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(71) Applicant: **Delphi Technologies, Inc.**
Troy, MI 48007 (US)

(72) Inventor: **Engel, Jos**
4671 Oberkorn (LU)

(74) Representative: **Beissel, Jean et al**
Office Ernest T. Freylinger S.A. 234, route d'Arlon B.P. 48
8001 Strassen (LU)

(54) Glow plug arrangement and method for operating said arrangement

(57) Glow plug arrangement comprising a glow plug (10) including heater means (18) and ion sensing means (20); a first voltage source (22) for generating a heater supply voltage to be applied to said heater means (18) during a heating function of said glow plug (10); and a second voltage source (24) for generating an ion sensor supply voltage to be applied to said ion sensing means (20) during an ion sensing function of said glow plug (10). The glow plug arrangement is characterised in that said ion sensor supply voltage has a different polarity than said heater supply voltage.

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Description

Introduction

[0001] The present invention relates to a glow plug arrangement and method for operating said arrangement.

State of the Art

[0002] In recent years, more effective emission control has been demanded in diesel engines for the protection of the environment. A more effective emission control can be achieved through an improved burning control system. Such a burning control system requires the detection of conditions of the burning of an air-fuel mixture in a combustion chamber of an engine. Many physical parameters, such as the pressure in the combustion chamber, the light generated by the burning of the air-fuel mixture, the ion current in the combustion chamber, and others can be detected as an indication of conditions of the burning of the air-fuel mixture. It is thought that particularly the ion current detection is useful. The detection of burning conditions in response to an ion current means a direct observation of a chemical reaction caused during the burning of an air-fuel mixture. In fact, ions are generated by the burning of the air-fuel mixture. During an ion sensing function of the glow plug, the ion sensing means and the walls of the combustion chamber form opposite electrodes for capturing the generated ions. The information of the ion current created by the migrating ions can then be used to control the burning.

[0003] Glow plugs have been introduced which, next to the heater element, comprise an ion sensing element for measuring an ion current generated by the burning of the air-fuel mixture. The electrical isolation of the two elements of the glow plug have been achieved by a fragile isolated heater design in a fully isolated shell. Both elements each have their own electrical circuit, which is independently controlled. The isolated heater design may experience temperature dependent leakage currents that interfere with the ion sense signal, and hence reduce its signal to noise ratio, thereby making the measured signal difficult to exploit.

[0004] In order to save space, glow plugs have been introduced, wherein the heater element and the ion sensing element share a single voltage supply line. Additional parts in the electronics however need to be introduced. The operation of the glow plug is controlled by a switch control operating two switches. A first switch is used to apply either a heater supply voltage, e.g. the car battery voltage, or an ion sensor supply voltage to the glow plug in order to perform either a heating or an ion sensing function of the glow plug. A second switch is used to open and close a heater circuit, i.e. the circuit comprising the heater element. By closing the heater circuit, a current is allowed to flow through the heater element.

[0005] Applying the ion sensor supply voltage to the heater element has to be avoided. In fact the ion sensing supply voltage source is a rather weak source, which means that its maximum current is rather low. Applying the ion sensor supply voltage to the low resistance heater element leads to a saturation of the ion sensing supply voltage source and accordingly to a breakdown of the ion sensing voltage. Furthermore the current flowing through the ion sensing supply voltage source, which is detected by the motor control as being the actual ion current, is outside of any meaningful range for the ion current so that an effective motor management based on this parameter is no longer possible. This can have annoying consequences for the engine operation. The requirements for noise reduction and emission reduction will not be met, especially during a cold start of the engine.

[0006] In order to prevent the ion sensor supply voltage of being applied to the heater element, the switch control has to check whether the right voltage is being applied to the glow plug. For this, the switch control generally relies on a comparison of voltage levels. However especially if ion sensing is carried out with an ion sensing supply voltage in the range of the heater supply voltage, this comparison is not reliable enough due to possible fluctuations in the heater supply voltage generated by the heater voltage supply source. These fluctuations might cause the switch control to close the heater circuit while the ion sensor supply voltage is being applied which leads to the above described negative consequences.

Object of the invention

[0007] The object of the present invention is to provide an improved glow plug arrangement and method for operating said arrangement. This object is achieved by a glow plug arrangement according to claim 1 and by a method according to claim 9.

