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(71) Applicant: **SIGNIFY HOLDING B.V.** [NL/NL]; High
Tech Campus 48, 5656 AE Eindhoven (NL).

(72) Inventor: **JU, Ji'an**; c/o High Tech Campus 7, 5656 AE
Eindhoven (NL).

(74) Agent: **VAN EEUWIJK, Alexander, Henricus,
Waltherus et al.**; High Tech Campus 7, 5656 AE Eindhoven
(NL).

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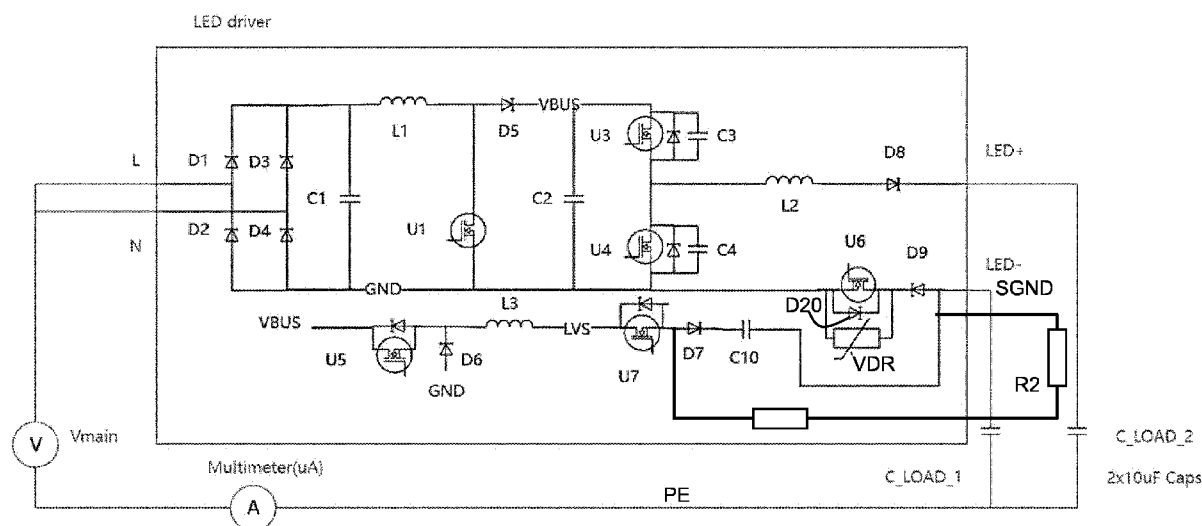


FIG. 11

(57) Abstract: A LED driver has a power input interface to receive an input power, a LED output interface to be connected to an LED and an auxiliary power converter coupled to the power input interface and configured to generate an auxiliary power from the input power. The LED driver is adapted to be operated in a standby mode to stop providing the LED driving power. A switch component is associated with the auxiliary power converter and decouples the input power from the LED output interface via the auxiliary power converter, in the standby mode. Leakage currents associated with the auxiliary interface of the LED driver are thereby blocked.

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LED driver and lighting device comprising the same

FIELD OF THE INVENTION

This invention relates to LED drivers, and in particular it relates to the issue of LED glow when in a standby mode.

5 BACKGROUND OF THE INVENTION

The issue of LEDs glowing when in standby is well known. The problem is known as glow in the dark. It arises from a leakage current flowing through the LEDs even when the LED driver has stopped from actively switching and delivering a drive current, but the electrical connection with the mains input is still conductive such as in a boost converter.

10 The leakage current is often a common mode leakage current between the mains terminals (L and N) and the protective earth. The LED module substrate or luminaire housing is often grounded to this protective earth, and there is often a parasitic capacitance between the LED chip and the module substrate. This parasitic capacitance is for example formed between a copper pad of the LED and the metal core of the substrate. The voltage
15 potential between the mains terminals and the protective earth alternates, thus alternate current flows through the parasitic capacitance and through the LED chip thereby making the LED emit light. Such a glow in the dark not only visually annoys the user, but also consumes energy in vain.

It is known to measure the common mode current in order to judge if a LED
20 driver will not experience the glow in the dark issue.

Figure 1 shows a LED driver 10 connected to mains terminals L, N and shows two 10uF capacitors to illustrate the parasitic capacitance to protective earth PE wherein the LED should be connected across the LED+ and the LED- terminals, and is not shown for simplicity. The voltage source Vmain represents the residual voltage between the mains
25 terminals L,N and protective earth. Figure 1 shows a test setup for measuring the common mode current by means of a multimeter 12. In the real environment the multimeter is not present.

Figure 1 shows the common mode currents that flow to the LED terminals LED-, LED+. The common mode current passes through the capacitive load, i.e., the LED

arrangement, and thereby causes the glow in the dark issue. The common mode voltage is an ac voltage, so that the common mode current is also an ac current. Thus, the common mode current is bidirectional as the arrows on the common mode current shows. Typically, the rms current level is measured.

5 Figure 2 shows the circuit of Figure 1 showing the internal structure of the driver 10. The driver comprises a full bridge diode rectifier D1, D2, D3, D4 followed by a switch mode DC-DC power converter comprising input capacitor C1, inductor L1, switch U1, diode D5 and output capacitor C2. This is a standard boost converter architecture. The boost converter is for example an AC-DC PFC stage.

10 An output stage is a synchronous buck converter and comprises series switches U3, U4 with parallel capacitances C3, C4. The junction between them connects to the LED+ terminal through output inductor L2. The internal ground reference of the LED driver connects to the LED- terminal. The output stage is for example a DC-DC constant current stage.

15 Figure 2 shows the leakage current paths which arise when the common mode voltage is positive.

 When the common voltage is positive, there is one possible current path 20 to the capacitive load via LED+. This path is through the upper rectifier diodes D1 and D3, the components L1, D5 of the switch mode power converter and the parasitic components C3 of the switch U3 and the inductor L2.

 There are three possible currents path 22a, 22b, 22c to the capacitive load via the terminal LED-.

 Path 22a is through the upper rectifier diodes D1 and D3 and the bus capacitor C2,

25 Path 22b is through the upper rectifier diodes D1 and D3, the inductor L1, diode D5 of the switch mode power converter and the output capacitor C2.

 Path 22c is through the upper rectifier diodes D1 and D3, the components L1, D5 of the switch mode power converter and the output stage C3, C4

30 Figure 3 shows the leakage current paths when the common mode voltage is negative.

 There are two possible current paths to the capacitive load via terminal LED+.

 Path 30a is through the output inductor L2 the internal diode of U3, the bus capacitor C2 and the lower rectifier diodes D2 and D4.

Path 30b is through the output inductor L2, the parasitic capacitor C4 of the switch U4 and the lower rectifier diode D2.

There is one possible current path to the capacitive load via terminal LED-.

Path 30c is through the lower rectifier diodes D2 and D4.

5 To reduce the common mode current, it is known to use a diode or active switch coupled to LED terminal to block the common mode current. For example, using a diode at the LED+ output and using a diode and a switch circuit coupled to the LED- output. This approach is shown in Figure 4.

10 The LED+ diode is shown as D+ and the circuit coupled to the terminal LED- comprises a MOS transistor T-. In order to protect the MOS transistor T-, practically often using a voltage dependent resistor VDR- in parallel with the transistor. There is also a diode D- in series with the transistor. The voltage dependent resistor is to protect the transistor.

15 The diode D+ blocks the negative current path for LED+, so that the ac common mode current becomes a dc current. The diode D- and transistor T- block the positive current path for LED-, so again the ac common mode current becomes a dc current. Such a DC current can only charge the parasitic capacitance in one direction and there is no DC current anymore once the parasitic capacitance has been charged, thus the glow in the dark is stopped for good. This approach is for example described in WO2016/192987.

20 SUMMARY OF THE INVENTION

It has been found that despite the known measures to reduce the common mode current, as described above, the glow in the dark issue can still arise. In particular, it has been found that the glow in the dark issue arises in particular when the LED driver is equipped with a low voltage auxiliary power supply for powering an auxiliary load different
25 from the LED, in addition to the main power supply for powering the LED. This auxiliary power supply is for example known for interrogating external components in order to set the operating parameters of the LED driver. The inventor has investigated and found out that such an auxiliary power supply may also allow/leak a continuous AC common mode current and cause glow in the dark.

30 The invention is defined by the claims.

It is a concept of the invention to block leakage currents associated with an auxiliary interface of a LED driver, to which an auxiliary power converter is coupled. A switch is used to decouple input power from the LED output interface of the LED driver, at least in one current flow direction, via the auxiliary power converter and the auxiliary

interface. This decoupling takes place in a standby mode. Thus in the standby mode, the input power cannot cause continuous AC common mode current to the LED/parasitic capacitance via the auxiliary power converter thus glow in the dark is prevented.

The invention is based on the recognition that when a LED driver has an auxiliary power supply and auxiliary interfaces which are powered by an auxiliary power supply, wherein said auxiliary power supply and other interfaces have a certain connection with the LED terminal, they provide a cause of common mode leakage current to the LED terminal which is not compensated by the known approaches. In the known approaches, measures are only applied to the main power supply and the LED terminals, not to the auxiliary power supply and auxiliary interfaces.

According to examples in accordance with an aspect of the invention, there is provided a LED driver, comprising:

a power input interface to receive an input power;

a LED output interface to be connected to an LED;

a LED power converter connected to the input interface and the LED output interface and configured to provide a LED driving power from the input power and to output the LED driving power to the LED via the LED output interface in an operation mode;

an auxiliary power converter coupled to the power input interface and configured to generate an auxiliary power from the input power; and

an auxiliary interface connected to the auxiliary power converter and to be connected to an auxiliary component and to apply said auxiliary power thereon,

wherein at least one of the auxiliary power converter and the auxiliary interface is electrically connected with at least one of the LED power converter and the LED output interface,

wherein the LED power converter is adapted to be operated in a standby mode to stop providing the LED driving power,

and wherein the LED driver further comprises:

a switch component associated with the auxiliary power converter and adapted to turn off a current path from the power input interface via the auxiliary power converter and/or the auxiliary interface to the LED output interface, at least in one current flow direction, in the standby mode.

