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(71) Applicants: **KELSEY-HAYES COMPANY** [US/US]; 12025 Tech Center Drive, Livonia, MI 48150 (US). **LUCAS AUTOMOTIVE GMBH** [DE/DE]; Carl-spaeter-strasse 8, 56070 Koblenz (DE).

(72) Inventors: **ROMERO, Antonio**; Carl-spaeter-strasse 8, 56070 Koblenz (DE). **ORTH, Johannes**; Carl-spaeter-strasse 8, 56070 Koblenz (DE). **HERMANN, Erik**; Carl-spaeter-strasse 8, 56070 Koblenz (DE). **LINDEMAN, William, J.**; 12025 Tech Center Drive, Livonia, MI 48150 (US).

(74) Agent: **DUGGAN, James, A.**; Macmillan, Sobanski & Todd, LLC, One Maritime Plaza, 5th Floor, 720 Water Street, Toledo, OH 43604 (US).

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(54) **Title**: GROUND LOSS DETECTION CIRCUIT

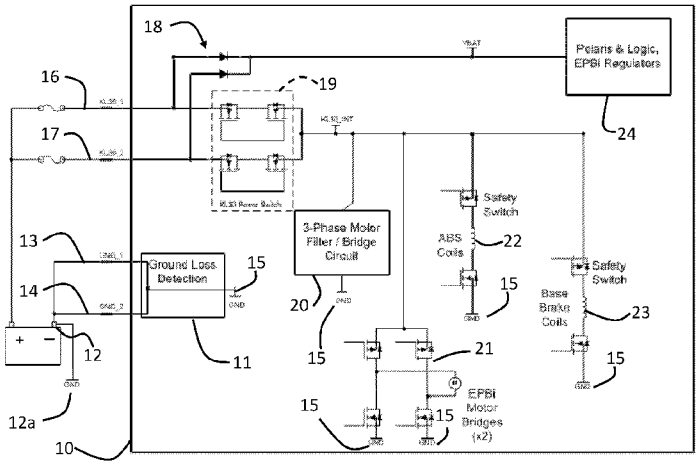

Fig. 1

(57) **Abstract**: A ground loss detection circuit identifies a faulty ground connection in a vehicle electrical system including a pair of redundant ground lines connected between a vehicle battery /chassis ground and an electronic control unit (ECU). In particular, a first ground line is connected between the battery/chassis ground and a first ECU ground connection, while a second ground line is connected between the battery /chassis ground location and a second ECU ground connection. The ECU includes a common ground associated with selected electronic components included in the ECU. A first shunt component is connected between the first ECU ground connection and the common ground, and a second shunt component is connected between the second ECU ground connection and the common ground. The currents through the first and second shunt components are monitored to identify a current imbalance to detect a faulty ground connection in one of the first and second ground lines.

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TITLE

GROUND LOSS DETECTION CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States Provisional Application No. 62/190,068, filed July 8, 2015, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] It is known in vehicle electrical systems that redundant ground lines may be used between a vehicle battery or chassis ground and a vehicle electronic control unit (ECU). This is particularly important in vehicle safety systems such as, for example, vehicle brake systems, vehicle stability control systems, vehicle steering systems, occupant restraint systems and driver assist systems.

SUMMARY OF THE INVENTION

[0003] This invention relates to vehicular electrical systems and, in particular, grounding circuits for vehicular electrical systems. The invention concerns a ground loss detection circuit for identifying a faulty ground connection in a vehicle electrical system including a pair of redundant ground lines connected between a vehicle battery/chassis ground and an electronic control unit (ECU). In particular, a first ground line is connected between the battery/chassis ground and a first ECU ground connection, while a second ground line is connected between the battery/chassis ground location and a second ECU ground connection. The ECU includes a common ground associated with selected electronic components included in the ECU. A first shunt component is connected between the first ECU ground connection and the common ground, and a second shunt component is connected between the second ECU ground connection and the common ground. The first and second shunt components can be trace resistors on the ECU circuit board.

[0001] The currents through the first and second shunt components are monitored to identify a faulty ground connection in one of the first and second ground lines. When the current level in one of the first and second ground lines is at or near zero, or falls below a predetermined level, a fault is identified. Alternatively, or additionally, when the current levels in the first and second ground lines differ by a predetermined amount (or a relative percentage), a fault is identified.