General description of the invention

[0008] In accordance with the present invention, a glow plug arrangement comprises a glow plug including heater means and ion sensing means, a first voltage source for generating a heater supply voltage to be applied to the heater means during a heating function of the glow plug; and a second voltage source for generating an ion sensor supply voltage to be applied to the ion sensing means during an ion sensing function of the glow plug. The glow plug arrangement is characterised in that the ion sensor supply voltage has a different polarity than the heater supply voltage. By using an ion sensor supply voltage, which has a different polarity than the heater supply voltage, the electrical isolation of both functions can be easily achieved. The polarity of the applied voltage can now be used as switching criterion for closing a heater circuit, i.e. the circuit comprising the heater means. Voltage level comparison can be replaced by polarity comparison, the latter being much easier and much more reliable. As the polarity of a voltage can only be either positive or negative, this switching criterion is precise. The polarity of the applied voltage can never change due to potential fluctuations caused by the heater supply voltage source.

[0009] The ion sensor supply voltage is preferably of negative polarity. In an ion sensing device operated with positive supply voltage, the presence of negatively charged ions and of free electrons is detected. Hence free electrons contained in the air fuel mixture before the burning contribute to the measured current thus leading to inaccuracies in the determination of combustion generated ions. If the ion sensor supply voltage is of negative polarity the ion sensing electrode will be negatively charged during the ion sensing function thus attracting only the positively charged ions in the combustion chamber. Free electrons contained in the air-fuel mixture do no longer contribute to the detected current. It follows that the use of negative polarity for the ion sensing function has particular advantages on the detection of the ion current.

[0010] The glow plug arrangement preferably further comprises a first switching device for applying either the heater supply voltage or the ion sensor supply voltage to the glow plug and a second switching device for closing the heater circuit during a heating function of the glow plug. By means of these two switching devices, one single voltage supply line can be used to apply the heater supply voltage to the glow plug during the heating function and the ion sensor supply voltage during the ion sensing function.

[0011] According to an embodiment of the invention, the glow plug arrangement comprises a switch control for controlling the second switching device wherein the switch control detects the polarity of the voltage applied to the glow plug and controls the second switching device based on the polarity detected. The switch control compares the polarity of the voltage applied to the glow plug to the polarity of the heater supply voltage. The switch control instructs the second switching device to close the heater circuit only if the polarity of the applied voltage matches the polarity of the heater supply voltage.

[0012] The second switching device can be located within the glow plug, hence saving a return line between the glow plug and a control module.

[0013] The switch control can be integrated in the second switching device. The second switching device can hence operate without direct instruction from the control module. A control line from the control module to the second switching device can be saved. The second switching device can for example be a diode, or a transistor, or any other switch able to open or close based on the polarity of the applied voltage. The second switching device can then be entirely located inside the glow plug.

[0014] In a very simple embodiment, the second switching device comprises a simple diode or a Schottky diode. Depending on the polarity of the voltage applied, said diode either opens or closes the heater circuit. It has to be noted, that a Schottky diode is preferred over a simple diode, because the power losses in the Schottky diode are smaller than in a simple diode.

[0015] In order to further reduce resistance and power losses in the second switching device, said second switching device comprises advantageously a FET. The voltage applied to the glow plug is also applied to the gate of the FET by means of a connection line from the power supply line to the gate of the FET. In case of a positive heater supply voltage and a negative ion sensor supply voltage, said FET is advantageously an n-channel enhancement MOS-FET. If a positive voltage is applied to the glow plug and accordingly to the gate of the FET, i.e. if a heating function of the glow plug should be performed, the FET opens and the drain-source path of the FET acts as a body diode that can conduct a high current. During the ion sensing function of the glow plug, i.e. if a negative voltage is applied to the glow plug and the gate of the FET, the FET blocks the current flow and has an impedance sufficient not to interfere with the ion sensing function.

[0016] It has to be noted, that the use of a diode or a FET as the second switching device also provides for a reverse battery protection of the heater means. In fact, if the battery is improperly connected, i.e. polarity is reversed, the diode respectively the FET is non conductive, thus preventing an uncontrolled current from flowing through the heater. In state of the art glow plug arrangements reverse battery connection can easily lead to the destruction of the heater means as the control module does no longer regulate the heating current flowing through the heater means.

