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(54) LED DRIVER CIRCUIT AND METHOD FOR CONTROLLING LED DRIVER CIRCUIT

(57) A controlling part of an LED driver circuit controls a first switch element with a first on-duty ratio if a first terminal voltage is lower than a preset first upper limit value, controls the first switch element with a second on-duty ratio smaller than the first on-duty ratio if the first terminal voltage reaches the first upper limit value, controls a second switch element with a third on-duty ratio if a second terminal voltage is lower than a preset second upper limit value, and controls the second switch element with a fourth on-duty ratio smaller than the third on-duty ratio if the second terminal voltage reaches the second upper limit value.

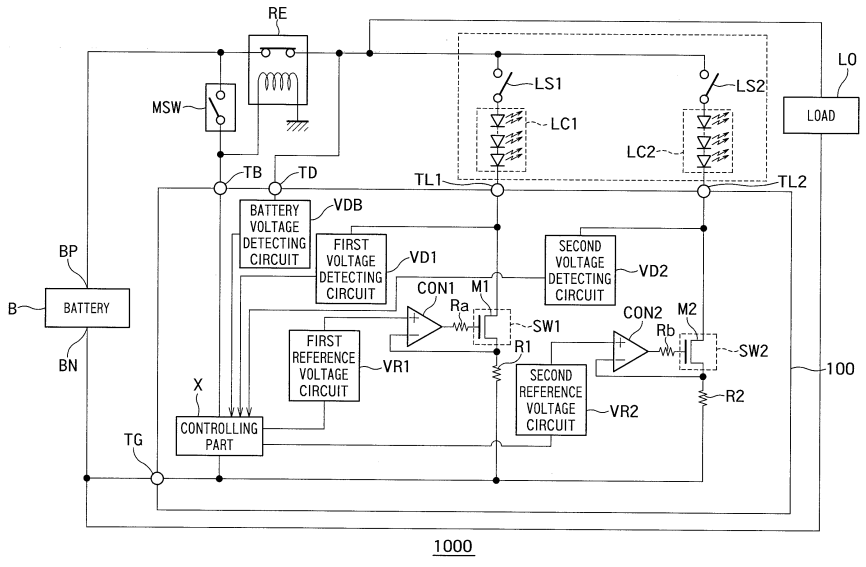

FIG. 1

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Description

[Technical Field]

[0001] The present invention relates to an LED driver circuit and a method of controlling the LED driver circuit.

[Background Art]

[0002] A conventional LED driver circuit that drives an LED circuit has a plurality of LED elements connected in series with each other (see Japanese Patent Laid-Open No. 2008-218457, for example).

[0003] For example, a conventional LED driver circuit 100a includes a first constant-current power supply (a voltage boosting circuit or a voltage lowering circuit, for example) Ia that supplies a constant current for turning on an LED element to a first LED circuit "LC1a" via a high-side terminal "TIa", a second constant-current power supply (a voltage boosting circuit or a voltage lowering circuit, for example) "Ib" that supplies a constant current for turning on an LED element to a second LED circuit "LC2a" via a low-side terminal "TIb", a controlling part "Xa" that controls the first and second constant-current power supplies "Ia" and "Ib", and a power supply "Sa" that supplies an electric power to the first and second constant-current power supplies "Ia" and "Ib" and the controlling part "Xa" (see Figure 2).

[0004] A positive electrode of a battery "Ba" is connected to the power supply "Sa" via a main switch "MSWa" and a battery terminal "TBa". A negative electrode of the battery "Ba" is connected to the controlling part "Xa" via a ground terminal "TGa".

[0005] The positive electrode of the battery "Ba" is connected to one end of a load "LOa" via a relay "REa", and the negative electrode of the battery "Ba" is connected to another end of the load "LOa".

[0006] A first LED switch "LS1a" capable of being turned on and off by a user is connected in series with the first LED circuit "LC1a" between the high-side terminal "TIa" (an output of the first constant-current power supply "Ia") and the ground terminal "TGa".

[0007] Similarly, a second LED switch "LS2a" capable of being turned on and off by a user is connected in series with the second LED circuit "LC2a" between the low-side terminal "TIb" (an output of the second constant-current power supply "Ib") and the ground terminal "TGa".

[0008] The first LED circuit "LC1a", the second LED circuit "LC2a", the first LED switch "LS1a" and the second LED switch "LS2a" form a head lamp unit 101a.

[0009] A switch detecting part "Da" detects states (on or off) of the first and second LED switches "LS1a" and "LS2a" switched by the user and outputs the detection result to the controlling part "Xa" via switching information terminals "TD1" and "TD2".

[0010] In the conventional LED driver circuit 100a, the controlling part "Xa" performs a control to make the first and second constant-current power supplies "Ia" and "Ib" supply a constant current to the LED elements, based on the detection result (an external signal) from the switch detecting part "Da" that is indicative of the states (on/off) of the first and second LED switches "LS1a" and "LS2a" switched by the user.

[0011] The controlling part "Xa" controls current supply as described above, thereby performing switching between a high beam and a low beam of the head lamp unit 101a (that is, a control to turn on and off the first and second LED circuits "LC1a" and "LC2a").

[0012] Furthermore, a conventional overheat protection circuit protects a transistor that controls an output of a constant-current power supply from overheating (see Japanese Patent Laid-Open No. 2010-277226, for example).

[Summary of the Invention]

[Problems to be resolved by the Invention]

[0013] As described above, the conventional LED driver circuit requires the first and second constant-current power supplies, such as a voltage boosting circuit or a voltage lowering circuit. In addition, the conventional LED driver circuit 100a requires the switch detecting part "Da" and requires information (an external signal) on switching (on/off) of the first and second LED switches "LS1a" and "LS2a" connected in series with the first and second LED circuits "LC1a" and "LC2a", respectively. In short, the conventional LED driver circuit 100a requires a terminal and wiring for the external signal.

[0014] As can be seen from the above description, the conventional LED driver circuit 100a has a problem that the circuit footprint is large, and the manufacturing cost is high.

[0015] Furthermore, the overheat protection circuit described above is not designed to protect the transistor in accordance with the voltage of the LED elements.