This LED drive circuit enables glow of a LED to be avoided when the LED power converter is in standby, caused by leakage through the circuit of an auxiliary power converter and/or the auxiliary interface. The auxiliary power converter is used to power an

external auxiliary interface, for example for measuring a so called “LEDset” current setting resistor or a temperature sensing resistor. In many implementations, the auxiliary power converter and/or the auxiliary interface has a connection, such as co-grounding, with the LED powering domain (including the LED power converter and/or the LED output interface) so as to operate normally. In standby the auxiliary power converter circuit creates a leakage path for currents through parasitic capacitances via this original connection. The invention proposes that this original connection is blocked by the switch component at least in one direction. This prevents a continuous ac loop common current flowing and thus prevents the problem of glow in the dark meanwhile the intended purpose of the auxiliary power converter and/or the auxiliary interface is still maintained. The issue arises for example when the ground connection for the auxiliary power converter is connected to the negative output interface terminal.

The LED driver is for example adapted to be connected to a protective earth of the input power via the LED output interface and the switch component is configured to decouple the power input interface from the protective earth via at least one of the auxiliary power converter and the auxiliary interface and via the LED output interface, thereby preventing a leakage current flowing to the LED through the LED output interface in response to a residual potential between the input voltage and the protective earth.

The LED driver for example further comprises a conduction component between the power input interface and one of a negative terminal and a positive terminal of the LED output interface and adapted to allow a leakage current in one direction between the one of the negative terminal and the positive terminal and the power input interface. This conduction component is often essential in LED driver for various purposes such as protection, but it causes the AC common mode leakage current. This embodiment of the invention is particularly useful for preventing the AC common mode leakage current of the auxiliary power converter via this conduction component. Thus, the original purpose can still be achieved and glow in the dark can also be prevented.

The switch component is for example configured, when switched to an open state, to block a leakage current flow in an opposite direction between the one of the negative terminal and the positive terminal of the LED output interface and the power input interface via at least one of the auxiliary power converter and the auxiliary interface, thereby preventing continuous alternation of leakage current flowing at the one of the negative terminal and the positive terminal. By limiting current to flow in one direction only, continuous ac current is avoided and glow in the dark is stopped for good.

The driver may comprise:

a first diode in a forward conduction direction between the LED power converter and the positive terminal of the LED output interface; and

5 a switching circuit and second diode between the LED power converter and the negative terminal of the LED output interface, with the second diode in the reverse conduction direction between the LED power converter and the negative terminal, wherein the switching circuit comprises the conduction component adapted to allow the leakage current from the negative terminal to the power input interface,

10 wherein the switch component is configured, when switched to the open state, to block the leakage current flow from the power input interface via at least one of the auxiliary power converter and the auxiliary interface to the negative terminal thereby preventing continuous alternation of leakage current flowing at the negative terminal.

This is one circuit configuration with the auxiliary interface coupled to the
15 negative terminal.

The auxiliary interface for example comprises a control interface to be connected to an external control component as the auxiliary component, and the LED driver comprises a controller adapted to control the LED power converter to regulate the LED driving power according to a signal on the control interface which is associated with the
20 control component.

The control component may thus be used to set the driver conditions. Many LED drivers have such a setting mechanism thus the present embodiment can be used to prevent leakage current through this setting mechanism. Therefore the present embodiment has wide applications.

25 In one example, the control interface is a LED current setting interface to be connected to an external LED current setting resistor as the external control component, and the controller is adapted to control the LED power converter to regulate the current in the LED driving power according to a signal, on the control interface, related to a resistance of the external LED current setting resistor. Thus, an external resistor is used to tune the current
30 output of the driver. This enables the LED driver to be configured for use with different LED loads.

In another example, the control interface is a sensing interface adapted to be connected to a sensor as the external control component.

For example, the control interface is a temperature sensing interface to be connected to an external temperature sensing component as the external control component, wherein the external temperature sensing component comprises a temperature-dependent resistor, and the controller is adapted to control the LED power converter to enter an over temperature protection and limit the LED driving power according to a signal, on the control interface, related to a resistance of the temperature-dependent resistor which signal meeting a certain condition. This enables the LED driver to have an over temperature protection function.

In another example, the auxiliary interface is an auxiliary power output interface to be connected to an auxiliary load such as a RF module.

Thus, there are different possible applications for an auxiliary power output interface, and they may each introduce a current leakage path which contributes to the problem of glow in the dark.

The auxiliary power output interface is for example adapted to be connected to a standalone sensor or RF module.

The LED power converter for example comprises a boost converter. A boost converter is just example, and those skilled in the art understand that the present application can be applied with other type of LED power converter as long as the auxiliary power converter may leak the common mode current through the LED power converter.

The auxiliary power converter, for example, comprises a buck converter.

The invention also provides a lighting device comprising:

the LED driver as defined above; and

an LED arrangement comprising the LED driven by the LED driver, wherein said LED arrangement comprises a parasitic capacitance between the LED and the protective earth so as to conduct the leakage current between the protective earth and the LED output interface.

The lighting device may further comprise the auxiliary component connected to the auxiliary interface, wherein the auxiliary component comprises:

a current setting resistor; and/or

a temperature sensing component.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:

- 5 Figure 1 shows a LED driver;
 Figure 2 shows the circuit of Figure 1 with the internal structure of the driver and also shows the leakage current paths when the common mode voltage is positive;
 Figure 3 shows the leakage current paths when the common mode voltage is negative;
10 Figure 4 shows a known circuit to reduce the common mode current;
 Figure 5 shows the driver of Figure 3 with an added auxiliary interface;
 Figure 6 shows the leakage currents that may flow;
 Figure 7 shows the current paths when there is a positive common voltage;
 Figure 8 shows the current paths when there is a negative common voltage;
15 Figure 9 shows an additional current path from ground and through an over temperature protection resistor when the common voltage is positive;
 Figure 10 shows an additional current path through the over temperature protection resistor when the common voltage is negative;
 Figure 11 shows a LED driver modified in accordance with the invention, and
20 in particular for a LED driver with over temperature protection, OTP, functionality;
 Figure 12 shows how the switch component may be configured for a LED driver with LEDset functionality;
 Figure 13 shows how the switch component is connected for a LED driver with LEDset functionality; and
25 Figure 14 shows how the switch component is connected for a LED driver with LEDset and OTP functionality.

DETAILED DESCRIPTION

The invention will be described with reference to the Figures.

- 30 It should be understood that the detailed description and specific examples, while indicating exemplary embodiments of the apparatus, systems and methods, are intended for purposes of illustration only and are not intended to limit the scope of the invention. These and other features, aspects, and advantages of the apparatus, systems and methods of the present invention will become better understood from the following

description, appended claims, and accompanying drawings. It should be understood that the Figures are merely schematic and are not drawn to scale. It should also be understood that the same reference numerals are used throughout the Figures to indicate the same or similar parts.

5 The invention provides a LED driver with a power input interface to receive an input power, a LED output interface to be connected to an LED and an auxiliary power converter coupled to the power input interface and configured to generate an auxiliary power from the input power. The LED driver is adapted to be operated in a standby mode to stop providing the LED driving power. A switch component is associated with the auxiliary power
10 converter and decouples the input power from the LED output interface via the auxiliary power converter, in the standby mode. Leakage currents associated with the auxiliary interface of the LED driver are thereby blocked.

 The invention is based on the recognition that another cause of common mode leakage current arises when a LED driver has an auxiliary power supply and other interfaces
15 such as LEDset or overtemperature protection, OTP, which auxiliary power supply and other interfaces have a connection with the LED output interface thus leaks current thereto.

 Figure 5 shows the driver of Figure 3 with these popular auxiliary interfaces. It also shows the leakage current reduction circuit of Figure 4 for preventing leakage via the main LED converter, as transistor U6 and parallel voltage dependent resistor VDR. U6 is also
20 turned off during standby and turned on during normal operation. It is an existing design for preventing leakage through the LED- terminal. The VDR protects U6.

 LEDset is an interface to be connected to an external resistance R3 normally on the LED board. The LED driver has a small auxiliary power supply to inject a fixed current into the LEDset resistor via a low voltage supply LVS and a voltage meter (not
25 shown in Figure 5) to measure the voltage across the LEDset resistor so as to measure the external resistance. The LED driver configures the current to the LED according to the external resistance.

 The auxiliary power supply is shown as a buck converter comprising switch U5, diode D6, inductor L3 and diode D7. The switch U5 is connected to the VBUS which is
30 the same output of the boost converter. The diode D6 is connected to the GND which is the same ground of the boost converter. It generates the low voltage supply LVS.

 OTP is an interface to be connected to an external temperature dependent resistor R2 also normally on the LED board. A resistor R1 is in series with the temperature dependent resistor R2 and is a general internal resistor. One terminal of R1 is connected to

the low voltage supply at LVS (or other power in the circuit) and the junction between R1 and R2 is connected to the microcontroller in the circuit. The other terminal of R2 is connected to the LED- terminal. The microcontroller measures the voltage at the junction to enable the resistance of R2 to be determined.

5 The power supply injects a fixed current into the OTP interface or a fixed voltage across the resistors R1 and R2, and the voltage meter also measures the voltage across the OTP resistor R2 to derive the resistance of the external temperature dependent resistor R2. The external temperature dependent resistor can reflect the temperature on the LED board. The LED driver configures the current to the LED according to the external
10 temperature dependent resistor to prevent over temperature of the LED board.

 In many cases (but not all cases), the LEDset and/or OTP resistors directly or indirectly share the same ground of the LED- terminal. As shown in Figure 5, the ground of the LEDset circuit is connected to the terminal LED-. The residual voltage across the mains terminals L, N and the protective earth may also flow to the LED via the LEDset or OTP
15 interface.