[0017] As a further advantage, the glow plug assembly of the present invention enables the use of a simplified first switching device. In this simplified embodiment. the first switching device comprises a FET arrangement including two FETs, i.e. one FET for switching each supply voltage. The two FETs, one n-channel FET and one p-channel FET, are connected in a back-to-back arrangement so that the FET arrangement allows either a heater supply voltage or an ion sensor supply voltage to be applied to the glow plug. A separate switch control applies a control voltage to the gates of the FETs. Due to the difference of the channel type of the two FETs, only one of the FETs can be conductive at any one time. It is hence impossible to short-circuit the power supplies, which would occur if both voltages were being connected to the glow plug at the same time.

[0018] It has to be noted that such an embodiment for the first switching device, when applied to a glow plug arrangement with supply voltages having the same polarity, implies severe limitations to the ion sensing voltage level. In fact if the ion sensing supply voltage is raised significantly above the heater supply voltage, the

FET switching the heater supply voltage gets conductive and a leakage current flows over the heater voltage supply source to the ground. It follows that in this case the ion sensing supply voltage level is limited. In the glow plug arrangement of the present invention, this limitation does no longer apply. In fact, due to the different polarity of the supply voltages the FET switching the heater voltage can not switch into a conductive state if the absolute value of the ion sensor supply voltage is higher than the absolute value of the heater supply voltage. Accordingly there is no more limitation to the absolute value of the ion sensor supply voltage and a higher ion sensor supply voltage can be applied leading to a better signal to noise ratio.

[0019] The invention also concerns a method for operating a glow plug arrangement. The glow plug arrangement comprises a glow plug including ion sensing means and heater means, the method comprising the steps of applying a heater supply voltage to the heater means during a heating function of the glow plug, and applying an ion sensor supply voltage to the ion sensing means during an ion sensing function of the glow plug. The method is characterised in that the ion sensor supply voltage has a different polarity than the heater supply voltage. By using an ion sensor supply voltage, which has a different polarity than the heater supply voltage, the electrical isolation of both functions can be easily achieved. The polarity of the applied voltage can now be used as switching criterion for closing a heater circuit. Polarity comparison is much easier and much more reliable than voltage level comparison. As the polarity of a voltage can only be either positive or negative, this switching criterion is precise. Furthermore, the polarity of the applied voltage can never change due to potential fluctuations caused by the voltage supply.

[0020] The ion sensor supply voltage is preferably of negative polarity. The use of negative polarity for the ion sensing function has the above mentioned particular advantages on the detection of the ion current.

[0021] The heater supply voltage or the ion sensor supply voltage are applied to the glow plug by means of a first switching device. A heater circuit is closed during a heating function of the glow plug by means of a second switching device. One single voltage supply line can hence be used to supply the glow plug with the heater supply voltage during the heating function and with the ion sensor supply voltage during the ion sensing function.

[0022] According to an embodiment of the invention, the second switching device is controlled by a switch control, which detects the polarity of the voltage applied to the glow plug and controls the second switching device based on the polarity detected. The switch control compares the polarity of the voltage applied to the glow plug to the polarity of the heater supply voltage. By checking the polarity of the voltage applied to the glow plug, instead of its voltage level, it is much easier to verify whether the adequate voltage is being delivered to the glow plug. The polarity of the voltage can only be either positive or negative and cannot change due to fluctuations in the heater supply voltage generated by the heater voltage supply source. The switch control instructs the second switching device to close the heater circuit only if the polarity of the applied voltage matches the polarity of the heater supply voltage.

[0023] The switch control preferably performs the following steps:

- detecting the polarity of the applied voltage, and
- setting the second switching device so as to close the heater circuit only if the detected polarity corresponds to the polarity of the heater supply voltage.

[0024] By performing the above steps, the switch control ensures that the ion sensor supply voltage will not be supplied to the heater means thereby avoiding the ion sensing supply voltage source reaching its limit of power. The ion sense generation circuit is hence protected.

[0025] It will be appreciated that, although the heater means and the ion sensing means are here provided as separate members, they may be formed by a single member having both a heating and an ion sensing function.