[Means of solving the problem]

[0016] An LED driver circuit according to the present invention is an LED driver circuit that drives a first LED circuit and a second LED circuit, the first LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to a positive electrode of a battery at an anode side thereof, and the second LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to the positive electrode of the battery at an anode side thereof, the LED driver circuit comprising:

a first LED terminal to which a cathode side of the first LED circuit is connected;
a second LED terminal to which a cathode side of the second LED circuit is connected;
a ground terminal connected to a negative electrode

of the battery;
a first switch element connected between the first LED terminal and the ground terminal;
a second switch element connected between the second LED terminal and the ground terminal;
a first voltage detecting circuit that detects a first terminal voltage at the first LED terminal;
a second voltage detecting circuit that detects a second terminal voltage at the second LED terminal; and
a controlling part that controls the first switch element and the second switch element in accordance with the first terminal voltage and the second terminal voltage,
wherein a first LED switch capable of being turned on and off by a user is connected in series with the first LED circuit between the positive electrode of the battery and the first LED terminal, and
the controlling part
controls the first switch element with a first on-duty ratio if the first terminal voltage is lower than a preset first upper limit value,
controls the first switch element with a second on-duty ratio smaller than the first on-duty ratio if the first terminal voltage reaches the first upper limit value,
controls the second switch element with a third on-duty ratio if the second terminal voltage is lower than a preset second upper limit value, and
controls the second switch element with a fourth on-duty ratio smaller than the third on-duty ratio if the second terminal voltage reaches the second upper limit value.

[0017] In the LED driver circuit, the LED driver circuit further comprising:

a battery voltage detecting circuit that detects a battery voltage of the battery,
wherein the controlling part
lowers the on-duty ratio of the first switch element if a first potential difference between the battery voltage and the first terminal voltage is equal to or lower than a first predefined value, and
lowers the on-duty ratio of the second switch element if a second potential difference between the battery voltage and the second terminal voltage is equal to or lower than a second predefined value.

[0018] In the LED driver circuit,
the controlling part
turns off the first switch element if the first potential difference is equal to or lower than a third predefined value lower than the first predefined value, and
turns off the second switch element if the second potential difference is equal to or lower than a fourth predefined value lower than the second predefined value.

[0019] In the LED driver circuit,
the controlling part
determines that a breakage has occurred in an LED element of the first LED circuit if the first terminal voltage is equal to or lower than a preset first determination value, and
determines that a breakage has occurred in an LED element of the second LED circuit if the second terminal voltage is equal to or lower than a preset second determination value.

[0020] In the LED driver circuit,
the first determination value and the second determination value are the ground voltage.

[0021] In the LED driver circuit,
the first on-duty ratio and the third on-duty ratio are an on-duty ratio of 100%.

[0022] In the LED driver circuit,
a second LED switch capable of being turned on and off by a user is connected in series with the second LED circuit between the positive electrode of the battery and the second LED terminal.

[0023] In the LED driver circuit,
a first end of a relay is connected to the positive electrode of the battery, and a second end of the relay is connected to the anode side of the first LED circuit and the anode side of the second LED circuit,
a load is connected between the second end of the relay and the negative electrode of the battery,
the first LED circuit and the second LED circuit are LEDs of a headlamp of a motorcycle, and
the load is an ignition device of an engine of the motorcycle.

[0024] In the LED driver circuit,
the first switch element is a first MOS transistor that is connected between the first LED terminal and the ground terminal and whose gate voltage is controlled by the controlling part,
the second switch element is a second MOS transistor that is connected between the second LED terminal and the ground terminal and whose gate voltage is controlled by the controlling pa rt,
the LED driver circuit further comprises:

a first reference voltage circuit that outputs a first reference voltage controlled by the controlling part;
a first detecting resistor connected between the first switch element and the ground terminal;
a first comparator that compares the first reference voltage with a first detection voltage between the first switch element and the first detecting resistor and outputs a first controlling signal that makes the first MOS transistor operate to make the first reference voltage and the first detection voltage equal to each other;
a first controlling resistor connected between an output of the first comparator and a gate of the first MOS transistor;
a second reference voltage circuit that outputs a second reference voltage controlled by the controlling part;

a second detecting resistor connected between the second switch element and the ground terminal;
a second comparator that compares the second reference voltage with a second detection voltage between the second switch element and the second detecting resistor and outputs a second controlling signal that makes the second MOS transistor operate to make the second reference voltage and the second detection voltage equal to each other; and
a second controlling resistor connected between an output of the second comparator and a gate of the second MOS transistor, and
the controlling part
controls the first reference voltage to make the first switch element operate with the first on-duty ratio with the first controlling signal if the first terminal voltage is lower than the first upper limit value,
controls the first reference voltage to make the first switch element operate with the second on-duty ratio with the first controlling signal if the first terminal voltage reaches the first upper limit value,
controls the second reference voltage to make the second switch element operate with the third on-duty ratio with the second controlling signal if the second terminal voltage is lower than the second upper limit value, and
controls the second reference voltage to make the second switch element operate with the fourth on-duty ratio with the second controlling signal if the second terminal voltage reaches the second upper limit value.

[0025] A method of controlling an LED driver circuit according to the present invention is a method of controlling an LED driver circuit, the LED driver circuit that drives a first LED circuit and a second LED circuit, the first LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to a positive electrode of a battery at an anode side thereof, the second LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to the positive electrode of the battery at an anode side thereof, and the LED driver circuit comprising a first LED terminal to which a cathode side of the first LED circuit is connected, a second LED terminal to which a cathode side of the second LED circuit is connected, a ground terminal connected to a negative electrode of the battery, a first switch element connected between the first LED terminal and the ground terminal, a second switch element connected between the second LED terminal and the ground terminal, a first voltage detecting circuit that detects a first terminal voltage at the first LED terminal, a second voltage detecting circuit that detects a second terminal voltage at the second LED terminal, and a controlling part that controls the first switch element and the second switch element in accordance with the first terminal voltage and the second terminal voltage,
wherein a first LED switch capable of being turned on and off by a user is connected in series with the first LED circuit between the positive electrode of the battery and the first LED terminal, and
the controlling part
controls the first switch element with a first on-duty ratio if the first terminal voltage is lower than a preset first upper limit value,
controls the first switch element with a second on-duty ratio smaller than the first on-duty ratio if the first terminal voltage reaches the first upper limit value,
controls the second switch element with a third on-duty ratio if the second terminal voltage is lower than a preset second upper limit value, and
controls the second switch element with a fourth on-duty ratio smaller than the third on-duty ratio if the second terminal voltage reaches the second upper limit value.

[0026] An LED driver circuit according to an aspect of the present invention includes a first switch element connected between a first LED terminal and a ground terminal, a second switch element connected between a second LED terminal and the ground terminal, a first voltage detecting circuit that detects a first terminal voltage at the first LED terminal, a second voltage detecting circuit that detects a second terminal voltage at the second LED terminal, and a controlling part that controls the first switch element and the second switch element in accordance with the first terminal voltage and the second terminal voltage.

