enhance controller hardware and software reliability.

However, there are too many risks and danger in testing the real system variously. And, the various tests 20 need vast expenses as well. Hence, it is recommended to perform a test using a reduced system.

DISCLOSURE OF THE INVENTION

TECHNICAL PROBLEM

25 Even though miniature models imitating the configuration and structure have been prepared in Korea, the reduced model having the basic principle of the magnetic levitation train applied thereto has never been prepared. Hence, it is unable to substantially perform a 30 simulation test of the magnetic levitation train.

TECHNICAL SOLUTION

Accordingly, the present invention is directed to an apparatus for controlling levitation of a magnetic 35 levitation train and method thereof that substantially obviate one or more of the problems due to limitations and

disadvantages of the related art.

An object of the present invention is to provide an apparatus for controlling levitation of a magnetic levitation train and method thereof, in which levitation control algorithm using DSP is applied the magnetic levitation train and by which test troublesomeness, economical expenses, risk factors, and the like can be efficiently managed.

Another object of the present invention is to provide an apparatus for controlling levitation of a magnetic levitation train and method thereof, in which the apparatus and method thereof are repeatedly applicable using DSP and by which the better apparatus and method thereof can be developed.

ADVANTAGEOUS EFFECTS

Accordingly, the present invention provides the algorithm of the DSP instead of developing that of the magnetic levitation train, thereby enhancing an economical effect. In developing the algorithm, the present invention lowers the risk factors with which the real train test is accompanied. And, the present invention is quickly adaptive to the risk factors, whereby the development of the improved algorithm can proceed efficiently.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

In the drawings:

FIG. 1 is a block diagram of a levitation control apparatus according to one embodiment of the present invention;

FIG. 2 is a block diagram of a DSP processing

sequence for simulating levitation control algorithm according to one embodiment of the present invention; and

FIG. 3 is a flowchart of a levitation control method operated by DSP according to one embodiment of the present invention.

<brief description of principal cord part of figures>

levitation controller 100

DC power supply unit 110

transformer unit 120

sensor 130

filter 140

DSP 150

radio control unit 160

diagnosis board 170

BEST MODE FOR CARRYING OUT THE INVENTION

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, an apparatus for controlling levitation of a magnetic levitation train, which controls a levitation controller of a magnetic levitation train, according to the present invention includes a DC power supply unit supplying power to the levitation controller, a transformer unit transforming a supply voltage supplied from the DC power supply unit to supply to the levitation controller, a sensor sensing a gap indicating a levitation distance of the magnetic levitation train from a railway and acceleration information of the magnetic levitation train, a filter removing noise of the gap and acceleration information sensed by the sensor, a DSP receiving magnetic levitation train system information transferred via the sensor and the filter to perform a levitation control, a radio control unit controlling to enable the sensor to detect/receive the gap and the acceleration information by wireless, and a diagnosis board analyzing data computed by the DSP to check whether the

magnetic levitation train normally operates.

MODE FOR CARRYING OUT THE INVENTION

5 Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

10 FIG. 1 is a block diagram of a levitation control apparatus according to one embodiment of the present invention.

15 In FIG. 1, a levitation controller according to one embodiment of the present invention includes a DC power supply unit 110, a transformer unit 120, a sensor 130, a filter 140, a DSP 150, a radio control unit 160, and a diagnosis board 170.

20 Referring to FIG. 1, the levitation controller 100 has a rack shape having a built-in slot for loading the diagnosis board 170 therein to facilitate its assembly/disassembly for a corresponding test. And, the DSP 150 is provided with an operation speed of 40MIPS, sixteen A/D channels, eight PWM (pulse width modulation) channels, a data memory of 2.5K words, and a programmable memory of 32Kbytes, and is capable of executing levitation control algorithm.

25 First of all, the DC power supply unit 110 supplies power to the rack type levitation controller 100.

30 The transformer unit 120 transforms the supply voltage supplied from the DC power supply unit 110 and then supplies the transformed power to each configurational board of rack units of the levitation controller. For instance, the transformer unit 120 supplies the power to the diagnosis board 170, the DSP 150, the radio control unit 160, the sensor 130, the filter 140, and the like.

35 The sensor 130, which is connected to a magnetic levitation train system 200, senses a gap value indicating how high the magnetic levitation train is levitated from a

railway in case that the magnetic levitation train is levitated and an acceleration speed value of the magnetic levitation train.

Information sensed by the sensor 130 passes through
5 the filter 140 to remove noise thereof and is then transferred to the DSP 150.