 Figure 6 shows the leakage currents that may flow. As shown, a bidirectional leakage current flows to the LED- terminal. Figure 6 uses LEDset interface as an example. The LEDset resistor is not drawn for simplicity. The block LEDset is the voltage meter as mentioned above.

20 It is to be noted that in other cases, the auxiliary supply may be associated with the LED+ terminal, and the configuration shown is for example only.

 The known LEDset circuit shown in Figure 6 also has a diode connected to the low voltage supply LVS, a MOS transistor and a diode connected to the LEDset signal. In practice it has been found that a large common mode current remains as will be explained
25 with reference to Figures 7 and 8.

 The invention is based on determining the cause of the remaining common mode current and providing a method to reduce the common mode current.

 Figure 7 shows the current paths when there is a positive common voltage.

 When the common voltage is positive, the current paths to the capacitive load
30 through the driver are the same as explained above wherein the switch U6 can block the leakage through the LED power converter to the LED-.

 However, there is also a current path to the capacitive load via terminal LED- through the LEDset circuit.

In particular, the currents flow in current paths to ground may then flow through the LEDset circuit. Three such paths are shown in Figure 7.

Path 70a is through the upper rectifier diodes D1 and D3 and the input capacitor C1 to ground GND. There is then a path 70 from ground through the diode D6,
5 inductor L3, diode D10 and capacitor C10.

Path 70b is through the upper rectifier diodes D1 and D3, the inductor L1, diode D5 and bus capacitor C2 to ground GND, and then along path 70 through the diode D6, inductor L3, diode D10 and capacitor C10.

Path 70c is through the upper rectifier diodes D1 and D3, the inductor L1,
10 diode D5 and parasitic capacitors C3, C4 of switches U3 and U4 to ground GND, and then along path 70 through the diode D6, inductor L3, diode D10 and capacitor C10.

Figure 8 shows the current paths when there is a negative common voltage.

When the common voltage is negative, the diode D8 to the LED+ terminal blocks the negative current path for LED+ so that the ac mode common current becomes a dc
15 common current.

There is one possible current path to the capacitive load via terminal LED- as shown. Path 80 is through the voltage dependent resistor VDR and the lower rectifier diodes D2, D4.

Thus, there is an ac loop on LED- (with different conduction paths in different
20 directions). This gives rise to a large and continuous AC common mode current to constantly turn the LED on to emit light.

The LEDset circuit includes a diode D6 with the anode side connected to ground, as shown. It is a freewheeling diode in the low voltage supply circuit and is a fundamental component of the switch mode power supply of the low voltage auxiliary
25 supply. However, it provides a possible current path from GND to the low voltage supply when the common voltage is positive, as explained above. Diode D7 also provides a possible current path from the low voltage supply LVS to LED-, when the common voltage is positive.

Thus, the typical circuitry of the low voltage supply provides a possible
30 current path from GND to the LEDset terminal (typically LED-) when the common voltage is positive. This gives rise to a large continuous AC common mode current. An ac loop is formed for the terminal LED- by the diode D6 of the low voltage power supply in one direction and the diode D9 and voltage dependent resistor VDR at the LED- terminal in the other direction.

A typical specification of the voltage dependent resistor is a maximum operating voltage $V_{rms}=320V$ and a voltage at $1mA$ $V_v=510V \pm 10\%$, wherein V_v could be regarded as the voltage to make the voltage dependent resistor carry the leakage current flow.

The common input voltage is $230V_{rms}$.

5 First, the common voltage will charge the voltage of the capacitive load through the diode D6 of the low voltage supply. When the common voltage changes direction, the voltage on the voltage dependent resistor VDR begins to increase. When the voltage on the voltage dependent resistor is larger than the value V_v , the leakage current of the voltage dependent resistor begins to increase, so that the voltage on the capacitive load
10 begins to decrease.

This conclusion has been tested by simulating the V/I curve of the voltage dependent resistor.

It was found that the common mode current (from L/N to ground) for the known circuit was $330 \mu A$. However, removing the voltage dependent resistor reduced the
15 common mode current to $15 \mu A$ however this is not practical since this voltage dependent resistor is essential, and removing the diode in the low voltage supply loop also reduced the common mode current to $15 \mu A$. This shows that the current paths concluded above are responsible for the large common mode current.

It has also been found that the over temperature protection function provides
20 an additional leakage path based on similar reasoning. Figure 9 shows an additional current path 90 from ground and through the over temperature protection resistor R2 when the common voltage is positive. Figure 10 shows an additional current path 100 through the over temperature protection resistor R2 when the common voltage is negative. It flows via the parasitic diode of the switch U5 to the VBUS and back to the diode bridge.

25 Figure 11 shows a LED driver modified in accordance with the invention, and in particular it relates to a LED driver with OTP functionality.

The driver comprises a power input interface L, N to receive an input power, in particular a mains input. A LED output interface LED+, LED- is for connection to a LED load. A switch mode LED power converter (boost converter C1, L1, U1, D5) is connected to
30 the input interface and the LED output interface and is configured to provide a LED driving power from the input power. The LED driving power is delivered to the LED load via the LED output interface LED+, LED- in an operation mode.

An auxiliary power converter comprising switch U5, diode D6, and the inductor L3 is connected to the power input interface (L, N), in particular, it is supplied by

the rectified bus voltage V_{bus} at the output of the main PFC stage. The auxiliary power converter generates a low voltage auxiliary power (LVS) from the input power. An auxiliary interface is connected to the auxiliary power converter and is for connection to one or more auxiliary components R2, R3 (only R2 is shown for the example of Figure 11) and to apply the low voltage auxiliary power to the auxiliary components.

The auxiliary power converter and the auxiliary interface are electrically coupled to the LED power converter and the LED output interface (more generally, at least one of the auxiliary power converter and the auxiliary interface is electrically coupled with at least one of the LED power converter and the LED output interface).

The LED power converter has a normal mode when it delivers power to the LED load to generate a light output, and it also has a standby mode when it stops providing the LED driving power.

The LED driver connects to a protective earth PE of the input power via the LED output interface.

The invention is based on reducing the leakage current during this standby mode. A switch component U7 is provided associated with the auxiliary power converter U5, D6, L3. It is used to decouple the input power from the LED output interface LED+, LED-, at least in one current flow direction, via the auxiliary power converter U5, D6, L3 and the auxiliary interface, in the standby mode. The switch component comprises a MOS transistor, and Figure 11 also shows the parallel body diode of the MOS transistor.

In particular, the switch component U7 decouples the power input interface L, N from the protective earth PE via at least one of the auxiliary power converter U5, D6, L3 and the auxiliary interface, and via the LED output interface. It thereby prevents a leakage current flowing to the LED through the LED output interface in response to a residual potential between the input voltage L, N and the protective earth PE.

The switch component U7 is turned off during standby and turned on during normal operation. Thus, turning off U7 blocks leakage current from the mains input terminals L, N to the power output terminal LED- or to the protective earth PE.

In the particular example shown, the switch component is used to block a current flow from ground through diodes D6 and D7 to the terminal LED-. Thus, it blocks the current path 70 of Figure 7 and the current path 90 of Figure 9 when there is a positive common voltage.

The switch component U7 disconnects the circuit loop between the low voltage supply and the LED output interface (terminal LED- in this example) when the driver

is in standby mode in the positive cycle. In the negative cycle, there may be leakage through the body diode of U7. However, there is leakage in any case from the protective earth PE and terminal LED- to the mains power input terminal L, N via diode D9 and the voltage dependent resistor VDR already. However, this is only a DC current and will stop after the parasitic capacitors are fully charged. Thus, there is no need for the transistor U7 to block the reverse direction current. By blocking the possible positive current path, even though there is still a negative current to LED-, it has become a dc current. In this way, the total ac current will be very small.

The same blocking function applies when the auxiliary power supply is used for the measurement of a LEDset resistor R3.

If the LED driver only has the LEDset functionality, a different design of the switch component can be used, as shown in Figure 12. Two MOSFETs U7a and U7b are provided in serial back-to-back connection. They again function to disconnect the circuit loop between the low voltage supply and the LED output interface, in particular terminal LED- in this example.

When two switches are used, they will block the current in both current flow directions. The two MOSFETs have the same gate signal so that they are both turned on and off at the same time by a common control signal.

Figure 13 shows how the switch component is connected when only a LEDset functionality is provided. The switch component U7a, U7b is connected between the ground terminal for the LEDset resistor and the LED- output terminal. For the LED+ terminal, the parasitic capacitor is only charged at positive polarity shown by the arrow and would not be discharged. For the LED- terminal, the parasitic capacitor is only charged at negative polarity shown by the arrow; at the positive polarity, the switches U7a and U7b are open thus the input power would not flow to the parasitic capacitor at the LED- terminal via the auxiliary power supply, the LVS and the LEDset block of voltage meter.

If the LED driver has both the LEDset functionality and OTP function, the switch component may be arranged as shown in Figure 14.

In this case, the switch component U7 is provided between the output LED- and the ground (common) terminal for the external resistors R2, R3.

The switch component shown schematically as switch U7 is again implemented as two MOSFETs in serial back-to-back connection.

When two MOSFETs are used, they block a positive current flow from the resistor LEDset to terminal LED- and also block the positive current flow from the OTP

resistor to the terminal LED-. There is still a negative current to LED- but it is a dc current. Thus, the total ac current is very small.

The invention can also be applied to other interfaces such as the auxiliary power supply interface for a sensor module. The invention may be applied to a non-isolated driver and to an isolated driver with a Y-capacitor.

Variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure and the appended claims.

For example, in the above embodiments, the switch component is placed between the auxiliary interface and the LED output interface. Alternatively, the switch component can also be placed at other proper location as long as it can cut off the input power and the LED output interface via the auxiliary power converter. For example, it may be placed at the input of the auxiliary power converter to isolate the ground of the auxiliary power converter and the ground of the PFC stage such that the input power is unable to flow into the auxiliary power converter. In one embodiment, the diode D6 can be replaced by an active switch which becomes open to disallow the leakage current 70, 90.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality.