[0027] A first LED switch capable of being turned on and off by a user is connected in series with the first LED circuit between a positive electrode of a battery and the first LED terminal.

[0028] The controlling part controls the first switch element with a first on-duty ratio if the first terminal voltage is lower than a preset first upper limit value, controls the first switch element with a second on-duty ratio smaller than the first on-duty ratio if the first terminal voltage reaches the first upper limit value, controls the second switch element with a third on-duty ratio if the second terminal voltage is lower than a preset second upper limit value, and controls the second switch element with a fourth on-duty ratio smaller than the third on-duty ratio if the second terminal voltage reaches the second upper limit value.

[0029] With such a configuration, the LED driver circuit according to the present invention requires no information on switching of the switches and therefore requires no external signal. In addition, the LED driver circuit requires no constant-current power supply.

[0030] That is, the number of terminals, wires and the like of the LED driver circuit can be reduced.

[0031] Furthermore, when a battery abnormality or the like occurs and an overvoltage occurs, the LED driver circuit according to the present invention can reduce heat generation of the MOS transistors and prevent the LED elements from suddenly going out, although the light intensity of the LED elements decreases.

[0032] If a first potential difference between the battery voltage and the first terminal voltage is equal to or lower than a first predefined value, the controlling part lowers the on-duty ratio of the first switch element. If a second potential difference between the battery voltage and the second terminal voltage is equal to or lower than a second predefined value, the controlling part lowers the on-duty ratio of the second switch element.

[0033] In this way, when the potential difference between the battery voltage and the voltage at an LED terminal is equal to or lower than a predefined value (specifically, when at least any of the LED elements is short-circuited), the on-duty ratio of the switch element (MOS transistor) can be lowered to reduce heat generation of the switch element (MOS transistor).

[0034] Furthermore, the controlling part determines that a breakage has occurred in an LED element of the first LED circuit if the first terminal voltage is equal to or lower than a preset first determination value, and determines that a breakage has occurred in an LED element of the second LED circuit if the second terminal voltage is equal to or lower than a preset second determination value.

[0035] In this way, if the voltage at an LED terminal for the low beam or high beam is zero (equal to or lower than the determination value), it can be determined that a breakage has occurred in the LED element for the low beam or high beam.

[0036] As described above, in a headlamp of a motorcycle, for example, a breakage of an LED element for the high beam and the low beam can be detected.

[Brief Description of the Drawings]

[0037]

Figure 1 is a diagram showing an example of a circuit configuration of a system 1000 including an LED driver circuit 100 according to a first embodiment; and

Figure 2 is a diagram showing an example of a circuit configuration of a system 1000a including a conventional LED driver circuit 100a.

[Detailed Description of the Invention]

[0038] In the following, an embodiment of the present invention will be described with reference to the drawings.

(First Embodiment)

[0039] In a system 1000 according to a first embodiment, an LED driver circuit 100 is configured to drive a first LED circuit "LC1" and a second LED circuit "LC2" that have one LED element or a plurality of LED elements connected in series with each other (Figure 1).

[0040] A positive electrode "BP" of the battery "B" is connected to a controlling part "X" via a main switch "MSW" and a battery terminal "TB". A negative electrode "BN" of the battery "B" is connected to the controlling part "X" via a ground terminal "TG". That is, the controlling part "X" is connected between the battery terminal "TB" and the ground terminal "TG" and is driven by an electric power supplied from the battery "B".

[0041] The first LED circuit "LC1" has one LED element or a plurality of LED elements connected in series with each other and is connected to the positive electrode "BP" of the battery "B" at an anode side thereof.

[0042] The second LED circuit "LC2" has one LED element or a plurality of LED elements connected in series with each other and is connected to the positive electrode "BP" of the battery "B" at an anode side thereof.

[0043] The first LED circuit "LC1" and the second LED circuit "LC2" are LEDs of a headlamp of a motorcycle, for example. For example, the LED elements of the first LED circuit "LC1" are LED elements for a low beam, and the LED elements of the second LED circuit "LC2" are LED elements for a high beam.

[0044] A first LED switch "LS1" capable of being turned on and off by a user is connected in series with the first LED circuit "LC1" between the positive electrode "BP" of the battery "B" and a first LED terminal "TL1".

[0045] If the first LED switch "LS1" is turned on by the user, a current can flow to the first LED circuit "LC1". On the other hand, if the first LED switch "LS1" is turned off by the user, the current flowing to the first LED circuit "LC1" is interrupted.

[0046] A second LED switch "LS2" capable of being turned on and off by the user is connected in series with the second LED circuit "LC2" between the positive electrode "BP" of the battery "B" and a second LED terminal "TL2".

[0047] If the second LED switch "LS2" is turned on by the user, a current can flow to the second LED circuit "LC2". On the other hand, if the second LED switch "LS2" is turned off by the user, the current flowing to the second LED circuit "LC2" is interrupted.

[0048] The first LED circuit "LC1", the second LED circuit "LC2", the first LED switch "LS1" and the second LED switch "LS2" form a headlamp unit 101 for a motorcycle.

[0049] The main switch "MSW" is capable of being turned on and off by the user.

[0050] A relay "RE" is connected between the positive electrode "BP" of the battery "B" and the anode sides of the first LED circuit "LC1" and the second LED circuit "LC2". More specifically, the relay "RE" is connected to the positive electrode "BP" of the battery at one end thereof and to the anode sides of the first LED circuit "LC1" and the second LED circuit "LC2" at another end thereof.

[0051] If the main switch "MSW" is turned on, a current flows to a coil of the relay "RE" to turn on the relay "RE".

[0052] A load "LO" is connected between the relay "RE" and the negative electrode "BN" of the battery "B". The load "LO" is an ignition device of an engine of a

motorcycle, for example.

[0053] As shown in Figure 1, the LED driver circuit 100 drives the first LED circuit "LC1" that has one LED element or a plurality of LED elements connected in series with each other and is connected to the positive electrode "BP" of the battery "B" at the anode side thereof, and the second LED circuit "LC2" that has one LED element or a plurality of LED elements connected in series with each other and is connected to the positive electrode "BP" of the battery "B" at the anode side thereof.

[0054] The LED driver circuit 100 includes the first LED terminal "TL1", to which a cathode side of the first LED circuit "LC1" is connected, and the second LED terminal "TL2", to which a cathode side of the second LED circuit "LC2" is connected.