[0002] Various aspects of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiment, when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 is a block diagram of one example of a vehicle electrical system having redundant ground lines and which uses the ground loss detection circuit of the invention.

[0004] FIG. 2a is simplified diagram showing the components of the ground fault detection circuit when in a normal operation.

[0005] FIG. 2b is similar to FIG. 2a but schematically showing a ground fault condition.

[0006] FIG. 3 is an example of one embodiment of a differential amplifier circuit that can be used to monitor the current flow in the redundant ground lines.

[0007] FIG. 4 is a flow diagram of showing one example of a method used to identify a ground fault condition.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0008] Referring now to the drawings, there is illustrated in FIG. 1 a block diagram illustrating one example of an operating environment for a circuit embodying the features of the present invention. In particular, the exemplary environment shown is a vehicular electronically controlled braking system which includes an electronic control unit (ECU) **10** for monitoring, controlling, actuating or otherwise operating the various electronic components of the system (e.g., sensors, motors, solenoid valve coils, switches, etc.). The invention provides a ground loss detection circuit **11** which

is connected to the vehicle battery ground **12** by a first ground line **13** and a second ground line **14**. The battery ground is connected to the various GND nodes of the ECU via the ground loss detection circuit **11**. Preferably all GND nodes are connected to a single "star point" ground **15**. The ground loss detection circuit is operable to monitor and detect a fault (open wire, increased resistance, etc.) in either or both the lines **13** and **14**.

[0009] In this particular embodiment, the ECU also has repeated power lines **16** and **17** connected to the vehicle battery. Dual diode **18** and dual high side power switch **19** provide a method of management for operating from both of these power lines or just one of them in case of a break in **17** or **18**. Some components included in the ECU consist of ABS coils **22** and base brake coils **23**. There are also control bridges **20, 21** to drive motors as well as a grouping of processors, logic and power regulators **24**. All these devices which make up the ECU for the electronically controlled braking system are referenced to the star point ground **15**.

[0010] In the event of a break in only one of the ground lines **13** or **14**, the ECU electronic components will all remain operable due to the single ground reference **15** which returns to the battery through the unbroken wire. The ground currents will be able to return to the battery ground via the unbroken line, and the ECU will be aware of the fault by the use a detection method used by the ground loss detection circuit **11**. While the FIG. 1 embodiment shows two separate line connections (i.e., redundant ground wires) between the vehicle battery ground and the ground loss detection circuit, it will be appreciated that, since the vehicle battery is conventionally connected to a chassis ground at **12a**, in some instances one or both lines **13** and **14** could alternatively be connected to a chassis ground.

[0011] FIG. 2a shows more details of the ground loss detection circuit **11**. As shown, the ground lines **13** (Ground 1) and **14** (Ground 2) from FIG. 1 are individually connected to ECU ground connections **13a** and **14a**. The connections **13a** and **14a** are then connected to the single star point ECU circuit ground **15** by shunt components such as current sensing resistors **27** and **28**, respectively. Each resistor can be, for example, a very low resistance trace (e.g., 0.5 milliohms) on the ECU circuit board. The current sense resistors **27** and **28** are balanced such that, when both

the ground lines, **13** and **14** are connected properly, the currents i1 and i2 are also balanced. The ground currents through lines **13** and **14** are monitored for faults by providing a separate differential amplifier, **25** and **26**, to sense the voltage across each of the current sense resistors, **27** and **28**. The outputs of the differential amplifiers are connected to a microcontroller **31** (which includes an A/D converter **29** and a microprocessor **30**) which monitors the sensed currents and provides status signals indicating whether either or both the Ground 1 and Ground 2 connections are faulty.

[0012] FIG. 2b is similar to FIG. 2a, except that the line **14** is (Ground 2) shown as broken at **14b**, such that differential amplifier **26** which monitors the respective current sense resistor **28** detects a zero or reduced level current flow. The microcontroller **31** identifies a faulty Ground 2 connection by reading though its A/D converter **29** that the current i2 is less than the current i1. Under normal operating conditions, currents i1 and i2 should be close to equal, assuming the wire length and resistance of lines **13** and **14** are similar.