The DSP 150 receives the system information, which is transferred via the sensor 130 and the filter 140, of the magnetic levitation train and then executes levitation
10 control algorithm.

The radio control unit 160 controls the sensor 130 so that the sensor can sense to receive the information of the magnetic levitation train from the magnetic levitation train system 200 by wireless.

15 And, the diagnosis board 170 controls the radio control unit 160, the DSP 150, and the like to enable data to be smoothly transferred. Moreover, the diagnosis board 170 analyzes data operated by the DSP 150 to check whether the magnetic levitation train normally operates or not.

20 FIG. 2 is a block diagram of a DSP processing sequence for simulating levitation control algorithm according to one embodiment of the present invention.

Referring to FIG. 2, a speed necessary for a control for sustaining a gap between a train and a rail, a relative speed, relative gap information are presumed via the AD
25 converter of the DSP 150 using a gap value and acceleration speed information received from the magnetic levitation train system 200 via the sensor 130 and are then multiplied by appropriate coefficients, respectively.

30 The coefficients are experimental numerical values to play an important role in having the magnetic levitation train levitate stably. The DSP 150 processes the algorithm fast to sustain a specific levitation state.

First of all, the magnetic levitation train system
35 200 starts operating. In doing so, amplified power is applied to the magnetic levitation train system 200. The

magnetic levitation train system having received the applied power starts to have a prescribed degree of acceleration while the gap occurs between the magnetic levitation train and the railway. The sensor 130 detects
5 the gap G and acceleration A of the magnetic levitation train to transfer to the filter 140.

Once the filter 140 finds Z_P and Z_{PP} from the acceleration value and G_{FP} and G_F from the gap, the DSP 150 computes each weight coefficient from the found values and
10 then totals the computed values to adjust a power amplification value of an amplification transformer 210 that applies the power to the magnetic levitation train.

FIG. 3 is a flowchart of a levitation control method operated by DSP according to one embodiment of the present
15 invention.

Referring to FIG. 3, once power is applied to the magnetic levitation train, the DSP 150 initializes all registers and variables and then waits for a levitation command (step 302).

20 In initializing the registers, a timer, PWM, and A/D converter are entirely initialized.

IT is then decided whether a termination command is inputted (step 304).

If it is decided that the termination command fails to be inputted as a decision result of the step 304 and if
25 the levitation command is received, the DSP 150 converts an analog value of a voltage state inputted from the sensor 130 to a digital value while the magnetic levitation train is not levitated and then diagnoses a presence or non-
30 presence of abnormality using the converted digital value (step 306).

The sensor 130 transfers the data value to the DSP 150 via the filter 140. For instance, the data value inputted from the sensor 130 is converted to the digital
35 value via the filter 140 and is then transferred to the DSP 150 (step 308).

The DSP 150 includes a DSP for diagnosing the presence or non-presence of abnormality and another DSP for performing an operation. The abnormality diagnosis in the step 306 is performed by the former DSP and the operation in the subsequent step is performed by the latter DSP. Moreover, the following algorithm is performed by the latter DSP as well.

The DSP 150 executes the algorithm using the received data (step 310). The algorithm execution corresponds to the same explanation of FIG. 2.

The DSP 150 decides whether the magnetic levitation train is in levitation or not on executing the algorithm or after completion of the algorithm execution (step 312).

If the magnetic levitation train is not in levitation as a decision result of the step 312, the magnetic levitation train is gradually levitated (step 314) to proceed to a next step of step 316. If the magnetic levitation train is in levitation as a decision result of the step 312, the levitation state is sustained (step 316).

Meanwhile, by adjusting the power value of the amplification transformer 210, the magnetic levitation train can be slowly started. The gap and acceleration values of the magnetic levitation train in progress or in the levitated state are received to be transferred to the DSP 130 (step 318). And, the corresponding procedure goes back to the step 308.

Such a process is carried out about 1,500 times per second. Via such a test, it is able to confirm whether the magnetic levitation train is in the stable state or not.

INDUSTRIAL APPLICABILITY

Accordingly, the present invention provides the algorithm of the DSP instead of developing that of the magnetic levitation train, thereby enhancing an economical effect. In developing the algorithm, the present invention lowers the risk factors with which the real train test is

accompanied. And, the present invention is quickly adaptive to the risk factors, whereby the development of the improved algorithm can proceed efficiently.