[0055] The LED driver circuit 100 includes the ground terminal "TG" that is connected to the negative electrode "BN" of the battery "B", the battery terminal "TB" that is connected to the positive electrode "BP" of the battery "B" via the main switch "MSW", and a voltage detecting terminal "TD" that is connected to the positive electrode "BP" of the battery "B" via the relay "RE".

[0056] The LED driver circuit 100 includes a first switch element "SW1" that is connected between the first LED terminal "TL1" and the ground terminal "TG", and a second switch element "SW2" that is connected between the second LED terminal "TL2" and the ground terminal "TG".

[0057] The LED driver circuit 100 includes a first voltage detecting circuit "VD1" that detects a first terminal voltage at the first LED terminal "TL1", a second voltage detecting circuit "VD2" that detects a second terminal voltage at the second LED terminal "TL2", and a battery voltage detecting circuit "VDB" that detects a battery voltage of the battery "B".

[0058] The battery voltage detecting circuit "VDB" detects the battery voltage of the battery "B" by detecting the voltage at the voltage detecting terminal "TD", for example.

[0059] As described above, the voltage detecting terminal "TD" is connected to the positive electrode "BP" of the battery "B" via the relay "RE". Therefore, when the relay "RE" is turned on, the battery voltage of the battery "B" is supplied to the voltage detecting terminal "TD". Therefore, the battery voltage detecting circuit "VDB" can detect the battery voltage of the battery "B" by detecting the voltage at the voltage detecting terminal "TD".

[0060] The LED driver circuit 100 includes the controlling part "X" that controls the first switch element "SW1" and the second switch element "SW2" in accordance with the first terminal voltage and the second terminal voltage. The controlling part "X" is connected between the battery terminal "TB" and the ground terminal "TG" and operates on the electric power that is supplied from the battery "B" when the main switch "MSW" is turned on.

[0061] As shown in Figure 1, the first switch element "SW1" is a first MOS transistor "M1" that is connected between the first LED terminal "TL1" and the ground terminal "TG" and whose gate voltage is controlled by the controlling part "X". As shown in Figure 1, the second switch element "SW2" is a second MOS transistor "M2" that is connected between the second LED terminal "TL2" and the ground terminal "TG" and whose gate voltage is controlled by the controlling part "X".

[0062] The LED driver circuit 100 includes a first reference voltage circuit "VR1" that outputs a first reference voltage controlled by the controlling part "X", and a first detecting resistor "R1" connected between the first switch element "SW1" and the ground terminal "TG". The LED driver circuit 100 includes a first comparator "CON1" that compares the first reference voltage with a first detection voltage between the first switch element "SW1" and the first detecting resistor "R1" and outputs a first controlling signal that makes the first MOS transistor "M1" operate to make the first detection voltage and the first reference voltage equal to each other, and a first controlling resistor "Ra" connected between an output of the first comparator "CON1" and a gate of the first MOS transistor "M1".

[0063] The controlling part "X" controls the first reference voltage described above based on the first terminal voltage, thereby controlling the first controlling signal output from the first comparator "CON1" and supplied to the gate of the first MOS transistor "M1". In other words, the controlling part "X" controls the gate voltage of the first MOS transistor "M1" by controlling the first reference voltage.

[0064] The LED driver circuit 100 includes a second reference voltage circuit "VR2" that outputs a second reference voltage controlled by the controlling part "X", and a second detecting resistor "R2" connected between the second switch element "SW2" and the ground terminal "TG". The LED driver circuit 100 includes a second comparator "CON2" that compares the second reference voltage with a second detection voltage between the second switch element "SW2" and the second detecting resistor "R2" and outputs a second controlling signal that makes the second MOS transistor "M2" operate to make the second detection voltage and the second reference voltage equal to each other, and a second controlling resistor "Rb" connected between an output of the second comparator "CON2" and a gate of the second MOS transistor "M2".

[0065] The controlling part "X" controls the second reference voltage described above based on the second terminal voltage, thereby controlling the second controlling signal output from the second comparator "CON2" and supplied to the gate of the second MOS transistor "M2". In other words, the controlling part "X" controls the gate voltage of the second MOS transistor "M2" by controlling the second reference voltage.

[0066] If the first terminal voltage is lower than a preset first upper limit value, the controlling part "X" controls the first reference voltage to control the first switch element "SW1" with a first on-duty ratio with the first controlling signal. The first on-duty ratio is an on-duty ratio of 100%,

for example.

[0067] If the first terminal voltage reaches the first upper limit value, the controlling part "X" controls the first reference voltage to control the first switch element "SW1" with a second on-duty ratio smaller than the first on-duty ratio described above with the first controlling signal.

[0068] If the second terminal voltage is lower than a preset second upper limit value, the controlling part "X" controls the second reference voltage to control the second switch element "SW2" with a third on-duty ratio with the second controlling signal. The third on-duty ratio is an on-duty ratio of 100%, for example.

[0069] If the second terminal voltage reaches the second upper limit value, the controlling part "X" controls the second reference voltage to control the second switch element "SW2" with a fourth on-duty ratio smaller than the third on-duty ratio described above with the second controlling signal.

[0070] Thus, the LED driver circuit 100 requires no information on switching of the switches and therefore requires no external signal. In addition, the LED driver circuit 100 requires no constant-current power supply.

[0071] That is, the number of terminals, wires and the like of the LED driver circuit 100 can be reduced.

[0072] Furthermore, when a battery abnormality or the like occurs and an overvoltage occurs, for example, the LED driver circuit 100 can reduce heat generation of the MOS transistors and prevent the LED elements from suddenly going out, although the light intensity of the LED elements decreases.

[0073] If a first potential difference between the battery voltage and the first terminal voltage is equal to or lower than a first predefined value, the controlling part "X" controls the first reference voltage to lower the on-duty ratio of the first switch element "SW1".

[0074] The first predefined value is set to be the potential difference between the first LED terminal "TL1" and the voltage detecting terminal "TD" at the time when the first LED switch "LS1" is in the on state and any of the LED elements of the first LED circuit "LC1" is short-circuited, for example.

[0075] If a second potential difference between the battery voltage and the second terminal voltage is equal to or lower than a second predefined value, the controlling part "X" controls the second reference voltage to lower the on-duty ratio of the second switch element "SW2".