[0013] FIG. 3 is a circuit schematic which illustrates the detailed circuitry associated with the differential amplifiers of FIG. 2a. The two ground wires connected to the ECU are lines **13** and **14**, and the star ground for the ECU circuit is node **15**. Similar to FIG. 2a and FIG. 2b, the star ground **15** is distributed to ground connections **13** and **14** though current sense resistors **27** and **28** respectively. Each sense resistor is part of its own differential amplifier circuit. Operational amplifier **25** is designed to amplify the voltage differential across current sense resistor **27**. The greater the amount current flowing through resistor **27**, the higher the voltage will be at node **41** compared to node **15**. Operational amplifier **26** is designed in the same way as amplifier **25**, but it will amplify the voltage differential across current sense resistor **28**. Series input resistor **32** and capacitor **33** create a low pass filter designed to remove noise, current irregularities, and ESD spikes that may trigger a false fault detection. Series input resistor **34** and capacitor **35** create a low pass filter on the second, non-inverting, terminal of differential amplifier **25**. Amplifier **26** also contains a similar low pass filter on each of its input terminals. Both amplifiers have a gain that is associated with how much they increase the small voltage sensed across shunt resistors **27** and **28**. In the case of amplifier **25**, this gain is defined by input

resistors **32**, **36**, **34**, and **37** in combination with feedback resistor **38**. Amplifier **26** has a similar configuration of input and feedback resistors. Lines **39** and **40** are the outputs of the differential amplifier which then lead to the analog to digital converter (ADC) **29** of FIG. 2. The ADC will convert the voltage sensed from resistors **27** and **28** into a digital reading that can be interpreted by the microprocessor. The microprocessor will then decide if there is a fault condition in one of the ground wires **13** or **14**.

[0014] FIG. 4 is a flow chart diagram representing the logic involved in detecting a fault condition. The first steps required are to measure the ground currents i1 and i2 through their individual ground lines. In the particular example displayed in FIGS. 2A, 2B, and 3, the ground currents are represented by the voltage across two shunt resistors, one for each ground line. If either one of the two measured currents are at or near 0, or below a defined threshold, then the ground line containing an abnormally reduced flow of current likely has a full or partial discontinuity somewhere in its structure. An additional, or optional, condition to check for is the relationship between the currents in each ground wire. If both wires are functioning properly, and they are designed to have similar impedances, then the total current returning to the battery ground from the ECU should be equally split between both ground lines where i1 = i2. If the current i1 is divided by i2, then the result should be somewhere near a value of 1. If the result of this calculation is not close to 1 then there is an abnormality in one of the wires to a point where it has increased resistance, causing an imbalance in the current distribution through both ground lines.

[0015] The principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope.

What is claimed is:

1. A ground loss detection circuit for a vehicle having a battery connected to an electronic control unit (ECU), the battery having a negative terminal connected to a chassis ground, the circuit comprising:

a first ground line connected between the negative terminal or chassis ground and a first ECU ground connection;

a second ground line connected between the negative terminal or chassis ground and a second ECU ground connection;

a common ground associated with selected electronic components included in the ECU;

a first shunt component connected between the first ECU ground connection and the common ground;

a second shunt component connected between the second ECU ground connection and the common ground; and

a monitoring circuit for sensing the current through the first and second shunt components to identify a faulty ground connection in one of the first and second ground lines.

2. The ground loss detection circuit of claim 1 wherein the first and second shunt components are resistors.

3. The ground loss detection circuit of claim 2 wherein the resistors are trace resistors located an ECU circuit board.

4. The ground loss detection circuit of claim 1 wherein the comparator includes a first differential amplifier coupler to monitor the current flow through the first shunt component by sensing the voltage across the first shunt component, and a second differential amplifier coupled to monitor the current flow through the second shunt component by sensing the voltage across the second shunt component.

5. The ground loss detection circuit of claim 1 wherein the ECU is a component of a vehicle safety system.

6. A method for detecting a ground loss in a vehicle electrical system having a battery connected to an electronic control unit (ECU), the battery having a negative terminal connected to a chassis ground, the vehicle electric system comprising:

a common ground associated with selected electronic components included in the ECU;

a first ground line connected between the negative terminal or the chassis ground and an ECU common ground; and

a second ground line connected between the negative terminal or the chassis ground and the ECU common ground;

and wherein the method comprises the steps of:

(a) monitoring the current in the first ground line;

(b) monitoring the current in the second ground line; and

(c) identifying a faulty ground connection in response to the current monitored in steps (a) and (b).