WHAT IS CLAIMED IS:

1. An apparatus for controlling levitation of a magnetic levitation train, which controls a levitation controller of a magnetic levitation train, the apparatus comprising:

a DC power supply unit 110 supplying power to the levitation controller 100;

a transformer unit 120 transforming a supply voltage supplied from the DC power supply unit 110 to supply to the levitation controller 100;

a sensor 130 sensing a gap indicating a levitation distance of the magnetic levitation train from a railway and acceleration information of the magnetic levitation train;

a filter 140 removing noise of the gap and acceleration information sensed by the sensor 130;

a DSP 150 receiving magnetic levitation train system information transferred via the sensor 130 and the filter 140 to perform a levitation control;

a radio control unit 160 controlling to enable the sensor 130 to detect/receive the gap and the acceleration information by wireless; and

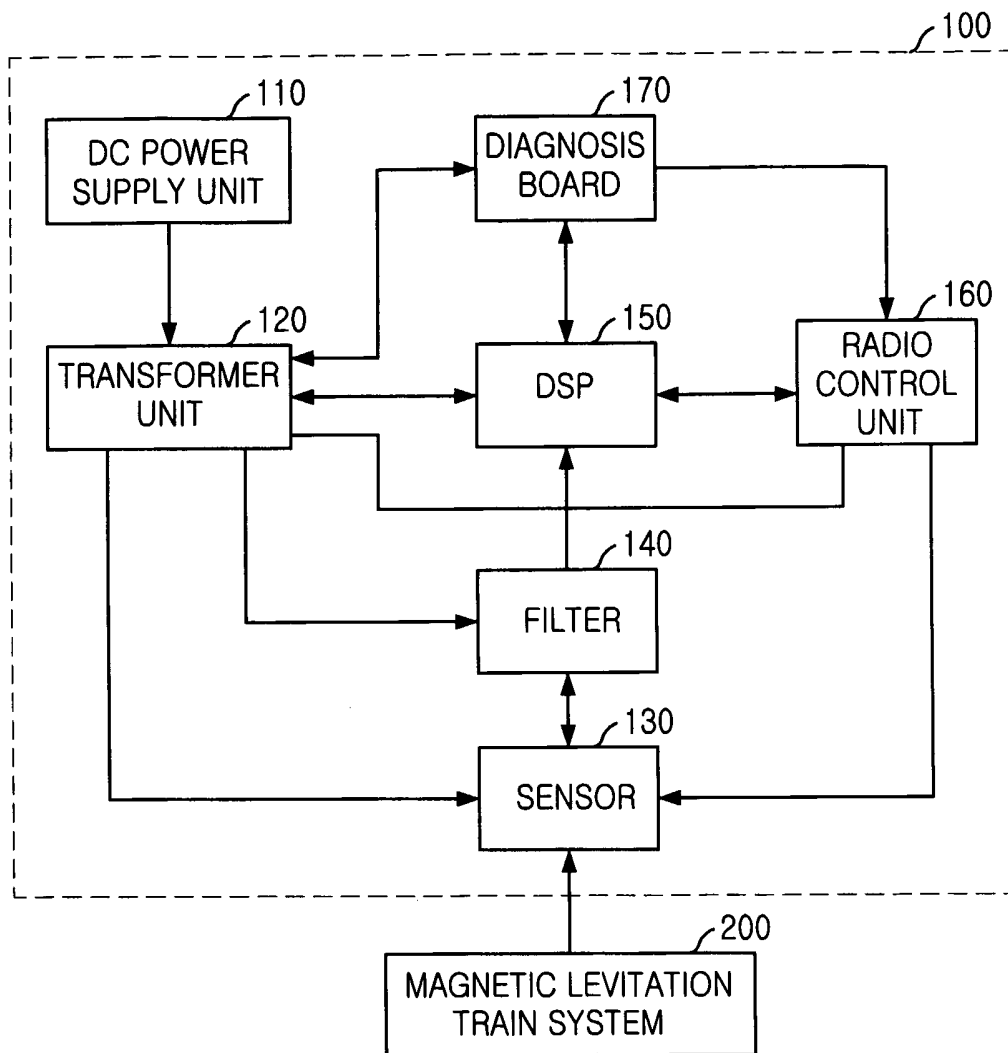
a diagnosis board 170 analyzing data computed by the DSP 150 to check whether the magnetic levitation train normally operates.