[0076] The second predefined value is set to be the potential difference between the second LED terminal "TL2" and the voltage detecting terminal "TD" at the time when the second LED switch "LS2" is in the on state and any of the LED elements of the second LED circuit "LC2" is short-circuited, for example.

[0077] In this way, when the potential difference between the battery voltage and the voltage at an LED terminal is equal to or lower than a predefined value (specifically, when at least any of the LED elements is short-circuited, for example), the on-duty ratio of the switch element (the MOS transistor) can be lowered to reduce heat generation of the switch element (the MOS transistor).

[0078] In particular, the controlling part "X" may turn off the first switch element "SW1" when the first potential difference described above is equal to or lower than the third predefined value lower than the first predefined value.

[0079] Similarly, the controlling part "X" may turn off the second switch element "SW2" when the second potential difference described above is equal to or lower than the fourth predefined value lower than the second predefined value.

[0080] In this way, when the potential difference between the battery voltage and the voltage at an LED terminal is equal to or lower than a predefined value (specifically, when at least any of the LED elements is short-circuited, for example), the switch element (the MOS transistor) can be turned off to reduce heat generation of the switch element (the MOS transistor) with higher reliability.

[0081] If a breakage occurs in an LED element of the first LED circuit "LC1", the connection between the positive electrode "BP" of the battery "B" and the first LED terminal "TL1" is interrupted. That is, the first terminal voltage at the first LED terminal "TL1" becomes equal to the voltage (the ground voltage) at the negative electrode "BN" of the battery "B".

[0082] The controlling part "X" determines that a breakage has occurred in an LED element of the first LED circuit "LC1" if the first terminal voltage described above is equal to or lower than a preset first determination value. The first determination value is the ground voltage (the voltage at the negative electrode "BN" of the battery "B"), for example.

[0083] Similarly, if a breakage occurs in an LED element of the second LED circuit "LC2", the connection between the positive electrode "BP" of the battery "B" and the second LED terminal "TL2" is interrupted. That is, the second terminal voltage at the second LED terminal "TL2" becomes equal to the voltage (the ground voltage) at the negative electrode "BN" of the battery "B".

[0084] The controlling part "X" determines that a breakage has occurred in an LED element of the second LED circuit "LC2" if the second terminal voltage described above is equal to or lower than a preset second determination value. The second determination value is the ground voltage (the voltage at the negative electrode "BN" of the battery "B"), for example.

[0085] In this way, the controlling part "X" can detect a breakage of the LED elements based on the first terminal voltage and the second terminal voltage. That is, the LED driver circuit 100 can detect a breakage of any of the LED elements for the high beam and the low beam of the headlamp of the motorcycle, for example.

[0086] Next, an example of a method of controlling the LED driver circuit 100 configured as described above will be described.

[0087] First, in response to the user turning on the main switch "MSW", for example, the controlling part "X" is made to operate (that is, activated) by an electric power supplied from the battery "B".

[0088] Once the main switch "MSW" is turned on, the relay "RE" is turned on. As a result, an electric power can be supplied from the battery "B" to the headlamp unit 101. At this point in time, if the first and second LED switches "LS1", "LS2" are in the off state, no current flows to the first LED circuit "LC1" and the second LED circuit "LC2".

[0089] The first terminal voltage then becomes equal to the ground voltage or, in other words, becomes lower than the first upper limit value. In addition, the second terminal voltage becomes equal to the ground voltage or, in other words, becomes lower than the second upper limit value.

[0090] Since the first terminal voltage is lower than the preset first upper limit value, the controlling part "X" controls the first reference voltage to control the first switch element "SW1" with the first on-duty ratio (an on-duty ratio of 100%, for example) with the first controlling signal.

[0091] Furthermore, since the second terminal voltage is lower than the preset second upper limit value, the controlling part "X" controls the second reference voltage to control the second switch element "SW2" with the third on-duty ratio (an on-duty ratio of 100%, for example) with the second controlling signal.

[0092] Suppose that the user then turns on the first LED switch "LS1", for example. In that case, since the first switch element "SW1" is controlled with the first on-duty ratio, a predetermined amount of current flows to the first LED circuit "LC1", and the LED elements emit light.

[0093] On the other hand, suppose that the user turns on the second LED switch "LS2". In that case, since the second switch element "SW2" is controlled with the third on-duty ratio, a predetermined amount of current flows to the second LED circuit "LC2", and the LED elements emit light.

[0094] As can be seen from the above description, the LED driver circuit 100 requires no information on switching of the switches and therefore requires no external signal. In addition, the LED driver circuit 100 requires no constant-current power supply.

[0095] After that, if a battery abnormality or the like occurs and an overvoltage occurs, for example, the first terminal voltage reaches the first upper limit value, and the second terminal voltage reaches the second upper limit value.

[0096] Since the first terminal voltage has reached the first upper limit value, the controlling part "X" controls the first reference voltage to control the first switch element "SW1" with the second on-duty ratio smaller than the first on-duty ratio with the first controlling signal.

[0097] As a result, the amount of current flowing to the first switch element "SW1" (the first MOS transistor "M1") is limited, and heat generation of the first switch element "SW1" is reduced.

[0098] Furthermore, since the second terminal voltage has reached the second upper limit value, the controlling part "X" controls the second reference voltage to control the second switch element "SW2" with the fourth on-duty ratio smaller than the third on-duty ratio with the second controlling signal.

[0099] As a result, the amount of current flowing to the second switch element "SW2" (the second MOS transistor "M2") is limited, and heat generation of the second switch element "SW2" is reduced.

[0100] In this way, when a battery abnormality or the like occurs and an overvoltage occurs, the LED driver circuit 100 can reduce heat generation of the switch elements (the MOS transistors) and prevent the LED elements from suddenly going out, although the light intensity of the LED elements decreases.

[0101] If any of the LED elements of the first LED circuit "LC1" is short-circuited, for example, the first potential difference between the battery voltage and the first terminal voltage becomes equal to or lower than the first predefined value. Since the first potential difference between the battery voltage and the first terminal voltage is equal to or lower than the first predefined value, the controlling part "X" controls the first reference voltage to lower the on-duty ratio of the first switch element "SW1".

[0102] If any of the LED elements of the second LED circuit "LC2" is short-circuited, for example, the second potential difference between the battery voltage and the second terminal voltage becomes equal to or lower than the second predefined value. Since the second potential difference between the battery voltage and the second terminal voltage is equal to or lower than the second predefined value, the controlling part "X" controls the second reference voltage to lower the on-duty ratio of the second switch element "SW2".