Detailed description with respect to the figures

[0026] The present invention will be more apparent from the following description of some not limiting embodiments with reference to the attached drawings, wherein

Fig.1: shows a schematic view of a glow plug arrangement according to a first embodiment of the invention; and

Fig.2: shows a schematic view of a glow plug arrangement according to a second embodiment of the invention.

[0027] Fig.1 shows a glow plug 10 and a control module 12 connected to the glow plug 10 via a power supply line 14 and a return line 16. The glow plug 10 comprises heater means 18 for heating a combustion chamber (not shown) of the glow plug 10. The glow plug further comprises ion sensing means 20 for detecting a concentration of ions generated by the burning of an air-fuel mixture in the combustion chamber. The control module 12 comprises a first voltage source 22 for feeding a positive heater supply voltage to the heater means 18 and a second voltage source 24 for feeding a negative ion sensor supply voltage to the ion sensing means 20. A first switching device 26 is provided in the control module 12 for connecting the voltage supply line 14 to the first voltage source 22 if a heater function of the glow plug 10 is to be used, and to the second voltage source 24 if an ion sensing function of the glow plug 10 is to be used. A second switching device 28, for closing the heater circuit, i.e. the circuit comprising the heater means 18, by grounding the heater means 18, is located downstream of the heater means 18. Operation of the first switching device 26 is controlled by a first switch control 30, whereas operation of the second switching device 28 is controlled by a second switch control 32.

[0028] During a heating function of the glow plug, the first switch control 30 sets the first switching device 26 so as to supply the positive heater supply voltage to the heater means 18 of the glow plug 10. The second switch control 32 checks whether the voltage being applied to the glow plug 10 is actually the heater supply voltage. In order to do so, the second switch control 32 compares the polarity of the heater supply voltage to the voltage applied to the glow plug 10. Only if these polarities match, will the second switch control 32 instruct the second switching device 28 to close the heater circuit. A closed circuit comprising the first voltage source 22, the first switching device 26, the voltage supply line 14, the heater means 18, the return line 16, the second switching device 28 and the ground connection is thereby formed. A current flowing through this circuit causes the heater means 18 to heat up the combustion chamber to a temperature where the air-fuel mixture in the combustion chamber can ignite.

[0029] During an ion sensing function of the glow plug, the second switch control 32 instructs the second switching device 28 to open the heater circuit. The current cannot flow through the heater means 18 anymore. The first switch control 30 then sets the first switching device 26 so as to supply the negative heater supply voltage to the ion sensing means 20 of the glow plug 10. The burning of the air-fuel mixture generates positive and negative ions in the combustion chamber, thereby making the air-fuel mixture conductive. A combustion chamber wall 34, generally the piston and the cylinder wall, of the combustion chamber is grounded. A closed circuit comprising the second voltage source 24, the first switching device 26, the voltage supply line 14, the ion sensing means 20, the air-fuel mixture in the combustion chamber, the combustion chamber wall 34 and the ground connection is hence created. The voltage applied to the air-fuel mixture by the second voltage source 24 causes the ions generated in the air-fuel mixture to migrate, thereby creating an ion current. The voltage drop of this ion current across a fixed resistor 36 located upstream of the second voltage source 24 can be measured. This voltage drop is proportional to the ion current, which in turn directly depends on the amount of ions generated by the burning of the air-fuel mixture. By measuring the voltage drop of the ion current through the fixed resistor 36, the amount of generated ions and hence the conditions of burning can be determined.

[0030] In a preferred embodiment of the invention, shown in fig.2, the second switching device 28 is replaced by a FET 38, which is located within the glow plug 10. The FET 38 used here is an n-channel enhancement MOSFET, the drain-source path of which is connected between the heater means 18 and the ground. A connection line 48 from the voltage supply line 14 to the gate of the FET 38 applies the voltage applied to the glow plug 10 to the gate of the FET 38. Accordingly FET 38 acts not only as switching device but also performs the operation of the second switch control. The FET 38 operates as switching device having the second switch control integrated therein. The FET 38 is able to switch automatically depending on the voltage applied to its gate. The FET 38 closes the heater circuit only if the positive heater supply voltage is being applied to the glow plug 10.

[0031] During a heating function of the glow plug, the first switch control 40 connects the first voltage source 22 to the glow plug 10 for applying a positive heater supply voltage to the heater means 18. This positive voltage is also applied via the connection line 48 to the gate of the FET 38, the FET 38 becomes conductive and closes the heating circuit. The drain-source path of the FET then acts as a body diode which can conduct a high power heating current.