7. The method according to claim 6 wherein the current in step (a) is monitored at a location along the first ground line proximate the ECU common ground.

8. The method according to claim 6 wherein step (c) identifies a faulty ground connection when the current in either the first or second ground line is below a predetermined level.

9. The method according to claim 6 wherein step (c) identifies a faulty ground connection in response to the difference in current levels in the first and second ground lines.

10. The method according to claim 6 wherein step (c) identifies a faulty ground connection in response to the ratio in current levels in the first and second ground lines.

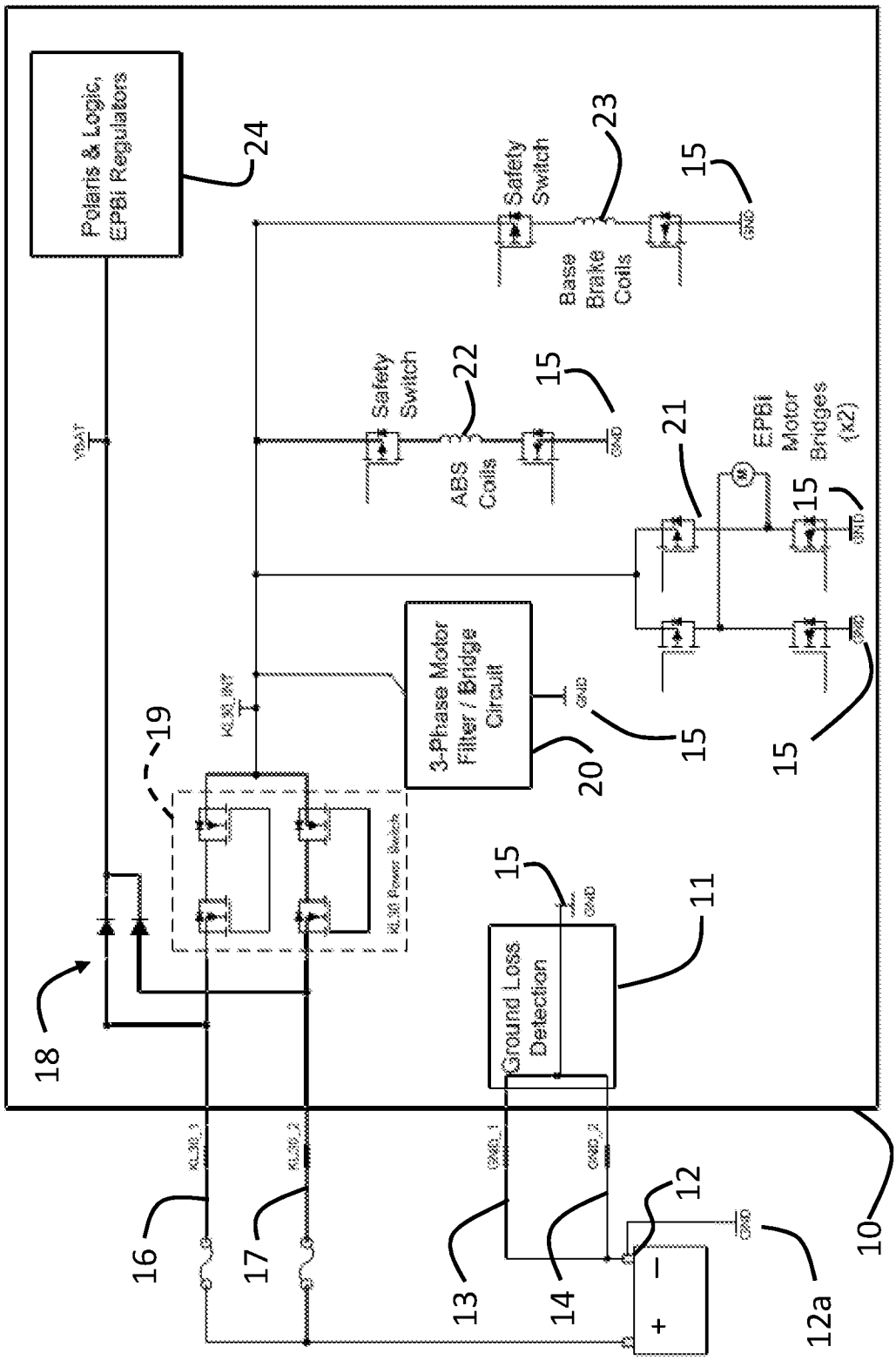
Polaris & Logic, EPBi Regulators
24
Safety Switch
23
Base Brake Coils
15
GND
Safety Switch
22
ABS Coils
15
GND
21
EPBi Motor Bridges (x2)
15
GND
3-Phase Motor Filter / Bridge Circuit
GND
20
15
15
19
KL30_PWR
KL30 Power Switch
18
15
GND
Ground Loss Detection
11
KL30_1
KL30_2
GND_1
GND_2
16
17
13
14
12
+
−
GND
12a
10