[0103] In this way, heat generation of the switch elements (the MOS transistors) can be reduced.

[0104] The same operation is then repeated.

[0105] As described above, the LED driver circuit 100 according to an aspect of the present invention includes the first switch element "SW1" that is connected between the first LED terminal "TL1" and the ground terminal "TG", the second switch element "SW2" that is connected between the second LED terminal "TL2" and the ground terminal "TG", the first voltage detecting circuit "VD1" that detects the first terminal voltage at the first LED terminal "TL1", the second voltage detecting circuit "VD2" that detects the second terminal voltage at the second LED terminal "TL2", and the controlling part "X" that controls the first switch element "SW1" and the second switch element "SW2" based on the first terminal voltage and the second terminal voltage.

[0106] The first LED switch capable of being turned on and off by the user is connected in series with the first LED circuit "LC1" between the positive electrode "BP" of the battery and the first LED terminal "TL1".

[0107] If the first terminal voltage is lower than the pre-

set first upper limit value, the controlling part "X" controls the first switch element "SW1" with the first on-duty ratio. If the first terminal voltage reaches the first upper limit value, the controlling part "X" controls the first switch element "SW1" with the second on-duty ratio smaller than the first on-duty ratio. If the second terminal voltage is lower than the preset second upper limit value, the controlling part "X" controls the second switch element "SW2" with the third on-duty ratio. If the second terminal voltage reaches the second upper limit value, the controlling part "X" controls the second switch element "SW2" with the fourth on-duty ratio smaller than the third on-duty ratio.

[0108] Thus, the LED driver circuit 100 according to the present invention requires no information on switching of the switches and therefore requires no external signal. In addition, the LED driver circuit 100 requires no constant-current power supply.

[0109] That is, the number of terminals, wires and the like of the LED driver circuit 100 can be reduced.

[0110] Furthermore, when a battery abnormality or the like occurs and an overvoltage occurs, the LED driver circuit 100 according to the present invention can reduce heat generation of the MOS transistors and prevent the LED elements from suddenly going out, although the light intensity of the LED elements decreases.

[0111] If the first potential difference between the battery voltage and the first terminal voltage is equal to or lower than the first predefined value, the controlling part "X" lowers the on-duty ratio of the first switch element "SW1". If the second potential difference between the battery voltage and the second terminal voltage is equal to or lower than the second predefined value, the controlling part "X" lowers the on-duty ratio of the second switch element "SW2".

[0112] In this way, when the potential difference between the battery voltage and the voltage at an LED terminal is equal to or lower than a predefined value (specifically, when at least any of the LED elements is short-circuited, for example), the on-duty ratio of the switch element (the MOS transistor) can be lowered to reduce heat generation of the switch element (the MOS transistor).

[0113] Furthermore, if the first terminal voltage is equal to or lower than the preset first determination value, the controlling part "X" determines that a breakage has occurred in an LED element of the first LED circuit "LC1". If the second terminal voltage is equal to or lower than the preset second determination value, the controlling part "X" determines that a breakage has occurred in an LED element of the second LED circuit "LC2".

[0114] Thus, if the voltage at an LED terminal for the low beam or high beam is zero (equal to or lower than the determination value), it can be determined that a breakage has occurred in the LED element for the low beam or high beam.

[0115] As described above, the LED driver circuit 100 can detect a breakage of any of the LED elements for the high beam and the low beam of a headlamp of a motorcycle, for example.

[0116] Although an embodiment of the present invention has been described, the embodiment is shown for illustrative purposes and is not intended to limit the scope of the present invention. Various other embodiments are also possible, and various omissions, replacements and modifications can be made to the embodiment without departing from the spirit of the present invention. The embodiment and variations thereof are included in the scope and spirit of the present invention and included in the scope of the present invention described in the claims and equivalents thereof.

Claims

1. An LED driver circuit that drives a first LED circuit and a second LED circuit, the first LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to a positive electrode of a battery at an anode side thereof, and the second LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to the positive electrode of the battery at an anode side thereof, the LED driver circuit comprising:

a first LED terminal to which a cathode side of the first LED circuit is connected;
a second LED terminal to which a cathode side of the second LED circuit is connected;
a ground terminal connected to a negative electrode of the battery;
a first switch element connected between the first LED terminal and the ground terminal;
a second switch element connected between the second LED terminal and the ground terminal;
a first voltage detecting circuit that detects a first terminal voltage at the first LED terminal;
a second voltage detecting circuit that detects a second terminal voltage at the second LED terminal; and
a controlling part that controls the first switch element and the second switch element in accordance with the first terminal voltage and the second terminal voltage,
wherein a first LED switch capable of being turned on and off by a user is connected in series with the first LED circuit between the positive electrode of the battery and the first LED terminal, and
the controlling part
controls the first switch element with a first on-duty ratio if the first terminal voltage is lower than a preset first upper limit value,
controls the first switch element with a second

on-duty ratio smaller than the first on-duty ratio if the first terminal voltage reaches the first upper limit value,
controls the second switch element with a third on-duty ratio if the second terminal voltage is lower than a preset second upper limit value, and
controls the second switch element with a fourth on-duty ratio smaller than the third on-duty ratio if the second terminal voltage reaches the second upper limit value.

2. The LED driver circuit according to claim 1, further comprising:

a battery voltage detecting circuit that detects a battery voltage of the battery,
wherein the controlling part
lowers the on-duty ratio of the first switch element if a first potential difference between the battery voltage and the first terminal voltage is equal to or lower than a first predefined value, and
lowers the on-duty ratio of the second switch element if a second potential difference between the battery voltage and the second terminal voltage is equal to or lower than a second predefined value.

3. The LED driver circuit according to claim 2, wherein the controlling part
turns off the first switch element if the first potential difference is equal to or lower than a third predefined value lower than the first predefined value, and
turns off the second switch element if the second potential difference is equal to or lower than a fourth predefined value lower than the second predefined value.

4. The LED driver circuit according to claim 1, wherein the controlling part
determines that a breakage has occurred in an LED element of the first LED circuit if the first terminal voltage is equal to or lower than a preset first determination value, and
determines that a breakage has occurred in an LED element of the second LED circuit if the second terminal voltage is equal to or lower than a preset second determination value.

5. The LED driver circuit according to claim 4, wherein the first determination value and the second determination value are the ground voltage.

6. The LED driver circuit according to claim 1, wherein the first on-duty ratio and the third on-duty ratio are an on-duty ratio of 100%.