The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

If the term "adapted to" is used in the claims or description, it is noted the term "adapted to" is intended to be equivalent to the term "configured to". If the term "arrangement" is used in the claims or description, it is noted the term "arrangement" is intended to be equivalent to the term "system", and vice versa.

Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A LED driver, comprising:

a power input interface (L, N) to receive an input power;

a LED output interface (LED+, LED-) to be connected to an LED;

a LED power converter (C1, L1, U1, D5) connected to the input interface and

the LED output interface and configured to provide a LED driving power from the input power and to output the LED driving power to the LED via the LED output interface (LED+, LED-) in an operation mode;

an auxiliary power converter (U5, D6, L3) coupled to the power input interface (L, N) and configured to generate an auxiliary power (LVS) from the input power;

and

an auxiliary interface (LEDset, NTC) connected to the auxiliary power converter and to be connected to an auxiliary component (R2, R3) and to apply said auxiliary power thereon,

wherein at least one of the auxiliary power converter and the auxiliary interface is electrically connected with at least one of the LED power converter and the LED output interface,

wherein the LED power converter is adapted to be operated in a standby mode to stop providing the LED driving power,

and wherein the LED driver further comprises:

a switch component (U7) associated with the auxiliary power converter (U5, D6, L3) and adapted to turn off a current path from the power input interface (L, N) via the auxiliary power converter (U5, D6, L3) and/or the auxiliary interface (LEDset, NTC) to the LED output interface (LED+, LED-), at least in one current flow direction, in the standby mode.

2. The LED driver of claim 1, wherein:

the LED driver is adapted to be connected to a protective earth (PE) of the input power via the LED output interface; and

the switch component (U7) is configured to decouple the power input interface (L, N) from the protective earth (PE) via at least one of the auxiliary power converter (U5, D6, L3) and the auxiliary interface and via the LED output interface, thereby preventing a leakage current flowing to the LED through the LED output interface via at least one of the auxiliary power converter (U5, D6, L3) and the auxiliary interface in response to a residual potential between the input voltage (L, N) and the protective earth (PE).

3. The LED driver of claim 1 or 2, wherein the LED driver further comprises:
a conduction component (VDR) between the power input interface and one of a negative terminal (LED-) and a positive terminal (LED+) of the LED output interface (LED+, LED-) and adapted to allow a leakage current in one direction between the one of the negative terminal (LED-) and the positive terminal (LED+) and the power input interface (L, N).

4. The LED driver of claim 3, wherein the switch component (U7) is configured, when switched to an open state, to block a leakage current flow in an opposite direction between the one of the negative terminal (LED-) and the positive terminal (LED+) of the LED output interface (LED+, LED-) and the power input interface (L, N) via at least one of the auxiliary power converter and the auxiliary interface, thereby preventing continuous alternation of leakage current flowing at the one of the negative terminal (LED-) and the positive terminal (LED+).

5. The LED driver of claim 3 or 4, comprising:
a first diode (D8) in a forward conduction direction between the LED power converter and the positive terminal (LED+) of the LED output interface; and
a switching circuit (U6, D20, VDR) and second diode (D9) between the LED power converter and the negative terminal (LED-) of the LED output interface, with the second diode in the reverse conduction direction between the LED power converter and the negative terminal, wherein the switching circuit comprises the conduction component (VDR) adapted to allow the leakage current from the negative terminal (LED-) to the power input interface (L, N),

wherein the switch component (U7) is configured, when switched to the open state, to block the leakage current flow from the power input interface (L, N) via at least one of the auxiliary power converter and the auxiliary interface to the negative terminal (LED-)

thereby preventing continuous alternation of leakage current flowing at the negative terminal (LED-).

6. The LED driver of any one of claims 1 to 5, wherein:

the auxiliary interface comprises a control interface to be connected to an external control component (R2, R3) as the auxiliary component; and

the LED driver comprises a controller adapted to control the LED power converter to regulate the LED driving power according to a signal on the control interface which is associated with the control component.

7. The LED driver of claim 6, wherein said control interface is a LED current

setting interface (LEDset) to be connected to an external LED current setting resistor (R3) as the external control component, and

the controller is adapted to control the LED power converter to regulate the current in the LED driving power according to a signal, on the control interface (LEDset), related to a resistance of the external LED current setting resistor.

8. The LED driver of claim 6, wherein said control interface is a sensing interface adapted to be connected to a sensor as the external control component.

9. The LED driver of claim 8, wherein said sensing interface is a temperature sensing interface (NTC) to be connected to an external temperature sensing component as the external control component, wherein the external temperature sensing component comprises a temperature-dependent resistor,

the controller is adapted to control the LED power converter to enter an over temperature protection and limit the LED driving power according to a signal, on the temperature sensing interface (NTC), related to a resistance of the temperature-dependent resistor which signal meeting a certain condition.

10. The LED driver of any one of claims 1 to 5, wherein said auxiliary interface is an auxiliary LED output interface to be connected to an auxiliary load.

11. The LED driver of claim 10, wherein the auxiliary LED output interface is adapted to be connected to a standalone sensor or RF module.

12. The LED driver of any one of claims 1 to 11, wherein the LED power converter comprises a boost converter and the auxiliary power converter comprises a buck converter.

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13. A lighting device comprising:
the LED driver of claim 2; and
an LED arrangement comprising the LED driven by the LED driver, wherein said LED arrangement comprises a parasitic capacitance between the LED and the protective
10 earth so as to conduct the leakage current between the protective earth and the LED output interface.

14. The lighting device of claim 13, further comprising an auxiliary component (R2, R3) connected to the auxiliary interface, wherein the auxiliary component comprises:

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a current setting resistor (R3); and/or
a temperature sensing component (R2).