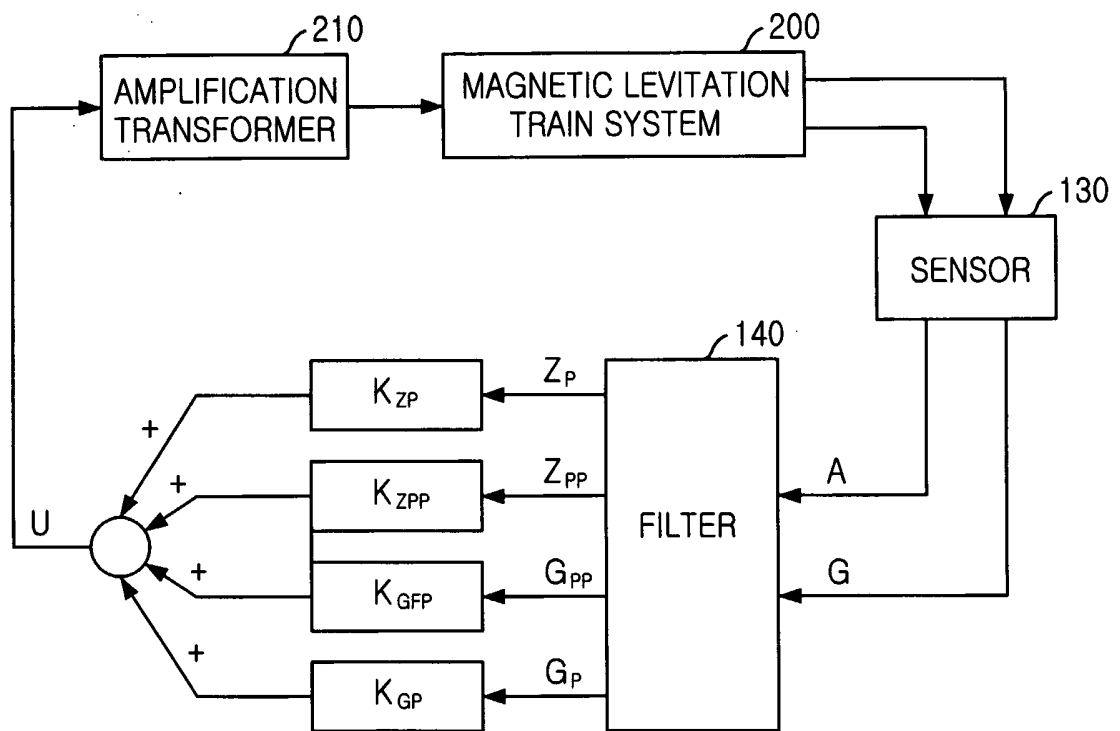
2. The apparatus of claim 1, wherein the DSP 150 presumes a speed necessary for a control for sustaining the distance between the train and the railway, a relative speed, relative gap information using the gap and the acceleration information received from the magnetic levitation train via the sensor 130, wherein the DSP 150 detects to transfer a gap value G and an acceleration value A of the magnetic levitation train to the filter 140 if the magnetic levitation train is actuated, and wherein once the filter 140 finds Z_p and Z_{pp} from the acceleration value and