7. The LED driver circuit according to claim 1, wherein a second LED switch capable of being turned on and off by a user is connected in series with the second LED circuit between the positive electrode of the battery and the second LED terminal.

8. The LED driver circuit according to claim 1, wherein a first end of a relay is connected to the positive electrode of the battery, and a second end of the relay is connected to the anode side of the first LED circuit and the anode side of the second LED circuit,
a load is connected between the second end of the relay and the negative electrode of the battery,
the first LED circuit and the second LED circuit are LEDs of a headlamp of a motorcycle, and
the load is an ignition device of an engine of the motorcycle.

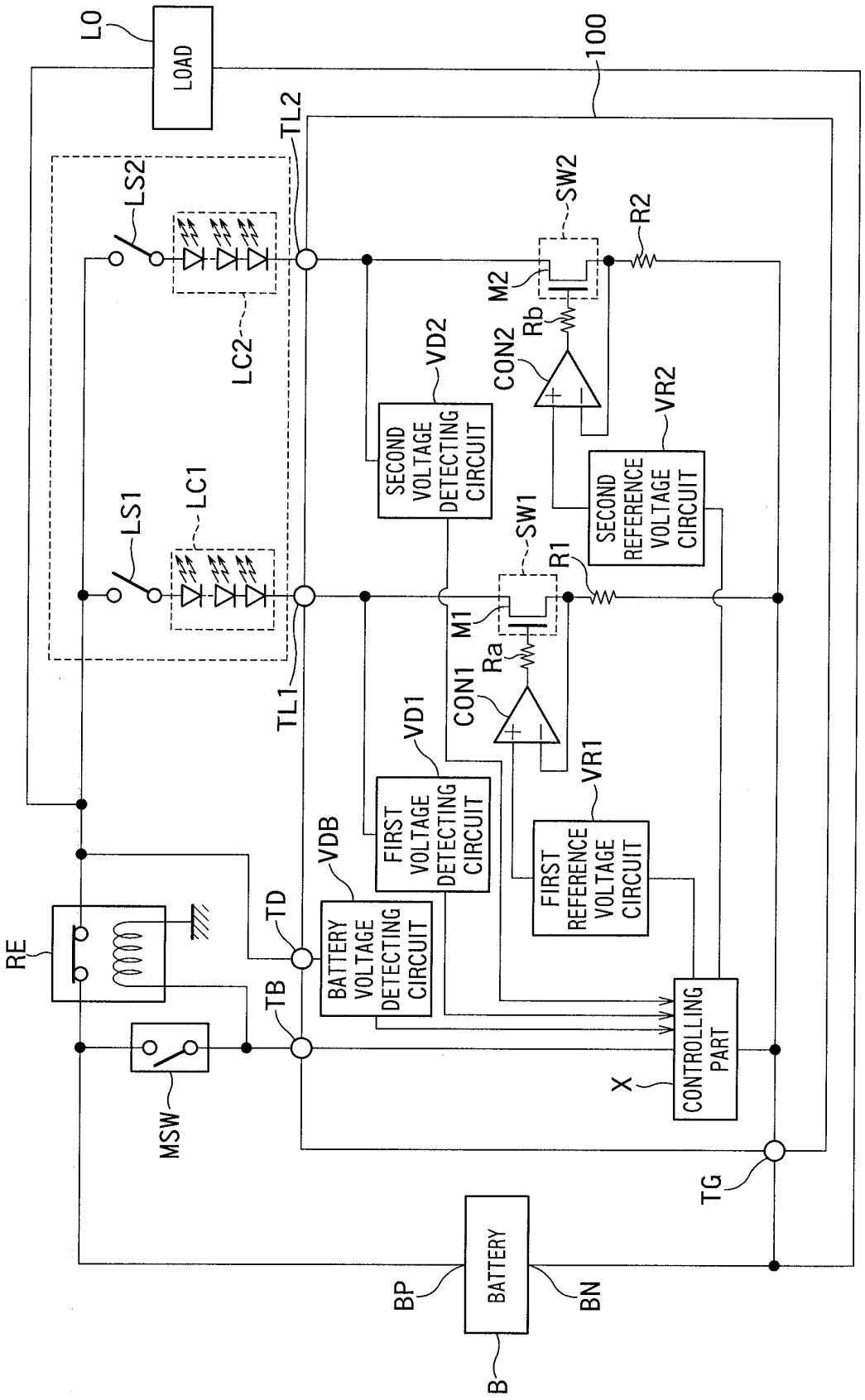
9. The LED driver circuit according to claim 1, wherein the first switch element is a first MOS transistor that is connected between the first LED terminal and the ground terminal and whose gate voltage is controlled by the controlling part,
the second switch element is a second MOS transistor that is connected between the second LED terminal and the ground terminal and whose gate voltage is controlled by the controlling part,
the LED driver circuit further comprises:

a first reference voltage circuit that outputs a first reference voltage controlled by the controlling part;
a first detecting resistor connected between the first switch element and the ground terminal;
a first comparator that compares the first reference voltage with a first detection voltage between the first switch element and the first detecting resistor and outputs a first controlling signal that makes the first MOS transistor operate to make the first reference voltage and the first detection voltage equal to each other;
a first controlling resistor connected between an output of the first comparator and a gate of the first MOS transistor;
a second reference voltage circuit that outputs a second reference voltage controlled by the controlling part;
a second detecting resistor connected between the second switch element and the ground terminal;
a second comparator that compares the second reference voltage with a second detection voltage between the second switch element and the second detecting resistor and outputs a second controlling signal that makes the second MOS transistor operate to make the second reference voltage and the second detection voltage equal to each other; and

a second controlling resistor connected between an output of the second comparator and a gate of the second MOS transistor, and

the controlling part
controls the first reference voltage to make the first switch element operate with the first on-duty ratio with the first controlling signal if the first terminal voltage is lower than the first upper limit value,
controls the first reference voltage to make the first switch element operate with the second on-duty ratio with the first controlling signal if the first terminal voltage reaches the first upper limit value,
controls the second reference voltage to make the second switch element operate with the third on-duty ratio with the second controlling signal if the second terminal voltage is lower than the second upper limit value, and
controls the second reference voltage to make the second switch element operate with the fourth on-duty ratio with the second controlling signal if the second terminal voltage reaches the second upper limit value.