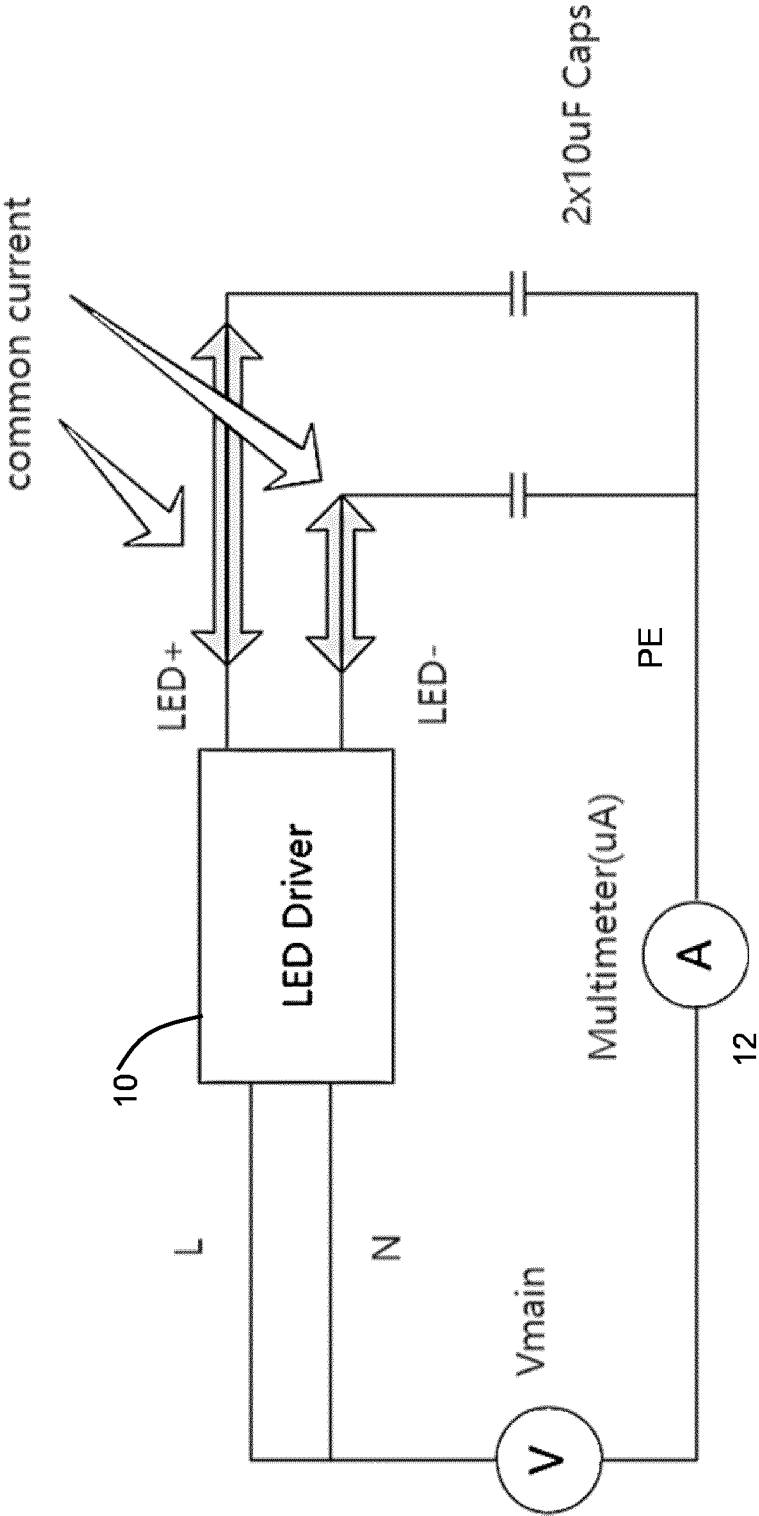


FIG. 1

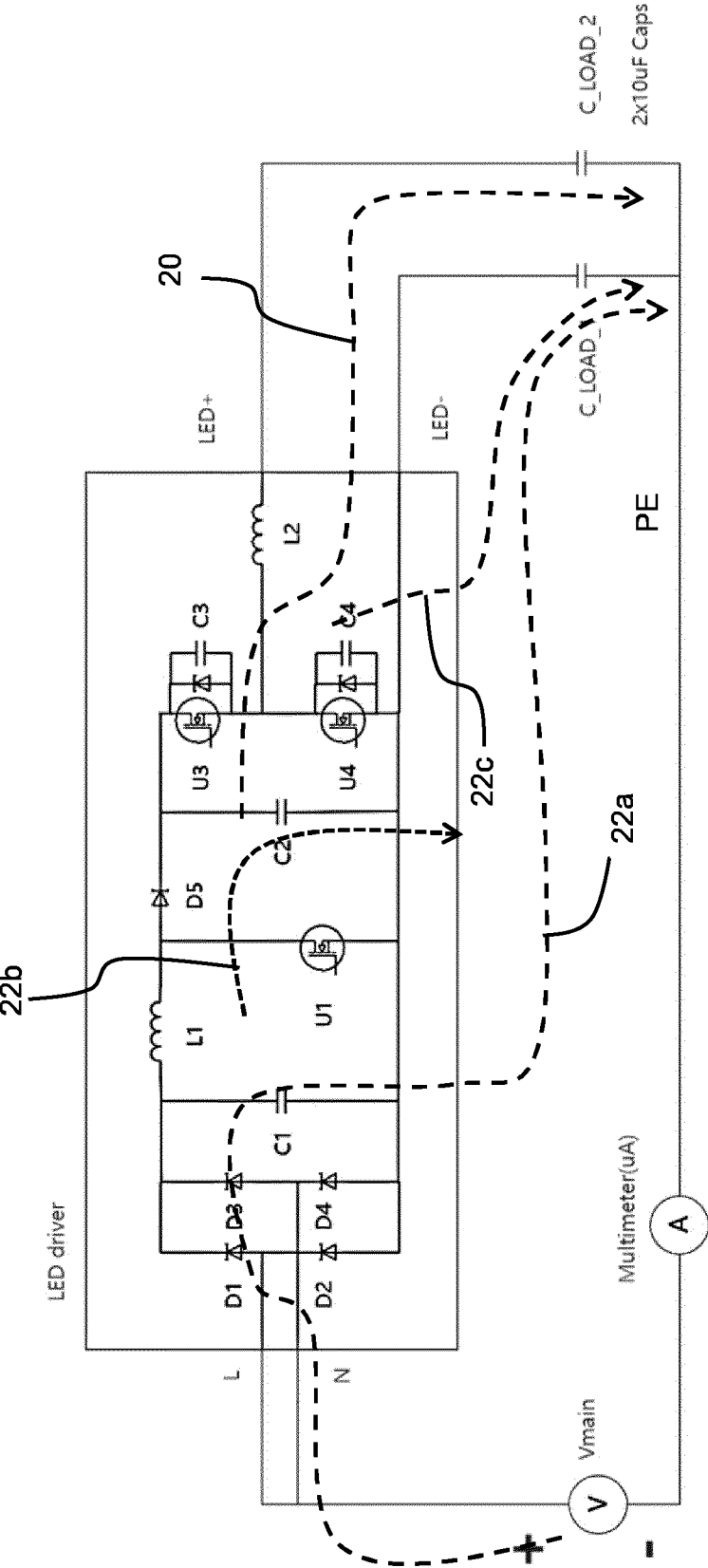


FIG. 2

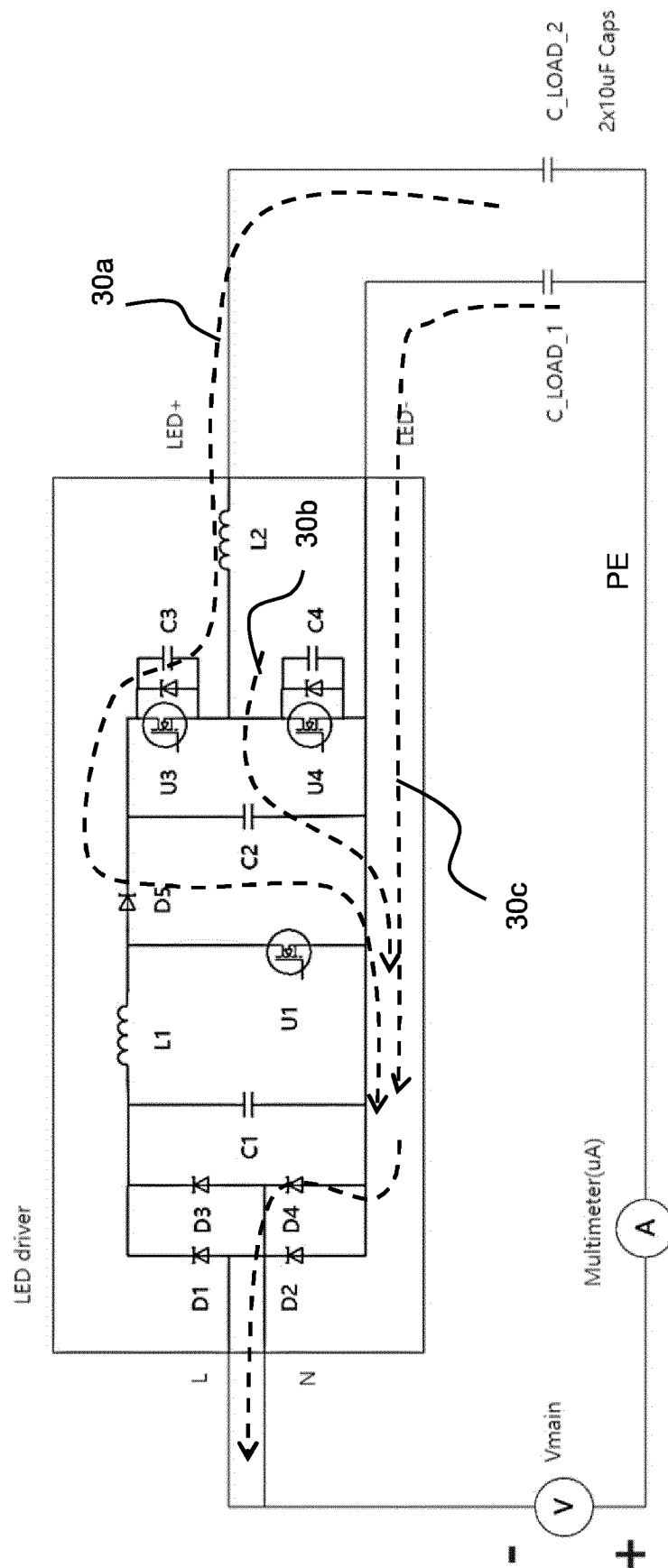


FIG. 3

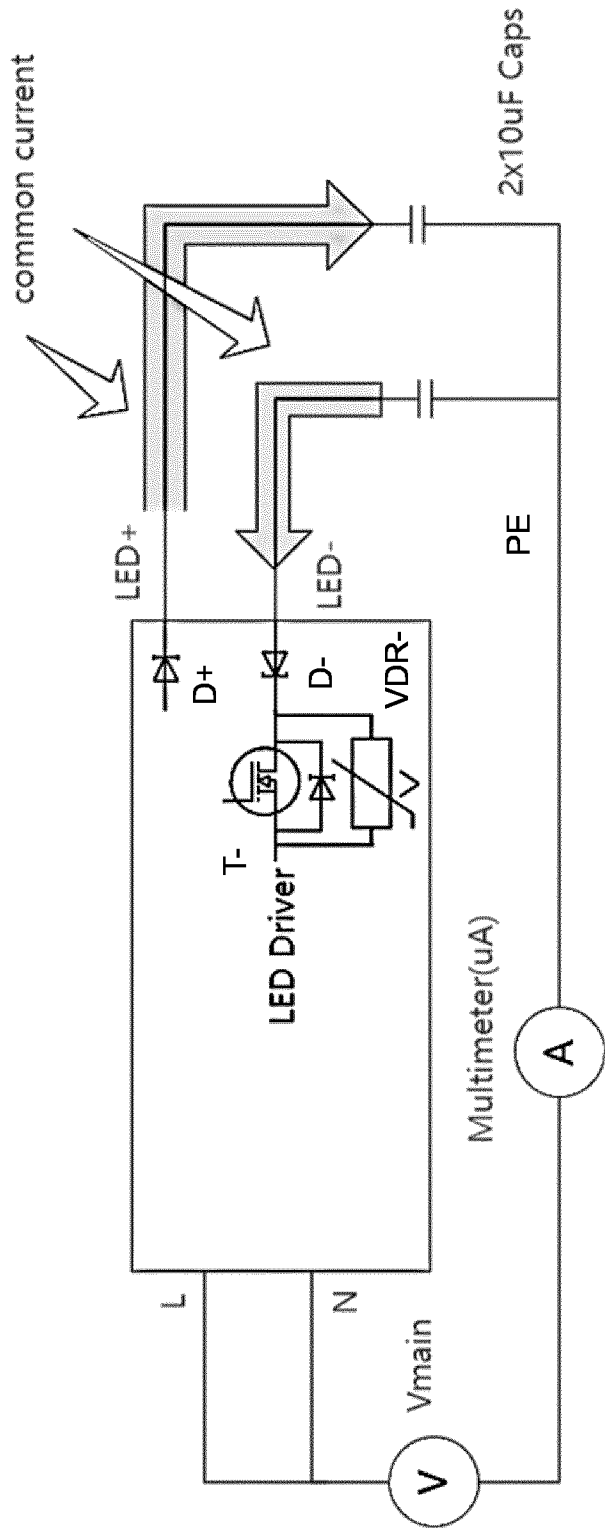


FIG. 4