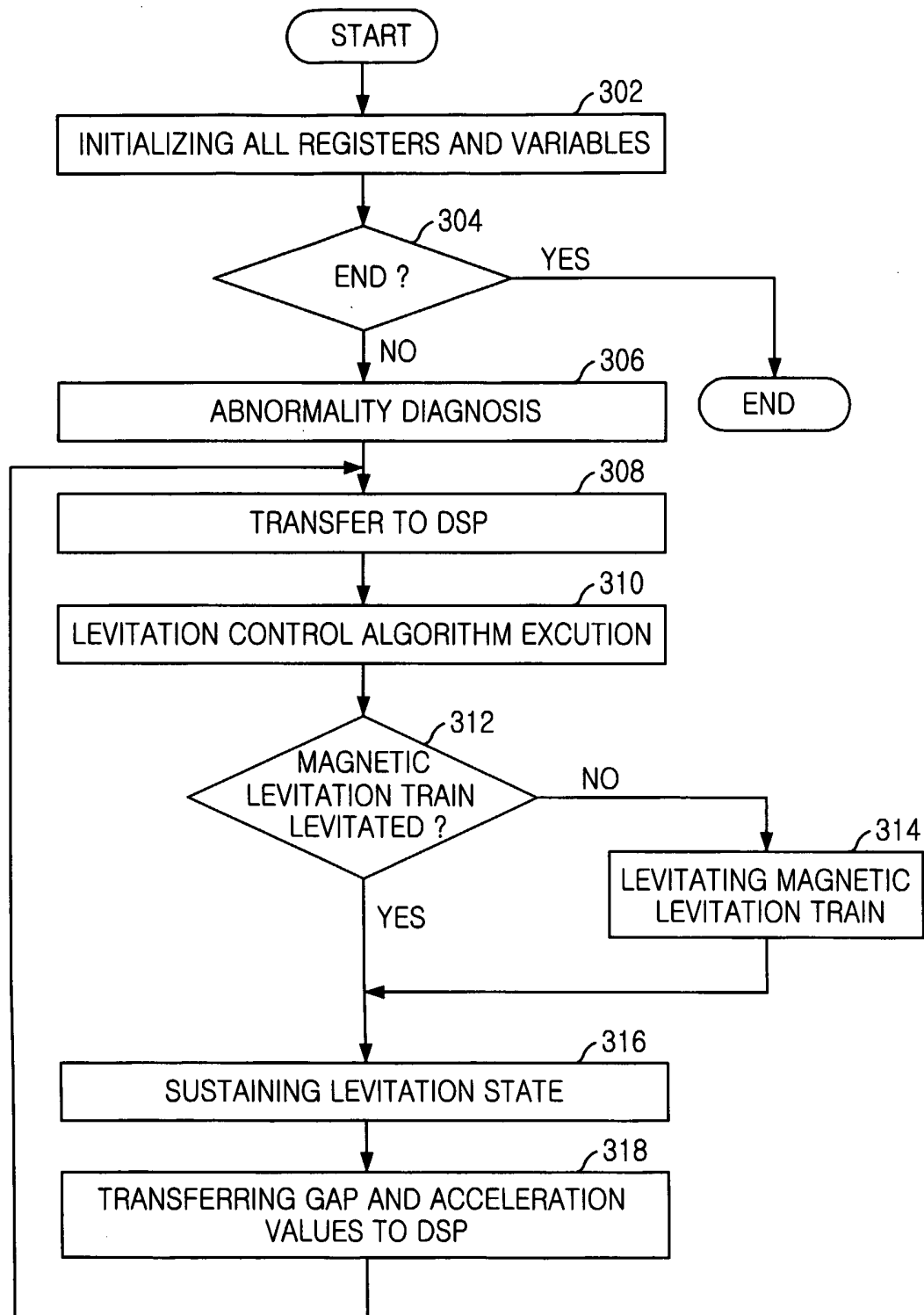
G_{FP} and G_F from the gap value, the DSP 150 computes each weight coefficient from the found values Z_P , Z_{PP} , G_{FP} , and G_F and then totals the computed values to adjust a power amplification value of an amplification transformer 210
5 that applies the power to the magnetic levitation train.

3. In controlling a levitation controller of a magnetic levitation train, a method of controlling levitation of the magnetic levitation train, comprising;
10 a first step of if power is applied to the magnetic levitation train, initializing all registers and variables to wait for a levitation command;
a second step of deciding whether a termination command is inputted in the process of the first step;
15 a third step of if the termination command is decided as not inputted in the second step and if the levitation command is received, converting a voltage value of the magnetic levitation train failing to levitate to a digital value and checking a presence or non-presence of
20 abnormality; and
a fourth step of if the termination command is not inputted, levitating the magnetic levitation train by adjusting a power value and receiving gap and acceleration value

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1/3
FIG. 1

2/3
FIG. 2

3/3
FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2004/003555

A. CLASSIFICATION OF SUBJECT MATTER**IPC7 G01M 17/08**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7 G01M 17/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Patents and applications for inventions since 1975Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKIPASS "levitate" "gap" "train" "control" "magnetic"**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	SEUNG-UG YI, GUN-BOK LEE "Digital control of an electromagnetic levitation system" In : Journal of the Korean Society of Mechanical Engineers, Vol.18, No.9, 1994, p.2312-2321. See the page 2318 of the document	1 2,3
A	JP 12-060169 A (EBARA CORP.) 25.FEB.2000 See the entire document	1-3
A	JP 09-112628 A (EBARA CORP., KAJIMA CORP.) 02.MAY.1997 See the entire document	1-3
A	KR 2002-058940 A(KOREA ELECTROTECHNOLOGY RESEARCH INSTITUTE) 12.JUL.2002 See the entire document	1-3



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 12-060169 A	25.FEB.2000	NONE	
JP 09-112628 A	02.MAY.1997	DE69630509D D1	2003-12-04
		DE69630509T T2	2004-08-12
		EP0789160 A2	1997-08-13
		EP0789160 A3	1998-07-08
		EP0789160 B1	2003-10-29
		JP3296973B2 B2	2002-07-02
		US5793598 A	1998-08-11
KR 2002-058940 A	12.JUL.2002	NONE	