10. A method of controlling an LED driver circuit, the LED driver circuit that drives a first LED circuit and a second LED circuit, the first LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to a positive electrode of a battery at an anode side thereof, the second LED circuit having one LED element or a plurality of LED elements connected in series with each other and being connected to the positive electrode of the battery at an anode side thereof, and the LED driver circuit comprising a first LED terminal to which a cathode side of the first LED circuit is connected, a second LED terminal to which a cathode side of the second LED circuit is connected, a ground terminal connected to a negative electrode of the battery, a first switch element connected between the first LED terminal and the ground terminal, a second switch element connected between the second LED terminal and the ground terminal, a first voltage detecting circuit that detects a first terminal voltage at the first LED terminal, a second voltage detecting circuit that detects a second terminal voltage at the second LED terminal, and a controlling part that controls the first switch element and the second switch element in accordance with the first terminal voltage and the second terminal voltage,
wherein a first LED switch capable of being turned on and off by a user is connected in series with the first LED circuit between the positive electrode of the battery and the first LED terminal, and
the controlling part
controls the first switch element with a first on-duty ratio if the first terminal voltage is lower than a preset first upper limit value,
controls the first switch element with a second on-duty ratio smaller than the first on-duty ratio if the first terminal voltage reaches the first upper limit value,
controls the second switch element with a third on-duty ratio if the second terminal voltage is lower than a preset second upper limit value, and
controls the second switch element with a fourth on-duty ratio smaller than the third on-duty ratio if the second terminal voltage reaches the second upper limit value.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LS1
LC1
SW1
R1
M1
Ra
CON1
TL1
VD1
FIRST VOLTAGE DETECTING CIRCUIT
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BATTERY
BP
BN
B
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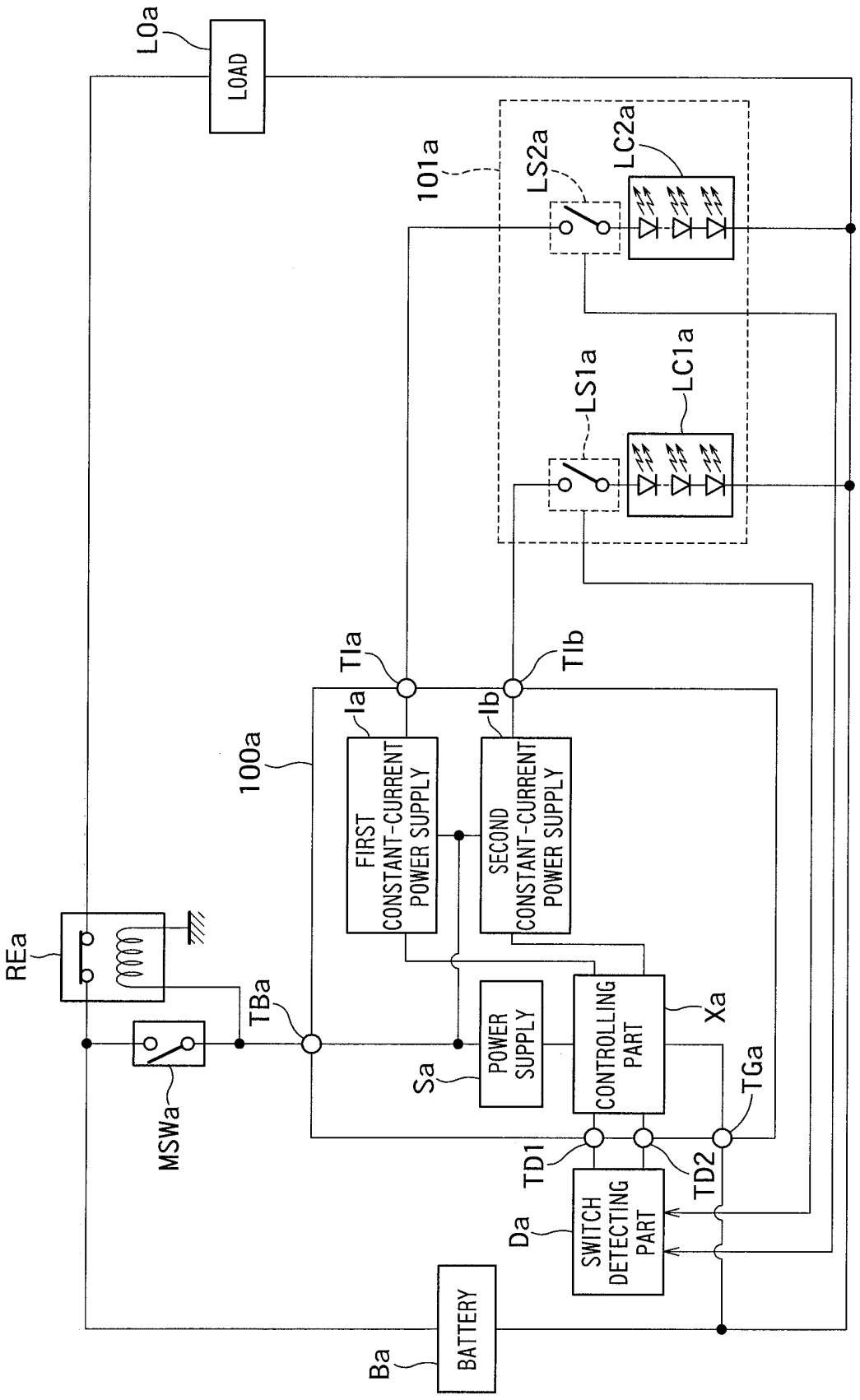
FIG. 1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LS1a
LC1a
1000a
TIa
TIb
Ia
Ib
100a
FIRST CONSTANT-CURRENT POWER SUPPLY
SECOND CONSTANT-CURRENT POWER SUPPLY
REa
TBa
MSWa
Sa
POWER SUPPLY
CONTROLLING PART
Xa
TGa
TD1
TD2
Da
SWITCH DETECTING PART
BATTERY
Ba

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/083706

A. CLASSIFICATION OF SUBJECT MATTER
H01L33/00(2010.01)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)
H01L33/00-33/64

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2014
Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2013-21117 A (Rohm Co., Ltd.), 31 January 2013 (31.01.2013), paragraphs [0025] to [0027], [0031], [0049], [0097], [0100], [0107]; fig. 7 & US 2013/0016310 A1 & CN 202759636 U	1-10
A	JP 2010-177531 A (Texas Instruments Japan Ltd.), 12 August 2010 (12.08.2010), entire text; all drawings & US 2010/0219773 A1	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 January, 2014 (16.01.14)	28 January, 2014 (28.01.14)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008218457 A **[0002]**
- JP 2010277226 A **[0012]**