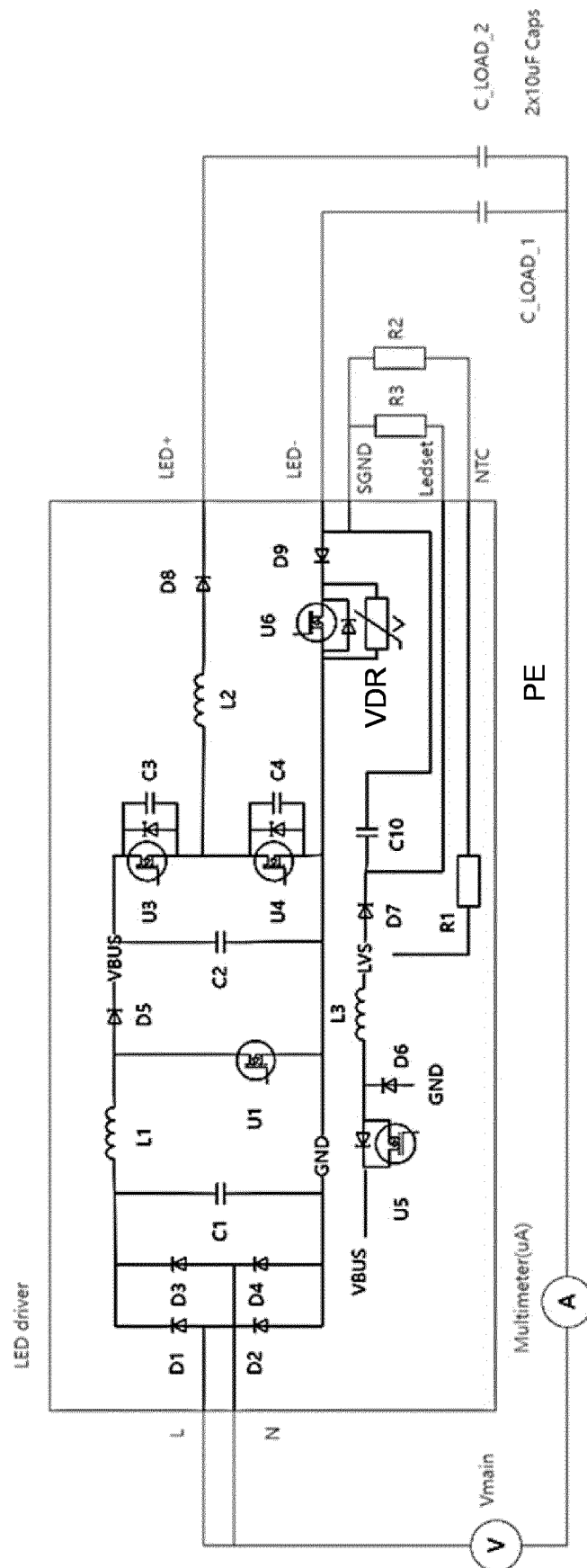


FIG. 5

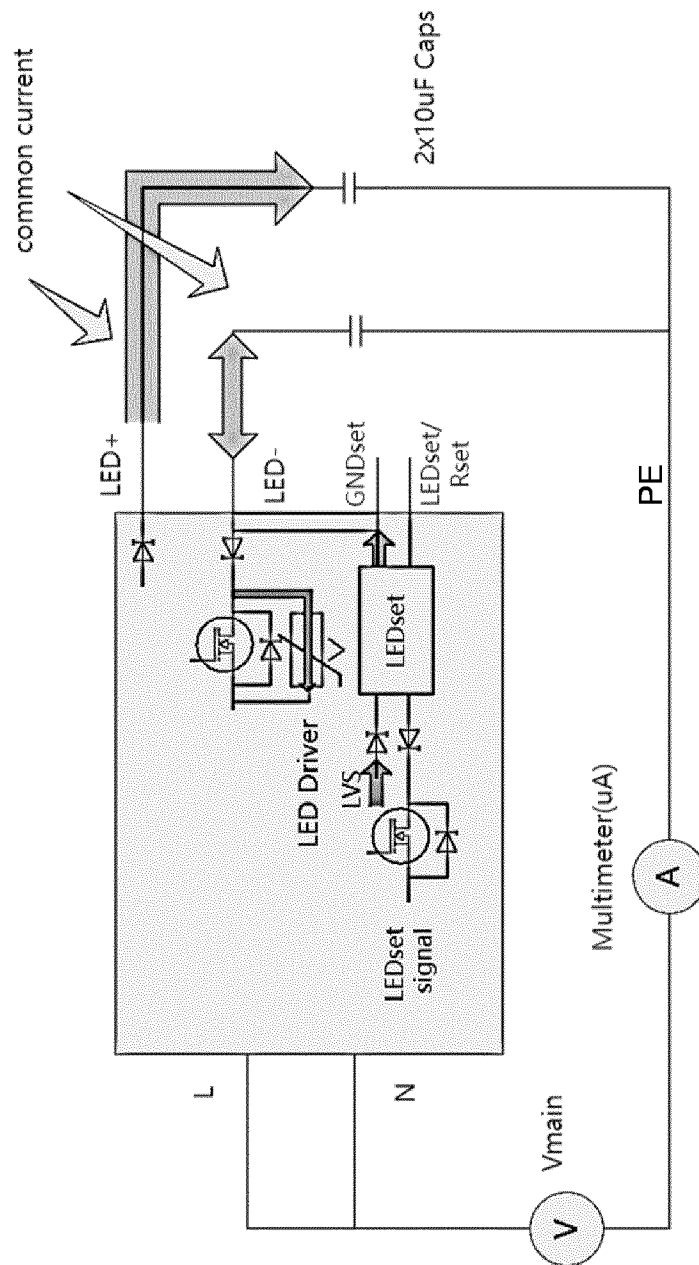


FIG. 6

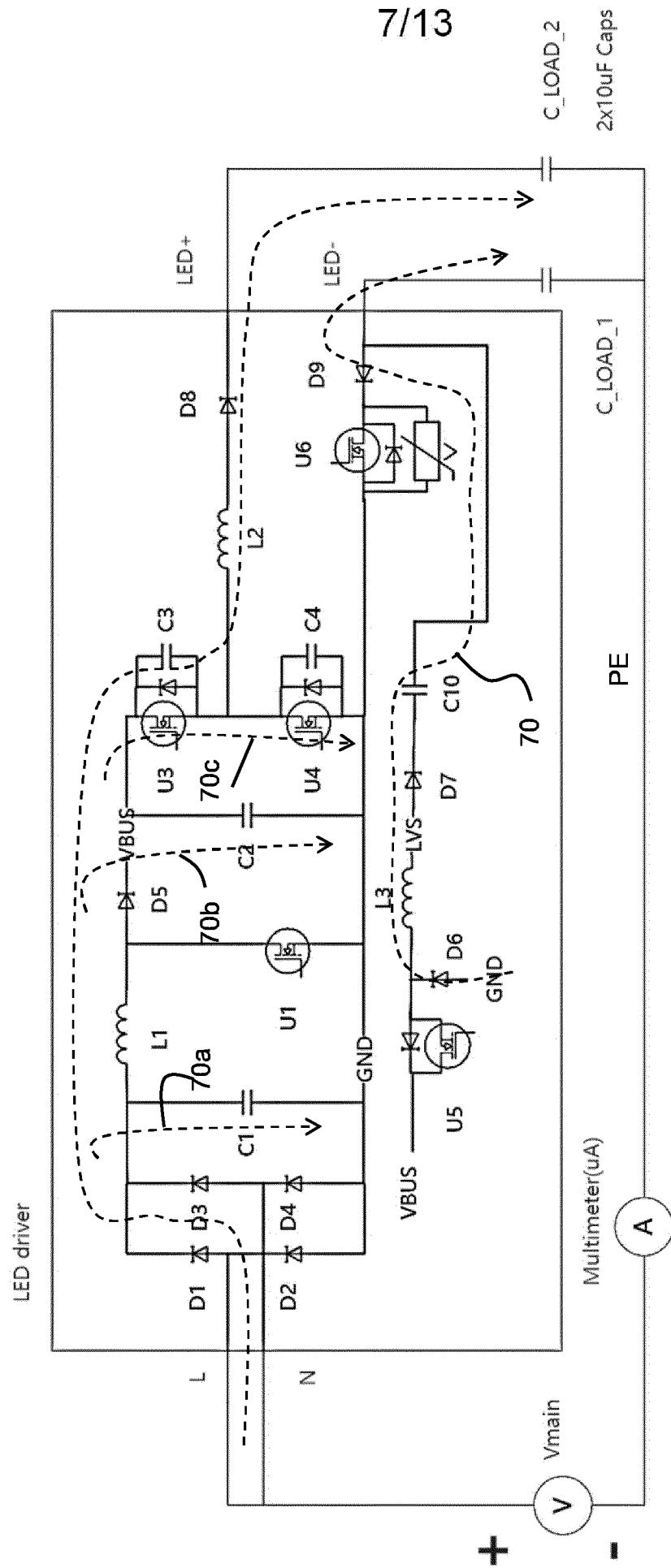


FIG. 7

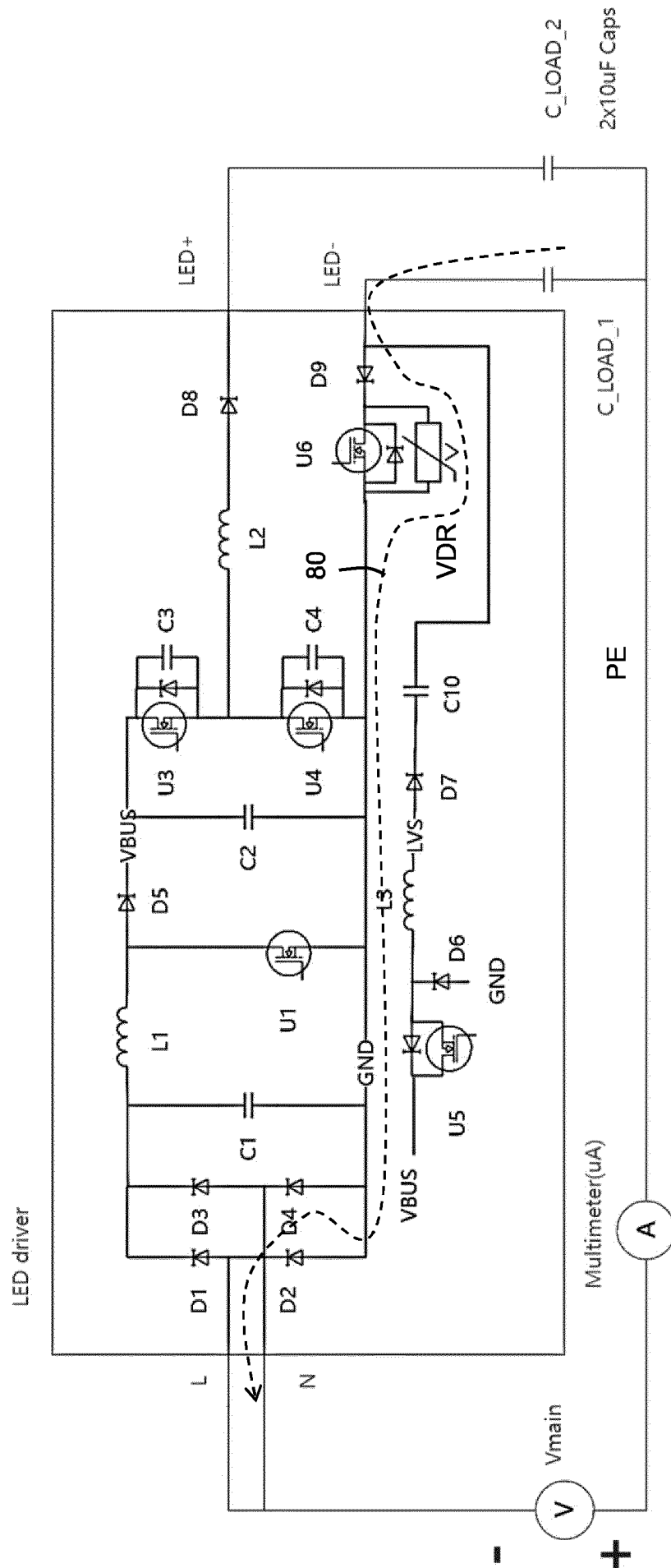


FIG.