[0032] During an ion sensing function of the glow plug, the first switch control 40 connects the second voltage source 24 to the glow plug 10 for applying a negative ion sensor supply voltage to the ion sensing means 20. The negative voltage is also applied to the gate or body diode of the FET 38 and the FET 38 returns to its non-conductive state.

[0033] The FET 38 is generally not conductive. It is only conductive when a positive voltage is being applied to its gate and returns to its non-conductive state as soon as the positive voltage disappears. It is hence impossible to apply the ion sensor supply voltage to the heater means 18, thereby protecting the ion sense generation circuit.

[0034] According to a preferred embodiment of the invention, the first switching device is replaced by a FET arrangement 42 comprising a p-channel MOSFET 44 for switching the heater supply voltage and an n-channel MOSFET 46 for switching the ion sensor supply voltage. Both FETs are connected in a back-to-back arrangement with their drain-source path connected in the respective voltage supply line and their gates connected to the first switch control.

[0035] During a heating function of the glow plug, the first switch control 40 applies a control voltage to the gates of the FETs 44, 46 so as to open FET 44 and close FET 46, thereby supplying the positive heater supply voltage to the heater means 18 of the glow plug 10. During an ion sensing function of the glow plug, the first switch control 40 applies a control voltage to the gates of the FETs 44, 46 so as to close FET 44 and open FET 46, so as to supply the negative heater supply voltage to the ion sensing means 20 of the glow plug 10.

[0036] Due to the fact that the two FETs have a different channel type, only one of the FETs 44, 46 will be conductive at any one time. A possibility of short-circuiting the voltage supplies 22, 24 is hence eliminated.

[0037] It will be appreciated that a positive voltage can also be applied to the ion sensing means, if a negative voltage is being applied to the heater means. P-channel FETs will then be used.

Claims

1. Glow plug arrangement comprising:

- a glow plug (10) including heater means (18) and ion sensing means (20);
- a first voltage source (22) for generating a heater supply voltage to be applied to said heater means (18) during a heating function of said glow plug (10); and
- a second voltage source (24) for generating an ion sensor supply voltage to be applied to said ion sensing means (20) during an ion sensing function of said glow plug (10);

characterised in that
said ion sensor supply voltage has a different polarity than said heater supply voltage.

2. Glow plug arrangement according to claim 1, wherein said ion sensor supply voltage has a negative polarity.

3. Glow plug arrangement according to claim 1 or 2, further comprising a first switching device (26, 42) for applying either said heater supply voltage or said ion sensor supply voltage to said glow plug (10) and a second switching device (28, 38) for closing a heater circuit during a heating function of said glow plug (10).

4. Glow plug arrangement according to claim 3, further comprising a switch control (32) for controlling said second switching device (28, 38), said switch control (32) detecting the polarity of the voltage applied to said glow plug (10) and controlling said second switching device (28, 38) based on the polarity detected.

5. Glow plug arrangement according to any one of claims 3 to 5, wherein said second switching device (28, 38) is located within said glow plug (10).

6. Glow plug arrangement according to any one of claims 4 to 5, wherein said switch control (32) is integrated in said second switching device (28, 38).

7. Glow plug arrangement according to claim 3 to 6, wherein said second switching device (28, 38) comprises a simple diode or a Schottky diode.

8. Glow plug arrangement according to claim 3 to 6, wherein said second switching device (28, 38) comprises a FET (38).

9. Glow plug arrangement according to any of claims 3 to 8, wherein said first switching device (26, 42) comprises a FET arrangement (42).

10. Method for operating a glow plug arrangement, said glow plug arrangement comprising a glow plug (10) including ion sensing means (18) and heater means (20), said method comprising the steps of applying a heater supply voltage to said heater means (18) during a heating function of said glow plug (10), and applying an ion sensor supply voltage to said ion sensing means (20) during an ion sensing function of said glow plug (10),
characterised in that
said ion sensor supply voltage has a different polarity than said heater supply voltage.

11. Method according to claim 10, wherein said ion sensor supply voltage has negative polarity.

12. Method according to claim 10 or 11, wherein said heater supply voltage or said ion sensor supply voltage are applied to said glow plug (10) by means of a first switching device (26, 42), and wherein a heater circuit is closed during a heating function of said glow plug (10) by means of a second switching device (28, 38).