Fig. 1

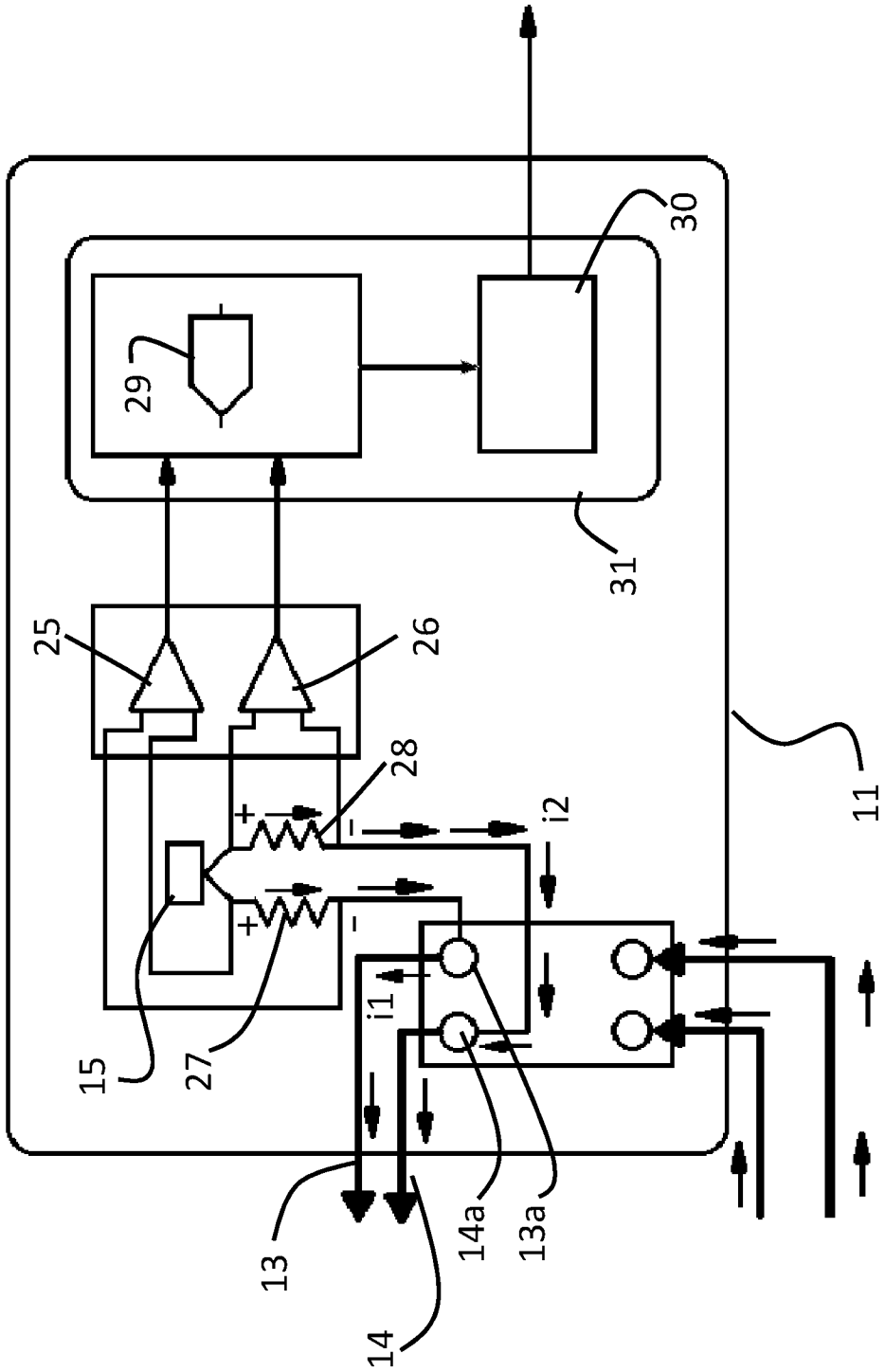

Fig. 2A

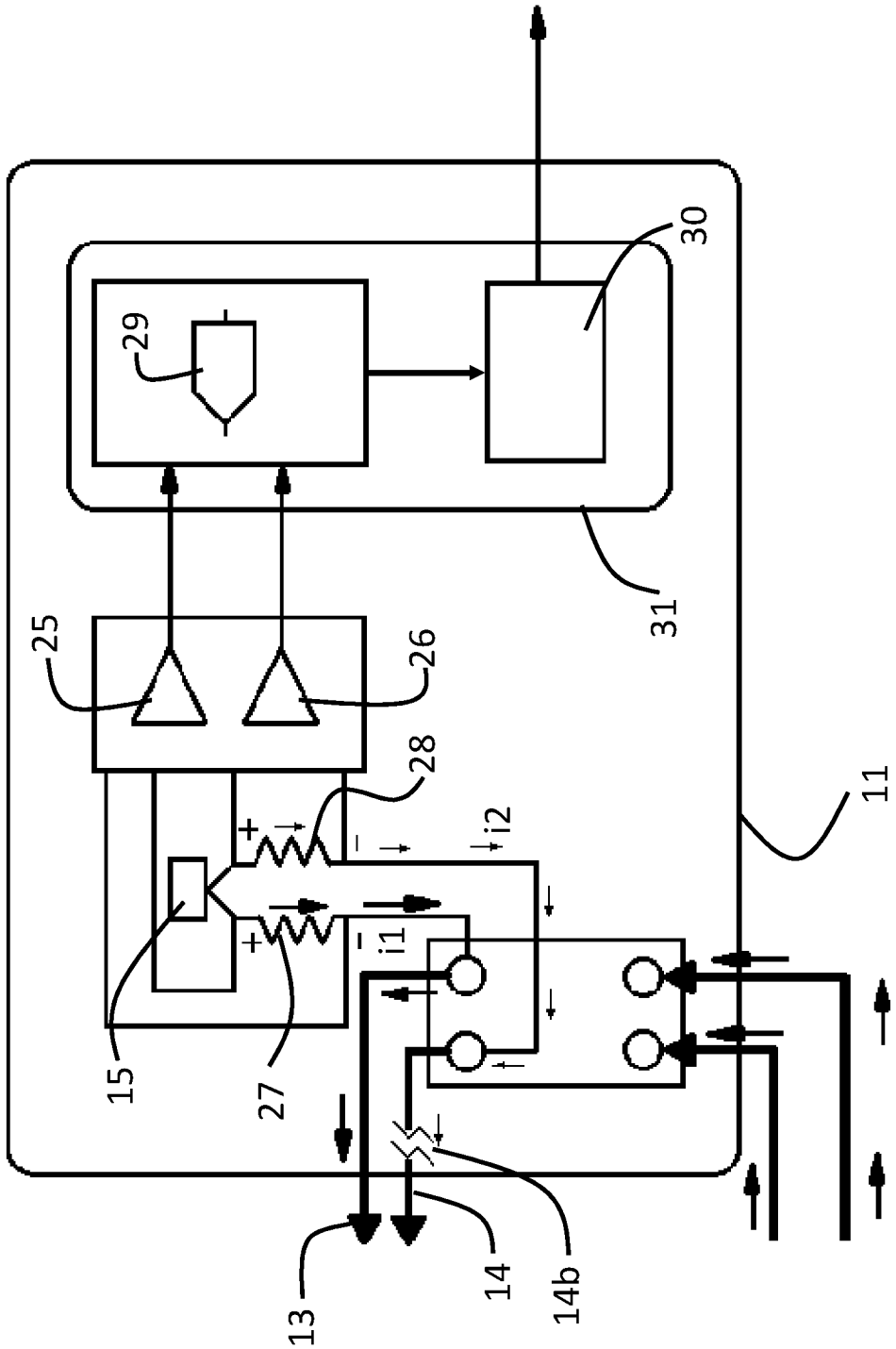

Fig. 2B

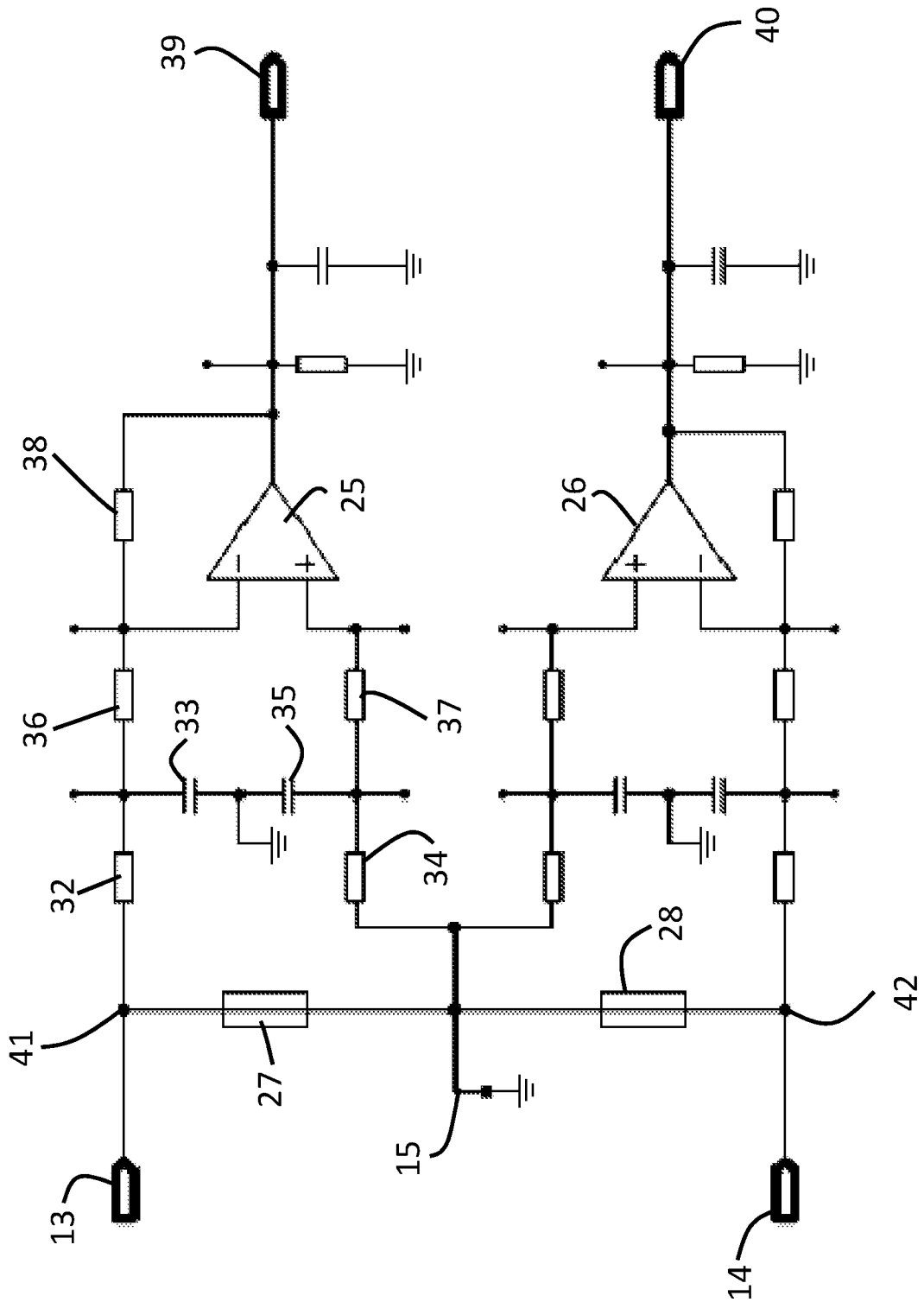

Fig. 3

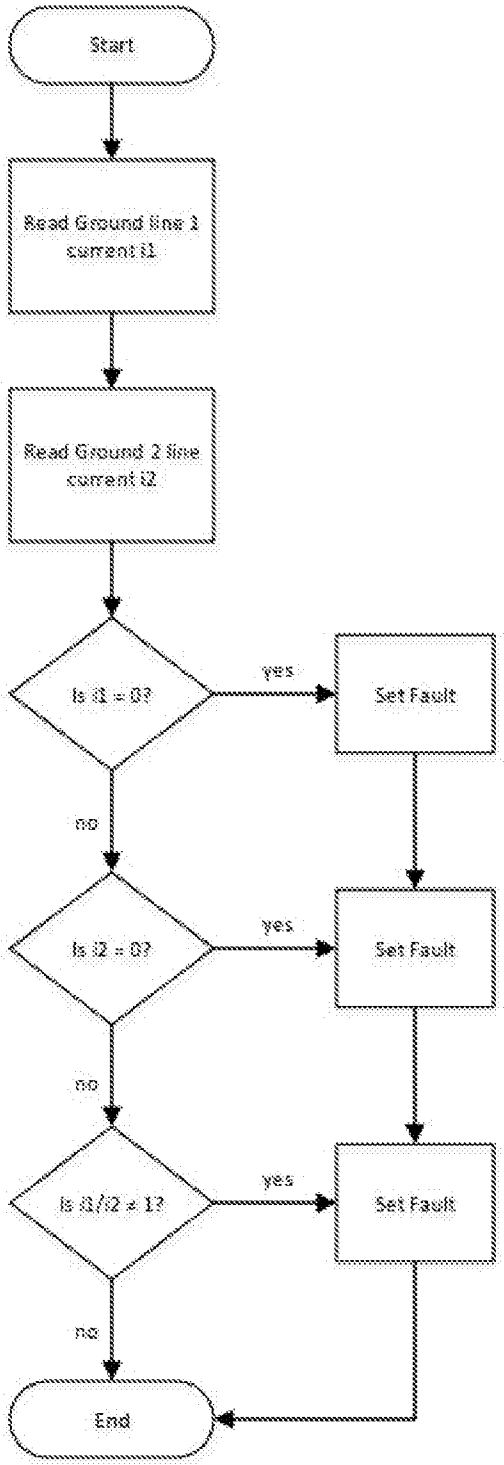
Start
Read Ground line 1 current i1
Read Ground 2 line current i2
Is i1 = 0?
yes
Set Fault
no
Is i2 = 0?
yes
Set Fault
no
Is i1/i2 ≠ 1?
yes
Set Fault
no
End

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/041635