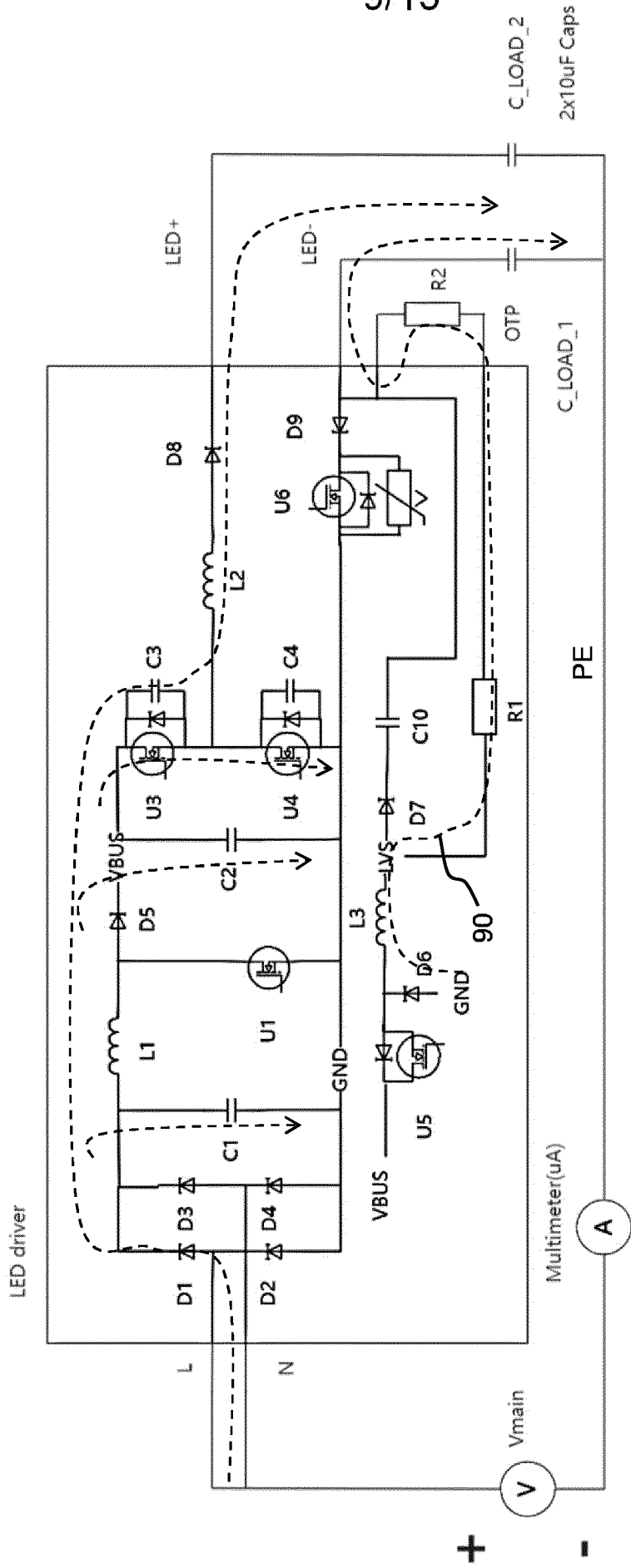


FIG. 9

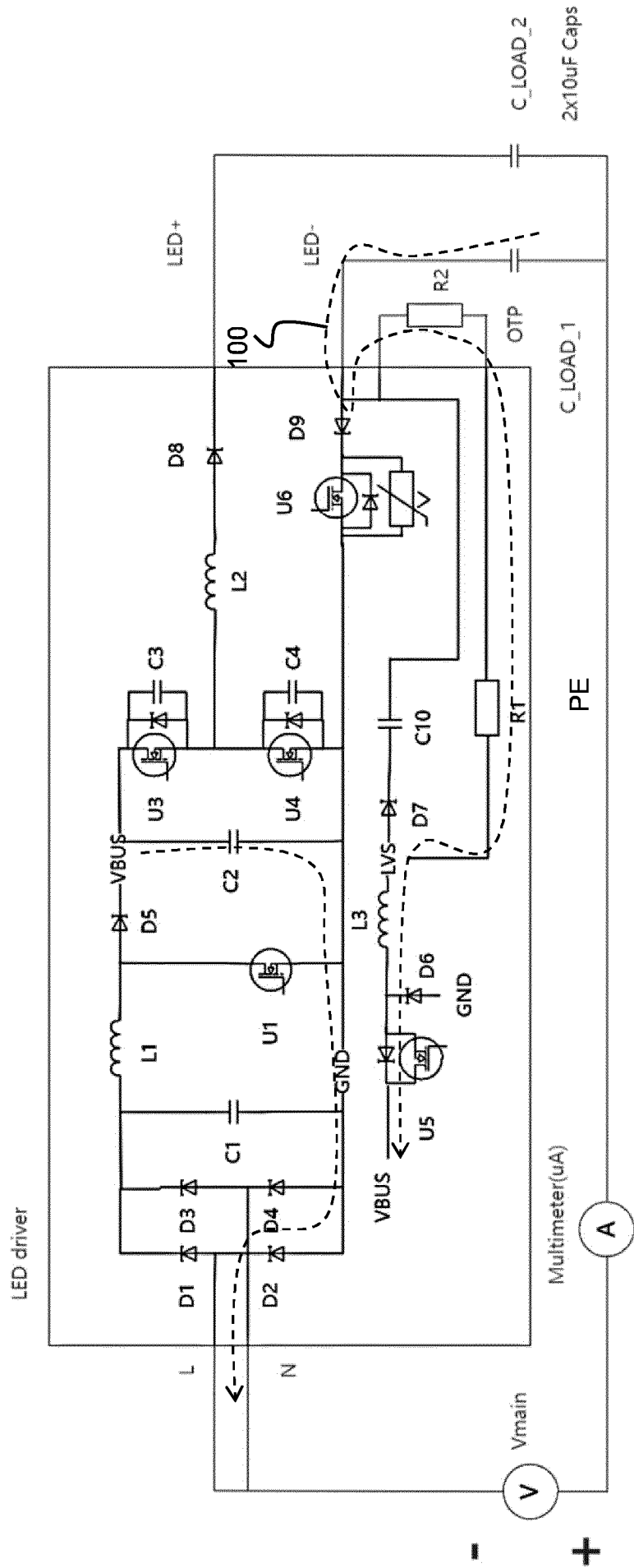


FIG. 10

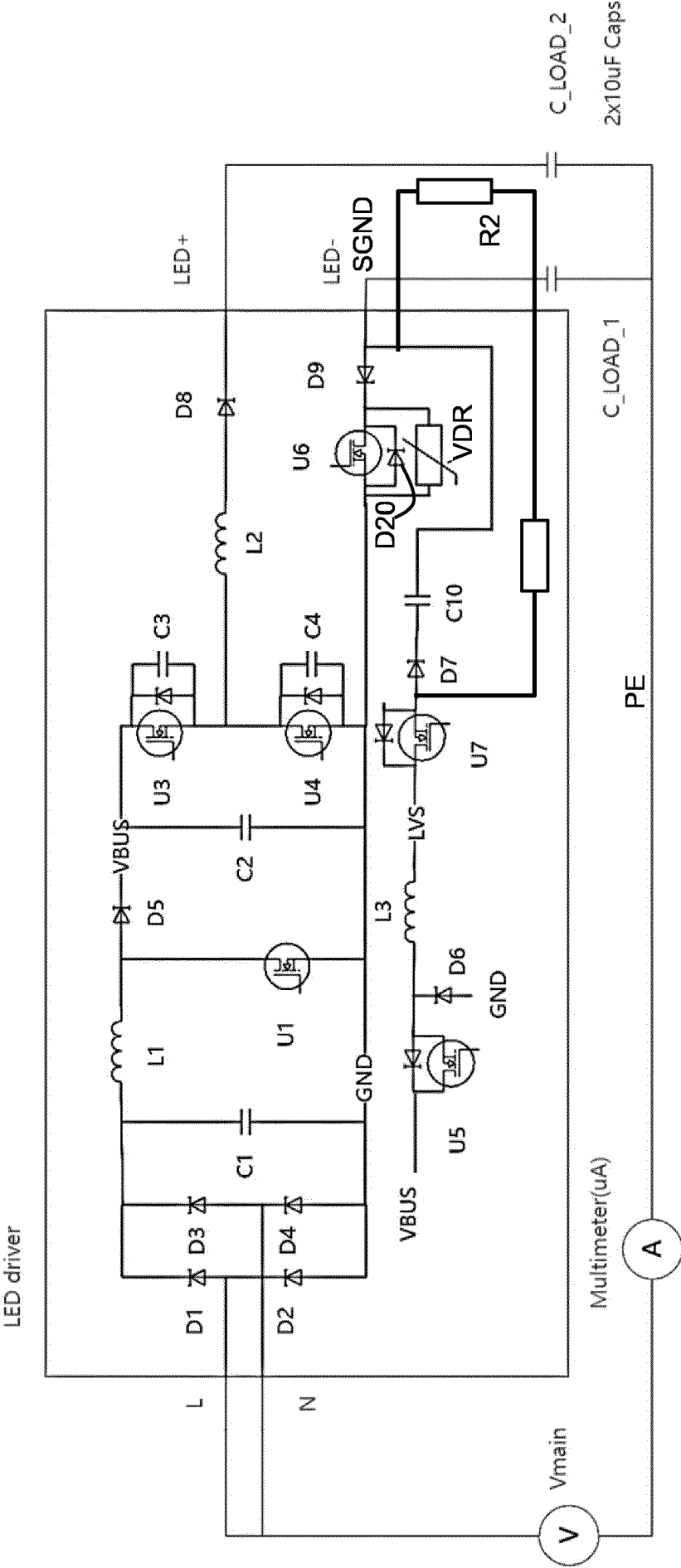


FIG. 11

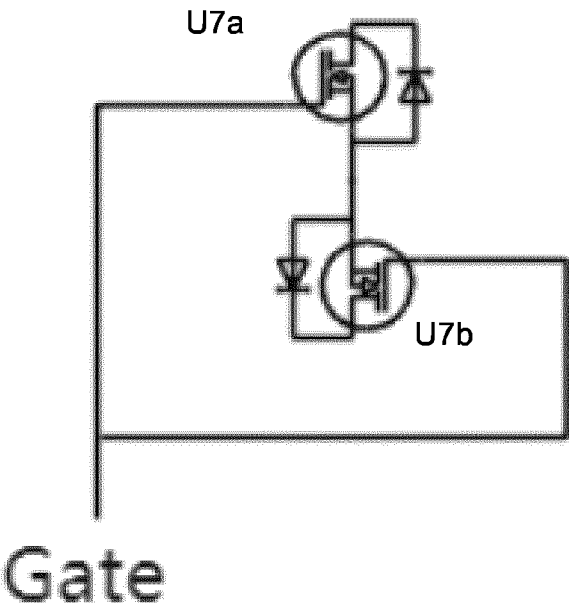


FIG. 12

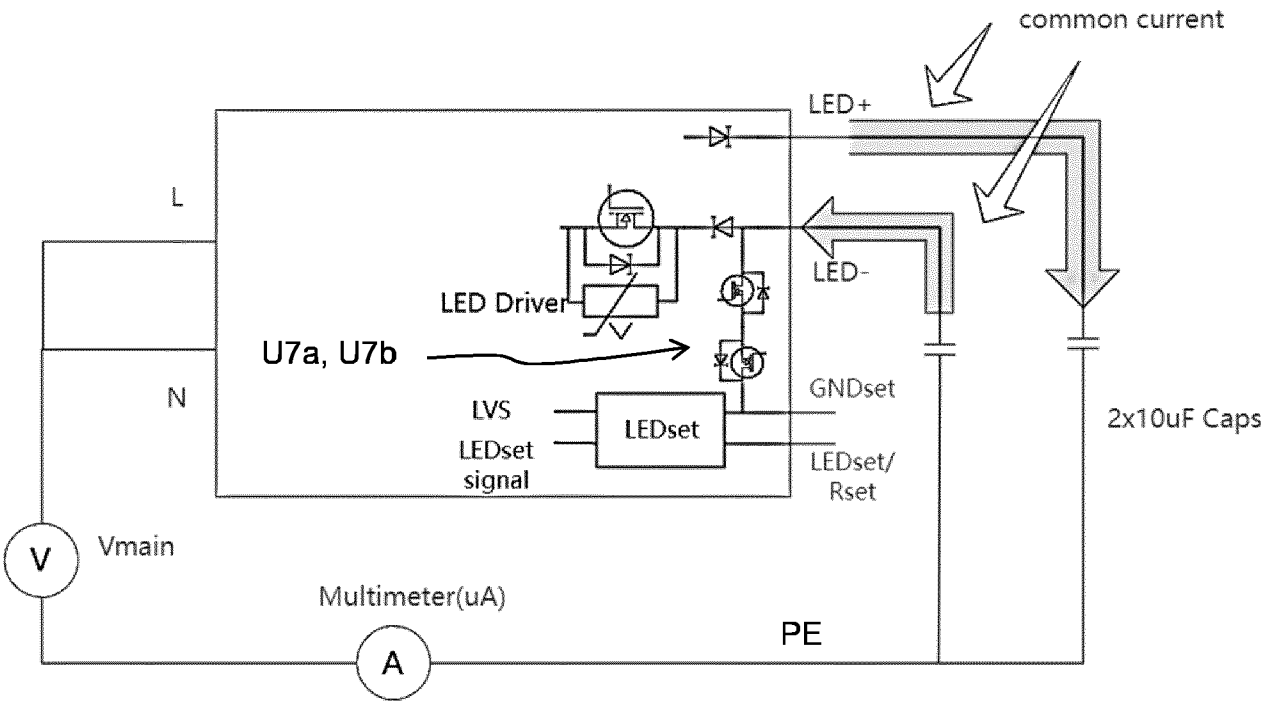


FIG. 13

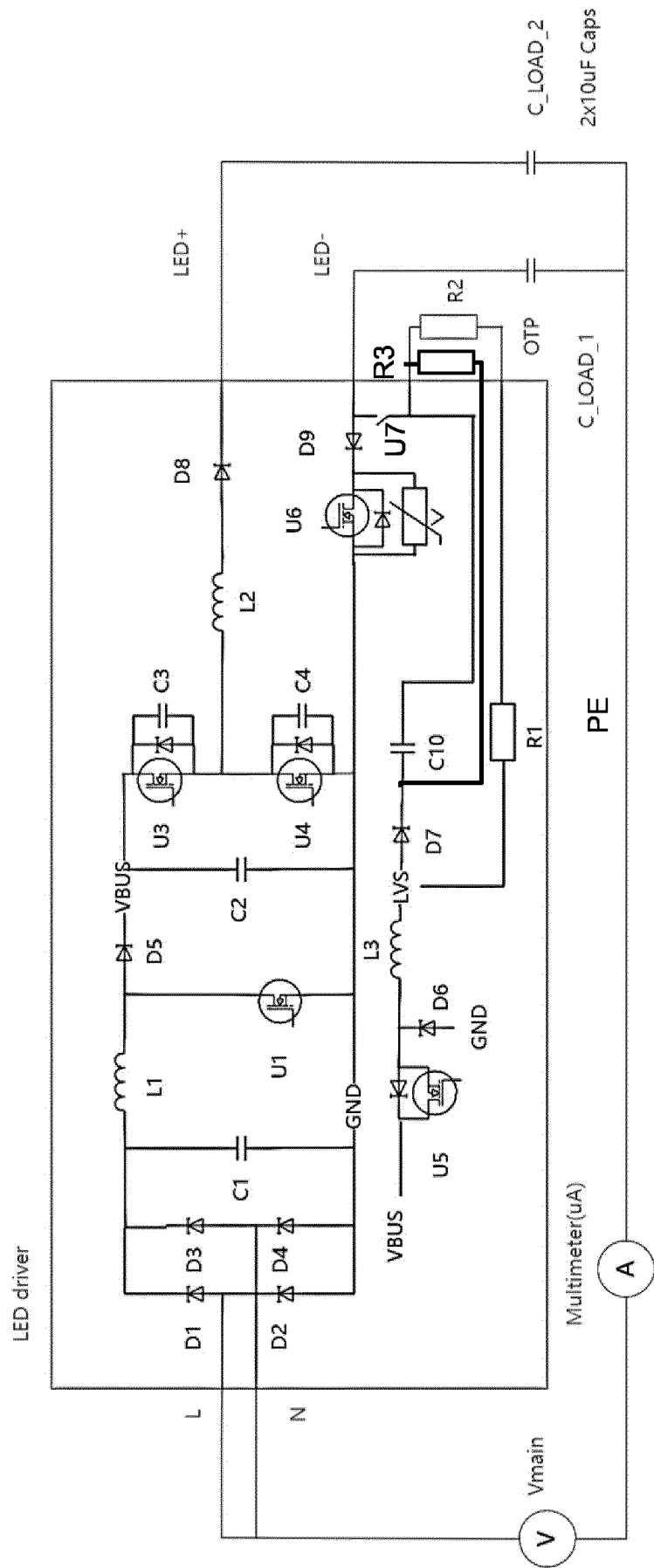


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/066372

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05B45/59

ADD.

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)

H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2020/092966 A1 (ZIJLMAN THEO GERRIT [NL] ET AL) 19 March 2020 (2020-03-19) paragraph [0055] - paragraph [0071]; figures 1, 2 -----	1 - 14
A	US 2020/383185 A1 (ZIJLMAN THEO GERRIT [NL] ET AL) 3 December 2020 (2020-12-03) claims 1-4; figures 1, 2 -----	1 - 14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"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

25 July 2024

Date of mailing of the international search report

21/08/2024

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2

NL - 2280 HV Rijswijk

Tel. (+31-70) 340-2040,

Fax: (+31-70) 340-3016

Authorized officer

Plamann, Tobias

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/066372

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