13. Method according to claim 12, wherein said second switching device (28, 38) is controlled by a switch control (32), said second switch control (32) detecting the polarity of the voltage applied to said glow plug (10) and controlling said second switching device (28, 38) based on the polarity detected.

14. Method according to claim 13, wherein said switch control (32) performs the following steps:

- detect the polarity of the applied voltage, and
- set said second switching device (28, 38) so as to close said heater circuit only if the detected polarity corresponds to the polarity of the heater supply voltage.

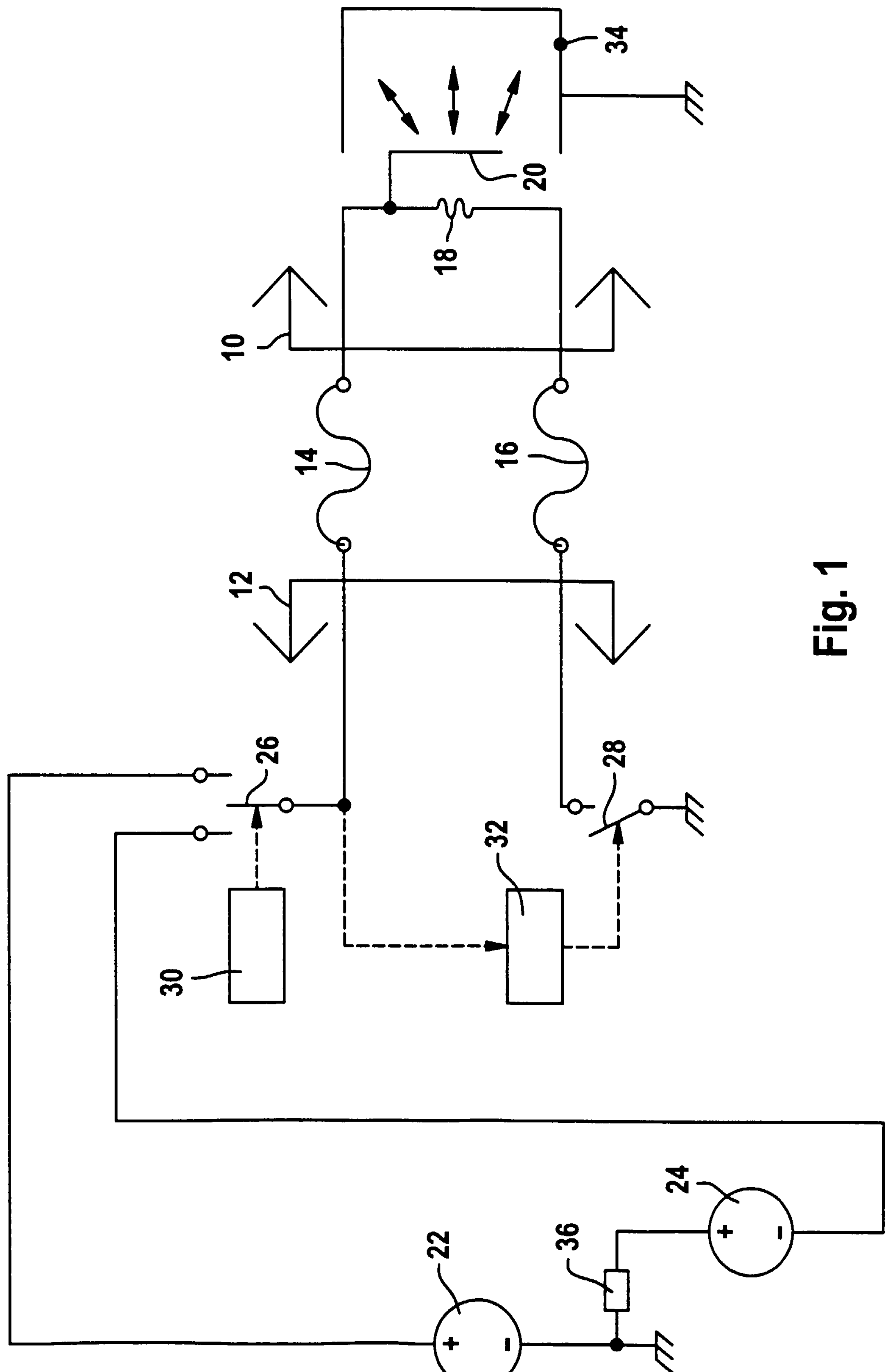

Fig. 1

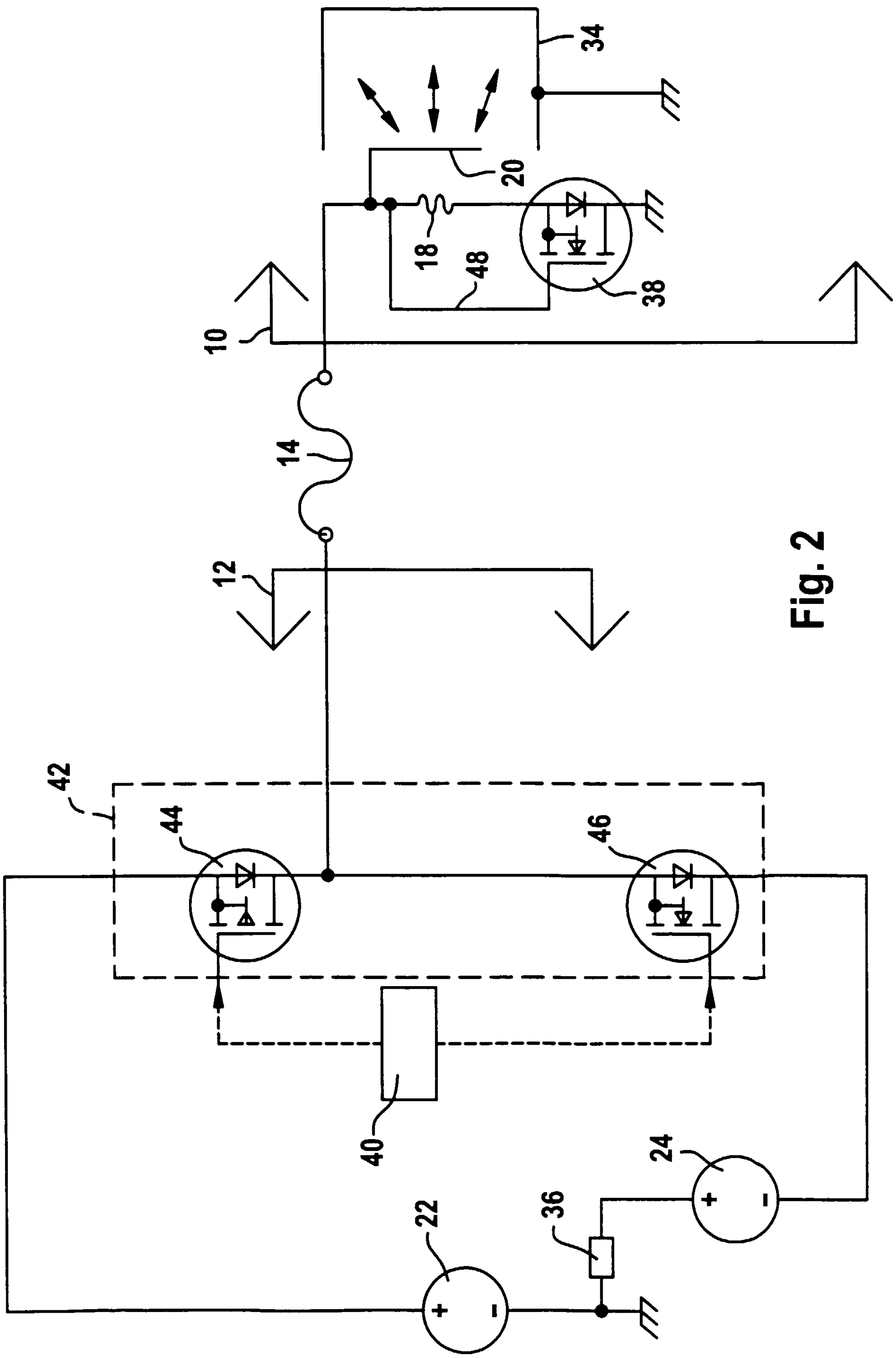

Fig. 2