A. CLASSIFICATION OF SUBJECT MATTER

G01R 31/02(2006.01)i, G01R 15/14(2006.01)i, G01R 1/20(2006.01)i, G01R 31/00(2006.01)i

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)
G01R 31/02; H02H 7/18; G06F 19/00; H02H 5/04; G01M 17/00; H02J 7/00; B60L 3/04; G01R 31/36; G01R 15/14; G01R 1/20; G01R 31/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: ground, loss, detection, battery, shunt, monitoring

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010-0052419 A1 (OOSAWA et al.) 04 March 2010 See abstract, paragraphs [13]-[32] and figures 1-3.	1-10
A	US 2005-0151559 A1 (LIAO et al.) 14 July 2005 See abstract, paragraphs [06]-[10], claim 1 and figures 2-4(b).	1-10
A	US 2014-0347769 A1 (PANASONIC CORPORATION) 27 November 2014 See abstract, claims 1-13 and figures 1-12.	1-10
A	US 7583483 B2 (TRENCHS et al.) 01 September 2009 See abstract, claims 1-7 and figures 1-3.	1-10
A	US 2004-0243288 A1 (KITO et al.) 02 December 2004 See abstract, paragraphs [34]-[53] and figures 1-4.	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 October 2016 (12.10.2016)	**12 October 2016 (12.10.2016)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
CHO, KI YUN
Telephone No. +82-42-481-5655

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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